Department of Science and Humanities

The journey of Department of Science and Humanities has started along with the establishment of Military Institute of Science and Technology shortly known as MIST since 19 April 1998. From the beginning, department has always played an essential role in laying the foundation of science and humanities for the potential engineers and emerged as one of the largest department at MIST. This vision of the department is providing the relevant fundamental undergraduate courses related to fundamental science (math, physics and chemistry) and socio-ethical values required for engineering education. A bunch of (45) highly qualified faculties are engaged to fulfill this vision by conducting approximately 432 contact hours in each semester. Besides undergraduate program, M. Phil program in Mathematics, Physics and Chemistry is being offered since October 2014 session. The well-equipped and modern physics and chemistry laboratory under department of science and humanities offers a strong platform for the fundamental research. Department of science and humanities is the flag barrier of extra-curriculum activities at MIST. It coordinates different clubs activities and organizes different extra-curricular activities for flourishing students' mental arena and also to develop the soft skills with a view to prepare them for the challenge of future career.

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Military Institute of Science and Technology

MIST | Technology for Advancement

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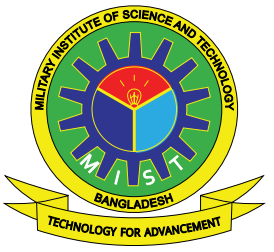

MIST | Technology for Advancement

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MIST Journal of Science and Humanities

Editorial Board

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Message
From the Chief Patron

Bismillahir Rahmanir Rahim

Following the honorable Prime Minister Sheikh Hasina's visionary leadership and spirit of independence, Military Institute of Science and Technology (MIST) was planned to establish. In pursuit of her vision, MIST started its journey since 19 April 1998, being the pioneer Technical Institute of Bangladesh Armed Forces. Besides, MIST plays a vital role in nation-building by providing engineering education to civil students as well. This institute aims at attaining its ultimate goal to be a 'Center of Excellence' by the concerted efforts of all its members.

The Department of Science and Humanities at MIST was established on the very same day as the foundation of MIST, with a commitment to creating an optimal learning environment, fostering innovation, and encouraging scientific exploration. The science and humanities courses, offered by the department, support a smooth transition to higher education, empowering both students and faculty to excel academically in their respective fields.

It is with great pleasure that I extend my warmest appreciation to Department of Science and Humanities for publishing the second volume of its academic journal, *MIST Journal of Science and Humanities*. I am really delighted by the remarkable dedication of the department in producing a journal of high standard.

Research is the cornerstone of academic growth, pushing the boundaries of our understanding and propelling us forward into the realms of innovation. The Department of Science and Humanities has consistently embodied this spirit, and this journal stands as a testament to the commitment and contributions of our institution.

I encourage all authors, reviewers, and editors to continue engaging with our journal and contributing to the pool of knowledge that it represents. Your groundbreaking research and insightful contributions play a crucial role in pushing the limits of what can be achieved.

I am excited about the future of *MIST Journal of Science and Humanities*, and I look forward to witnessing the groundbreaking research and ideas that will undoubtedly be featured within its pages.

I wish the *MIST Journal of Science and Humanities* will continue to thrive and set new standards in academic excellence. May Allah bless us all.

Maj Gen Mohammed Saidul Islam, rcds, ndc, psc
Commandant
Military Institute of Science of Technology (MIST)

Message
from Chief Advisor

Bismillahir Rahmanir Rahim

It is my privilege to address the occasion of launching the second volume of our research journal, *MIST Journal of Science and Humanities*, from the department of Science and Humanities of MIST. This journal is a record of the collective efforts and intellectual dedication, containing original articles, review articles, and editorial.

In the world of academia, research is the catalyst of progress, the driving force that guides us towards innovation and enlightenment. Our department, in particular, has been a stronghold of intellectual exploration, where scientific and humanistic pursuits get merged to create a dynamic harmony.

I am immensely grateful to the editorial team, the authors, and all those who have contributed to this journal. Your dedication and hard work are a testament to the strength of our academic community and our unwavering commitment to excellence.

Finally, let this journal serve as a beacon of inspiration and a reminder of our duty to advance in pursuing knowledge. May we continue to explore, innovate, and make a positive impact on society through the harmonious union of intellect and morality.

Thank you, and I extend my best wishes to all for continued success in your academic and ethical endeavors.

Colonel Eare Md Morshed Alam, MPhil, PhD
Head of the Department
Department of Science and Humanities, MIST

Editorial

Size Matters: Tiny Size, Big Impact, The World of Nanoscience and Nanotechnology

In the sophisticated arrays of scientific exploration, there exists a realm where size is more incredibly important. Nanoscience and nanotechnology, the twin pillars at the forefront of this tiny domain, have reshaped our understanding of matter and unlocked boundless avenues for innovation.

Nanoscience is the study of phenomena and manipulation of materials at the nanoscale which reveals the novel properties as the matter is scaled down to dimensions below 100 nanometers. It's complement, nanotechnology, harnesses the novelty to fabricate innovative materials, devices, and systems that redefine industries and augment human capability.

The origin of nanoscience can be traced back to a famous lecture delivered by the eminent physicist Richard Feynman at the American Physical Society meeting at Caltech in 1959. In his visionary seminal lecture titled "There's Plenty of Room at the Bottom," Feynman articulated a profound idea: the possibility of manipulating matter at atomic and molecular levels. This lecture laid the foundation for the exploration of the nanoscale world, creating a revolutionary trajectory in the scientific community.

Nanoscale semiconductor particles which are known as the quantum dots, are one of the remarkable advancements in the field of nanoscience and nanotechnology awarded the prestigious Nobel Prize in Chemistry in 2023. Congratulations to the award winners Moungi G. Bawendi from Massachusetts Institute of Technology (USA), Louis E. Brus from Columbia University (USA), and Alexei I. Ekimov from Nanocrystals Technology Inc. (USA) for the discovery of quantum dots. This recognition highlighted the pivotal role of nanotechnology in transforming imaging technology, solar cells, and medical diagnostics—a testament to the profound impact of this rapidly increasing field on society.

At the nanoscale, the laws governing matter diverge from classical physics to quantum effects. Quantum mechanics come into play and take over classical physics, leading to a realm where materials exhibit unique properties and the properties can be tuned by changing their size, this phenomenon is often termed as size-dependent properties. Louis Brus, one of the Novel Laureate in Chemistry, 2023 demonstrated the size-dependent optical properties of cadmium sulphide quantum dots. He compared the absorption of light by the cadmium sulphide quantum dots of different size and observed that the smaller particles had an absorption that shifted towards blue i.e, smaller the particle bluer the light they absorb as shown in fig. This observation was explained by the size-dependent quantum confinement

effect. Due to the tiny size of the nanomaterials, electrons are confined in a small space, therefore quantum confinement effect dictate the behaviour of nanomaterials, steering in an era of unprecedented innovation and exploration.

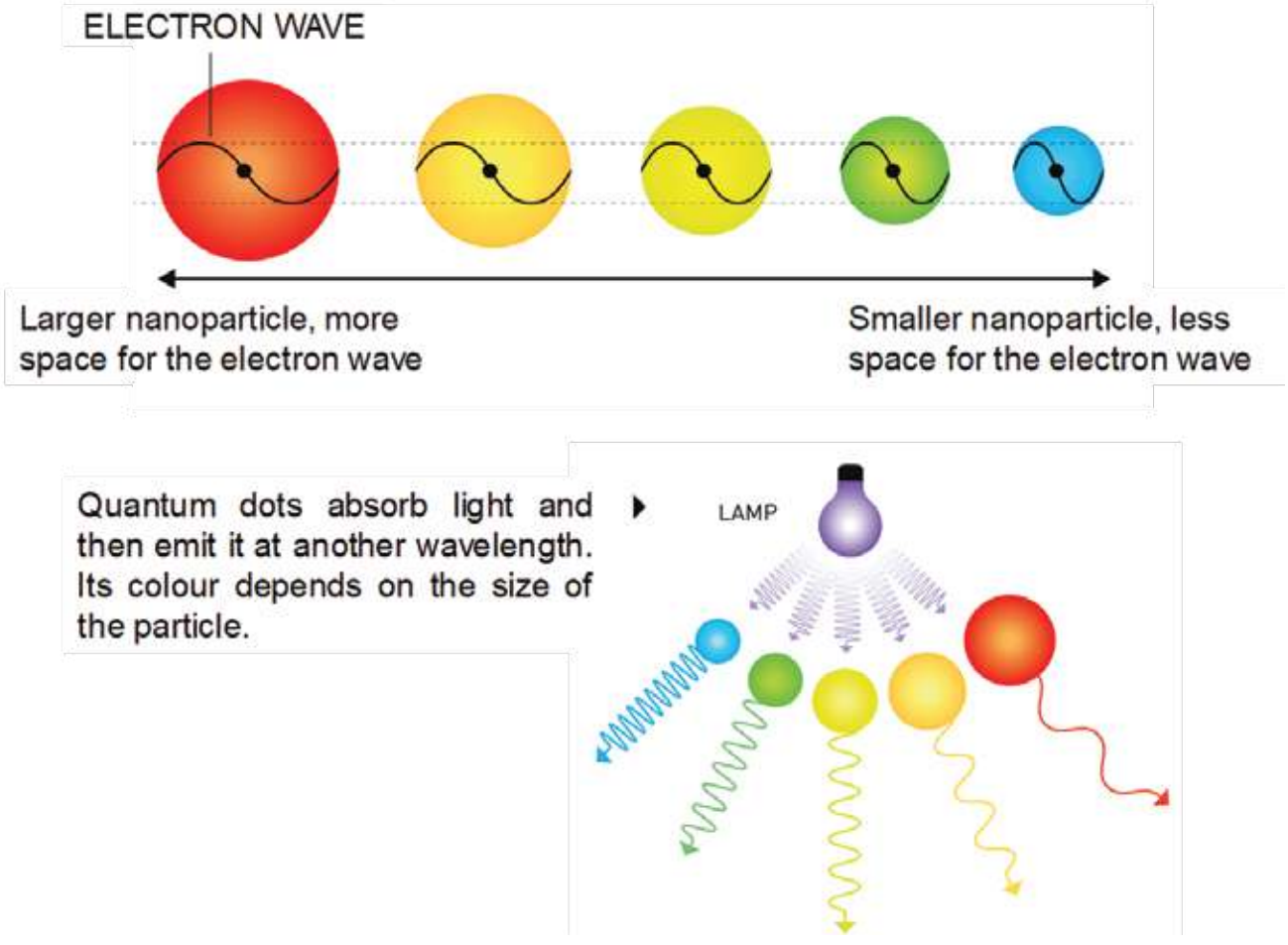

Fig. Quantum effect in optical of properties of cadmium sulphide particles.

Applications of nanotechnology thrive across diverse domains, promising transformative changes. The tiny nanostructures enable innovative functionalities with various practical applications across numerous disciplines including chemistry, biology, physics, materials science, mechanical, electrical, bio-medical, medicine, energy, optoelectronics, and so on. Therefore, in the dynamic landscape of nanomaterials, size indeed matters, where the tiny size brings about a huge impact.

Lieutenant Colonel Md Jafar Sharif, PhD, Sigs
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INDEX

IMPACT OF SOCIAL MEDIA ON CONSUMER CULTURE AMONG THE YOUTHS OF BANGLADESH

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***Abstract*—Online shopping is becoming a widely adopted practice among young people in Bangladesh, especially in urban areas, and the social media is playing a significant role in this regard. This study intended to examine how digital media, especially various social media applications and forums influenced the way of thinking and decision making of the potential consumers about purchasing products on digital platforms, and its overall impact on consumer culture among the younger generation aged from 15 to 30. The relationship between social media interactions and customers' views of different brands is also discussed in the current study. This research was conducted by carrying out a survey among 430 regular (young) university students who had access to social media. It was found that young people are mostly interested in online shopping and the increasing usage of social media significantly influences their taste, brand choice and attitude towards consumerism in Bangladesh, leading to change in their purchasing behaviour, brand preferences and overall consumption patterns.**

Keywords*—Social Media, Consumer Culture, Brand Image, Young Generation

I. INTRODUCTION

Virtual reality is replacing the real, tangible world. Internet makes great achievements possible, both noble and ignoble. Increasingly, younger people are logging into various social media platforms and virtual networks. The range of outcomes from all this, both good and undesirable, is easily imaginable. This undeniable power of the internet must be utilized in the best possible manner to get the best possible benefit for the nation. Social media platforms have become the preeminent digital communication vehicle via which consumers learn about, evaluate and share information about, and engage with merchants and companies they are considering to buy [1]. As the usage of social networks grows, it becomes increasingly critical to understand whether customers' online shopping behaviours are connected to their use of social networks and, if so, how [2]. Following the coronavirus epidemic, people's lives, consumption patterns, and approaches to health protection changed. The only way to fully understand the consequences of the changing environment and how consumers interpret it is to study consumer culture in conjunction with customers' lives. Social media platforms gained popularity in the first 10 years of the twenty-first century, which improved accessibility and reduced the cost of digital advertising for a variety of businesses [3]. Consequently, enterprises started utilizing social media platforms to disseminate advertisements, gradually shaping them into novel marketing tools [4]. In Bangladesh nearly 50.3 million people which is around 30 % of the total population are active social media users. These digital media users keep profiles on various platforms and spend, on average, several hours every day engaging on social media [5]. Facebook, YouTube, Instagram, IMO (a messaging app), and Messenger held the distinction of being the most popular social media sites in Bangladesh. As

predicted earlier approximately 29 % of the nation's populace, equivalent to about 50 million individuals, were actively engaged with Facebook. This utilization served a variety of functions, such as assisting customers in their endeavors to study items, buy them, use them, and share their experiences with others. Marketers had increased their use of digital marketing channels in response to this fundamental shift from in-person trading towards e-commerce [6]. Even more was anticipated, with digital platforms expected to receive almost one-third of all worldwide advertisement spending [7]. Social media and cell phones play a big role in current consumer-focused marketing techniques.

As we know COVID-19 had a great impact on the rise of online shopping in Bangladesh which is still persisting. People are more comfortable in online shopping because it saves their time [8]. In this capitalist era, time is a precious commodity, it is money [9]. Therefore, young professional and students choose online shopping for saving their time so that they can attend to other pursuits. A variety of digital platforms or pages for every conceivable product and service are available online, so the shopper can choose their products from an array of diverse choices and sources. Sometimes they get discounts for online shopping which they might not be able to get from in-person shopping. Therefore, it is crucial for consumer research to carefully examine and understand customer behaviour in a digital environment which has been growing over the past ten years, with a growing emphasis on problems related to digital consumer behaviour. This shift has prompted marketers to revise their tactics to effectively engage with consumers who are becoming more interconnected through social media [10]. Simultaneously, there has been an increased emphasis on contending for consumers' attention on social media platforms to enhance customer engagement [11]. Through social media, marketers can engage in bi-directional conversations with existing and potential customers, swiftly gaining valuable, unfiltered insights into consumer preferences and opinions, which is a clear advantage compared to physical in-person trading.

By following celebrities, sometimes the consumers are impressed to buy products which can have a great impact on their mindset too [12, 13]. People who were not too much conscious regarding contemporary fashion trends became aware through the social media influencer [14]. Such influence can cause and strengthen the desire for buying more and more products, which they probably would not do without exposure to these influencers and celebrities [15]. If any product is searched, the same or similar products are seen on other platforms too [16]. By sharing links, by participating in competitions, social media users are getting discount which raises the number of "strikes" (view and viewers) [17]. The people who are fashion addicts use their social media time by watching videos of different pages [18]. By reading other people's comments, buyers should get a fair and balanced idea about the products because some people give their negative feedback too. Unfortunately, different pages hire people for praising their products for some benefits or other [19].

II. RESEARCH OBJECTIVES

This study focused on three specific areas of objective that were deemed relevant:

a) The purpose of this study is to determine how digital media have influenced consumer culture.

b) The study wants to understand how purchasing behaviour, brand preference and overall consumption patterns have been changed because of the impact of social media.

c) The study wants to discover the connection between consumer views and their interactions with brands on social media.

III. LITERATURE REVIEW

Iqbal *et al.* found that while many businesses have had major internet-related effects, relatively few have undergone the same level of change as marketing [20]. Wilska *et al.* conducted a study to ascertain the extent to which social media influencers influence consumer attitudes and purchasing intentions in Indonesia, with the aid of 180 participants who were active users of social media and had followed social media influencer accounts [21].

Al-Ansi *et al.* did a study to find out which social media platforms individuals use, why they use them, and how they view the advantages and disadvantages of using social media. The use of social media by teenagers has a big impact on their internet addiction, sleeping patterns, communication preferences, language acquisition, academic endeavour, task performance, and need for immediacy [22]. Additionally, internet slang activates the contextual language of social media. Samuel S. and Anitas T. investigated the relationship between advertisement, promotion, and lifestyle toward the repurchase intention of university students engaging in online shopping through a quantitative method of research among 212 university students [23].

Jibril *et al.* showed how social media platforms may successfully foster consumer-brand interaction and user-brand partnerships [24]. According to a study by Khamis *et al.*, the rise of social media influencers (SMI) is responsible for the persistence of self-branding [25]. The results show that SMIs have a large positive effect on adolescents' intellectual development, but they also have a significant negative effect on adolescents' social and moral development in Middle Eastern countries.

According to Palalic *et al.*, examination of data from a self-administered online survey in Pakistan, word of mouth and content trustworthiness are the two factors that affect purchasing consumers' decisions [26]. According to the study findings of Apple *et al*, there is a correlation between social media use and the strength of brand relationships. This correlation is stronger when consumers perceive brands to be more anthropomorphic. They learn that brand trust, which serves a crucial mediating role, enables the effects of enhanced connections in the brand community to be turned into brand loyalty [27].

Nobi *et al.* conducted an online survey utilizing Facebook in 2023 with a convenience sample of 244 respondents who were dispersed over the city of Dhaka. The study found that social media marketing increased purchase behaviour among Bangladeshi adolescent consumers by 53.5 % per unit, with the remaining 46.5 % probably influenced by other non-market external and internal factors [28].

The study by Kamal (2013) found that Arab social media users used social media more frequently and had higher degrees of materialism than American users. Additionally, they had more favorable sentiments toward social media advertisements, and there were links between materialism and the intention to purchase expensive clothing [29]. Through the analysis of server log data, Shahzad *et al.* made an attempt to objectively quantify how website technologies were used by users. The results of the investigation demonstrate that, despite variations in the effect for various technologies and goods, customers' use of information technology has a big influence on the sales to them [30, 31].

IV. THEORETICAL FRAMEWORK

Consumer culture theory (CCT) looks at consumption from a social and cultural perspective as opposed to researching it from an economic or psychological angle. The phrase "consumer culture theory" (Arnould and Thompson, 2005) describes the notion that consumer behaviour can

be interpreted as a part of a complex network of interconnected behaviours, or a culture of practices. Baudrillard defined hyperreality as "the generation by models of a real without origin". When Baudrillard first proposed the theory of hyperreality in 1981, it was seen as a highly controversial and polarizing idea. According to popular belief, hyperreality is a condition in which the boundaries between reality and fiction are hazy, making it difficult to determine where one starts and the other ends. The visual language is the primary concern in hyperreality. Entering hyperreality normally has little effect on a person unless they are cognitively unable to distinguish between the real and the fake [32, 33].

C. H. Cooley outlines the method by which people build their sense of self based on how they believe others view them in his book "The Looking-Glass Self". People utilize social interaction as a sort of mirror, comparing their own actions, values, and worth to how other people perceive them. As people wants to present themselves towards other, they become more fashion conscious [34]. According to sociologist Pierre Bourdieu, the term 'cultural capital' refers to a variety of symbolic characteristics, such as skills, preferences, posture, attire, mannerisms, material assets, credentials, etc., that one develops as a result of being a member of a particular social class. In sociology, cultural capital refers to a person's social assets, such as education, intellect, speech pattern, and wardrobe preference, that facilitate social mobility in a class-based society. Capitalist society has created such type of mentality through continuous advertising. They created a society where without brands people have less importance. Specific brands can determine social standards, social class and status.

V. METHODOLOGY

A quantitative data collection method was followed to conduct the research to find out the impact of the use of social media on the current consumer culture among the young generation aged from 15 to 30 years. Young people, regardless of gender, who are using social media, formed the population for this research. Four hundred and forty five (445) respondents were selected as a sample from the students' community, following the purposive sampling method. For the survey questionnaire, first, the objective of the study has been defined, based on which, the questionnaire was designed. Then pre-testing of the questionnaire was then carried out. After that, the questionnaire was then modified according the feedback from pre-test/ piloting results and then the data were collected. All the collected data were included in the research process accurately and in full with no omission or addition. Any individual preference and bias were carefully avoided during the whole process. All the quantitative data were categorized and analyzed following proper methods and statistical tools such as SPSS.

VI. FINDINGS

This study was conducted to find out the impact of using social media on consumer culture among the four hundred forty-five (445) respondents from the students' community who use social media, 63.1 % of respondents were male and the rest were female. The study has found that 92.13 % of respondents have experience of online shopping which indicates that online shopping is increasing day by day. The number of being cheated in online shopping is a staggering 19.33 %, which is a matter of great concern. Concerned authorities need to be more concerned to ensure the safety in online shopping.

The study has found that Facebook, Youtube, WhatsApp, Instagram, and Tiktok are the dominant social media platforms in Bangladesh as shown in Fig. 1. Almost every young person is using at least one social media platform. As the number of social media users is increasing day by day, social media has become an influential platform for businessmen and capitalists to promote and sell their products. They are targeting social media users with different persistent

[1] *Available at: www.mixmarket.org*

advertisements. They are constantly trying to attract their customers through social media influencers to impress them to buy products which can have a great impact on their mindset too.

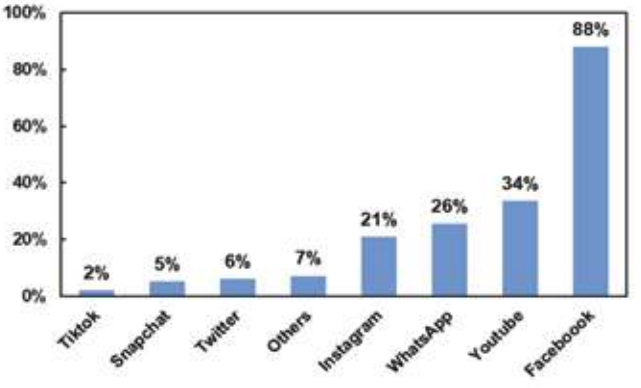

*Fig. 1. Different social media platforms used by the respondents. (*Multiple Response)*

In this study, 34 % of respondents expressed that they are trendy and fashion conscious and 29 % of respondents expressed that though they are not fashion addicts, their friends are. Over 37 % of the respondents expressed they are not fashion trendy. However, some respondents do not claim to be trendy, but their friends think they are (fashion trendy). If we can add them to the fashion trendy category, it shows that right now most of the young people, (more than two-thirds) are fashion trendy.

In this study, 33 % of respondents have expressed that shopping is one of their favorite hobbies. Besides 25 % said that though they don't care about shopping, however, they go to market often as shown in Fig. 2. This figure gave a clear idea that the trend of shopping or practicing consumer culture is quite high which is almost 6 out of every 10 young persons.

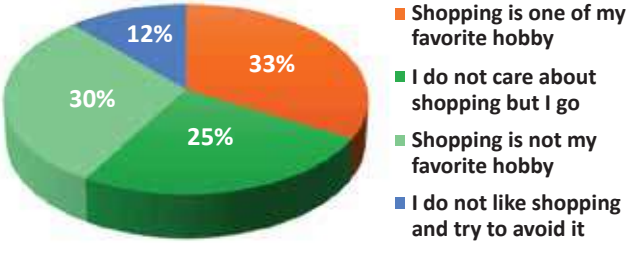

Fig. 2. Shopping habits of the respondents.

The study has discovered that 31 % of respondents are following celebrities on social media, 36 % of respondents are following celebrities sometimes and only 33 % don't follow any celebrity. Following celebrities has both positive and negative impacts on life. Following celebrities sometimes impresses them to buy products which can have a great impact on their mindset too.

This study found that advertisements and content of social media are playing an influential role in shopping decisions of the respondents. 47 % of respondents expressed that they constantly feel the influences of social media on their shopping choices and decisions, and 25 % of respondents feel this influence sometimes. At present, we see that social media influencers and advertisements are available everywhere which has a great impact on the shopping culture of young people. It creates an unstoppable desire to buy products. There is no limit to this demand because fashion trends are changing constantly.

This investigation also discovered that young generations are more interested in online shopping as opposed to traditional in-person shopping. Nearly two-thirds of the respondents (66 %) expressed that they are interested in online shopping as shown in the Fig. 3. Only 7 % expressed that they don't have any interest in online shopping. This is not surprising given the many perceived and real advantages of online shopping over in-person shopping.

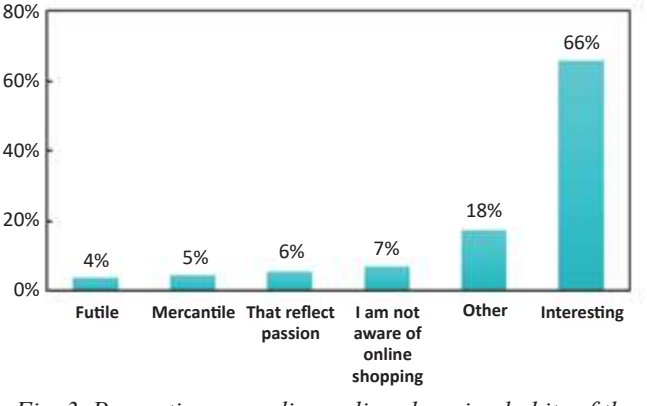

*Fig. 3. Perception regarding online shopping habits of the respondents. (*Multiple Response)*

It was found that the trend of shopping is becoming higher among the young generation. 24 % of respondents are so conscious of fashion trends that they go shopping and look for new trends every day, 13 % of respondents go in every week and 15 % of respondents look for new trends once a month as shown in Fig. 4. In keeping with the general global trend, the younger generation in Bangladesh today seems to be focusing on shopping and new trends more than before. Because of the influence of social media, some young people are persuaded to go for online shopping, even every day. Some of them use social media like Facebook to follow fashion pages, search for brands, discounts and other facilities related to online shopping.

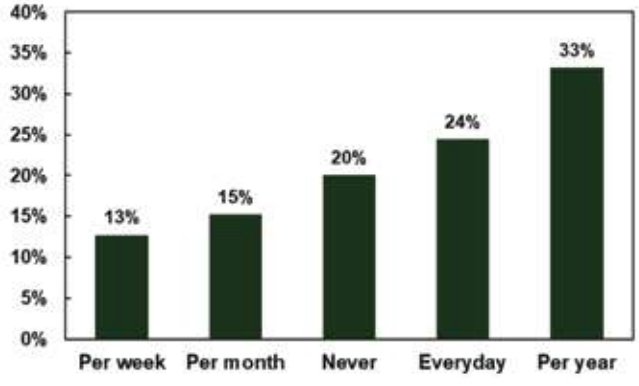

*Fig. 4. Respondents' trend for new fashion trends. (*Multiple Response)*

The study has revealed that 33 % of respondents go for shopping every day as shown in Fig. 5. About 53 % expressed that they go for shopping once every week. It is interesting to note that, as shown in the previous graph, the number of people 'going for shopping' every day (33 %) exceeds the number that 'look for new trends' every day (24.40 %). Likewise, while 13 % go looking for new trends once every week, a far bigger number (53 %) buy fashion products once every week. This suggests that many of these purchases are not necessarily a result of active search for new trends and fashions, but new trends and fashions they stumbled upon while surfing the social media. This is a grave situation because it clearly indicates a high percentage of unplanned online shopping or impulse buying.

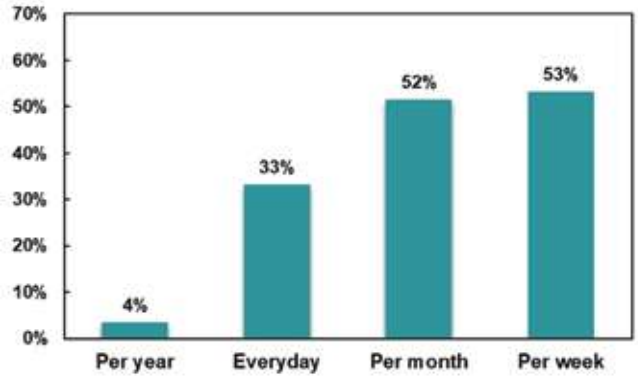

*Fig. 5. Frequency of buying fashion products among the respondents. (*Multiple Response)*

The study found that 23 % of respondents buy products from brands they like through social media as shown in Fig. 6. 25 % of respondents watch videos and photos shared by different fashion brands. 25 % routinely read other people's comments on the fashion page. 16 % recommend fashion brands to their nearest people they like. 3 % of respondents participate in some kind of product-related competition and 23 % of respondents share pictures, videos and news from the brand.

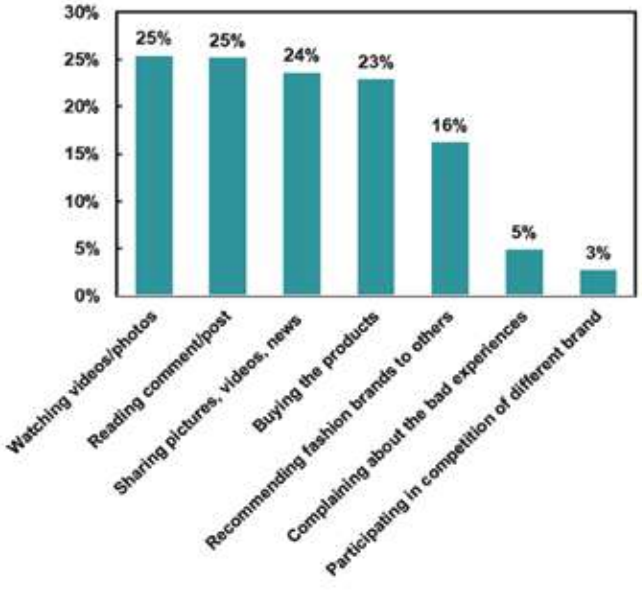

*Fig. 6. The activities of the respondents in social media (*Multiple Response)*

Financial gains, (in this case saving of costs) can be a strong motivation, especially among the respondents of this study, as they are university students. It was found that over half (54 %) of the

respondents follow fashion brands so that they get discounts. 52 % of respondents follow fashion brands to get the latest news about the latest trends. At present, brand value has become very important because the consumers' social status is defined by the brand of products consumed. This may promote a more consumption based society. Consumerism may decrease our happiness because there is no limit to consumerism. New products are coming into the market all the time, and through advertisements and social media influencers, people are influenced to buy more and more products. Brands are giving seasonal or special discounts at different times of the year. The users need to follow the social media platforms and pages so that they don't miss out any information

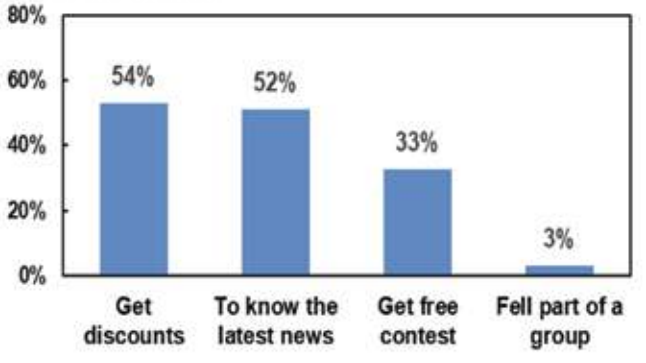

*Fig. 7. Motivation to interact with fashion brands in social media. (*Multiple Response)*

Now a days, among the young generation, demand for specific brands has increased. Nearly 59 % of the respondents insist on specific established products. Among others, a direct consequence is that despite an overall increase in consumerism, the bulk of the business stays with established big brands while small entrepreneurs suffer. Social media platforms are helping in the formation of brand image among the young generation because they believe that using specific brands can determine personality and social status. Almost 72 % of respondents believed that using a specific brand has an impact on social status. Consumerism, therefore, is influenced by a deceptive need (aspiring for a status symbol) rather than a real need among the populace.

VII. DISCUSSION

We are living in an era of globalization. Globalization and capitalism both demand a society based on consumerism. Because the capitalist craves for more capital, they need to sell more. To sell more they need to produce more. However, producing more does not serve the purpose by itself; the surplus product must be consumed. There comes the need for product promotion and create or reinforce a false sense of need. To increase consumption through a false sense of need, the capitalist has to ensure the emergence of needs among the customers through SMI and continuous advertisements.

To ensure that the abundance of products is consumed by the society, the capitalist targets the most vulnerable group first, the young people. We know social media has the capacity to influence peoples' mindsets. That is why companies, capitalists and business houses are increasingly using social media as a platform for their advertisements and product promotion. Often they are competing one other using every means available to them and then creating new ones. As new products come to the market, they hire social media influencers for raising the profile of their products, often appealing to the ego rather than intelligence of the unsuspecting youth. Besides product promotion through the social media platforms, sometimes social media influencers even appear in person at different physical outlets. The influencer is always influencing young people regarding buying products by expressing the positive side of the products. But, promoting a false sense of need through these advertised products, lots of people are being cheated in terms of quality and price offered. Policy makers need to be concerned about these issues.

Policy makers also need to be concerned about social media advertisements because among the young generation, the trend of online shopping using social media has been shown to be high. The majority of the respondents expressed satisfaction with online shopping. Surveys show

that social media encourages shopping. Besides, the young generation seems to be dependent on social media to know about new products, new trends and discounts. They get discounts if they share the link. So, awareness of overconsumption needs to be raised among young people.

VIII. LIMITATIONS OF THE STUDY

Considering the cost of the study, and the available resources of this personally funded study, it was not possible to conduct this research in the whole of Bangladesh. Although Bangladesh is socio-culturally largely homogeneous in nature, only 445 respondents are relatively small sample sizes that may fail to represent the whole country properly. This limitation is likely to be more pronounced because the research participants were purposively selected and a very small number of university students were selected as a respondent. The findings, therefore, are very largely based on responses from 4 university students. Obviously, the rural population has been left outside the preview of this study. Quantitative data may not cover all the insight that such a study rightfully deserves. In order to fully comprehend the effects of social media on the consumer culture of the younger generation, more elaborate qualitative research is needed to complement the data gathered through this study. A longitudinal study could bring to light, the continuum in terms of the consumers' exposures to digital media, social media platforms, online social interactions, and behaviours over an extended period. However, at the very least, this study is anticipated to serve as the starting point for additional follow-up research in the future, taking into account some of the above-mentioned shortcomings. It might not be the complete architecture in all its splendor, but it does offer a base for further investigations.

IX. CONCLUSION

Social media is one of the most dominant advertisement platforms in today's world. This study has revealed the correlation between social media use and online shopping or practicing consumer culture among the youth of Bangladeshi society. Online shopping has become popular among the youths. As social media influencers and advertisements influence their attitudes and purchasing intentions, not always in a beneficial way, policy makers need to be more concerned about the advertisement and promotion of online products. Lots of fraud and cheating events or scams are happening in online shopping. Young people may lose control over their shopping addiction. Besides they may seek happiness only in consumption, trying to satisfy more perceived needs rather than real needs, which may make them more self-centered, conceited, individualistic and wasteful. With the greater social awareness about the problems and pitfalls of online shopping, specially among the youth, the situation can still be improved.

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REFERENCES

[1] J. Dutta and M. Bhattacharya, "Impact of social media influencers on brand awareness: A study on college students of Kolkata," Communications in Humanities and Social Sciences, vol. 3, pp. 27–33, Jul. 2023.

[2] A. N Azman, A. R Ridzwan, S. N. F. F. Ab Ghani, F. Y. Yohya, A. F. Ramlan & M. H. Baker, "The Impact of Social Media Influencers on the Youth in Malaysia," e-Journal of Media and Society, pp. 56-64, 2022.

[3] A. Khanza Zhafira and M. Sigit, "The influence of Discount Framing towards Brand Reputation and Brand Image on Purchase Intention in Somethinc Products at Shopee," International Journal of Science, Technology & Management, vol. 4, pp. 1090-1095, Sep. 2023.

[4] A. Hermida, F. Fletcher, D. Korell, and D. Logan, "SHARE, LIKE, RECOMMEND: Decoding the social media news consumer," Journalism Study, vol. 13, pp. 815–824, 2012.

[5] K. Y. Kwahk and B. Kim, "Effects of social media on consumers' purchase decisions: evidence from Taobao," Service Business, vol. 11, pp. 803–829, Dec. 2017.

[6] W. H. S. Tsai and L. R. Men, "Consumer engagement with brands on social network sites: A cross-cultural comparison of China and the USA," Journal of Marketing Communications, vol. 23, pp. 2–21, Jan. 2017.

[7] J. Donnellan, M. McDonald, and M. Edmondson, "Impact of Social Media on Consumer Buying Patterns," International Journal of Marketing Studies, vol. 12, pp. 71-79, 2020.

[8] S. Ziyadin, R. Doszhan, A. Borodin, A. Omarova, and A. Ilyas, "The role of social media marketing in consumer behaviour," in E3S Web of Conferences, EDP Sciences, vol. 135, pp. 04022, Dec. 2019.

[9] D. S. Wuisan and T. Handra, "Maximizing Online Marketing Strategy with Digital Advertising," Startupreneur Bisnis Digital, vol. 2, pp. 22-30, Feb. 2023.

[10] A. A. Bailey, C. M. Bonifield, and A. Arias, "Social media use by young Latin American consumers: An exploration," Journal of Retailing and Consumer Services, vol. 43, pp. 10–19, Jul. 2018.

[11] D. Voramontri and L. Klieb, "Impact of social media on consumer behaviour," International journal of information and decision sciences, vol. 11, pp. 209-233, Sep. 2019.

[12] X. J. Lim, A. R. bt Mohd Radzol, J.H. (Jacky) Cheah, and M. W. Wong, "The Impact of Social Media Influencers on Purchase Intention and the Mediation Effect of Customer Attitude," Asian Journal of Business Research, vol. 7, Dec. 2017.

[13] M. R. Azkiah and A. Hartono, "The Influence of Social Media Influencers on Consumers' Buying Attitudes and Intentions," Business and Investment Review, vol. 1, pp. 147-167, Jul. 2023.

[14] D. V. Dunas and S. A. Vartanov, "Emerging digital media culture in Russia: modeling the media consumption of Generation Z," Journal of Multicultural Discourses, vol. 15, pp. 186–203, Apr. 2020.

[15] Y. JianAi, C. C. Sze, Y. S. Fern, and C. Y. Wan, "Malaysian Young Consumers' Purchase Intention Through Social Media Platform During Global Pandemic," International Journal of Entrepreneurship, Business and Creative Economy, vol. 2, pp. 14–22, Jan. 2022.

[16] N. I. Suhaimi and N. A. A Rahman, "The Impact of Colourism in Social Media Advertising on Young Consumers' Attitude and Behaviour in Malaysia," Jurnal Pengajian Media Malaysia, vol. 25, pp. 49–66, Jun. 2023.

[17] V. Dutot and J. Lichy, "The Role of Social Media in Accelerating the Process of Acculturation to the Global Consumer Culture," in Research Anthology on Social Media Advertising and Building Consumer Relationships, IGI Global, pp. 1875–1898, 2022.

[18] U. Choudhary, P. Jhamb, and S. Sharma, "Perception of Consumers towards social media practices used by marketers for creating brand loyalty," Academy of Marketing Studies Journal, vol. 23, pp. 1-12, 2019.

[19] S. Alhassan, M. Majeed, A. Gideon, and S. Shani, "The Impact of Social Media on Consumer Purchase Behaviour," Springer Science and Business Media Deutschland GmbH, pp. 163–191, 2023.

[20] P. Iqbal, S. S. Begum, A. Mirza, P. Rani, A. Nagpal, and R. Sharma, "A Study on Impact of Digital Marketing and Social Media on Purchasing Decision of Consumers," International Journal of Membrane Science and Technology, vol. 10, pp. 2330–2340, Oct. 2023.

[21] T. A. Wilska, M. Holkkola, and J. Tuominen, "The Role of Social Media in the Creation of Young People's Consumer Identities," Sage Open, vol. 13, Apr. 2023.

[22] A. M. Al-Ansi, M. Hazaimeh, A. Hendi, J. AL-hrinat, and G. Adwan, "How do social media influencers change adolescents' behaviour? An evidence from Middle East Countries," Heliyon, vol. 9, May 2023.

[23] S. Samuel and T. L. Anita, "The relationship between trends in technology use and

repurchase intention," International Journal of Data and Network Science, vol. 7, pp. 449–456, Dec. 2023.

[24] A. B. Jibril, M. A. Kwarteng, M. Chovancova, and M. Pilik, "The impact of social media on consumer-brand loyalty: A mediating role of online based-brand community," Cogent Business and Management, vol. 6, pp. 1673640, Jan. 2019.

[25] S. Khamis, L. Ang, and R. Welling, "Self-branding, 'micro-celebrity' and the rise of Social Media Influencers," Celebrity Studies, vol. 8, pp. 191–208, Apr. 2017.

[26] R. Palalic, V. Ramadani, S. Mariam Gilani, S. Gërguri-Rashiti, and L. Dana, "Social media and consumer buying behaviour decision: what entrepreneurs should know?," Management Decision, vol. 59, pp. 1249–1270, 2020.

[27] G. Appel, L. Grewal, R. Hadi, and A. T. Stephen, "The future of social media in marketing," J Acad Mark Sci, vol. 48, pp. 79–95, Jan. 2020.

[28] M. N. Nobi, M. S. Rahman, M. M. Ali, A. Obayda, A. Shohel, and T. Tani, "Impact of Social Media Advertising on Buying Decision of Young Group of Consumers in Bangladesh: A Study Dhaka City" Studies of Applied Economics, vol. 41, May 2023.

[29] S. Kamal, S.C. Chu, and M. Pedram, "Materialism, Attitudes, and Social Media Usage and Their Impact on Purchase Intention of Luxury Fashion Goods Among American and Arab Young Generations," Journal of Interactive Advertising, vol. 13, pp. 27–40, Jan. 2013.

[30] M. S. Gul and H. Shahzad, "The Relationship of Social Media with Fashion Consciousness and Consumer Buying Behaviour," Journal of Management Info, vol. 1, pp. 12–20, Jun. 2014.

[31] L. H. Wei, O. C. Huat, and R. Thurasamy, "The impact of social media communication on consumer-based brand equity and purchasing intent in a pandemic," International Marketing Review, pp. 1213-1244, 2023.

[32] K.T. Yeung and J. L. Martin, "The Looking Glass Self: An Empirical Test and Elaboration*," Social Forces, vol. 81, pp. 843-879, Mar. 2003.

[33] M. Waqas, Z. L. Hamzah, and N. A. M. Salleh, "Branded content experience in social media settings: a consumer culture theory perspective," Journal of Brand Management, vol. 29, pp. 225–240, Mar. 2022.

[34] A. King, "A critique of Baudrillard's hyperreality: towards a sociology of postmodernism.'' Philosophy & Social Criticism, vol. 24, pp. 47-66, 1998.

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A REVIEW ON TRANSITION METAL DICHALCOGENIDES BASED PHOTOCATALYTIC HYDROGEN GENERATION: A FUTURE ENERGY SOURCE

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***Abstract*— The exploitation of green and renewable energy sources becomes essential for the environmental sustainability and to face the emerging energy crisis. The implication of H_2 gas instead of non-renewable carbon based fossil fuel has gained immense attention since it is a low-cost, low-energy consuming, and environmentally friendly process. Recently, the generation of H_2 gas via photocatalytic and photoelectrocatalytic water splitting is widely acknowledged owing to its high efficiency. Transition metal dichalcogenide based catalyst is found to be effective catalysts for photochemical water splitting to produce hydrogen. In this review, the recent developments of transition metal dichalcogenide and transition metal dichalcogenide-based nanomaterials for photochemical H_2 production are discussed in detail.**

Keywords*— *Photochemical reaction, Hydrogen generation, Photocatalyst, TMD, Nanocomposite

I. INTRODUCTION

High energy demand and the reduction of sources of fossil fuels have become the most significant challenges facing the twenty-first century. To fulfill the increasing global energy demand while dependence on fossil fuels and mitigating the environmental impact, the adoption of green renewable energy sources is imperative [1]. Combustion of fossil fuels emits carbon dioxide, which has diverse effects on climate change. The process of generating hydrogen through water splitting is considered a pivotal source of clean and renewable energy as it effectively reduces the usage of fossil fuels and, therefore, is capable of propelling progress in the advancement of alternative energy solutions toward achieving net-zero carbon emissions [2, 3]. Consequently, hydrogen has received much attention due to its eco-friendly applications. Additionally, there is a growing research focus on its potential to serve as a future energy source and potentially replace fossil fuels. In catalyst-based water splitting for hydrogen production, there are typically three different types of techniques utilized such as photoelectrochemical, electrochemical, and photochemical in which photochemical and photoelectrochemical transform solar energy directly into chemical energy. Numerous catalysts, including metals, metal carbides, metal oxides, and metal chalcogenides, have been used in photocatalytic water splitting [4, 5]. Among these catalysts transition metal dichalcogenides (TMD) are found to be studied extensively because of their unique structure and chemical properties [6]. TMDs have the common formulae MX_2, where M are the transition metal (Mo, Ti, W, Cr, Mn, etc) and X are the chalcogen (S, Se, Te etc). TMDs are useful in a wide range of fields, including catalysis, photoelectrodes, storage systems and transformation, transistors, photodetectors, optoptoelectronic, secondary

batteries, and catalysis due to their superior catalytic activity, unique structural characteristics, active sites, electrochemical properties, and photophysical attributes, therefore, TMDs have drawn growing scientific attention [7-10]. Numerous promising properties of TMD for hydrogen evolution reactions have also been investigated, such as band offsets [11], active edge effects [12], and the phase transition from a semiconductor (2H) to metallic (1T) phase [13]. In addition, the band gap electrical properties, and conductivities of TMDs are thickness-dependent.

Though TMDs have drawn much attention, inappropriate band alignment, rapid charge carrier combination, and a lack of active sites for hydrogen reduction are the main causes of low catalytic activities [14]. Numerous synthetic and technical methods have been developed to overcome these limitations of TMDs. These methods include heteroatom doping (such as Cr- or Pt-doped MoS_2), the production of multinary chalcogenides and dichalcogenides, fabrication of heterojunctions, crystal phase transition, and morphology tuning, all aimed at reducing charge carrier recombination and increasing catalytic activity [15]. To create active sites for surface reactions and promote the separation of photogenerated charge carriers, a variety of co-catalysts (Pt, Au, Co_2P, Fe_2P, Cu_2P, etc.) are frequently used [16]. It has been established that the inclusion of a co-catalyst efficiently increases the active sites for H^+ ions (or H_2O) at the catalyst surface and lowers the energy barrier for hydrogen evolution [17]. In this review, we discussed the photocatalytic generation of H_2 from water using different TMDs and their nanocomposites and discussed the effect of structural parameters of TMDs on H_2 generation.

II. PHOTOCATALYTIC HYDROGEN EVOLUTION MECHANISM

The mechanism of photocatalytic water splitting, which is similar to the process of photosynthesis in living things powered by sunlight, is regarded as artificial photosynthesis. [18]. Photocatalysis is the process by which photonic energy is changed into chemical energy. This photocatalytic system typically needs a reactant, photocatalyst, photoreactor, and light source. Utilizing the sunlight that strikes the planet's surface every day, the generation of hydrogen from organic compounds in water could be accomplished using the theory of photocatalytic reactions [19]. The water-splitting process encourages the accumulation of Gibbs's free energy throughout this reaction. Two techniques are used in the photocatalytic process to produce hydrogen: (i) photocatalytic reforming of organics and (ii) photocatalytic water splitting. Water splitting performs a redox reaction with electrons/holes in the first phase, however, in the second phase, organic materials give electrons and oxidize to produce proton ions [20]. By using electrons on the photocatalyst, the proton ions are ultimately converted into H_2. Water itself in a mixture containing a sacrificial reagent can behave as the reactant. However, photocatalysts that absorb visible light may ensure that they will collect a considerable portion of the energy generated by sunlight therefore, photocatalysts must be operated with light of either ultraviolet light or visible region [21]. An effective interaction between light, catalysts, and reactants would be required for efficient hydrogen synthesis [22, 23].

The photocatalytic water-splitting mechanism that produces hydrogen is illustrated in Fig. 1 [24]. Four main mechanisms comprise photocatalytic water splitting: light acquisition, charge stimulation, charge separation and transmission, and surface catalytic reaction [25]. Initially, the reaction is initiated by the absorption of a photon with the proper energy, which excites electrons from the valence band maximum (VBM) to the conduction band minimum (CBM), where a semiconductor's band gap should be higher than 1.23 eV. At the surface active sites water is oxidized to produce oxygen while water is reduced to hydrogen by the electrons.

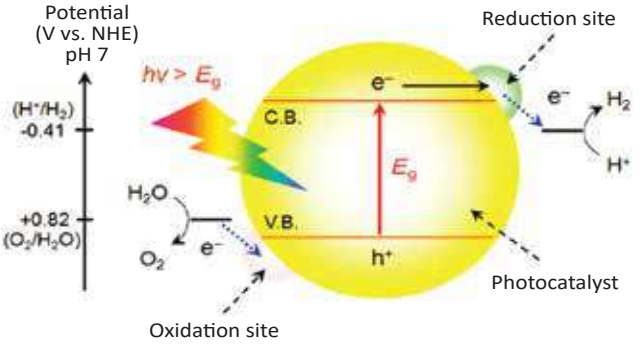

Fig. 1. A schematic representation of water splitting over a photocatalyst [26].

The overall reaction mechanism is as follows; equation (1) describes how the photocatalyst produces e^-/h^+ pairs when exposed to the proper photon excitation, which triggers electronic transitions (Fig. 1). The electrons are then stimulated from the VBM to the CBM, leaving holes in the VBM and the oxidation and reduction reactions with water takes place due to the photo-generated electrons, and holes. Redox reactions take place on the surface of the photocatalyst when the reduction and oxidation potentials are, respectively, above and below the CBM and VBM levels. The oxidation reaction includes the breakdown of water into H^+ as illustrated by the electron to form H_2. As shown in Eq. (3), (4), and (5) photo-excited holes are strong oxidants that may oxidize both water and organic materials like alcohol. At room temperature, the process of water splitting can be achieved by utilizing a photocatalyst and light irradiation with energy greater than the band gap. The reaction can be carried out with thermal dissociation of water at temperatures higher than 2070 K.

$$\text{Catalyst} \rightarrow \text{Catalyst}\ (e^- + h^+) \quad (1)$$

$$\text{Catalyst}\ (e^- + h^+) \rightarrow \text{Catalyst} \quad (2)$$

$$H_2O + h^+ \rightarrow O_2 + 2H^+ \quad (3)$$

$$2e^- + 2H^+ \rightarrow H_2 \quad (4)$$

$$RCH_2OH + h^+ \rightarrow RCH_2OH + 2H^+ \quad (5)$$

The recombination process, however, is the biggest obstacle to photocatalytic water splitting. As shown in Eq. (2), The electron-hole pairs could recombine with the discharge of waste heat. As a result, it is less effective for the H_2 generation. Due to the rapid recombination of photo-generated charge carriers, it is challenging to perform water splitting for H_2 production utilizing photo-catalysts, especially in distilled water. Therefore, sacrificial reagents (ethanol, methane, glycerol, and methanol) and electrolytes are typically included when photocatalytic water splitting is explored. The CBM electrons and VBM holes are not reducing or oxidizing the electrolytes. Electrolytes carry ions and move electrons from one semiconductor to another. This means that they will improve photocatalytic water-splitting reactions. To improve charge separation, the sacrificial reagent or electron donors react with the VBM holes [27]. The performance of photocatalytic activity can be increased by studying thermodynamic analysis, considering factors such as energy levels, band gap, and redox potential. This approach is crucial since there are inherent limitations when it comes to generating H_2 from pure water.

III. PREPARATION OF TMD-BASED COMPOSITES

Transition metal dichalcogenides are generally synthesized through various methods, including chemical vapor deposition, liquid-phase exfoliation, and hot injection method or chemical intercalation, enabling the controlled fabrication of two-dimensional nanostructures with diverse electronic and optical properties. Distinctive properties have been found when TMDs are modified by combining with other functional nanomaterials, such as semiconductors, metallic nanoparticles [28, 29], carbon-based materials, metal oxides, etc. [30]. An overview of the most recent progress in TMD materials synthesized by different methods, which have emerged as an attractive new class of materials for photocatalytic activity is summarized in Table I.

A. EXFOLIATION METHOD

Exfoliation is a process used to separate and isolate individual layers or sheets from a bulk

material, typically in the context of two-dimensional (2D) materials like TMDs. TMD have the structural formula of MX_2, where M is a transition metal (W, Ti, Mo, Nb, etc.) and X_2 is a chalcogen element (S, Se, or Te). TMD monolayers have the structural formula X-M-X, with two planes of chalcogen atoms sandwiching a hexagonally packed plane of metal atoms [31]. Transition metal dichalcogenides have weak Van der Waals bonds outside of planes and strong in-layer bonding similar to graphite. TMD layered structure and weak Van der Waals contact with the transition metal chalcogenide make it easier for monolayers to form through physical and chemical means [32]. The two types of exfoliation methods are physical exfoliation and chemical exfoliation. Physical exfoliation is regarded as one of the most popular techniques for separating materials into their 2D geometry while keeping key characteristics, and without changing the crystal phase or chemical structure of the TMD. The main factors taken into account include a variety of external pressures such as ultrasonification, shear mixing, and the huge growth of supercritical solutions. Exfoliation is often done in liquid form by dissolving components in a solvent and then applying external forces. Microcavities are produced in the solution as a result of the process known as sonication, which tends to cause high-frequency pressure differences. The exfoliation of TMD is primarily caused by shear stresses generated by the collapse of the cavities as shown in Fig. 2. Choosing the appropriate solvent is crucial in liquid-based exfoliation. An effective solvent has the capability to reduce the interlayer potential energy required to overcome attractive Van der Waals forces, and its interaction with the nanosheet helps maintain a delicate equilibrium that counteracts the attractive forces between the layers, thus preventing them from reassembling.

Coleman's group was the first to describe the exfoliation of TMD using solvents. They discovered promising solvents are N-methyl-pyrrolidone (NMP) and isopropanol (IPA). MoS_2 and WS_2 were found to have maximum concentrations of 0.15 mg/mL and 0.3 mg/mL in NMP following different method optimization. According to Sukumaran *et al.*, water is essential for the stability of MoS_2 in NMP. MoS_2 nanosheet can break in NMP when there is no water present [34]. The edge of TMD can be oxidized by the addition of H_2O_2 to an organic solvent, increasing the interplanar distance and promoting exfoliation.

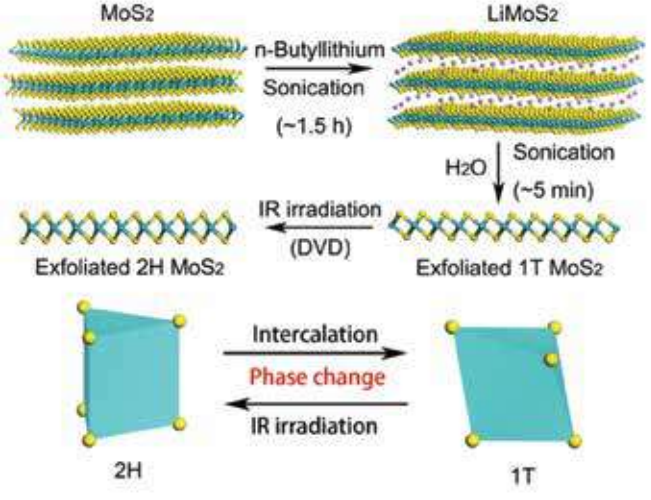

Fig. 2. Schematic diagram for the synthesis of exfoliated 2H MoS_2 [33]

B. HOT INJECTION METHOD

The 'hot-injection method' is a widely employed synthesis technique for preparing high-quality TMDs in the form of nanocrystals or nanosheets. This method allows precise control over the size, morphology, and properties of the TMD materials. The most suitable example is the preparation of molybdenum disulfide (MoS_2) nanosheets by using hot-injection methods. The hot-injection method for preparing MoS_2 nanosheets involves dissolving ammonium tetrathiomolybdate, a precursor, in a high-boiling-point solvent, typically oleylamine, and heating it to 200-300 °C under an inert atmosphere. Simultaneously, a highly reactive reducing agent solution, often n-butyl lithium in a nonpolar solvent, is prepared separately. The key step involves a rapid injection of the

reducing agent into the hot precursor solution, initiating nucleation and controlled growth of MoS_2 nanosheets. This results in the formation of monodisperse MoS_2 nanosheets. Post-synthesis, purification techniques like centrifugation and washing can be employed to refine the nanosheets further [35]. In addition to hot injection, X. Zhou *et al.* [36] synthesized hierarchical ultrathin $MoSe_{2-x}$ nanosheets with a thickness of 2–5 Se–Mo–Se atomic layers under mild conditions as shown in Fig. 3.

In the test of photocatalytic hydrogen evolution rate (HER), the nanohybrids showed good photocatalytic HER performance. Using the hot-injection technique and the heating-up method, recently a number of synthetic ways to produce a variety of TMD, including TiS_2, ZrS_2, WS_2, MoS_2, and WS_2, with precisely controlled layer counts and shape [37]. These significant findings could serve as valuable guidelines for the creation of diverse TMD-based composites for HER.

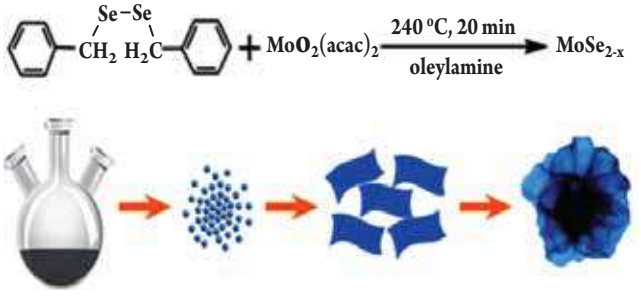

Fig. 3. A schematic diagram of the formation process of hierarchical ultrathin $MoSe_{2-x}$ nanosheets by hot injection method.

C. TMD-BASED NANO-COMPOSITES

TMD based composites offer enhanced photocatalytic activity and enable efficient utilization of solar energy for clean hydrogen production. Figure 4 shows the schematic that illustrates the general theory of dye and semiconductor hydrogen evolution in 2D-MX_2.

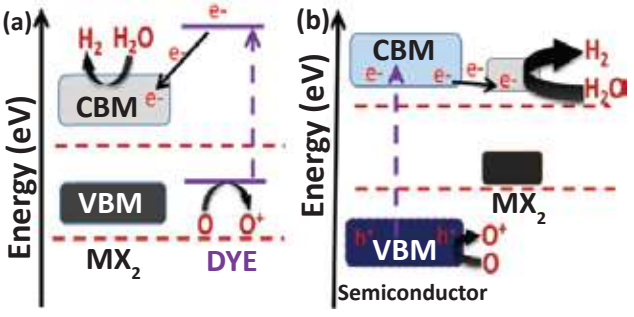

Fig. 4. The schematic illustration of the general concept of semiconductor mediated hydrogen evolution method, (a) with dye or organic system (b) only semiconductor system [38].

Research has shown that surface modification of semiconductors by the addition of co-catalysts can speed up the reaction by supplying active and reaction sites, inhibiting charge recombination, and lowering the activation barriers for H_2 or O_2 generation [39]. As a result, the photocatalytic activity is greatly increased, in addition, co-catalysts can improve catalyst photostability by quickly consuming photogenerated charges, particularly holes [40]. To increase the photocatalytic hydrogen evolution activity, a lot of work has been put into developing TMD-based composites since TMD nanosheets are less expensive than noble metals. The process that is most frequently used to prepare TMD-based composites is the hydro (solvo) thermal method. This method provides an effective means to produce numerous composites based on TMD. It allows for the use of various metal sources, ligands, surfactants, and solvents to customize the size and shape of these composites within specific parameters. This method has been used to prepare a number of TMD-based composites, such as S_2/CdS, MoS_2/TiO_2, $MoS_2/ZnIn_2S_4$, MoS_2/G/CdS, and ZnS/G/ MoS_2 [41-43].

IV. EFFECTS OF DIFFERENT STRUCTRAL PARAMETERS ON THE EFFICIENCY OF HYDROGEN EVOLUTION REACTION

Researchers have employed various synthesis methods to tune the structural properties, e.g.,

size, shape, and have invesigated the effects of them on photocatalytic H_2 evolution.

A. SIZE AND SHAPE BASED INVESTIGATION

Shape and size analysis plays an important role in determining the catalytic activity of TMDs in hydrogen evolution reactions. The surface-active site of semiconductor-based materials is an essential property of the catalytic activity. It depends on the surface atom configurations and crystal structures. Recently, a number of techniques have been used to manufacture nanostructures with specified shapes and crystal sides. The synthesis of different kinds of nanocrystals shows exclusive catalytic activity, provides a large number of active sites, and increases their productivity [44]. A prime example is molybdenum disulfide (MoS_2) nanosheets. When synthesized as nanosheets with specific shapes and sizes, MoS_2 exhibits enhanced catalytic activity for hydrogen evolution. In a study Liu *et al.* studied the importance of shape and size on the catalytic efficiency of TMD for sustainable hydrogen production where excellent catalytic efficiency with a hydrogen evolution rate of 3,500 mmole g^{-1} h^{-1} were obtained by MoS_2 nanosheets synthesized via a hydrothermal method [45].

B. EFFECT OF DOPING ON CATALYTIC PROCESS

Doping methods are techniques used to intentionally introduce specific atoms or molecules into a semiconductor material. This process is carried out to modify or enhance the material's electrical, optical, or chemical properties. Doping can be used to control the conductivity, bandgap, and other properties of semiconductor materials, making them suitable for various electronic, photonic, or catalytic applications. Analyzing the impact of doping methods on TMD for hydrogen evolution, doping plays a critical role in tailoring their performance as catalysts. Nitrogen doping is a widely used method in TMD catalysts. When nitrogen atoms are incorporated into the crystal lattice of TMD, they can modify the electronic structure and surface properties of the material. This alteration enhances the catalytic activity of TMD for the hydrogen evolution reaction. In a study by Jiao *et al.* they investigated the impact of nitrogen doping on TMD like molybdenum disulfide (MoS_2) and tungsten disulfide (WS_2) as catalysts for hydrogen evolution [46]. Nakamura *et al.* found that, nitrogen doping enhanced the catalytic properties of MoS_2 catalysts [47]. This precise nitrogen doping led to a significant increase in hydrogen evolution efficiency, with an impressive rate of 50 m mole $g^{-1}h^{-1}$ achieved. The results demonstrated the effectiveness of doping methods in enhancing TMD catalytic activity, illustrating their significance in advancing sustainable hydrogen production processes.

TABLE I. TMD-based photocatalysts for photocatalytic hydrogen evolution

Sl No	Catalyst (photo catalyst)	Synthesis Method	Sacrificial electron donor	Hydrogen evolution activity	Ref
1	WS_2/ CdS	Impregnation and calcination methods	---	4200 m mole $g^{-1}h^{-1}$	[50]
2	MoS_2/ RGO	Hydrothermal method	---	4190 m mole $g^{-1}h^{-1}$	[51]
3	MoS_2g-C_3N_4	Impregnation method	---	231 m mole $g^{-1}h^{-1}$	[52]
4	MoS_2/ TiO_2	Hydrothermal method	---	16 700 m mole $g^{-1}h^{-1}$	[53]
5	TiO_2/ MoS_2/G	Hydrothermal method	---	2066.25 m mole $g^{-1}h^{-1}$	[54]
6	MoS_2/ CdS	Solvothermal method	---	6850 m mole $g^{-1}h^{-1}$	[55]
7	2D-MoS_2/ CdS	Solvothermal method	Lactic acid	0. 137 m mol $g^{-1}h^{-1}$	[56]
8	CdS/CoS_2 /P	Hydrothermal method	Na_2S and Na_2SO_3	0.0578 m mole $g^{-1}h^{-1}$	[57]
9	ZnS–rGO/ MoS_2	Hydrothermal method	0.005 M Na_2SO_3	2.258 m mole $g^{-1}h^{-1}$	[58]
10	CdSAu/ MoS_2	Solvothermal + Hydrothermal	Lactic acid	7.00 m mole $g^{-1}h^{-1}$	[59]

C. P-N HETEROJUNCTION

The p-n heterojunction is a type of semiconductor device that plays a crucial role in modern electronics and optoelectronics. Compared to other

types of heterojunctions, p-n heterojunctions offer superior electron-hole separation due to the presence of an internal electric field. This electric field arises at the interface of p-type and n-type semiconductors, and it accelerates the separation of electron-hole pairs across the interface. As a result, p-n heterojunctions are commonly used in solar cells, light-emitting diodes, and other electronic devices.

Moreover, it is to be mentioned that p-n heterojunction is thermodynamically more favorable than the type-II heterojunction, as the former creates a higher potential barrier. In a recent study, Keyu Si *et al.* [48] have constructed a novel type of p-n heterojunction using two-dimensional materials. The team synthesized p-type MoS_2 and n-type WSe_2 monolayers and then stacked them on top of each other to create a p-n heterojunction. It was found that the p-n heterojunction exhibited excellent electrical properties, with a high rectification ratio and low leakage current. The team also observed a significant enhancement of the photoluminescence intensity and lifetime in the heterojunction compared to the individual monolayers. These results demonstrate the potential of two-dimensional p-n heterojunctions for use in next-generation electronic and optoelectronic devices.

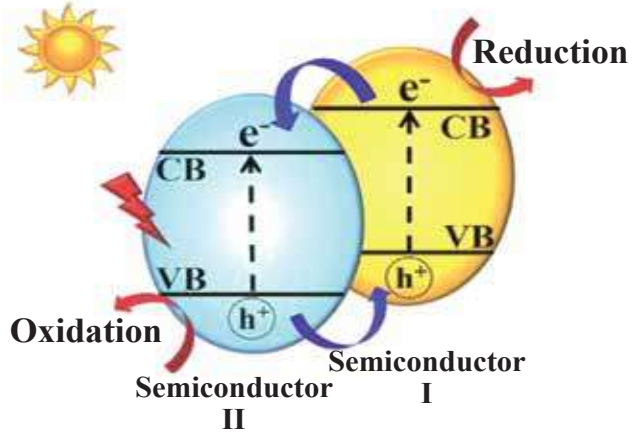

Fig. 5. Schematic illustration of p-n heterojunction photocatalyst [49].

VI. CONCLUDING REMARKS

The generation of hydrogen by water splitting is a promising way for sustainable and environmentally friendly energy production. The utilization of TMD composites as photocatalysts for hydrogen generation represents a rapidly advancing field with tremendous potential. In this review recent advances on fabrication techniques and photocatalytic properties of TMDs along with the composited of TMDs when combined with various materials are highlighted. However, it is important to acknowledge that while significant strides have been made, the exploration of 2D layered TMD composites for photocatalysis is still in its early stages. Therefore, still it remains a challenge to develope more efficient and robust TMD based photocatalysts for practical application in future. We foresee that in the upcoming decades, TMDs will emerge as a key material in the field of photocatalysis to address the energy and environmental challenges.

REFERENCES

[1] S. Chu and A. Majumdar, "Opportunities and challenges for a sustainable energy future," Nature, vol. 488, pp. 294-303, Aug. 2012.

[2] K. A. Davis, S. Yoo, E. W. Shuler, B. D. Sherman, S. Lee, and G. Leem, "Photocatalytic hydrogen evolution from biomass conversion," Nano Converg., v ol. 8, pp. 6, Feb. 2021.

[3] Q. Wang and K. Domen, "Particulate Photocatalysts for Light-Driven Water Splitting: Mechanisms, Challenges, and Design Strategies," Chem. Rev., vol. 120, pp. 919–985, Jan. 2020.

[4] H. V. S. R. M. Koppisetti, S. Ganguli, S. Ghosh, H. R. Inta, G. Tudu, and V. Mahalingam, "Fe-Rich $Ni_{0.06}Fe_{0.94}OOH$ Nanorods as Efficient Electrocatalysts for the Oxygen Evolution Reaction," ACS Appl. Energy Mater., vol. 5, pp. 1681–1689, Feb. 2022.

[5] R. Shen et al., "Carbon Nanotube-Supported Cu_3P as High-Efficiency and Low-Cost Cocatalysts for Exceptional Semiconductor-Free Photocatalytic H_2 Evolution," ACS Sustain. Chem. Eng., vol. 7, pp. 3243–3250, Feb. 2019.

[6] M. Tekalgne, A. Hasani, Q. v an Le, and S. Y. Kim, "Transition metal dichalcogenide- based

composites for hydrogen production," Funct. Compos. Struct., vol. 1, 2019.

[7] D. Voiry, J. Yang, and M. Chhowalla, "Recent Strategies for Improving the Catalytic Activity of 2D TMD Nanosheets Toward the Hydrogen Evolution Reaction," Adv. Mater., vol. 28, no. 29, pp. 6197–6206, 2016.

[8] Q. Lu, Y. Yu, Q. Ma, B. Chen, and H. Zhang, "2D Transition- Metal- Dichalcogenide-Nanosheet- Based Composites for Photocatalytic and Electrocatalytic Hydrogen Evolution Reactions," Adv. Mater., vol. 28, pp. 1917–1933, 2016.

[9] J. Chen et al., "One-pot Synthesis of CdS Nanocrystals Hybridized with Single-Layer Transition-Metal Dichalcogenide Nanosheets for Efficient Photocatalytic Hydrogen Evolution," Angew. Chem., vol. 127, pp. 1226–1230, 2015.

[10] X. Cao, C. Tan, X. Zhang, W. Zhao, and H. Zhang, "Solution-Processed Two-Dimensional Metal Dichalcogenide-Based Nanomaterials for Energy Storage and Conversion," Adv. Mater., vol. 28, pp. 6167–6196, 2016.

[11] H. Li, Y. Shi, M.-H. Chiu, and L.-J. Li, "Emerging energy applications of two-dimensional layered transition metal dichalcogenides," Nano Energy, vol. 18, pp. 293–305, Nov. 2015.

[12] T. F. Jaramillo, K. P. Jørgensen, J. Bonde, J. H. Nielsen, S. Horch, and I. Chorkendorff, "Identification of active edge sites for electrochemical H_2 evolution from MoS_2 nanocatalysts," Science, vol. 317, pp. 100–102, Jul. 2007,

[13] B. Mahler, V. Hoepfner, K. Liao, and G. A. Ozin, "Colloidal Synthesis of 1T-WS_2 and 2H-WS_2 Nanosheets: Applications for Photocatalytic Hydrogen Evolution," J. Am. Chem. Soc., vol. 136, pp. 14121–14127, Oct. 2014.

[14] B. Hinnemann et al., "Biomimetic Hydrogen Evolution: MoS_2 Nanoparticles as Catalyst for Hydrogen Evolution," J. Am. Chem. Soc., vol. 127, pp. 5308–5309, Apr. 2005.

[15] M. D. Sharma, C. Mahala, B. Modak, S. Pande, and M. Basu, "Doping of MoS_2 by 'Cu' and 'V': An Efficient Strategy for the Enhancement of Hydrogen Evolution Activity," Langmuir, vol. 37, pp. 4847–4858, Apr. 2021.

[16] W. Feng et al., "Tuning the interfacial electronic structure via Au clusters for boosting photocatalytic H_2 evolution," J. Mater. Chem. A, vol. 9, pp. 1759–1769, Jan. 2021.

[17] J. Kang, S. Tongay, J. Zhou, J. Li, and J. Wu, "Band offsets and heterostructures of two-dimensional semiconductors," Appl. Phys. Lett., vol. 102, pp. 012111, Jan. 2013.

[18] N. Shi, X. Li, T. Fan, H. Zhou, D. Zhang, and H. Zhu, "Artificial chloroplast: Au/chloroplast-morph-TiO_2 with fast electron transfer and enhanced photocatalytic activity," Int. J. Hydrog. Energy, vol. 39, pp. 5617–5624, Apr. 2014.

[19] L. Clarizia, D. Spasiano, I. Di Somma, R. Marotta, R. Andreozzi, and D. D. Dionysiou, "Copper modified- TiO_2 catalysts for hydrogen generation through photoreforming of organics. A short review," Int. J. Hydrog. Energy, vol. 39, pp. 16812–16831, Oct. 2014.

[20] R. Abe, "Recent progress on photocatalytic and photoelectrochemical water splitting under visible light irradiation," J. Photochem. Photobiol. C Photochem. Rev., vol. 11, pp. 179–209, Dec. 2010.

[21] M. Tahir and N. S. Amin, "Advances in visible light responsive titanium oxide-based photocatalysts for CO_2 conversion to hydrocarbon fuels," Energy Convers. Manag., vol. 76, pp. 194–214, Dec. 2013.

[22] N. Chouhan, R. Ameta, R. K. Meena, N. Mandawat, and R. Ghildiyal, "Visible light harvesting Pt/CdS/Co-doped ZnO nanorods molecular device for hydrogen generation," Int. J. Hydrog. Energy, vol. 41, pp. 2298–2306, Jan. 2016.

[23] T. Grewe, M. Meggouh, and H. Tüysüz, "Nanocatalysts for Solar Water Splitting and a Perspective on Hydrogen Economy," Chem. – Asian J., vol. 11, pp. 22–42, 2016.

[24] Y. Xu and R. Xu, "Nickel-based cocatalysts for photocatalytic hydrogen production," Appl. Surf. Sci., vol. 351, pp. 779–793, Oct. 2015.

[25] J. Wen, J. Xie, X. Chen, and X. Li, "A review on g-C3N4-based photocatalysts," Appl. Surf. Sci., vol. 391, pp. 72–123, Jan. 2017.

[26] K. Maeda and K. Domen, "Photocatalytic water splitting: Recent progress and future challenges," J. Phys. Chem. Lett., vol. 1, pp. 2655–2661, 2010.

[27] C. Acar, I. Dincer, and C. Zamfirescu, "A review on selected heterogeneous photocatalysts for hydrogen production," Int. J. Energy Res., vol. 38, no. 15, pp. 1903–1920, 2014.

[28] X. Huang, C. Tan, Z. Yin, and H. Zhang, "25th Anniversary Article: Hybrid Nanostructures Based on Two-Dimensional Nanomaterials," Adv. Mater., vol. 26, no. 14, pp. 2185–2204, 2014.

[29] C. Tan and H. Zhang, "Two-dimensional transition metal dichalcogenide nanosheet-based composites," Chem. Soc. Rev., vol. 44, pp. 2713–2731, Apr. 2015.

[30] W. Zhou et al., "Synthesis of Few-Layer MoS_2 Nanosheet-Coated TiO_2 Nanobelt Heterostructures for Enhanced Photocatalytic Activities," Small, vol. 9, pp. 140–147, 2013.

[31] H. Li et al., "Mechanical Exfoliation and Characterization of Single- and Few-Layer Nanosheets of WSe_2, TaS_2, and $TaSe_2$," Small, vol. 9, pp. 1974–1981, 2013.

[32] Q. H. Wang, K. Kalantar-Zadeh, A. Kis, J. N. Coleman, and M. S. Strano, "Electronics and optoelectronics of two-dimensional transition metal dichalcogenides," Nat. Nanotechnol., vol. 7, pp. 699-712, Nov. 2012.

[33] X. Fan et al., "Fast and Efficient Preparation of Exfoliated 2H MoS_2 Nanosheets by Sonication-Assisted Lithium Intercalation and Infrared Laser-Induced 1T to 2H Phase Reversion," Nano Lett., vol. 15, pp. 5956–5960, Sep. 2015.

[34] A. Gupta, V. Arunachalam, and S. Vasudevan, "Liquid-Phase Exfoliation of MoS_2 Nanosheets: The Critical Role of Trace Water," J. Phys. Chem. Lett., vol. 7, pp. 4884–4890, Dec. 2016.

[35] X. Zhu et al., "Exfoliation of MoS_2 Nanosheets Enabled by a Redox- Potential- Matched Chemical Lithiation Reaction," Nano Lett., vol. 22, pp. 2956–2963, Apr. 2022.

[36] X. Zhou et al., "Fast colloidal synthesis of scalable Mo-rich hierarchical ultrathin $MoSe_2$-x nanosheets for high-performance hydrogen evolution," Nanoscale, vol. 6, pp. 11046–11051, Sep. 2014.

[37] O. Samy, S. Zeng, M. D. Birowosuto, and A. El Moutaouakil, "A Review on MoS_2 Properties, Synthesis, Sensing Applications and Challenges," Crystals, vol. 11, p. 355, Mar. 2021.

[38] U. Gupta and C. N. R. Rao, "Hydrogen generation by water splitting using MoS_2 and other transition metal dichalcogenides," Nano Energy, vol. 41, pp. 49–65, Nov. 2017.

[39] J. Yang, D. Wang, H. Han, and C. Li, "Roles of Cocatalysts in Photocatalysis and Photoelectrocatalysis," Acc. Chem. Res., vol. 46, pp. 1900–1909, Aug. 2013.

[40] J. Ran, J. Zhang, J. Yu, M. Jaroniec, and S. Z. Qiao, "Earth-abundant cocatalysts for semiconductor-based photocatalytic water splitting," Chem. Soc. Rev., vol. 43, pp. 7787–7812, Oct. 2014.

[41] J. Zhang, Z. Zhu, and X. Feng, "Construction of Two-Dimensional MoS_2/CdS p–n Nanohybrids for Highly Efficient Photocatalytic Hydrogen Evolution," Chem. Eur. J., vol. 20, pp. 10632–10635, 2014.

[42] M. Shen, Z. Yan, L. Yang, P. Du, J. Zhang, and B. Xiang, "MoS_2 nanosheet/TiO_2 nanowire hybrid nanostructures for enhanced visible-light photocatalytic activities," Chem. Commun., vol. 50, pp. 15447–15449, Nov. 2014.

[43] C. Liu et al., "Vertical single or few-layer MoS_2 nanosheets rooting into TiO_2 nanofibers for highly efficient photocatalytic hydrogen evolution," Appl. Catal. B Environ., vol. 164, pp. 1–9, Mar. 2015.

[44] C. Li, L. Han, R. Liu, H. Li, S. Zhang, and G. Zhang, "Controlled synthesis of CdS micro/nano leaves with (0001) facets exposed: enhanced photocatalytic activity toward

hydrogen evolution," J. Mater. Chem., vol. 22, pp. 23815–23820, Oct. 2012.

[45] D. Wang, Z. Pan, Z. Wu, Z. Wang, and Z. Liu, "Hydrothermal synthesis of MoS_2 nanoflowers as highly efficient hydrogen evolution reaction catalysts," J. Power Sources, vol. 264, pp. 229–234, Oct. 2014.

[46] Y. Jiao, Y. Zheng, M. Jaroniec, and S. Z. Qiao, "Design of electrocatalysts for oxygen- and hydrogen-involving energy conversion reactions," Chem. Soc. Rev., vol. 44, pp. 2060–2086, Apr. 2015.

[47] R. Li et al., "Nitrogen doped MoS_2 nanosheets synthesized via a low-temperature process as electrocatalysts with enhanced activity for hydrogen evolution reaction," J. Power Sources, vol. 356, pp. 133–139, Jul. 2017.

[48] K. Si et al., "A two-dimensional MoS_2/WSe_2 van der Waals heterostructure for enhanced photoelectric performance," Appl. Surf. Sci., vol. 507, pp. 145082, Mar. 2020.

[49] J. Low, B. Cheng, and J. Yu, "Surface modification and enhanced photocatalytic CO_2 reduction performance of TiO_2: a review," Appl. Surf. Sci., vol. 392, pp. 658–686, Jan. 2017.

[50] J. He, L. Chen, Z.-Q. Yi, C.-T. Au, and S.-F. Yin, "CdS Nanorods Coupled with WS_2 Nanosheets for Enhanced Photocatalytic Hydrogen Evolution Activity," Ind. Eng. Chem. Res., vol. 55, pp. 8327–8333, Aug. 2016.

[51] U. Maitra, U. Gupta, M. De, R. Datta, A. Govindaraj, and C. N. R. Rao, "Highly effective visible-light-induced H_2 generation by single-layer 1T-MoS_2 and a nanocomposite of few-layer 2H-MoS_2 with heavily nitrogenated graphene," Angew. Chem. Int. Ed., vol. 52, pp. 13057–13061, Dec. 2013.

[52] M. Wang, P. Ju, J. Li, Y. Zhao, X. Han, and Z. Hao, "Facile Synthesis of MoS_2/g-C_3N_4/GO Ternary Heterojunction with Enhanced Photocatalytic Activity for Water Splitting," ACS Sustain. Chem. Eng., vol. 5, pp. 7878–7886, Sep. 2017.

[53] S. Shanmugaratnam, D. Velauthapillai, P. Ravirajan, A. A. Christy, and Y. Shivatharsiny, "CoS_2/TiO_2 Nanocomposites for Hydrogen Production under UV Irradiation.," Mater. Basel Switz., vol. 12, p. E3882, Nov. 2019.

[54] D. Cao et al., "Hydrothermal construction of flower-like MoS_2 on TiO_2 NTs for highly efficient environmental remediation and photocatalytic hydrogen evolution," Sep. Purif. Technol., vol. 265, pp. 118463, Jun. 2021.

[55] X. Zong et al., "Photocatalytic H_2 Evolution on MoS_2/CdS Catalysts under Visible Light Irradiation," J. Phys. Chem. C, vol. 114, pp. 1963–1968, Jan. 2010.

[56] J. Zhang, Z. Zhu, and X. Feng, "Construction of Two-Dimensional MoS_2/CdS p–n Nanohybrids for Highly Efficient Photocatalytic Hydrogen Evolution," Chem. Eur. J., vol. 20, pp. 10632–10635, 2014.

[57] H. Huang et al., "Bridging localized electron states of pyrite-type CoS_2 cocatalyst for activated solar H_2 evolution," Nano Res., vol. 15, pp. 202–208, Jan. 2022.

[58] B. Zhu et al., "Enhanced photocatalytic H_2 evolution on ZnS loaded with graphene and MoS_2 nanosheets as cocatalysts," J. Mater. Chem. A, vol. 2, pp. 3819–3827, Feb. 2014.

[59] R. K. Chava, J. Y. Do, and M. Kang, "Smart Hybridization of Au Coupled CdS Nanorods with Few Layered MoS_2 Nanosheets for High Performance Photocatalytic Hydrogen Evolution Reaction," ACS Sustain. Chem. Eng., vol. 6, pp. 6445–6457, May 2018.

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A DESCRIPTIVE STATISTICAL STUDY ON THE VOLATILITY OF THE DHAKA STOCK EXCHANGE

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***Abstract*— The present study focusses on the volatility of the Dhaka Stock Exchange (DSE) and forecast the subsequent volatility of selected companies by employing a variety of mathematical and statistical tools along with GARCH (Generalized Autoregressive Conditional Heteroscedasticity) models. The daily closing price of Trust bank limited (TBL), Grameenphone limited (GP) and British American Tobacco Bangladesh (BATB) is considered to examine the stock market variability from January, 2018 to June, 2023. Our findings indicate a non-stationary trend with negative and positive skewness in the time series distribution of daily returns of the companies. The scenario of high volatility and rapidly fluctuation is observed, particularly in GP and BABT compare to TBL. Computed standard deviation shows highest level of volatility in 2019 (4.619 %) and 2021 (4.678 %) of BATB, indicating significant fluctuations and uncertainty in the stock's price during those periods. Finally, the stock volatility of TBL has shown a downward trend over the last five years compare to the others two companies.**

Keywords*— *Volatility, Stock Price, DSE. Return

I. INTRODUCTION

Volatility in stock price is mostly related to investment markets and it is a measure of fluctuation or movement in the price of particular stock or index over certain period of time. However, the rapid and unpredictability in asset prices are the usual definition of volatility [1]. Investors expect to get profit but it always creates risk which is associated with the degree of swing price around the average. Sometimes, the stock market collaps for various causes which always tends to trigger a financial crisis and push the economy into recession. Most of the major stock markets in the world were greatly affected by this global financial crisis [2]. In 1996 and 2011 Bangladesh stock market weathered a challenge by collapsing prices in the last two decades.

In the context of emerging economies like Bangladesh, the study of market volatility is remarkably vital. The Dhaka Stock Exchange (DSE), a key driver of the economic growth of the country's financial system, works as the facilitator for allocating investments. Understanding the deviation patterns, determinants, and implications of volatility in the DSE is essential for market participants and regulators alike, as it helps in making informed decisions and formulating effective policies [3].

The stock market could contribute to the country's economic growth through the creation of wealth, facilitating access to capital and penetrating untapped markets. The last few decades have seen major changes to the DSE, including higher participation, regulatory changes, monitoring activities and shifting macroeconomic circumstances [4, 5]. In addition, temporary measures have been taken that halt trading to curtail panic selling on stock exchanges. Due to these reforms, the market now has new characteristics, thus it is crucial to look at how volatility has changed over time and what causes it.

Volatility is the standard deviation of stock's annualized returns over a given period and shows the range in which its price may increase or decrease. Hence, the study of stock volatility over the specific period January, 2018 to June, 2023 provides a reasonable practical implication for the investors to invest the market. In this paper, to give a general sense of variability, historic volatility and daily return time series values of DSE are analyzed. Moreover, this study provides a simple way of understanding distribution of stock return and give idea about the distribution's centrality, dispersion, and other features applying descriptive method. Finally, this research work intends to give comparative study of volatility among the companies, while implied volatility will follow expected future volatility.

II. LITERATURE REVIEW

Volatility is the amount of price swing ups and downs of a stock exchange experiences over a given episode of time. In the case of higher volatility, a dramatic change occurs in the security of price that can be transformed to the other direction within a short period of time. Hassan *et. al.* [6] examined the effect of microeconomic variables on stock return volatility in Bangladesh using monthly data from January 2001 to December 2015. They found that all of the variables do not follow normal distribution and the variables exhibit leptokurtosis. The effects of institutional elements, such as circuit breakers, and time-varying risk-return relationships on the market volatility of the DSE [7, 8]. They have found a substantial correlation between conditional volatility and market return, but risk return parameters vary quickly between samples and as data frequency varies. The classic portfolio theory is rejected when the overall correlation coefficient between risk and return is negative. This could also mean that investors in emerging markets aren't asking for a higher risk premium. Contrast lock-in with a circuit breaker device; the latter significantly affects the realized return's volatility.

An investigation concludes that the DSE return series follows a random walk rather than satisfying the normality assumption, indicating inefficient capital markets [9]. Another research conducted by Islam and Khaled discovered conflicting evidence about the market efficiency of the DSE [10]. They examined market efficiency with and without heteroscedasticity adjustment using monthly and daily DSE data collected prior to and following the 1996. The empirical findings imply that the DSE's post-1996 market crash market efficiency was weak. In order to assess the weak form market efficiency examined the monthly returns of sixteen developed and emerging markets in the Asia Pacific area, covering the period from January 2004 to December 2009. Results imply that all markets are strong and efficient, and that investors can profit from the process of market arbitrage [11]. A number of government and Bangladesh Bank policies, including tight monetary policy, decisions regarding margin loans and CRR, among others, have a significant impact on stock prices in 2011 [12].

In 1909, DSE index was found an ascending direction volatility and most of the stakeholder have a firm believe that this would keep up regardless of the country's present developing economy. However, this raising situation fall

down very quickly and could not be a sustainable trend for long time. Skilled investors usually get benefit to this volatility by understanding the market value through buying more what is cheaper and selling more what is expensive. But it can be risky for the first-time investors in this situation. The developing stock market economics are more subject matters to regime switching within a short time [13-15]. Since the majority of investors are risk adverse, risk return behavior study of the stock market is especially crucial in developing nations. The stock market's extreme volatility forces investors to demand a greater risk premium, which raises the cost of capital and impedes economic growth [16].

In statistics, heteroskedasticity (or heteroscedasticity) happens when the standard deviations of a predicted variable are non-constant. Heteroskedasticity often arises in form of conditional and unconditional. Conditional heteroskedasticity identifies non constant volatility related to prior periods volatility. Various studies have been conducted on modeling and forecasting stock market volatility by using conditional heteroskedasticity (ARCH and GARCH) [17- 20].

It is evident from a number of newspaper articles that the market monitoring has an effect on share prices. The share price drops when remittance inflows rise slowly and withdrawals are large enough to reduce the money supply. DSE returns exhibit positive skewness, excess kurtosis, and divergence from normalcy [4]. The DSE volatility has a tendency to fluctuate over time and exhibits serial correlation, which suggests inefficiency in the stock market. They also verified that there is a strong correlation between conditional volatility and market performance [5]. Another study also revealed that the return series of DSE are not normally distributed [21]. The DSE return series also exhibit volatility clustering and leptokurtosis as seen from the high excess kurtosis values [22]. The DSE volatility trends to be change over time, and serially correlated implying stock market efficiency. Therefore, the descriptive statistical analysis has been done on stock price volatility which can be used most widely in volatility further conditional study.

III. METHODOLOGY

Methodology employed in this work is considered to statistical analysis and to understand the variability of the DSE. The daily closing company prices of stock exchange market index of three Bangladeshi companies namely TBL, GP and BATB are selected for this study. Statistical tool like mean, median, and standard deviation are determined to give an overview idea of the volatility of the data set during the period. In addition, skewness and kurtosis are also calculated to provide the information for the prediction of the distortion of symmetrical distribution and measure of the tailedness of a distribution about the mean in a sample data series respectively. Finally, time series analysis plots and volatility charts are also studied to envisage volatility trends.

A. Data Collection

The primary data source for this study is closing price of trade and trading volume data of the Stock Exchange. This data is collected from the DSE library (https://www.dse.com/, accessed on 18 Sep 2023). The study covers a specified time period from 01 January 2018 to 30 June 2023. Over this period, two months' values are unavailable in the data series from April to May 2020 due to Covid-19 pandemic as, the DSE was dysfunctional. There are 1278 rows in the data sets for each company.

B. Data Preprocessing

The daily volatility is the measure of fluctuations within a day closing price. Since the daily closing price is normally nonstationary, it is inappropriate for the analysis. However, in past several studies proposed estimating the volatility of the return series [23, 24]. Daily returns of the DSE index are calculated using the formula

$$R_t = \frac{P_t - P_{t-1}}{P_{t-1}} \quad (1)$$

where R_t is daily return at time t, P_t is the closing price at time t, and P_{t-1} is the closing price at the previous time period.

C. Standard Deviation

Standard deviation of the daily return is computed monthly and yearly to examine the rate of variation of the return of the companies. The standard deviation is as follows:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}(X_i - \mu)^2}{N}} \quad (2)$$

when mean is $\mu = \sum_{i=1}^{N} X_i$

D. Skewness

In order to calculate sample skewness and kurtosis, a small adjustment is added to the empirical formula of skewness (the function of the adjustment is to correct a bias inherent in small samples):

$$\text{Sample skewness} = \frac{\sqrt{n(n-1)}}{(n-2)} \times (\textit{population skewness})$$

$$= \frac{\sqrt{n(n-1)}}{(n-2)}\sqrt{n}$$

$$= \frac{n\sqrt{n-1}}{(n-2)} \frac{\sum_{i=1}^{n}(x_i - \bar{x})^3}{\left(\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\right)^3} \quad (3)$$

E. Kurtosis

Kurtosis is the ratio of the fourth moment and second moment-squared. We also make adjustment to calculate the sample kurtosis as follows:

$$\frac{(n+1)(n-1)}{(n-2)(n-3)} \times (\textit{population kurtosis}) - \frac{3(n-1)^2}{(n-2)(n-3)}$$

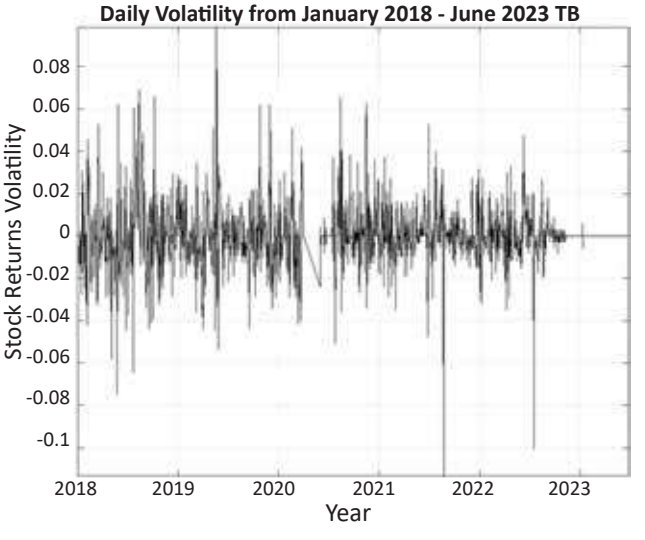
$$= \frac{n(n+1)(n-1)}{(n-2)(n-3)} \frac{\sum_{i=1}^{n}(x_i - \bar{x})^4}{\left(\sum_{i=1}^{n}(x_i - \bar{x})^2\right)^2} - \frac{3(n-1)^2}{(n-2)(n-3)}$$

$$= \frac{n(n+1)(n-1)}{(n-2)(n-3)} \frac{\sum_{i=1}^{n}(x_i - \bar{x})^4}{\left(\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\right)^4} - \frac{3(n-1)^2}{(n-2)(n-3)} \quad (4)$$

IV. RESULTS AND DISCUSSION

This section presents the results analysis for the volatility of nominated companies of the DSE applying historical volatility trends. The discussion provides insights into the nature of volatility in the DSE and its implications for shareholders and policymakers.

Fig. 1 shows the time series graph of daily returns values during the sample period. The figure depicts that the pattern of returns for TBL and GP is more volatile whereas less volatile is observed at BATB of DSE. Periods of low volatility tends to be followed by periods of low volatility for a sample time of BATB but suddenly sharp positive and negative jump is observed. The most substantial price fluctuations occurred in April 2019, marked by a sharp decline from 4565.50 to 1616.90 TK, and in March 2021, when the prices plummeted from 1554.00 to 556.80 TK. Similarly, the scenario of high volatility and rapidly oscillation is followed most of the time of the sample period for the companies GP. This indicates both time series have significant time varying returns variances and it's also a strong sign of volatility clustering. This unsteadiness occurs due to the numerous irregularities stock fizz surge in the Bangladesh stock market.



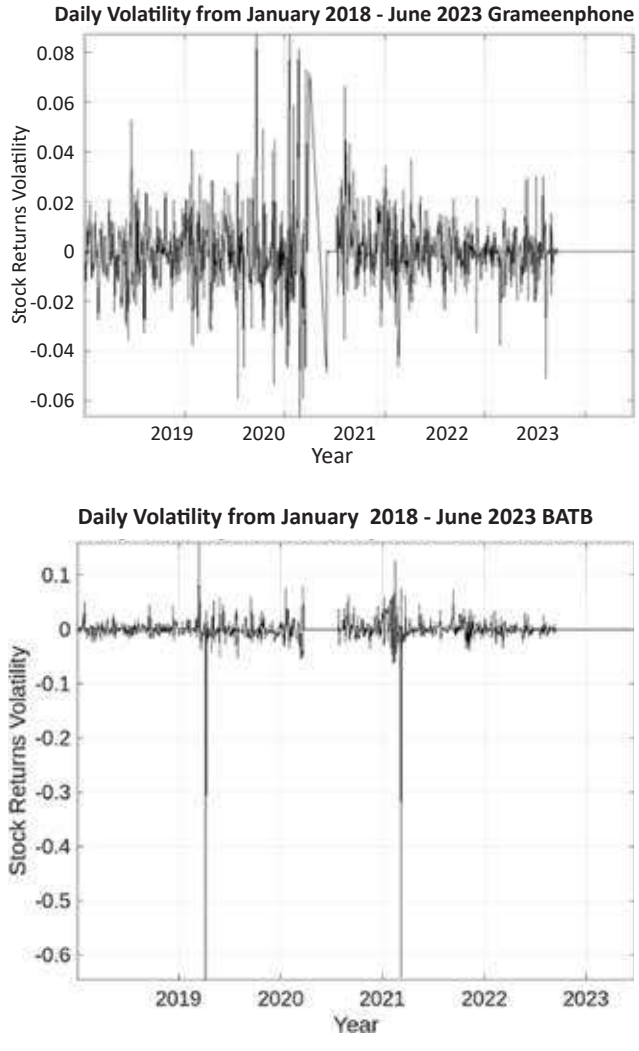
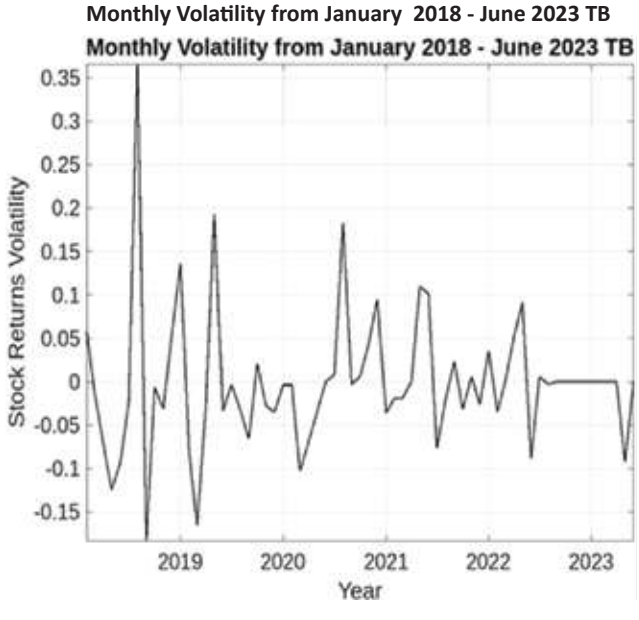


Fig. 1. Variation of daily return time-serise graph for the selected companies of DSE.



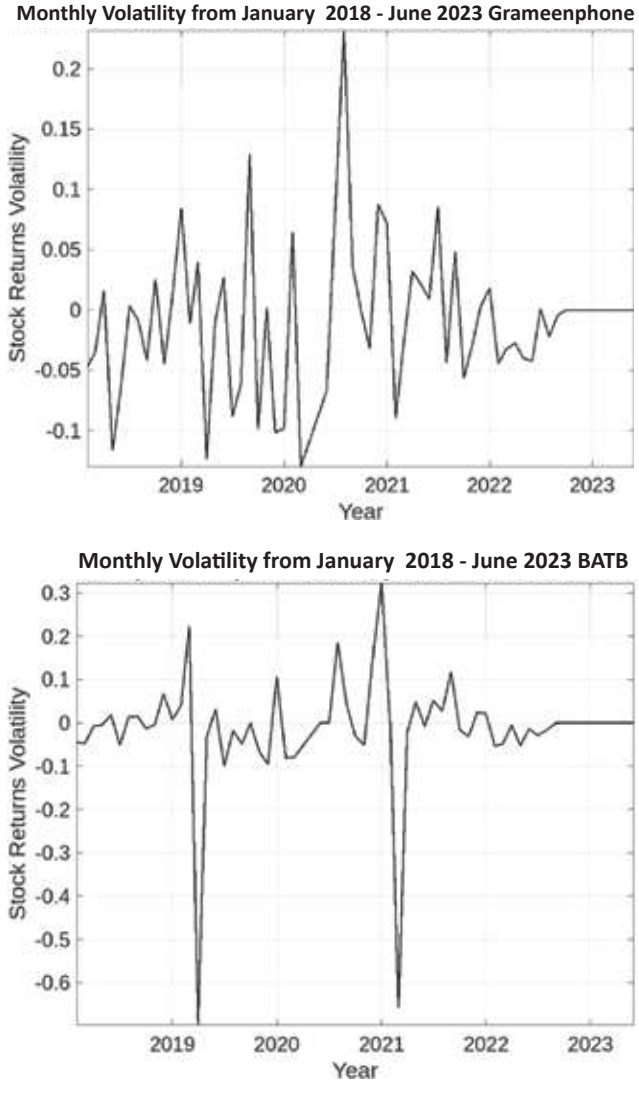


Fig. 2. Variation of monthly returns index of companies from January 2018 to June 20

Stock return price fluctuation is illustrated by calculating monthly as shown in Fig. 2. From the plot, it is seen that over the period of the study, the returns seem to be volatile and suggesting that the pattern of trend monthly has been changing. Hence, we accomplish that the daily return values of TBL, GP, and BATB are not stationary.

Descriptive statistics offer a simple way of understanding distributions of stock returns. They give us an idea about a distribution's centrality, dispersion, and other features. The descriptive statistics presented in the Table I is the overall scenario of three companies TBL, GP

and BABT from January 2018 to June 2023. Year wise computed statistical values shown in Table I (a-c) are based on the daily returns value of a stock market.

In Table I (a), the mean value of TBL suggests that the highest average daily return was obtained 0.124 % in 2020 while the lowest average daily return was –0.107 % in the year 2018. It indicates that the daily return price is highest increased in 2020 and lowest decrease in 2018 within the study of period. In addition, the skewness of 2020 is 0.595 which is nearly zero. The value of the skewness for the rest of the years indicates that the stock market return of TBL were not symmetrically distributed and their nature were leptokurtic throughout referring that stock market return volatility exist in the company over the years. Moreover, the value of kurtosis of 2018 and 2020 indicates platykurtic while for the rest of the years the nature was leptokurtic. Hence, this company too do not follow normal distribution throughout the sample period.

Next, if we look at data of GP, the highest average daily return was also found to be 0.118 % in 2020 while the lowest average daily returns in the year 2018 is –.0099 %. The stock market return is seen symmetrical only in 2018 and asymmetrical for the rest of the years. The value of kurtosis of 2018 and 2021 indicates platykurtic while in 2019 and 2022 implies leptokurtic. The kurtosis of 2020 is approximately 3.88 expressing just about the normality of return. Here too, the data are not normally distributed.

Finally, the company BATB exhibited the highest average daily return was in 2020 (0.0934 %) like the other two companies while the lowest average daily return was in the preceding year 2019 (–0.372 %). The skewness of 2020 is 0.214 which is nearly zero. Skewness of rest of the year depicts that the daily return is not symmetrically distributed and their nature were leptokurtic over the period. As a result, the return volatility occurs. From normality test, BATB do not follow normal distribution in the long run.

Table I (a). Year wise descriptive statistics (TBL)

Year	2018	2019	2020	2021	2022	2023
Mean	−0.107 %	−0.056 %	0.124 %	0.0396 %	−0.004 %	0.00003 %
Median	0.000 %	−0.277 %	0.000 %	0.000 %	0.000 %	0.000 %
Maximum	6.897 %	9.859 %	6.539 %	5.263 %	4.747 %	0.573 %
Minimum	−7.485 %	−5.363 %	−5.058 %	−11.340 %	−10.076 %	−0.569 %
Std. Dev.	2.104 %	1.797 %	1.658 %	1.442 %	1.221 %	0.075 %
Skewness	0.258	1.057	0.595	−1.746	−2.061	0.0656
Kurtosis	1.602	5.106	2.343	16.754	19.896	58.502
Jarque-Bera stat	28.088	299.022	59.292	2904.587	4162.809	16827.255
p-value	7.959E -07	1.169E -65	1.333E -13	0	0	0
Observations	238	235	206	238	242	118

Table I (b). Year wise descriptive statistics (GP)

Year	2018	2019	2020	2021	2022	2023
Mean	−0.099 %	−0.092 %	0.118 %	0.0088 %	−0.079 %	0.00
Median	−0.0752 %	−0.175 %	0.000 %	−0.0582 %	0.000 %	0.00
Maximum	5.271 %	8.722 %	8.712 %	3.659 %	3.010 %	0.00
Minimum	−3.556 %	−5.889 %	−6.633 %	−4.602 %	−5.088 %	0.00
Std. Dev.	1.156 %	1.725 %	2.179 %	1.085 %	0.828 %	0.00
Skewness	0.1425	0.875	0.887	−0.124	−0.874	-
Kurtosis	1.858	4.678	3.879	2.111	9.097	-
Jarque-Bera stat	35.039	244.253	156.190	44.793	865.195	-
p-value	2.463E-08	9.144E-54	1.213E-34	1.876E-10	1.335E-188	-
Observations	238	235	206	238	242	118

Table I (c). Year wise descriptive statistics of BATB

Year	2018	2019	2020	2021	2022	2023
Mean	0.021 %	−0.372 %	0.0934 %	−0.054 %	−0.082 %	0.00
Median	0.0014 %	−0.288 %	0.000 %	−0.062 %	0.000 %	0.00
Maximum	4.967 %	15.964 %	7.832 %	12.625 %	3.319 %	0.00
Minimum	−2.323 %	−64.584 %	−5.395 %	−64.169 %	−3.429 %	0.00
Std. Dev.	0.968 %	4.619 %	1.791 %	4.678 %	0.822 %	0.00
Skewness	1.221	−11.343	0.763	−10.799	0.214	-
Kurtosis	5.328	161.384	4.004	150.066	5.011	-
Jarque-Bera stat	340.56	260061.96	157.581	227946.703	255.012	-
p-value	1.118E-74	0	6.051E-35	0	4.215E-56	-
Observations	238	235	206	238	242	118

The standard deviation of a company's stock price is a measure of its volatility or the degree of variation in its returns over a specific period. When prices swing up or down significantly, the standard deviation is high, meaning there is high volatility. Stocks or assets with higher volatility are generally considered riskier investments since they have a greater potential for price swings in both directions, leading to the possibility of larger gains but also larger losses. On the other hand, when there is a narrow spread between trading ranges - prices are relatively stable, the standard deviation is low. This indicates lower volatility, suggesting that the stock's price movements are more predictable and less subject to large fluctuations.

Standard deviation of daily returns is illustrated in Fig. 3(a-c). It is seen that the TBL stock volatility has followed a downward trend for the last five years suggesting that the company's stock has become less volatile or exhibited reduced price fluctuations over the years. Decreasing volatility means increasing stability in the stock's price movements which is generally as a positive sign, especially for the investors who prioritize less risk and seek a more predictable investment.

For GP, the bar graph presents an upward trend till 2020 which indicates that the company experienced increasing volatility or greater price fluctuations during that period. Then from 2020 onwards, there is evidence of a downward trend suggesting that GP stock exhibited decreasing

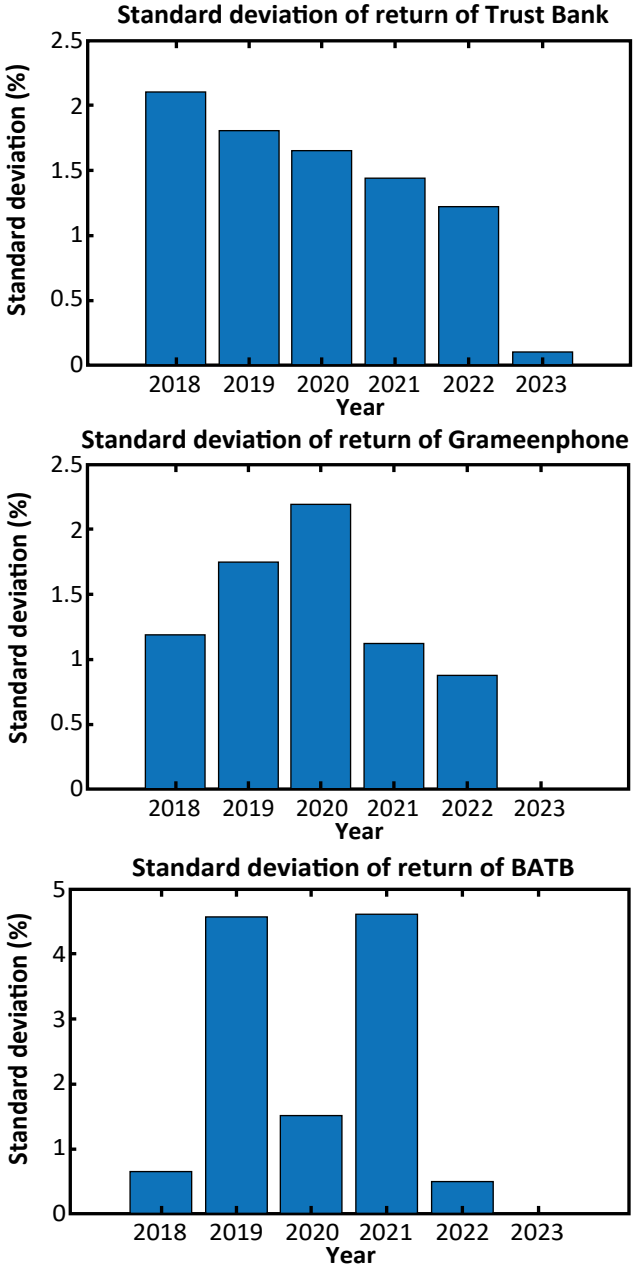


Fig. 3. Standard deviation of return (2018-2023) of TBL, GP and BABT

volatility or reduced price fluctuations in the recent years. This could imply that market conditions or factors affecting the stock became more stable or predictable from 2020 onward.

Finally, for BATB, it is seen that standard deviation is constantly fluctuating, which indicates that the stock's price movements have been highly unpredictable and have experienced significant fluctuations in the last 5 years. From the graph it is evident that the company faced its highest level of volatility in 2019 and 2021, which means that there were significant fluctuations and uncertainty in the stock's price during those periods. This implies that the stock was riskier and had larger price swings in these two particular years. Shorter bar lengths in the years 2018, 2020, and 2022 implies lower volatility or reduced-price fluctuations which suggests that the company's stock was relatively stable and less volatile price movements during these particular years.

V. CONCLUSION

Volatility is directly associated with risks and returns and understanding the statistical properties of the volatility also has important practical implications. In this study, the degree of measurement of market volatility is described by applying statistical and mathematical method. The daily and monthly returns values are computed of three companies (TBL, GP and BABT) over the episode from 01 January, 2018 to 31 June, 2023. Firstly, the return time series of DSE are not symmetrically distributed which means volatility exist. Secondly, the DSE returns series also exhibit volatility clustering and leptokurtic in nature due to negative and positive skewness calculated.

In addition, the histogram and the overall data confirm stock returns of the three companies do not follow a normal distribution. Instead, they exhibit characteristics associated with a non-normal distribution, particularly being leptokurtic and having “big fat tails”. Out of the three companies, only BATB seemed to be negatively skewed showing that BATB have a higher likelihood of large negative returns compared to the other companies. Moreover, the TBL stock volatility has followed a downward trend for the last five years gradually.

The study outlines directions for future researches that could be investigated to improve the modeling (family of GARCH model) and volatility forecasts of the Dhaka stock market returns. Due to the fact that we use five-year time series of returns (2018–2023), longer time series would allow estimation with greater precision.

REFERENCES

[1] R. W. Hafer, Hein, “The stock market”. Green wood Press, 2007.

[2] I. O. Oseni, P.I. Nwosa, “ Stock Market Volatility and Macroeconomic Variables Volatility in Nigeria: An Exponential GARCH Approaches.” European Journal of Business and Management, vol. 3, pp. 43-53, 2011.

[3] P. A. Abken, Nandi,“Options & Volatility”. Economic Review, pp. 21-35, 1996.

[4] A. Chowdhury, “Micro and Macro Dynamics of the Stock Market: An investigation into the Dhaka Stock Exchange (DSE)”. The York Management School, 2014.

[5] A. Chowdhury, M. Uddin, K. Anderson, “Investors’ behaviour and Weekend Effect: Evidence from an Emerging Market.” 1st Paris Financial Management Conference, 2013.

[6] A. Hasan, A. Zaman, “Volatility Nexus Between Stock Market and Macroeconomic Variables In Bangladesh: An Extended Garch Approach.” Journal of Scientific Annals of Economics and Business, vol. 64, pp. 233-243, 2017.

[7] T. Abu., Mollik, “ Risk-Return Trade-off in Emerging Markets: Evidence from Dhaka Stock Exchange Bangladesh”. 22nd Australasian Finance and Banking Conference, 2009.

[8] A. Sayed, M. K. Bashera, “Time Varying Volatility and Equity Returns in Bangladesh

Stock Market .” Applied Financial Economics, vol. 17, pp.1393-1407, 2007.

[9] A.T. Mollik, K. Bapari, “Weak-Form Market Efficiency of Dhaka Stock Exchange (DSE) of Bangladesh.” 22nd Australasian Finance and Banking Conference, 2009.

[10] Ainul Islam, “Tests of Weak-Form Efficiency of the Dhaka Stock Exchange.” Journal of Business Finance and Accounting, pp. 1613-1623, 2005.

[11] Ariff, “Announcement Effects and Market Efficiency in a Thin Market: An Empirical Application to the Singapore Equity Market.” Asia Pacific Journal of Management, pp. 243-267, 1986.

[12] S. Hossain, M. A. Baten, “Forecasting Volatility of Selected Banks of Dhaka Stock Exchange (DSE), Bangladesh with GARCH (p, q) Type Models” Journal of Economic Cooperation and Development, vol. 42, pp. 117-142, 2021.

[13] R. Gancy, F. Selcuk, Extrem Value Theory and Value- at- risk : Relative Performance in Emerging Markets.” International Journal of Forcasting . vol. 20, pp. 287-303, 2004.

[14] R. Laudes, F., Salman, M., Chivakul, “ The Impact of the Great Recession on Emarging Markets.” IMF Working Papers. pp. 1-34, 2010.

[15] N. Naik, B. R. Mohon, “Stock Price Volatility Estimation Using Regime Switching Technic-Emperical Study on the Indian Stock Market.” Mathematics, vol. 9, 2021.

[16] Rajani Mala, “Measuring Stock Market Volatility in an Emerging Economy.” International Research Journal of Finance and Economics, pp. 126-132, 2007.

[17] T. Bollerslev, “Generalized Autoregressive Conditional Heteroskedasticity.” Journal of Econometrics, vol. 31, pp. 307-32, 1986.

[18] A. Babikir, R., Gupta, C., Mwabutwa, E., Owusu-Sekyere, “Structural Breaks and GARCH Models of Stock Return Volatility: The Case of South Africa.” Economic Modelling, vol. 29, pp. 2435-2443. 2012.

[19] M. S. I., Aziz, M. N., Uddin, “Volatility estimation in the Dhaka stock exchange returns by GARCH models.” Asian Business Review, vol. 4, pp. 41–49, 2015.

[20] D. Z. Xing, H.,F., Li., J.C. Long, “Forecasting price of financial market crash via a new nonlinear potential GARCH model”. Phys. A Stat. Mech. Its Appl. 2021.

[21] M. Mia, A., Rahman, “Modelling Volatility of Daily Stock Returns: Is GARCH (1, 1) Enough.” American Scientific Research Journal for Engineering, Technology, and Sciences, vol 18, pp. 29-39, 2016.

[22] M. N. Siddique, N. N. Begum, “Volatility of Dhaka Stock Exchange.” International Journal of Economics and Finance, vol. 8, 2016.

[23] M. Karmakar, “Modelling Conditional Volatility of the Indian Stock Markets.” Vikalpa, vol. 30, pp. 21-38, 2005.

[24] S. M. Abdullah, S. Siddiqua, M. S. H. Siddiquee, N. Hossain, “Modelling and Forecasting Exchange Rate Volatility in Bangladesh Using GARCH Models: A Comparison Based on Normal and Student’s T-Error Distribution.” Financial Innovation, vol. 3, pp.1-19, 2017.

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MISSION DRIFT OF MFI: TRADE-OFF BETWEEN FINANCIAL SUSTAINABILITY AND OUTREACH IN BANGLADESH

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Abstract*— Microfinance institutions (MFIs) play an important role in reducing poverty by providing financial services to vulnerable groups of society in developing countries as well as all over the world. In the latter half of twentieth century, the microfinance sector had expanded through experiments in Latin America and South-Asia while the best experiment was conducted in Bangladesh in 1976. The study employs panel data regression to analyze the relation among important issues like sustainability, outreach, and loan repayment performance. Based on the results it is concluded that there is no trade-off between outreach and financial sustainability. The findings of ALBPBG model reveal that greater loan size can improve financial performance.

***Keywords*—Microfinance, Sustainability, Outreach, Panel-data**

I. INTRODUCTION

Microfinance is not a new development tool. For more than three decades, microfinance institutions (MFIs) worked as an effective tool in reducing poverty that helps to gain comprehensive attention in the world among the policy makers, governments, international donors and academicians [1-3]. For the time being, MFIs have been facing challenges i.e., sustainability and outreach of the institutions. Day by day the pressure on MFIs for dependency of donations, grants and subsidized funding is growing rapidly which lead MFIs to become financially unsustainable. Going by the 2007 report of Deutsche Bank, less than 1-2 percent of the world's MFIs are financially sustainable. The report reveals that 70 percent of all the MFIs relying almost wholly on subsidies and only 8 percent being somewhat close to what can be called profitable. Those advocating poverty lending approach argue that the steps toward financial viability involve detriment to those coming under the sweep of poverty. The high cost incurred in lending to the poor pitches outreach and sustainability in an inverse relationship, thus calling for the intervention of an enquiry on empirical bases. Improving outreach is a way for a Micro Finance Institution to achieve growth and offer services on a long-term basis to increase sustainability [4]. Outreach has been defined as the capacity of an MFI to make financial services available to a large number of poor clients. It is "a social benefit of microfinance" targeting at developing the welfare of the poor [5, 6]. Outreach can also mean the extent to which MFIs make provision of financial services to a large number of clients. It is gauged by evaluating the access of MFI to those for whom formal financial services are inaccessible [6, 7].

An MFI's financial performance, including self-sufficiency and consequently financial sustainability, is mainly regulated by two factors namely institutional efficiency and return on

portfolio [8]. The capability to generate maximum output at a given level of input is called efficiency. The delivery of small loans to those who are quite poor can be best carried out in effect through efficiency [8]. Therefore, greater outreach can be synonymous with efficient MFI management. Efficiency of MFIs is indicated by numerous factors broadly classified under three heads: management of liability and assets, human resources management and loan portfolio quality which show its directly proportional relationship to financial sustainability [9].

Financial sustainability of MFIs is the most crucial component of microfinance sustainability. Financial sustainability stipulates that revenue from microfinance activities must exceed operational expenses. The ability of an MFI to cover all of its costs out of generated income from services without any outside assistance has been referred to as financial sustainability [10]. Cost in this context refers to current expenses incurred to support ongoing operations and expansion. The term "financial sustainability" is frequently used in microfinance literature to define the institutional sustainability of MFIs [11]. Mere efficiency does not speak for the financial sustainability of an MFI. That is why an effective return from activities and operations is also sought after, gauged by the return on the portfolio. The greater the outreach the greater the portfolio. The effective interest rate is what portfolio yield primarily incorporates and one of the common measures of return on portfolio along with interest spread. The portfolio yield is calculated by taking the ratio of the total of interest income to the loan portfolio average. The range limit of price tagging of products by an MFI with the purpose of covering its total costs (administration costs) is indicated by the interest spread [8]. It is, therefore, a measure of how much the interest income is able to cover the incurred costs by the MFI. Some factors, like the regulatory framework of MFIs that characterizes the setting within which an MFI carries out its operations, are beyond the internal management and are called external factors [12].

The sustainability of MFI depends on its profitability. But a greater outreach may require smaller loan size. Smaller loans may reduce the profitability of MFIs for which sustainability could be hampered. This study aims to analyze the trade-off between sustainability and outreach in the context of MFIs in Bangladesh.

II. LITERATURE REVIEW

Many studies looked into the connection between MFI outreach and financial viability. None of them found a causal link between financial sustainability and outreach [13-15]. Certain MFIs have deviated from their social purpose. By raising interest rates to a commercial level, MFIs deviate from their social goal. The MFIs that have deviated the most show that the social mission of microfinance has failed. As a result, interest rates must be lowered [16].

A number of research on MFIs in the Indian economy indicate that expanding their scope enhances their financial performance. It is concluded that MFIs can accomplish their dual goals of financial performance and outreach [17, 18]. Another study supports the presence of a trade-off between poverty outreach and profitability but not for sustainability. The study advises the MFIs to place a strong emphasis on sustainability in order to make it possible to meet operating costs with a smaller reliance on external financial assistance while maintaining a high level of outreach to the disadvantaged [19]. High-disclosure MFIs have demonstrated a beneficial connection between outreach & financial sustainability. However, depth of outreach for low disclosure MFIs has no impact on financial sustainability [14]. Evidence also points to the existence of endogenous impact of peers for credit borrowing, which are comparable to those observed in the purchase and ownership of consumer products like bicycles, cell phones, and televisions. They show

that social groups have a major impact on credit access. Additionally, they found that borrowing from microlenders is favorably correlated with educational attainment but inversely correlated with the wealth of social network households' villages and churches [20].

MFIs with a higher proportion of female borrowers typically have lower average balances. Profitability is affected by this. According to the results of the association between efficiency indicators and outreach, MFIs' profitability is inversely correlated with their level of outreach [21]. In response to surveillance, profit-oriented MFIs maintain profit rates but cut back outreach to two groups, the poorest and the women clients who are more difficult for them to reach [22]. According to a different study, individual-based MFIs provide wealthier clients more attention than group-based lenders do [23]. A study examined the impacts of the type of ownership on MFS organization performance. This study considers six aspects of performance dimensions namely cost, depth, breath, length, scope and worth. The findings of the study revealed that difference is minimum between SHFs and NGOs in terms of social and financial performance [24]. As of 2013, there are 650 MFIs in Bangladesh. Out of these only top 20 MFIs (stated in previous chapter) contributed more than 75 per cent share of microfinance sector. 17 MFIs out of top 20 have reported their information to the MIX market and are taken as samples in the study. The remaining 11 countable MFIs have been taken as samples from the MIX market. Therefore, it is clear from the above discussion that the balanced panel data of 28 MFIs for the period 2006 to 2014 is considered for analyzing and explanation. These MFIs represent more than 75 per cent of total activities of MFIs in microfinance sector of Bangladesh.

III. RESEARCH METHODOLOGY

A. Data and Methodology

The population for the study is all MFIs of Bangladesh. The empirical outcomes of the study depend on the secondary financial data of MFIs obtained from Microfinance Information Exchange Market, USA. MIX market makes available data about historical and social achievement of over twenty-one hundred MFIs serving more than 94 million customers all over the world. The present study used balanced panel data including 28 MFIs focused over the time period (2006-2014) with overall 252 observations. Till 31st March 2014 almost 86 Bangladeshi MFIs reported to the MIX market. Out of 86 MFIs, 28 have been selected for this study. The Microfinance Institutions have been selected on the basis of time period of 09 years (2006-2014). However, complete data is not available on the website which MFIs have reported. Therefore, in order to fill the missing data, the average of the available data have been taken. Finally, 28 MFIs have been considered for this study by this criterion.

B. Conceptual Model

The relationship between the dependent and explanatory factors has been explained in this study using panel data models. Datasets comprising identical observations recorded over several periods are known as longitudinal data or panel data [22, 25, 26]. Panel data is synthesis of cross-sectional and time-series data [27]. However, panel data groups individual identities over time (MFIs) and is expected to be heterogeneous in these identities. Such variability is specifically taken into account in the panel data technique by allowing for MFI-specific variables [27]. With a focus on factors impacting financial sustainability, repayment of loans performance, and the trade-off between outreach and financial sustainability, this study aims to build up the linkages between dependent and explanatory variables.

The panel data model was chosen for this investigation because it is efficient at identifying and quantifying the effects of relationships, which cannot be discovered in pure cross-sectional or pure time-series data [26-28]. Additionally, panel data offer more accurate information, greater variability, high efficiency, a lower degree of freedom, and less changeable collinearity. The conceptual or general regression model for panel data is used in the form:

$$Y_{it} = \alpha_i + \beta X_{it} + \varepsilon_{it} \quad (1)$$

Where, Y_{it} = Dependent Variable for cross-sectional units *i* at time *t*, where i = 1, ….., n and t = 1, …., and T, α_i is a heterogeneity or individual effect. It possesses a constant term and set of individuals or group specific variables which may be measured, such as unobserved MFIs specific characteristics (like skills of personnel or preference and so on) which are considered as to be constant over time [28]. β the partial effect of X_{it} in the period *t* for the unit i, X_{it} represents the j^{th} explanatory variables for the unit i at time t. There are k explanatory variables indexed as j = 1, ….., k and therefore, X_{it} is a k-dimensional vector, and ε_i is the error term [27, 28]. There are different models which are often used in the estimation of panel data including the pooled regression model, the Fixed Effects model (within effect estimator), and the Random Effects model (Error Component Method). Fixed Effects Model (FEM) measures group differences in intercept for each by using a separate dummy variable for each group for this reason it is also known as least squares dummy variable method. The Random Effects Model (REM), by contrast estimates variance components for groups (or times) and error, assuming the same intercepts and slope. In the earlier section we have discussed the factors affecting financial sustainability. Out of those factors the depth of outreach was measured by the average loan balance per borrower. The literature suggests that outreach and sustainability are related to each other. Their relationship is two ways with each determining the other [29-31].

Microfinance literature reveals that depth and breadth of outreach is commonly used as a measure of outreach of the MFIs. However, there are six aspects of outreach which are generally used to measure the relationship between outreach and sustainability [32]. These are: worth of outreach, breadth of outreach, depth of outreach, cost of outreach, scope of outreach and length of outreach. Some researchers have used Schreiner's dimensions of outreach to explain the determinants of financial sustainability [12, 24, 30, 33, 34]. Depth of outreach is the value that society attaches to the net gain of a given client [35]. It is argued [36] that an MFI would be considered as no longer different from bank if there are no poor clients. Their argument is that outreach should not be measured only by the total number of clients but also the number of poor clients. Only the total number of clients should be considered to measure the outreach of an MFI, who are facilitated through different products of an MFI without their relative level of poverty [37]. Average loan size is used as a proxy measure of depth of outreach and the low average loan size (smaller loans) indicate poorer clients [6, 12, 14, 29, 30, 38-42]. Existing literature showed that there is an indirect relationship between the breadth of outreach and financial sustainability [30]. They disprove the long-held belief that making small loans is extremely risky and a barrier to establishing financial sustainability in their findings. Other studies found that loan size and loan volume are connected to financial sustainability [38]. Providing small loans to the underserved is difficult to do and "inherently" expensive [36, 43]. However, others contend that institutions that make smaller loans are not consistently less profitable than those that make larger loans [29]. Furthermore, a negative link between the depth of outreach and the subsidy dependency index was discovered, demonstrating that both sustainability and depth of outreach can be accomplished at the same time [31]. In this research, a weak and insignificant correlation between the extent of outreach and financial

[1]Available at: www.mixmarket.org

self-sufficiency was found. In this part, we examine how the depth of outreach is impacted by financial sustainability and other variables. On the basis of empirical studies pertaining to outreach and average loan balance per borrower, the following table shows variable descriptions and associated hypotheses. The operational models utilized in this section are presented in the next subsection along with their interpretation.

TABLE I. VARIABLES DESCRIPTION

	Variable Standard Name	Description	Variable name as used in the model	Expected effect on the ALBPBG
1	Financial Self-sufficiency	Adjusted Financial revenue/ (Operating expense + financial expenses + loan loss provisional expenses + Expense adjustment)	*FSS*	Positive/ negative
2	Operational Self-Sufficiency	Financial revenue/ (Financial expense+ Impairment losses + Operating expenses)	*OSS*	Positive/ Negative
3	Equity	Total Equity	*EQUITY*	Positive
4	Size of MFI	The size of MFIs measured by value of its Assets	*SIZE*	Positive/ Negative
5	MFI Age	Years since its establishment to when evaluation is considered. It also measures length of it outreach.	*AGE*	Negative
6	Gross loan portfolio to total assets ratio	Gross loan portfolio/total assets	GLPA	Positive/ Negative
7	Cost per Borrower	Adj. operating expense/ number of active borrowers	*CPB*	Positive
8	Debt to Equity ratio	Debt as a percentage of total equity	*DE*	Uncertain
9	Portfolio at risk (30 days)	The fraction of loan portfolio that is overdue past 30 days or more, that is PAR 30 = Portfolio at risk/Gross loan portfolio	*P30*	Uncertain

The primary goal of this study is to clarify empirical data that can refute the notion that an MFI's outreach efforts are negatively impacted by its concentration on financial sustainability. In this section, the term "outreach" refers to the depth of outreach as determined by the average loan balance per borrower, which has been adjusted for gross national income (GNI). Financial self-sufficiency (FSS) and operational self-sufficiency (OSS) are the metrics we use to assess financial performance. In this context, the terms "financial self-sufficiency ratio" and "operational self-sufficiency ratio" refer to the adjusted financial revenue divided by the financial expense, operational expense, loan loss provision expense, and expense adjustment, respectively.

The size of the institution is determined by the MFI's asset. The MFI will be able to loan more money to the poor as its operations grow larger. The impact of the gross loan portfolio to total asset ratio on the breadth of outreach is another issue the study aims to analyse. It could go up

either because there are more borrowers but the average loan balance per borrower stays the same or because there are fewer borrowers, the average loan balance goes up. The level of outreach remains unchanged in the first scenario, whereas it would decrease in the second. Therefore, it can be assumed that the size of the MFI and the gross loan portfolio to total asset will either have no effect or have a negative impact on depth of outreach. All the MFIs set their primary goal as to provide loans to the vulnerable groups of the society. Thus, larger levels of equity allow an MFI to reach this goal and lead towards achieving a greater level of outreach, especially for non-profit MFIs. Similarly, debt to equity ratio has also a positive effect on outreach.

Generally, most of the female borrowers demands for small loans. Therefore, higher percentage of women borrowers is expected to lead an MFI towards better outreach. Age of the MFIs is measured from the establishment year. Generally, it can be assumed that the outreach performance of an MFI increased over time. Therefore, it has been taken into consideration to measure its effect on outreach either positive or negative. Portfolio at risk measures the repayment performance of the borrowers. A higher repayment rate helps an MFI to achieve a better outreach. Therefore, it can be assumed that portfolio at risk has a positive impact on depth of outreach. The following hypotheses are framed:

HP1: Financial self-sufficiency ratio is hypothesized to be positively or negatively associated with depth of outreach measured by average loan balance adjusted by GNI.

HP2: Operational self-sufficiency ratio is hypothesized to be positively or negatively associated with depth of outreach measured by average loan balance adjusted by GNI.

HP3: Total Equity is hypothesized to be positively associated with depth of outreach measured by average loan balance adjusted by GNI.

HP4: Size of MFIs is hypothesized to be positively or negatively associated with depth of outreach measured by average loan balance adjusted by GNI.

HP5: MFIs AGE is hypothesized to be negatively associated with depth of outreach measured by average loan balance adjusted by GNI.

HP6: Gross loan portfolio to total assets ratio is hypothesized to be positively or negatively associated with depth of outreach measured by average loan balance adjusted by GNI.

HP7: Cost per borrower is hypothesized to be positively associated with depth of outreach measured by average loan balance adjusted by GNI.

HP8: Debt to equity ratio is hypothesized to be positively associated with depth of outreach measured by average loan balance adjusted by GNI.

HP9: Portfolio at risk is hypothesized to be positively or negatively associated with depth of outreach measured by average loan balance adjusted by GNI.

C. Assumption Test

1) Test of Multicollinearity

Multicollinearity is the assumption that independent variables are highly correlated with one another, or one independent variable is near linear combination of another independent variable [44]. Without satisfying this assumption, estimated result of regression will mislead the researcher through inflated standard errors, reduced power of regression coefficients and unreliable t-statistics results. There are different methods to avoid the problem of multicollinearity such as increasing the sample size, standardization of variables, using stepwise regression method, use of principal component analysis regression method. There is another method Variable Inflation Factor (VIF) test used

in this study to investigate the problem of multicollinearity among the independent variables. The rule of thumb for allowable limit is 10 [44]. However, if VIF value is more than ten, it indicates strong linear relationship among the predictor variables.

There is debate among the researchers that how much correlation causes multicollinearity. It is stated that multicollinearity problem is not a big deal if the value of correlation coefficient is below 0.9 [45]. Whereas it is suggested any correlation coefficient below 0.7 is acceptable, anything above that leads to inefficient estimation and unreliable results [46]. Pairwise correlation analysis was employed to detect that multicollinearity problem among the variables [26]. In this study correlation coefficient below 0.7 is considered acceptable [46]. The pairwise correlation analysis result revealed that the number of borrowers is highly correlated with MFI size at 0.96687. Another correlation, although not strong, is the ratio of loan outstanding to total assets (–0.69834). To further identify the multicollinearity issue with the data, the authors applied the Variance Inflation Factor (VIF) for each coefficient. The question of how much VIF is acceptable is being debated once more. Whereas some studies claimed that the multicollinearity issue is caused by VIF values exceeding 20, and others contend that the multicollinearity issue is caused by VIF values exceeding 10 [18, 27, 45]. In our data, the value of VIF is less than 10, for all the variables in the Financial Self-Sufficiency (FSS) model. The variables (the number of borrowers and the ratio of loan outstanding to total assets) are excluded from the VIF test based on the results of pairwise correlation analysis.

The Econometric literature offers numerous solutions to the multicollinearity issue in the data set. These are: omit one or more of the variables causing it to increase the sample size; or obtain more data as multicollinearity is not a problem in large samples above 100 observations [27, 45-48]. Additionally, variable transformation method can be applied [21]. All these solutions are taken into consideration; and the sample size is larger than 100 observations. Considering the above discussion about the methods of dealing with multicollinearity problem, the study adopts "omit variable" strategy. This strategy has been adopted because, if the study omits the number of borrowers and the ratio of loan outstanding to total assets, the VIF test shows no multicollinearity problem among the variables. The VIF value of all the variables in this study is less than 10 which means there exists no multicollinearity problem. In addition, it has been found that the VIF values like 10, 20, and 40 or even higher do not affect so much in the results of regression analyses [49]. Moreover, the study used panel data with large sample size which led to more data points and decrease the effect of multicollinearity problem [24, 32, 48].

2) Test of Normality

To run the regression analysis, it is assumed that the samples are taken from the population, which is normally distributed. The assumption of normality is much significant when constructing reference intervals for variables [27]. This study utilized Q-Q plots to check the normality of variables. The graphical tools are considered better to check normality than other tests because it presents the pictorial representation of variables which could help in identifying the exact nature of distribution.

From the Q-Q plot it is evident that the distributions of all the variables of Financial Self-sufficiency and outreach models are normal except the variable of capital structure (CPS). If there are any scattered points which are away from best fit line known as outliers, variable transformation techniques are suggested in the econometric literature to remove that problem [26, 28, 32, 45, 47]. With logarithmic transformation all the variables become more normal except capital structure (CPS). In case if sample is based on 30 or more observations, the sampling distribution of mean can be safely

assumed to be normal [50]. Moreover, non-normality is a very common phenomenon while using financial and economic data and it is difficult to get perfect normal data. While in our study, we take 28 MFIs and 252 observations. Therefore, the study continues with same data and interprets the results cautiously.

3) Test of Autocorrelation

The autocorrelation does not cause biasness problem in estimation of coefficients, but it reduces the efficiency of the model in forecasting. This study used Durbin-Watson d test to justify the null hypothesis framed as those errors are not serially correlated against the alternative that they follow a first-order autoregressive process [26]. If d = 2 it indicates absences of autocorrelation problem in the sample. Statistically the d value lies between 0 and 4. If the d value is less than 2, there is evidence of positive autocorrelation. As a rough rule of thumb, d values less than 1 or smaller indicate successive error terms to be positively correlated. On the contrary, if d > 2, it indicates that successive error terms are negatively correlated. As the problem of autocorrelation exists in the model, the study used Heteroskedasticity and Autocorrelation consistent robust standard errors (HAC) errors of white standard errors. The HAC errors are reliable for both serial autocorrelation and heteroskedasticity problem. Observations more than 50 can be considered reasonably large to apply HAC test to correct standard errors whereas this study consists of more than 250 observations [51].

Furthermore, we examined the Durbin-Watson statistics for two models, namely, FSS and ALBPBG. If the d statistic is higher than the upper bound (d_u = 1.898) it indicates no positive correlation among the errors. As like as, if the d statistic is less than the lower limit (d_l = 1.462) it indicates presence of positive autocorrelation among the standard errors. The results of Durbin-Watson (d) test indicate that there is presence of positive serial autocorrelation in two models, because of, the d statistics are below the lower limit (d_l = 1.462) i.e., 1.315609 and 1.228786, respectively. Hence, heteroskedasticity and autocorrelation consistent (HAC) errors are followed in the respective models where the problem of autocorrelation arises [52].

4) Stationarity Test

Regression analysis also needs to make the crucial assumption that the values of the dependent variables over two distinct time periods are stable, or independent of one another. Unit root processes are described as occurring when the value of the current period is equal to the value of the previous period plus a specific time-dependent amount (disturbance) [11]. The projected results of a regression when a unit root is present are spurious and have no practical application. The study uses the Fisher Test for Panel Unit Root through Augmented Dickey-Fuller (ADF) test to check for stationarity in the dependent variable (FSS) and confirm the presence of a unit root in the dependent variable. The null hypothesis, however, is that there is a unit root. The test statistic (chi square (196) = 83.7226) has a statistically significant p-value (Prob. chi square = 0.0096). As a result, the null hypothesis would be rejected. The variable is hence stationary.

D. Operational Model

This section presents the econometric results of depth of outreach model which is measured in terms of average loan balance per borrower adjusted by gross national income (GNI). The main aim of this section is to show the impact of financial sustainability and other factors on depth of outreach respectively. The fixed effect model is more appropriate to analyse this relationship which has been checked in the research methodology chapter. The equation estimated as follow:

$$ALBPBG_{it} = \alpha_i + \beta_1 FSS_{it} + \beta_2 OSS_{it} + \beta_3 EQUITY_{it} + \beta_4 AGE_{it} + \beta_5 SIZE_{it} + \beta_6 P30_{it} + \beta_7 GLPA_{it} + \beta_8 DE_{it} + \beta_9 CPB_{it} + \varepsilon_{it} \quad (2)$$

Where ALBPBG is the dependent variable, which is the natural log of the average loan balance per borrower divided by the gross domestic product. X_{it} are the explanatory variables as mentioned in table 1, i is a constant term, and it measures the partial influence of the explanatory factors on the unit i (MFI) in period t. Where i = MFIs (1 to n) and t = 1 to 9, both the dependent and independent variables have cross-section units of i at time t.

IV. RESULTS AND DISCUSSION

The econometric findings from the equation describing how the depth of outreach are influenced by financial sustainability are presented in Table II. Average loan balance per borrower divided by gross national income in log form is the dependent variable for this model. For the ALBPBG model that was tested above in the research technique chapter, a fixed effect model is adequate. The dependent variable's changes are described by the independent variables in the model to a degree of 70.18 percent, according to the R-square value of 0.701850 (70.18 %). The explanatory variables do not fully account for about 30 % of variations. The R-square value of 0.2 in the case of panel data is more than sufficient for drawing trustworthy inferences [32, 48]. It is clear from the econometric results that the overall F-statistic is statistically significant at 1 per cent significance level indicating the rejection of the null hypothesis that all the coefficients of the predicted variables are equal to zero. Therefore, we can say that the explanatory variables are significant in affecting the changes in the depth of outreach. Thus, it can be concluded from the results of R-square and F-statistics that the model fits well. The results are shown in Table II.

The econometric results show that financial self-sufficiency (FSS) and depth of outreach have positive connections, although these relationships are statistically insignificant even at the 10 % level of significance. In order to determine the connection between the breadth of outreach and financial sustainability, sample firms were separated into high and low disclosure [14]. The author found that the FSS coefficient is unfavorable and insignificant for the entire sample, positive for low disclosure, and unfavorable (significant at the 1 % level) for high disclosure businesses. Increased financial independence facilitates deeper outreach where there are no other barriers [14]. Therefore, according to the literature, bigger loans are better for financial sustainability because they are more profitable and have higher cost effectiveness. Because smaller loans reflect stronger outreach to the core poor, the positive correlation between financial performance proxies and average loan size suggests mission drift where MFIs serve non-poor clientele. The depth of outreach and the operational self-sufficiency coefficient (OSS) have a poor and negligible relationship.

TABLE II. RESULTS

Variable	*Coeff.*	*Std. error*	*p-value*
Const.	–0.1013	0.13509	0.4594
FSS	0.04868	0.04408	0.2792
OSS	–0.02047	0.03276	0.5374
AGE	–0.20629	0.06954	**0.0062** ***
SIZE	0.01746	0.01549	0.2696
GLPA	–0.03765	0.03111	0.2368
DE	0.00030	0.00014	**0.0449** **
P30	–0.0577	0.04550	0.2149
CPB	0.01574	0.01373	0.2617
EQUITY	0.04071	0.00852	**0.00006** ***
R-square	0.70185	Adjusted R-square	0.272276
F-Statistic (27, 80.1)	14.0586	p-value	3.84e-31

*** significant at 1 %, ** significant at 5 %, * significant at 10 %

The estimated coefficient of MFI age has a negative relation with depth of outreach which is significant at the 1 percent level of significance. That means MFI age has negative impact on depth of outreach. The econometric results reveal that the coefficient of size and the gross loan portfolio to total assets have positive and negative relation respectively with depth of

outreach and are statistically insignificant even at 10 per cent level of significance. This suggests that the size of MFI and gross loan portfolio has a negative impact on outreach.

The estimated coefficient of debt equity ratio and equity shows a positive relation associated with depth of outreach and also statistically significant at 1 percent level of significance. This implies both debt equity ratio and equity have positive impact on depth of outreach [14]. It has been argued that higher level of equity leads to achieve a better outreach. However, portfolio at risk has negative and cost per borrower has positive relationship with depth of outreach but both are statistically insignificant even at 10 percent level of significance.

V. CONCLUSION

The earlier finding provides proof that the depth of outreach has no significant effect on financial sustainability. Hence, the study finds out the effect of financial self-sufficiency and other factors on the depth of outreach. The findings show that financial self-sufficiency has no significant effect on depth of outreach, indicating that there is no trade-off between financial sustainability and depth of outreach. The study also found the insignificant relationship between financial self-sufficiency and depth of outreach when pooled for the entire sample for analysis [14]. However, this finding contradicts the finding that positive profitability and average loan size are positively related [38, 53]. Though, MFI age affects the depth of outreach significantly and negatively, debt equity ratio and total equity affect the depth of outreach significantly and positively. However, MFI size, gross loan portfolio to total assets, portfolio at risk (30 days) and costs per borrower do not have significant effect on depth of outreach.

The findings of ALBPBG model suggest that improving financial performance is associated with larger size loans. The positive relationship associated with financial sustainability proxies with average loan size indicate mission drift where MFIs serve non-poor clients because lower or small loan size indicates better outreach to poor.

REFERENCES

[1] ADB. “Finance for the Poor: Microfinance Development Strategy,” Asian Development Bank, 2000.

[2] A. Hollis, and A. Sweetman, “Microcredit what can we Learn from the Past?”, World Development, vol. 26, pp. 1875-1891, 1998.

[3] M. Robinson, The microfinance revolution: Sustainable banking for the poor, Washington, DC: The World Bank, 2001.

[4] R. Cull, A. Demirgüç-Kunt, and J. Morduch, “Does Regulatory Supervision Curtail Microfinance Profitability and Outreach?” World Development, vol. 39, pp. 949-965, 2011.

[5] M. Chen, and D. Snodgross, Managing resources, Activities and Risk in Urban, 2001.

[6] M. Schreiner, “Aspects of Outreach: A Framework for Discussion of the Social Benefits of Microfinance”, Journal of International Development, vol. 14, pp. 591-603, 2002.

[7] J. Yaron, “What Makes Rural Finance Institutions Successful?”, The World Bank, Research Observer, vol. 9, pp. 49-70, 1999.

[8] G. Woller, “Reassessing the Financial viability of village Banking . Past Performance and Future Prospects”, Micro-Banking Bulletin, Microfinance Information Exchange (MIX), vol. 5, pp. 5-8. 2000.

[9] M. W. E.Glautier, and B. Underdown, Accounting Theory and Practice. 7th ed. United Kingdom: FT Prentice-Hall, 2001.

[10] G. B. Thapa, J. Chalmers, K. W. Taylor, and J. Conroy, “Banking with the Poor, Report and Recommendations Based on Case Studies.

[11] A. Hollis, and A. Sweetman, “Microcredit what can we Learn from the Past?”, World Development, vol. 26, pp. 1875-1891, 1998.

[12] G. D. Nyamsogoro, "Financial Sustainability of Rural Microfinance Institutions (MFIs) in Tanzania", Doctoral Dissertation, University of Greenwich, 2010.

[13] A. Gashayie, & M. Singh, "Relationship of financial Sustainability and Outreach in Ethiopian Microfinance Institutions: Empirical Evidence", Research Journal of Finance and Accounting, vol. 5, pp. 207-211, 2014.

[14] S. Quayes, "Depth of Outreach and Financial Sustainability of Microfinance Institutions", Applied Economics, vol. 44, pp. 3421-3433, 2012.

[15] B. Zerai, and L. Rani, "Technical Efficiency and its Determinants of Micro Finance Institutions in Ethiopia: A Stochastic Frontier Approach", African Journal of Accounting, Economics, Finance and Banking Research, vol. 8, pp. 1, 2012.

[16] C. Serrano-Cinca, and B. Gutiérrez-Nieto. Microfinance, the Long Tail and Mission Drift. International Business Review, vol. 23, pp. 181-194, 2014.

[17] K. Gakhar, "Financial performance and outreach of microfinance institutions: is there a trade-off? an empirical study of Indian economy", Global management review, vol. 7, 2013.

[18] P. Louis, "Financial Efficiency and Social Impact of Microfinance Institutions Using Self-Organizing Maps", World Development, vol. 46, pp. 197-210, 2013.

[19] F. E. Kipesha, and X. Zhang, "Sustainability, Profitability and Outreach Tradeoffs: Evidences from Microfinance Institutions in East Africa", European Journal of Business and Management, vol. 5, 2013.

[20] B. Wydick, H. K. Hayes, and S. H. Kempf, "Social Networks, Neighbourhood Effects, and Credit Access: Evidence from Rural Guatemala", World Development, vol. 39, pp. 974-982, 2011.

[21] N. Hermes, and R. Lensink, "Microfinance: its Impact, Outreach, and Sustainability", World Development, vol. 39, pp. 875-881, 2011.

[22] C. F. Baum, An Introduction to Modern Econometrics Using Stata. USA: Stata Press Publication, 2006.

[23] N. Hermes, and R. Lensink, "The Empirics of Microfinance: what do we Know?", The Economic Journal, vol. 117, pp. 1-10, 2007.

[24] R. Mersland, and R. Ø. Storm, "Performance and Governance in Microfinance Organization: Does Ownership Matter?", Journal of International Development, vol. 20, pp. 598-612, 2008.

[25] J. Johnson, and J. Dinardo, Econometric Methods. 4th International ed. New York: McGraw-Hill, 2007.

[26] J. Marc Wooldridge, Introductory Econometric: A Modern Approach. International Student Edition, 3rd ed. Canada: Thomson South- Western, 2006.

[27] D. N. Gujarati, Basic Econometrics. 4th International ed. USA: McGraw Hill, 2003.

[28] W. Greene, Econometric Analysis. 5th International ed. New Jersey: Prentice Hall, 2003.

[29] R. Cull, A. Demirguc-Kunt, & J. Morduch, "Financial Performance and Outreach: A Global Analysis of Leading Microbanks", Economic Journal, vol. 117, pp. 107-133, 2007.

[30] G. Woller, and M. Schreiner, "Poverty Lending, Financial Self-Sustainability and the Six Aspects of Outreach", The SEEP network. Poverty Lending Working Group, Washington, D.C., 2002.

[31] J. Paxton, and C. Cuvas, "Outreach and Sustailibility of Member-based Rural Financial Intermediaries in Latin America: A Comparative Analysis Sustainable Banking with Poor", Washington , D.C: World Bank, 1998.

[32] A. C. Cameron, and P. K. Trivedi, Microeconometric Using Stata. USA: Stata Press Publication, 2009.

[33] R. M. Rao, "Concepts and Measures of Outreach and Sustainability in Microfinance Institutions: A comprehensive literature review", Research Journal of Finance and Accounting, vol. 5, 2014.

[34] G. Woller, "Evaluating MFIs' Social Performance: A Measurement Tool", Micro Report, Vol. 35, 2006.

[35] S. Navajas, M. Schreiner, R. L. Meyer, C. Gongalez-Vega, and J. Rodriguez-Meza, "Microcredit and the Poorest of the Poor: Theory and Evidence from Bolvia", World Development, vol. 28, pp. 333-346, 2000.

[36] D. Hulme, and P. Mosley, Finance Against Poverty, vol. I, London: Routledge, 1996.

[37] J. Ledgerwood, Microfinance Handbook: An Institutional and Financial Perspective. USA: The World Bank Publications, 1999.

[38] J. Adongo, and C. Stork, "Factors influencing the financial sustainability of selected microfinance institutions in Namibia. Namibian Economic Policy Research Unit", 2005.

[39] V. Hartarska, "Governance and Performance of Microfinance Institutions in Central and Eastern Europe and the Newly Independent States", World Development, vol. 33, pp. 1627-1643, 2005.

[40] B. A. Kinde, "Financial Sustainability of Microfinance Institutions (MFIs) in Ethiopia", European journal of Business and Management, vol. 4, pp. 1-10, 2012.

[41] R. Mersland, and R. Ø. Strøm, "Performance and governance in microfinance institutions", Journal of Banking & Finance, vol. 33, pp. 662-669, 2009.

[42] S. Quayes, "Outreach and Performance of Microfinance Institutions: A Panel Analysis", Applied Economics, vol. 47, pp. 1909-1925, 2015.

[43] J. Conning, "Outreach, Sustainability and Leverage in Monitored and Peer-Monitored Lending. Journal of Development Economics", vol. 60, pp. 51-77, 1999.

[44] T. Keith, Multiple Regression and Beyond. USA: Allyn & Bacon, 2006.

[45] J. F. Hair, W. C. Black, B. J. Babin, R. E. Anderson, and R. L. Tatham, Multivariate Data Analysis, NJ: Pearson Prentice Hall, 2006.

[46] G. A. Churchill, & D. Iacobucci, "Making Microfinance Work: Managing for Improved Performance", Geneva: International Labour Office (ILO), 2005.

[47] M. Verbeek, A Guide to Modern Econometric. 2nd ed. England: John Willey & Sons Ltd, 2004.

[48] C. Hsiao, Analysis of Panel Data, 2nd ed., vol. 34, New York: Cambridge University Press, 2007.

[49] R. M. O'brien, "A Caution Regarding Rules of Thumb for Variance Inflation Factors", Quality and Quantity, vol. 41, pp. 673-690, 2007.

[50] J. T. Mordkoff, The Assumption(s) of Normality, USA: Lowa, 2011.

[51] D. N. Gujarati, & Sangeetha. "Basic Econometrics" Tata McGraw Hill Publishing Company Limited, New Delhi, vol. 110, pp. 451-452, 2007.

[52] M. Arellano, Panel Data Econometric: Advanced Text in Econometric, New York: Oxford University Press, 2003.

[53] K. Beg, "A Critical Apprisal of Microfinance Institutions in India: A Case Study of Seemandhra (Andhra Pradesh)", Doctoral Dissertation, Aligarh Muslim University, India, 2016.

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THE IMPACT OF METAL ION DOPING IN MULTIFERROIC BARIUM TITANATE - COBALT FERRITE COMPOSITE USING SOLID STATE REACTION METHOD: A SHORT REVIEW

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Abstract—In the last decade, scientists have placed significant emphasis on investigating magnetoelectric (ME) multiferroic (MF) materials for their potential in various cutting-edge applications in the field of sensors, nonvolatile memory elements, ferroelectric photovoltaics, nanoelectronics, etc. The composites of these materials show the coexistence of multiple ferroic orders, where two or more distinct properties like magnetic spin, polarization, ferroelastic ordering, and ferrotoroidicity are present simultaneously due to the interconnected and cross-coupling effects. One of the mostly studied ME-MF composites is comprised of barium titanate, $BaTiO_3$ (BTO) and cobalt ferrite, $CoFe_2O_4$ (CFO) where BTO is the ferroelectric phase and CFO is the ferromagnetic phase. BTO is familiar for its high dielectric constant and extensive use in the electrical industry, while CFO is known for low magnetic losses, high resistivity, and excellent mechanical properties. However, the structural, electrical, and magnetic characteristics of BTO and CFO can be modified by doping different metal ions. This modification is done due to the interaction of metal atoms having different atomic radii which produces stress and strain in structure of BTO and CFO. In this review, we provide a short overview of the effects that are occurring in both electric and magnetic properties of BTO - CFO composite due to doping of different metal ions as well as the limitations that exist within this sector and highlight the intriguing future prospects.

Keywords— Multiferroic, Ferroelectric, M-H loop, Dielectric constant, P-E loop

I. INTRODUCTION

Multiferroic materials (MMs) have received a great deal of attention in the scientific community due to their applications in the field of memory, spintronics, and sensors in next-generation devices and so on [1, 2]. In addition, multiferroic magnetoelectric (ME) materials not only demonstrate ferroelectric and ferromagnetic properties, but they also show coupling effect in dielectric polarization caused by an external magnetic field or a magnetization stimulated by an applied electric field [3]. Effects of magnetoelectric coupling have been seen in both single phase compounds and composite materials. However, in single phase multiferroic compounds, the coupling effects deteriorates because of chemical incompatibility of the materials, existence of weak coupling between the order parameters at room temperature, and the difficulty in tuning the magnetoelectric (ME) response [4-6]. Therefore, researchers are paying more and more attention to magnetoelectric composites that have both ferroelectric and ferromagnetic phases [7, 8]. As Magnetoelectric effects are higher for composite material compared to single phase multiferroic, the composite materials have vast applications. Barium titanate, $BaTiO_3$ (BTO) is a ferroelectric material which shows high dielectric

constant, low dielectric loss, and ability to function under high electric fields over a wide range of temperatures (from 30 to 400 K) [9-11]. As a result, BTO is considered to be an essential material for microwave devices with variable characteristics. On the other hand, cobalt ferrite, $CoFe_2O_4$ (CFO) is a ferromagnetic material which has high resistivity and significant magneto strictive coefficient and the chemical stability, curie temperature, and magneto-crystalline anisotropy of $CoFe_2O_4$ are also high [12]. Because of its high magnetostriction, CFO is a promising multiferroic material [13]. In addition to these advantageous features of individual phases, the spinodal decomposition that prevents any chemical reaction between these phases at high sintering temperatures is an essential advantage of multiferroic composites made from $BaTiO_3$ and $CoFe_2O_4$ phases [14]. Moreover, the electrical and multiferroic properties of these composites can be modified by doping different metal ions. The notable characteristics observed in the host material as a result of metal ions doping can be attributed to the alteration of valence states among various cations at distinct sites. On the other hand, metal ions have a greater tendency to inhabit the octahedral position (B-site) in the spinel structure due to their large size [28]. Jamaluddin *et al.* [15] investigated the properties of strontium (Sr) doped barium titanate powder, $Ba_xSr_{1-x}TiO_3$ (x = 1 %, 2 %, 3 %, 4 %, 5 %) which has prepared by solid state reaction method . It has been observed that with increasing Sr, the dielectric constant was increasing linearly which has the impact on capacity of storage. Mansour *et al*. [16] investigated the influence of La doping and synthesis method on the properties of $CoFe_2O_4$ nanocrystals and found that with increasing La doping, saturation magnetization increases linearly. This review summarizes the dielectric and magnetic properties of pure and doped BTO + CFO nanostructures focusing the effect of concentration of ferrite with ceramics and different kind of doping on the dielectric, ferromagnetic, and ferroelectric properties.

II. SYNTHESIS

A range of multiferroic composites, consisting of $(1 - x)$ BTO + (x) CFO, usually fabricated using the usual sintering ceramic technique, applying a variety of concentrations. Oxides and carbonates are usually by solid state reaction method. In terms of their purity and grain distribution, these compounds should conform to specified specifications in order to meet the requirements. Because of its flexibility and low cost, the solid-state reaction process is mostly employed for the large manufacture of bulk powders.

Generally, BTO ceramic is prepared using raw ingredients including $BaCO_3$ and TiO_2 with a purity of 99.99 % as shown in Fig. 1. Similarly, for the preparation of the CFO ferrite, raw materials such as Fe_2O_3 and Co_2O_3 with a purity of 99.99 % employs. Afterwards, the powders undergo hand milling using an agate mortar for a minimum duration of 6 hours. Subsequently, the well amalgamated powders form into disks by employing a steel die and a hydraulic press, applying a unidirectional pressure of 7000 pounds per square inch (psi). At the moment, a small quantity of polyvinyl alcohol (PVA) employs as a binding agent for the powders. Then, the disks undergo calcination in a furnace at a temperature of 700 ℃ for a duration of 4 hours, in order to accelerate the desired reaction between the precursors. The calcined disks undergo a subsequent smashing process lasting 2.5 hours in order to achieve homogeneity. The powders of spinel and perovskite phases are then weighed and amalgamated based on their respective weight percentages inside the composite materials. Next, the powders undergo an additional manual milling process lasting 1.5 hours in order to get an even combination. The toroids and pellets are shaped by applying forces of 15 kN and 20 kN, respectively, and are consolidate using a single drop of PVA. Subsequently, the consolidated materials are subjected to sintering in air at a temperature of 1250 ℃ (can varies this temperature based on samples melting point) for a duration of 4 hours.

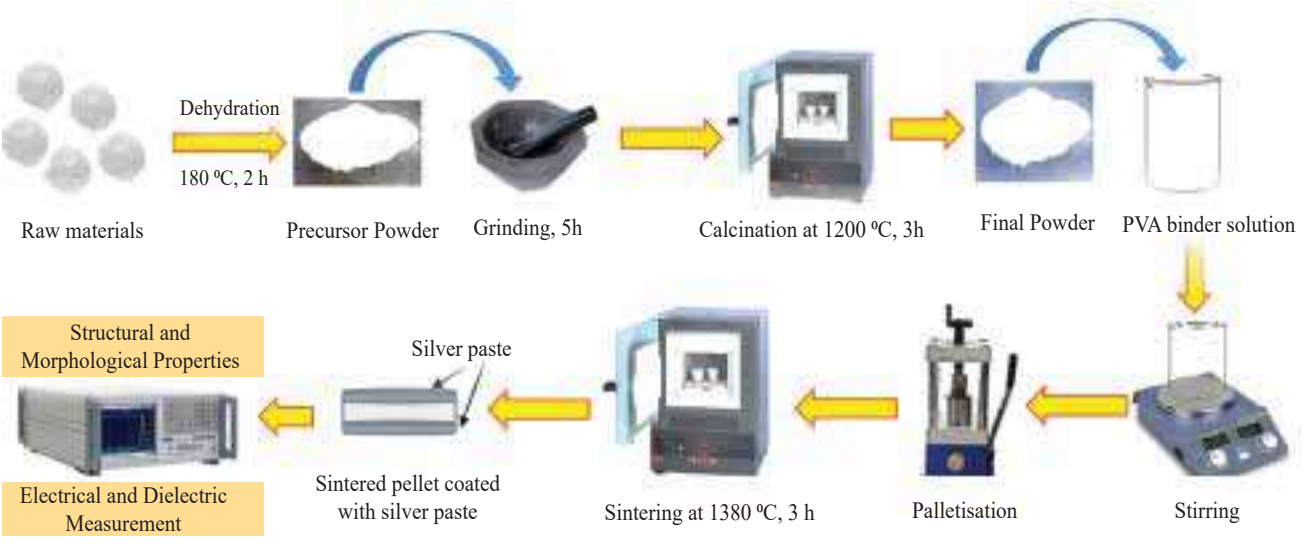

Fig. 1. Schematic diagram showing the different steps of the solid-state reaction method. [17]

III. RESULTS AND DISCUSSION

A. Dielectric properties

Exploring the dielectric properties of a substance is crucial as it offers valuable insights into the material's capacity to store electrical energy within an electric field. This information proves beneficial in diverse applications like electrical insulation, capacitors, and dielectric heating. Moreover, delving into a material's dielectric properties can yield valuable knowledge about its chemical and physical characteristics, encompassing factors such as chemical composition, crystal structure, and thermal stability. In search of more effective results doping has been done on different materials. So many finest works have been done in this field. Some examples are given below-

Dung *et al.* [18] investigated the relaxor behaviour in (*x*) $BaTiO_3$ - (1-*x*) $CoFe_2O_4$ materials using the solid-state reaction method with a sintering temperature of 1200 °C (*x* = 1, 0.5, and 0 respectively). In the plot of real permittivity, ε' versus temperature (Fig. 2a-d), board peaks have been observed. Strong frequency dispersions are observed below the maximum temperature (T'm), with a distinct frequency-dependent shift in the position of T'm. It is well known that $BaTiO_3$ is not a conventional relaxor, but the data acquired in this study reveals an atypical behavior in which the $BaTiO_3$ sample exhibits the strongest relaxor behavior among the samples studied.

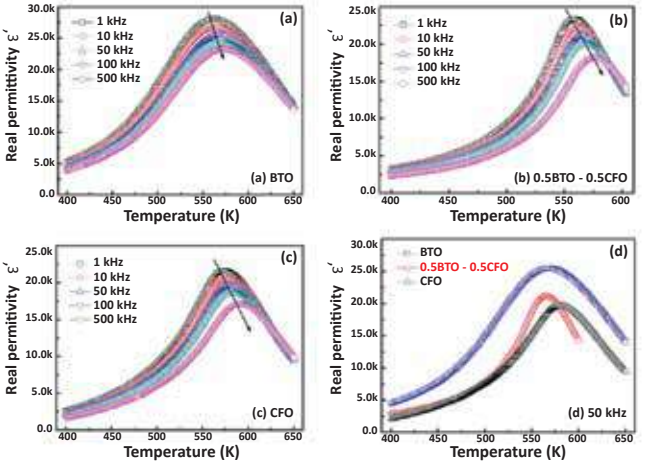

Fig. 2. At various frequencies, temperature-dependent dielectric spectra ε' of composite (*x*) $BaTiO_3$ – (1-*x*) $CoFe_2O_4$ materials with *x* = 1, 0.5, and 0 are presented. [18]

Wang *et al.* [19] has used the standard solid state reaction method, to analyses the dielectric, ferromagnetic and ferroelectric properties of (1-*x*) $Ba_{0.8}Sr_{0.2}TiO_2$ – (*x*) $CoFe_2O_4$ ceramic composites (x = 0 – 0.4 and 1). The variations of dielectric constant (ε') and dielectric loss (tanδ) with frequency has conducted in the range of 40 Hz to

1 MHz for composites at room temperature. As shown in Table I, the dielectric constant of composites reduces as the concentration of ferrite increases which can be described by Curier - Weiss law. As followed by Cooper's law, the dielectric loss increases initially to a peak with increasing frequency and then decreases at higher frequencies. The composites exhibit relaxor ferroelectric properties.

Table I. The values of dielectric constant (ε') and dielectric loss ($\tan\delta$) for the composites (1-x) $Ba_{0.8}Sr_{0.2}TiO_2$ – (x) $CoFe_2O_4$ where x = 0 – 0.4 and 1. [19]

Concentration, x	*Dielectric constant, ε'*	*Dielectric loss, tanδ*
0.1	1498.2	.0055
0.2	966.5	.0068
0.3	601	.0078
0.4	384.6	.0093
1.0	–	–

Sharma *et al.* [20] used the solid state reaction method to examine the structural, dielectric, ferromagnetic, ferroelectric, and ac conductivity of (1-x) $BaTiO_3$ – (x) $CoFe_{1.8}Zn_{0.2}O_4$ multiferroic particulate composites where x = 10, 20, 30 and 40 wt. %. With increasing ferrite content, the dielectric constant increases (See Fig. 3). The evident high values of dielectric constant are explained by the effect of space charges and the hopping conduction mechanism, both of which plays a significant role in such composites.

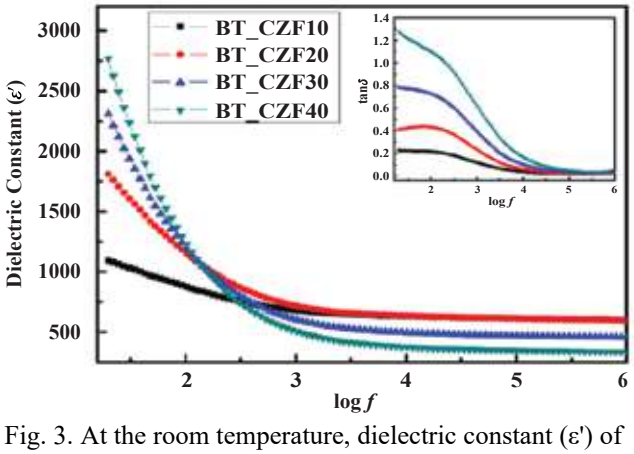

Fig. 3. At the room temperature, dielectric constant (ε') of composites with variation of frequency is investigated. (The inset illustrates the loss tangent ($\tan\delta$) variation with frequency. [20]

A study on a multiferroic composite material characterized by the general formula (1 - x) $BaTiO_3$ - (x) $CoFe_2O_4$, where x = 0.05, 0.15, 0.25, 0.35 and 0.45 was conducted by Padmapriya *et al.* [21] using a conventional solid-state reaction method. The dielectric constant, which is dependent on frequency, was determined at room temperature within the frequency range of 1 kHz to 1 MHz for pure barium titanate (BTO), cobalt ferrite (CFO) and composite materials consisting of (1 - x) $BaTiO_3$ – (x) $CoFe_2O_4$. It has been observed from Fig. 4 that the dielectric constant exhibits a slow fall and then reaches a nearly consistent value up to 1 MHz across all the samples following Curier-Weiss law.

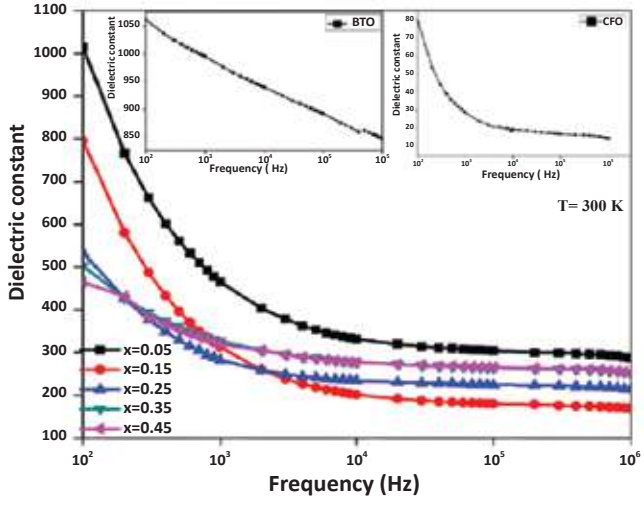

Fig. 4. Variation between the dielectric constant and frequency for a composite material consisting of (1 - x) $BaTiO_3$ and (x) $CoFe_2O_4$, where x =0.05, 0.15, 0.25, 0.35, and 0.45 respectively. Pure BTO and CFO are represented by inset figure. [21]

Arshad *et al.* [22] employed solid state reaction method to explore the electrical and dielectric properties of Sr-doped $Ba_{1-x}Sr_xTiO_3$ (barium strontium titanate, BST) ceramics where x = 0, 0.25, 0.3, and 0.35 respectively. Fig. 5 illustrates the frequency dependent loss tangent and dielectric constant of BST samples at various fixed temperatures. Every sample has exhibited higher dielectric constants in the low frequency and temperature region and lowered dielectric constants in the higher frequency and temperature region.

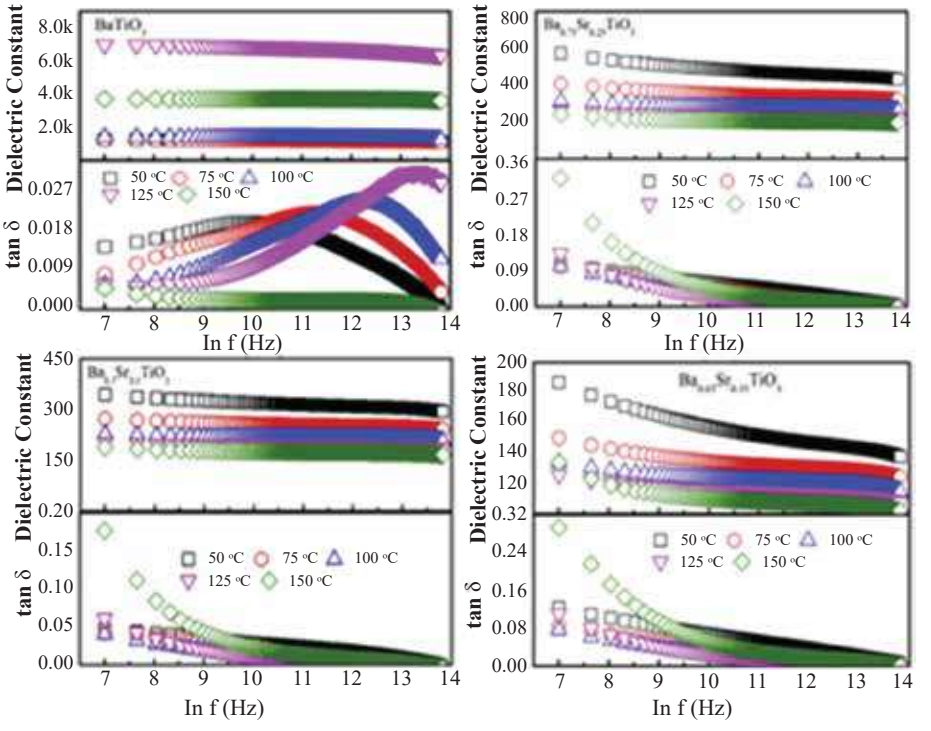

Fig. 5. At different temperatures dielectric constant, and loss, tan with the variation of frequency. [22]

To investigate the effect of the diffuse phase transition caused by Sr doping in BT ceramics, the modified Curie–Weiss law fitting was applied to BST samples as shown in Fig. 6. Materials with $\gamma = 1$ have normal ferroelectric properties, materials with $\gamma = 2$ have full relaxor properties, and materials with $\gamma = 1$ to 2 have diffuse ferroelectric properties [23, 24]. Based on the diffusivity factor value, it is confirmed that by adding Sr^{2+} up to (x = 0.3) in BT, the diffusivity factor decreases with the increase in concentration and reaches the normal ferroelectric materials, whereas increasing the concentration of Sr^{2+} further results in the BST ceramic materials exhibiting relaxation behavior.

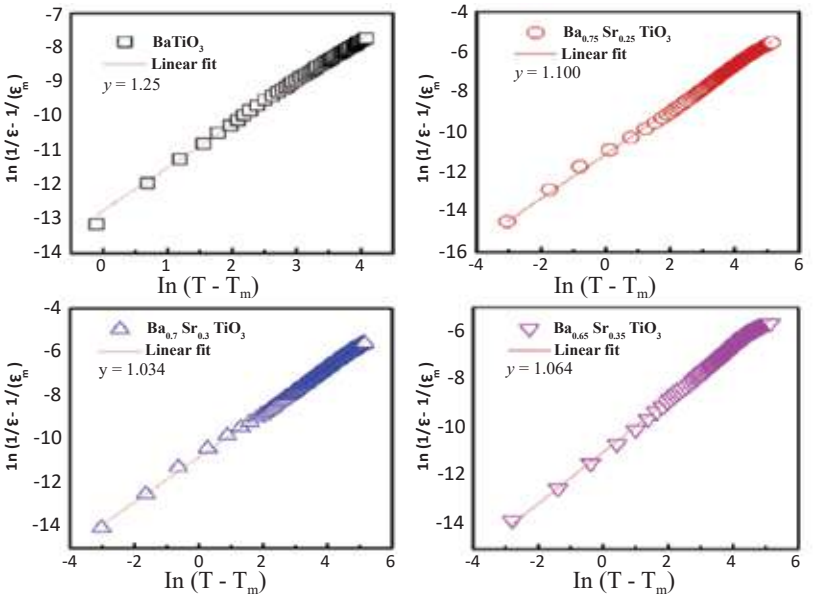

Fig. 6. Graph of ln $(\frac{1}{\varepsilon} - \frac{1}{\varepsilon_m})$ versus ln (T-Tm) in accordance with the modified Curie-Weiss law. [22]

B. Ferroelectric properties

P-E loop analysis, which stands for polarization - electric field loop analysis, is particularly important in the study of multiferroic materials because it provides crucial insights into the coupling between electric and magnetic order parameters in these materials. P-E loops help in identifying phase transitions in ferroelectric materials. The loop shape and the presence of hysteresis in the P-E curve are indicative of the material's ferroelectric nature and its ability to maintain a remnant polarization. Some examples have been provided below regarding this measurement.

Puli *et al.* [25] investigated crystal structure, dielectric, ferroelectric and energy storage properties of La-doped $BaTiO_3$ ($Ba_{1-x}La_xTiO_3$ where, x = 0, 0.0005, 0.001, 0.003) semiconducting ceramics using the solid state reaction method with a sintering temperature of 1350 °C for 4 hrs. He has observed that when the La doping concentration increased, the P–E hysteresis loops became increasingly thinner, indicating ferroelectric behavior shown in Fig. 7.

Ferroelectric hysteresis loops demonstrated that as the measuring electric field increased, the P–E loops of ceramics became progressively well saturated. It has been observed that for concentration x = 0.001, the saturation polarization, P_s was maximum with a value of 21.55 $\mu C/cm^2$ and energy storage efficiency was 39.1 %. That means this concentration can be a potential candidate for the improvement of memory application devices. This material can be a good candidate for potential energy storage devices [23].

Rather *et al.* [26] investigated enhanced magnetoelectric effect in multiferroic composites containing ytterbium-doped (YbBT) $BaTiO_3$ – $CoFe_2O_4$. The P-E hysteresis loops were traced in order to determine the ferroelectric properties of the YbBT phase and all composites. For YbBT phase, a well-saturated P-E hysteresis loop with a saturation polarisation of 5.76 $\mu C/cm^2$ is observed. Due to the leakage currents in the composites, the non-saturated and rounded margins of the P-E loops are caused as shown in Fig. 8.

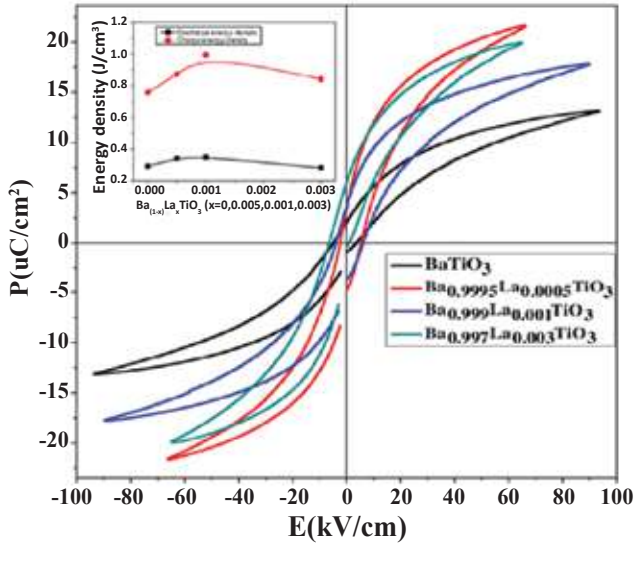

Fig. 7. Ferroelectric (P–E) hysteresis loops of $Ba_{1-x}La_xTiO_3$ (x= 0, 0.0005, 0.001, 0.003) ceramics sintering at 1350 °C for 4 h and (inset) composition-dependent energy densities. [25]

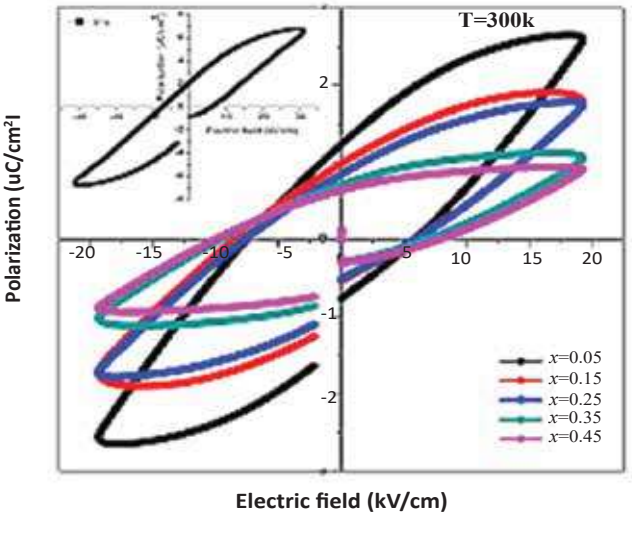

Fig. 8. The hysteresis loops of the polarization versus electric field (P-E) characteristics. [26]

Table II. Values on ferroelectric parameters of BTO, CFO and (1 - x) $BaTiO_3$ – (x) $CoFe_2O_4$ composites. [21]

Sample x	*Saturation polarization, P_s ($\mu C/cm^2$)*	*Remnant polarization, P_r ($\mu C/cm^2$)*
0.0	6.84	2.06
0.05	2.62	1.24
0.15	1.78	1.00
0.25	1.74	0.85
0.35	1.05	0.70
0.45	0.90	0.65
1.0	—	—

Padmapriya *et al.* [21] investigated the P-E loops for the sample (1 - *x*) $BaTiO_3$ - (*x*) $CoFe_2O_4$, where x = 0.05, 0.15, 0.25, 0.35, and 0.45. The unsaturated characteristics observed in the P-E loops of all the composite samples can be attributed to the leaking of polarised charges through the ferrite content CFO, which exhibits a greater leakage current density. With increasing doping, reduction in saturation polarization (P_s), remnant polarization (P_r) and enhancement in coercive field (E_c) values has been observed as shown in table 2.

C. Ferromagnetic Properties

In multiferroic materials, the M-H (magnetization vs. applied magnetic field) curve is measured to understand and characterize the magnetic properties of the material. It helps in characterizing the magnetic behavior of the material, such as the saturation magnetization, coercive field, and remnant magnetization. These parameters are essential for understanding how the material responds to an applied magnetic field. M-H curve is used by the researchers to optimize the magnetic properties of multiferroic materials. This involves adjusting factors such as composition, temperature, and external parameters to enhance the overall performance of the material for specific applications. Some finest works on M-H curve has given below.

Sharma *et al.* [20] used the solid state reaction methodto examine the ferromagnetic properties of (1-*x*) $BaTiO_3$ – (*x*) $CoFe_{1.8}Zn_{0.2}O_4$ multiferroic particulate composites where *x* = 10, 20, 30 and 40 wt. %. Magnetization (*M*) versus Magnetic Field (*H*) loops were measured at room temperature to determine the magnetic properties of BT– CZF composites as shown in Fig. 9.

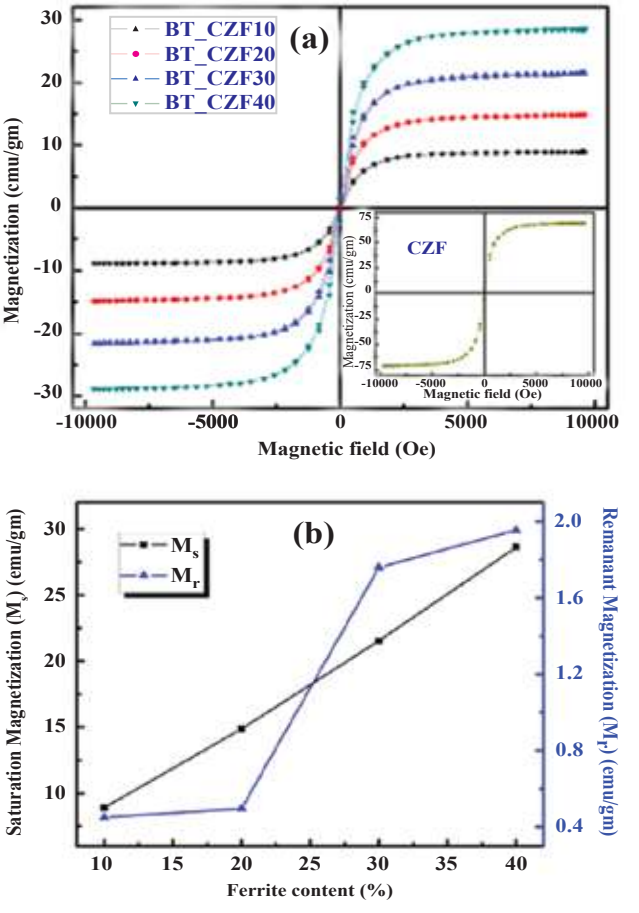

Fig. 9. (a) Magnetization (M) versus magnetic field (H) for composites with various amounts of ferrite at room temperature. The inset depicts the hysteresis curve for the pure $CoFe_{1.8}Zn_{0.2}O_4$ (CZF) phase. (b) Variation of saturation magnetization (Ms) and remanant magnetization (Mr) on the ferrite content of the composites. [20]

At room temperature, all composites exhibit distinctive M–H loops, confirming the existence of an orderly magnetic structure in the composites. The saturation magnetization (M_s) and remanant magnetization (M_r) tend to increase as the ferrite content rises. As saturation magnetization has increased with increasing ferrite content, that means it is exhibiting hard magnetic behavior which has useful application in data storage devices, electronic circuits.

Rather *et al.* [26] investigated magneto-dielectric characteristics of (x) $CoY_{0.1}Fe_{1.9}O_4$ - (1-x) $Ba_{0.95}Y_{0.05}TiO_3$ (where x = 0.05, 0.1, and 0.15). The magnetic properties of YBC1, YBC2, and YBC3 composites, including coercivity (H_c), remanence (M_r) and saturation magnetization (M_s) were evaluated using magnetic hysteresis measurements at room temperature. A Vibrating Sample Magnetometer (VSM) was employed, applying a magnetic field within the range of –20 kOe to 20 kOe. It is noticeable that with a rise in temperature, there is a reduction in the area of the hysteresis loop, resulting in a decrease in the saturation magnetization (M_s). As shown in Fig. 10, coercivity increases with decreasing temperature, which can be related to an increase in anisotropy field which can be a good candidate in the application of magnetic recording media.

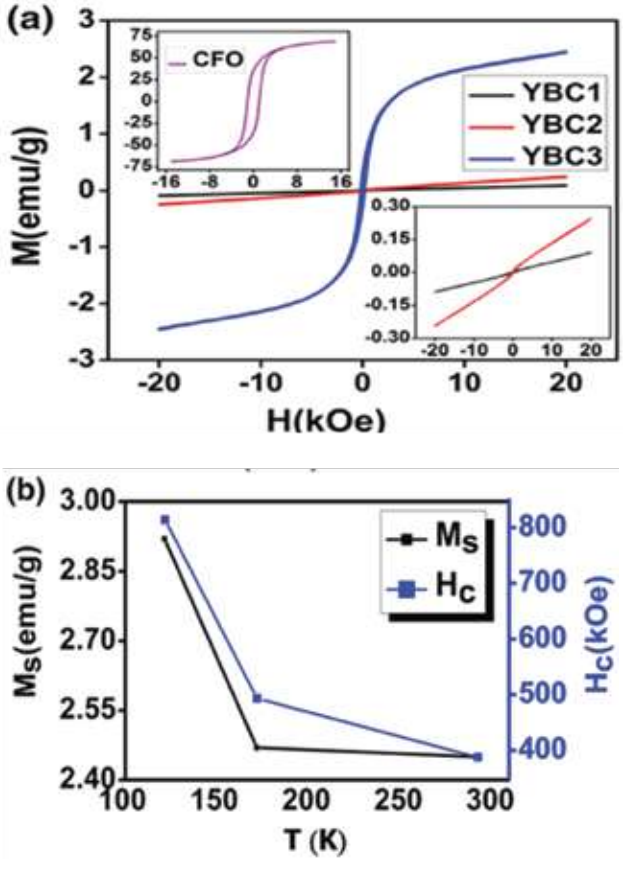

Fig. 10. (a) M–H hysteresis loops at room temperature for YBC1, YBC2, and YBC3, with an inset displaying the M–H loop of the YCFO phase and (b) Variation of M_S and H_C with temperature. [26]

Mansour *et al.* [27] synthesized nanocrystals of La-doped $CoFe_2O_4$ via three distinct techniques: flash autocombustion, citrate–nitrate, and the conventional ceramic technique. Among these three method, from M-H loop analysis, it has been found that both saturated magnetization and coercive field has showed anomalous behavior with increasing La content. The highest saturated magnetization has found 54.40 emu/g for x = 0.1. The coercive field has at first decreased with increasing La doping. But suddenly it increased with a value of 362.23 O_e for x = 0.25.

Roongtao *et al.* [28] effectively synthesized a series of $CoFe_{2-x}Mn_xO_4$ (x = 0.00, 0.10, 0.15, 0.20 and 0.25) ceramics using conventional solid-state reactions in order to study their magnetic properties. The magnetic properties of Mn-substituted cobalt ferrite were measured at room temperature with a maximal applied field of 8 kO*e*, as depicted in Fig. 11.

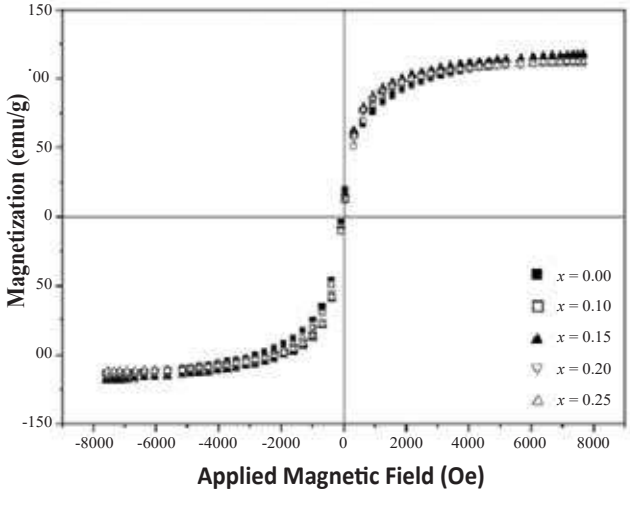

Fig. 11. At ambient temperature, magnetic hysteresis loops of $CoFe_{2x}Mn_xO_4$. [28]

From Table III, it has been seen that with increasing Mn doping, saturated magnetization at first increased and then decreased linearly. The coercive field has decreased continuously with increasing Mn content. That means it is behaving like a soft magnet. Soft magnets are very useful for magnetic memory device and transformer.

Table III. The magnetic properties of $CoFe_{2-x}Mn_xO_4$. [26]

Sample, x	*Saturation magnetization, M_s* (emu/g)	*Magnetic field, H_c* (Oe)
0.0	115.33	78.86
0.10	116.82	40.89
0.15	118.11	46.89
0.20	113.97	40.89
0.25	112.81	37.97

IV. CONCLUSION AND FUTURE INSIGHTS

In this review paper, the effects of different metal ion dopants on the magnetic and electrical properties of barium titanate - cobalt ferrite (BTO - CFO) were examined. Observations indicate that progress has been made at each doping site, allowing for the investigation of diverse multiferroic properties. As a result of both A-site and B-site modification, the leakage problem of multiferroic materials was reduced, as reported. Existence of several characteristics, such as ferroelectricity, ferromagnetism, and ferro elasticity, in multiferroic materials has generated significant interest. These materials hold promise for a range of applications in multifunctional devices that are characterized by low power consumption and environmental friendliness. Even though significant progress has been made in the development of both bulk and film-based ME composites, it is likely that the quest will keep going. Devices based on microelectromechanical systems (MEMS) have desirable characteristics such as compactness, lightweight design, rapid reaction, reduced noise levels, and energy efficiency. Consequently, they present themselves as feasible replacements to some conventional electrical and magnetic devices already in use. To achieve robust ME coupling and high-performance ME composites, it is necessary to choose the proper combination of piezoelectric, magneto strictive, and film-based ME composites. Due to its minimal cost, the convectional solid state reaction method is a widely used technique in industry. But other techniques, such as the rolling film method, spark plasma sintering, and pulsed laser deposition, should also be investigated more to achieve even better outcomes, which will lead us to the materials that can be the best candidates for various applications to achieve the desired outcome, the industrial sector ought to explore more frequently alternative preparation methods. Several noteworthy advancements and accomplishments have been made in energy storage and photovoltaic applications, but there are still a few issues that must be resolved before they can reach their optimum performance.

REFERENCES

[1] C.W. Nan, "Magnetoelectric effect in composites of piezoelectric and piezomagnetic phases," Phys. Rev. B, vol. 50, pp. 6082–6088, Sep. 1994.

[2] B. Li, C. Wang, and G. Dou, "Synthesis of multiferroic $Bi_{0.9}La_{0.1}Fe_{0.95}Mn_{0.05}O_3$ – $Ba_{0.7}Sr_{0.3}TiO_3$ – $Ni_{0.8}Zn_{0.2}Fe_2O_4$ nanotubes with one closed end using a template-assisted sol–gel process," CrystEngComm, vol. 15, pp. 2147–2156, Jan. 2013.

[3] K. C. Verma, R. K. Kotnala, and N. S. Negi, "Improved dielectric and ferromagnetic properties in Fe-doped $PbTiO_3$ nanoparticles at room temperature," Appl. Phys. Lett., vol. 92, pp. 152902, Apr. 2008.

[4] D. Khomskii, "Classifying multiferroics: Mechanisms and effects," Phys., vol. 2, pp. 20, Mar. 2009.

[5] G. Catalan and J. F. Scott, "Physics and Applications of Bismuth Ferrite," Adv. Mater., vol. 21, pp. 2463–2485, 2009.

[6] C.-W. Nan, M. I. Bichurin, S. Dong, D. Viehland, and G. Srinivasan, "Multiferroic magnetoelectric composites: Historical perspective, status, and future directions," J Appl. Phys., vol. 103, pp. 031101, Feb. 2008.

[7] Q. H. Jiang, Z. J. Shen, J. P. Zhou, Z. Shi, and C.-W. Nan, "Magnetoelectric composites of nickel ferrite and lead zirconnate titanate prepared by spark plasma sintering," J Eur. Ceram. Soc., vol. 27, pp. 279–284, Jan. 2007.

[8] H. Zheng et al., "Multiferroic $BaTiO_3$-$CoFe_2O_4$ Nanostructures," Sci., vol. 303, pp. 661–663, Jan. 2004.

[9] M. U. D. Rather, R. Samad, and B. Want, "Improved magnetoelectric effect in ytterbium doped $BaTiO_3$-$CoFe_2O_4$ particulate multiferroic composites," J Mater Sci: Mater Electron, vol. 755, pp. 89–99, Jul. 2018.

[10] S. Das, C. W. Manpoong, S. S. Gautam, A. Madheshiya, and C. R. Gautam, "Tribological study of strontium bismuth titanate borosilicate glass ceramics," Materials Today: Proceedings, vol. 5, pp. 20306–20313, Jan. 2018.

[11] K. D. Schomann, "Electric breakdown of barium titanate: A model," Appl. Phys., vol. 6, pp. 89–92, Feb. 1975.

[12] J. Zhai, N. Cai, Z. Shi, Y. Lin, and C.-W. Nan, "Coupled magnetodielectric properties of laminated $PbZr_{0.53}Ti_{0.47}O_3$ - $NiFe_2O_4$ ceramics," J Appl. Phys., vol. 95, pp. 5685–5690, May 2004.

[13] L. Zhang, L.-Y. Chen, and L. Wang, "Surface Modification of Titanium and Titanium Alloys: Technologies, Developments, and Future Interests," Adv. Eng. Mater., vol. 22, pp. 2070017, May 2020.

[14] Y. Wang, "Dielectric, ferromagnetic and ferroelectric properties of the (1−x) $Ba_{0.8}Sr_{0.2}TiO_3$ – x $CoFe_2O_4$ multiferroic particulate ceramic composites," J Mater Sci: Mater Electron, vol. 23, pp. 1064–1071, May 2012.

[15] A. Jamaluddin, Suwarni, A. Supriyanto, and Y. Iriani, "Properties of strontium doped barium titanate powder prepared by solid state reaction," J. Phys.: Conf. Ser., vol. 776, pp. 012052, Nov. 2016.

[16] S. F. Mansour, O. M. Hemeda, S. I. El-Dek, and B. I. Salem, "Influence of La doping and synthesis method on the properties of $CoFe_2O_4$ nanocrystals," J Magn. Magn. Mater., vol. 420, pp. 7–18, Dec. 2016.

[17] S. Kumari, "Structural, dielectric and ferroelectric properties of Cu^{2+}- and Cu^{2+}/Bi^{3+}-doped BCZT lead-free ceramics: a comparative study," J Mater Sci: Mater Electron, vol. 32, pp. 16900–16915, Jun. 2021.

[18] C. T. M. Dung et al., "Relaxor Behaviors in x $BaTiO_3$ - (1-x) $CoFe_2O_4$ Materials," J. Magn., vol. 20, pp. 353–359, Dec. 2015.

[19] Y. Wang et al., "Dielectric, ferromagnetic and ferroelectric properties of the (1-x) $Ba_{0.8}Sr_{0.2}TiO_3$ – x $CoFe_2O_4$ multiferroic particulate ceramic composites," J Mater Sci: Mater Electron, vol. 23, pp. 1064–1071, May 2012.

[20] R. Sharma, P. Pahuja, and R. P. Tandon, "Structural, dielectric, ferromagnetic, ferroelectric and ac conductivity studies of the $BaTiO_3$ – $CoFe_{1.8}Zn_{0.2}O_4$ multiferroic particulate composites," Ceram. Int., vol. 40, pp. 9027–9036, Aug. 2014.

[21] D. Padmapriya, "Composition-dependent structural, electrical, magnetic and magnetoelectric properties of (1−x) $BaTiO_3$ – x $CoFe_2O_4$ particulate composites," Bull Mater Sci, vol. 43, pp. 276, Dec. 2020.

[22] M. Arshad, "Fabrication, structure, and frequency-dependent electrical and dielectric properties of Sr-doped $BaTiO_3$ ceramics," Ceram. Int., vol. 46, pp. 2238–2246, Feb. 2020.

[23] D. Li, "Progress and perspectives in dielectric energy storage ceramics," J Adv Ceram., vol. 10, pp. 675–703, Aug. 2021.

[24] S. I. Ahmad, "Nano cobalt ferrites: Doping, Structural, Low-temperature, and room temperature magnetic and dielectric properties – A comprehensive review," J Magn. Magn. Mater., vol. 562, pp. 169840, Nov. 2022.

[25] V. S. Puli, P. Li, S. Adireddy, and D. B. Chrisey, "Crystal structure, dielectric, ferroelectric and energy storage properties of La-doped $BaTiO_3$ semiconducting ceramics," J. Adv. Dielect., vol. 05, pp. 1550027, Sep. 2015.

[26] M. U. D. Rather, R. Samad, and B. Want, "Ferroelectric and magneto-dielectric properties of yttrium doped $BaTiO_3$–$CoFe_2O_4$ multiferroic composite," J Mater Sci: Mater Electron, vol. 29, pp. 19164–19179, Nov. 2018.

[27] S. F. Mansour, O. M. Hemeda, S. I. El-Dek, and B. I. Salem, "Influence of La doping and synthesis method on the properties of $CoFe_2O_4$ nanocrystals," J Magn. Magn. Mater., vol. 420, pp. 7–18, Dec. 2016.

[28] R. Roongtao, R. Baitahe, N. Vittayakorn, P. Seeharaj, and W. C. Vittayakorn, "Influence of Mn Doping on the Magnetic Properties of $CoFe_2O_4$," Ferroelectrics, vol. 459, pp. 119–127, Jan. 2014.

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A SYSTEMATIC REVIEW ON TISSUE REJECTION PHENOMENA AMONG BANGLADESHI ESL LEARNERS IN TERTIARY LEVEL

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Abstract*— The demand of English language proficiency has been increasing remarkably all around the world- as well as in Bangladesh, due to various reasons, such as globalization, better job opportunities, increasing importance of English in digital and global age, etc. Consequently, English language learning institutions and online resources have witnessed a significant increase in popularity, reflecting the growing enthusiasm and pressure for mastering this global language-which is evident in Bangladeshi contexts as well. However, like many other countries, Bangladesh too has a tendency to often ignore the actual socio-economic conditions and embrace western approaches to teaching English, just to compete with the advanced world, which leads to contextual and cultural complexities and differences. As a result, the aim of learning English remains unresolved rather learners face 'tissue rejection' phenomena i.e., rejecting the language just like body rejects tissue after organ transplantation. Here, this systematic review investigates on the mentioned phenomenon- 'tissue rejection' among the Bangladeshi English as a Second Language (ESL) learners at the tertiary level, focusing on the existing perspectives of students' feedbacks and teachers' responses. The review also synthesizes a broad spectrum of literature, encompassing socio-economic factors, limited exposure to English, pedagogical approaches and its shortcomings, teacher competency, language anxiety and cultural as well as historical influences. Furthermore, the study signifies the pivotal role and scopes of collaborative rectification of teachers' as well as curriculum developers' in tissue rejection, mainly focusing on our local context. By reflecting on the framework of Byun *et al.* (2011), contextual opportunities and challenges of tissue rejection among the learners are derived.

Keywords*— *Tissue rejection, ESL, CLT, Systematic review, Challenges, Pedagogical approaches

I. INTRODUCTION

Language is such a social practice that demonstrates individual and group identity depending on the learner's ability, proficiency, motivation, which is often shaped by historical, socio-cultural, economic and educational factors. In this modern era of globalization, the rising status of English as a language, more precisely as a global language, is nothing new for the economic, social and intellectual development of countries, especially the South-Asian ones. Bangladesh, having the influence of its colonial period and being an aspiring middle-income country of South-Asia, lets English play its role as a global lingua franca and a tool for upward mobility in educational and professional pursuits [1].

In the context of Bangladesh, introduction of English into the existing linguistic space is pretty challenging, especially in educational contexts, considering the positive and negative shifts of

learners - based on their ability, proficiency, motivation and will power to learn the language. According to Beckett and Macpherson, English is considered as an asset of God which has gained monopoly by attracting human in economic exploitation and ideological and cultural hegemony [2]. This powerful position of English contributes to a continuous reformulation of structural and cultural inequalities [3]. Moreover, the lack of contextualization prevents learners to develop critical language thinking and consciousness in order to change or prevent the course of linguistic domination such is the case of Bangladesh. Bangladesh adopted Communicative Language Teaching (CLT) in 1990s in the place of Grammar Translation Method (GTM), a traditional approach of teaching, considering the importance of communicative English in global horizon which could not attain its desired goal due to the absence of contextual errors in terms of socio-economic condition of Bangladesh.

The primary reason behind this failure is that the approaches are mainly developed by foreign experts without any participation of the actual implementers who have a vast socio-cultural/ political knowledge of the actual conditions of the classrooms. Briane cited an Indian-born medical doctor Abraham Verghese who puts a nice view on the participation of foreign experts "like a transplanted organ- lifesaving and desperately needed, but rejected because we are foreign tissue" which means western teaching methods cannot be simply imported, it must be modified to match the sociocultural/ political contexts [4]. As most English Language Education innovations are developed with a BANA (British, Australian and North-American)- like native-institutional environment in mind, attempting to implement them in a TESEP (Tertiary, Secondary and Primary English language schools)- oriented context is likely to result in 'tissue rejection' [5]. In Bangladesh, CLT is the most widely used approach for teaching English and there is abundance of studies on the advantages of CLT and its challenges. However, there is not much research on how the poor implementation of CLT can result in 'tissue rejection' among students, destroying the whole agenda of learning second language.

The aim of this paper is to fill this gap by conducting systematic review on tissue rejection, especially among tertiary level ESL learners, by analyzing students' feedback and teachers' response. This review will follow the framework of Byun *et al.* [6] who conducted research at Korean University on EMI. According to Byun *et al.* to avoid negative effects like 'tissue rejection', the implementation of CLT needs to be successful considering three areas: 1) the students' and instructors' language proficiencies, 2) the varying demands of different academic subjects, and 3) a facilitative body which can support this implementation. As a result, curriculum designers may get assistance to implement context-appropriate curriculums by observing the teacher and student-feedbacks from this research arena.

II. LITERATURE REVIEW

The significance of English as a global lingua franca has a strong position among Bangladeshi learners even Bangladesh has been following that path where learning English is more valued than leaning mother tongue. At the same time, there is a huge pressure of learning English for basic survival which creates social and psychological displacement resulting in 'tissue rejection' [7].

As stated briefly in the introduction, the term 'tissue rejection' is taken from medicine, where it is used to describe cases in which organ transplant fails because it is not accepted by the host. Hoyle [8] uses the term to describe what happens when curriculum innovation 'does not become an effectively functioning part of the system'. In Bangladesh, English Language

Education system has always been questionable in terms of curriculum formation and implementation. Hamid and Baldauf [9] used the term "bogged down" to indicate the poor condition of English in rural Bangladesh. Though Bangladesh is considered to have the largest population in the world learning English with over 17 million children-learners, we are still debating over the fact that whether English is considered as the second (English as a Second Language, ESL) or a foreign (English as a Foreign Language, EFL) language in Bangladesh. Recently, however, Bangladesh government refers English as second language through its curriculum [10]. In short, Bangladesh always lacks consistent English Language Teaching (ELT) education policy, clear vision and certainty; on top of that, having three different education systems e.g., 'mainstream' secular system, 'madrasah' system of religious education and 'English-medium' education system – the education policy suffers from an added labour in this process.

In Bangladesh, National Curriculum and Textbook Board (NCTB) introduced CLT curriculum without proper training and guidance to the teachers. As teachers do not have clear idea of CLT curriculum and they are expected to adopt westernized method, which is an entirely different culture of teaching and learning – it creates complications in the implementation of CLT. As both Fullan and Marsh & Willis [11, 12] have argued, "the frequent incompatibility of curriculum innovations with the existing perceptions, beliefs, and values of the teachers charged with implementing these innovations is perhaps the single biggest constraint in curriculum change". This lack of compatibility between the social-context and theoretical practice is contributing to the continuous failure of CLT in Bangladesh over several years. Kumaravadivelu [13] shares his views on post-method pedagogy for having context-sensitive language education that promotes understanding of local linguistic, political and socio-cultural particularities. Evdokia Karavas-Douka [14] opines, "The curriculum developers believe that Greek English language teachers would gradually become convinced of the benefits of a communicative learner-centered approach and understand its principles by using the textbooks in the classroom, proved naive and unrealistic". This belief not only shows a preference for imported methodologies as superior but also a lack of awareness of the adverse effects that such methodologies may have on teachers and learners and on the likely success of a project.

According to Shabnam Mahtab [15], CLT is not feasible in Bangladesh as the traditional method, GTM, is much prevalent here and people are not still ready to accept it and thus, tissue rejection occurs. However, it can be compatible if some measures are taken. Though CLT promotes speaking practice in the classroom, in Bangladeshi context with a huge number of students, it becomes ironic and tissue rejection comes from the teachers first. Besides, because of the failings in equipment, teachers do not follow the planned speaking lessons; rather GTM is followed. In cases, students are eager to practice speaking, however, because of lack of logistic support, they cannot [16]. In Asian culture, speaking without much thought is not valued. Besides, if any grammatical item is not taught, rather conversation practice takes place, it is considered both by students and teachers that nothing solid or concrete has been taught. Therefore, like Minfang, so many of the students in Bangladesh go through the same phase with similar feelings of insecurity and discomfort [17]. Randomly accepting English language projects will not be beneficial if the foreign country methods are blindly used as the method will be rejected because of non-compatibility; rather context-appropriateness and teachers' beliefs should be considered as well [18].

III. RESEARCH METHODOLOGY

The methodology section is consisted of two sections – firstly, there is a cursory overview of the themes that emerge from the literature review section. Secondly, there is a systematic and expanded discussion on how the three areas of Byun *et al.*'s [6] research framework reflects on the findings of tissue rejection among the tertiary level students in the Bangladeshi context.

A. *The First Stage of Analysis*

A purposive sampling approach was used to locate sources for content analysis [19]. Some standards were set to meet certain criteria; the publications had to be internationally acknowledged, there had to be the implementation of teaching methodology along with its advantages and challenges being mentioned, the publications had to be from English as a Second Language (ESL) or English as a Foreign Language (EFL) contexts, and they had to be published at least post 1990, as CLT was introduced as an approach of English teaching in the national English curriculum of Bangladesh for the first time in 1990s [15]. By maintaining these criteria, sources were located by exploring international publications.

The mentioned criteria worked as a guidance for the purposive sampling approach, which helped in the systematic review of the framework of the paper. The database includes some papers from international conferences as well, however, the number is quite low, considering the total portion of the reviewed papers.

Through the purposive sampling approach, a good number of sources were identified to guide the systematic approach, which helped the framework of the paper. The number of papers were too much to handle for the small scale of the research. Thus, based on other researchers' recommendations, a sample of each source was analyzed to arrive at an overview of themes which emerged from the data [20] [21]. Abstracts and chapter introductions were used as samples where journal articles and book chapters were used as sources. Sources not intended for international audience were avoided throughout the process of the research. Table 1 provides a tabulation of relevant words that were selected using the Lextutor software in the first stage of analysis. It includes various items such as adaptability, interact, speaking, comprehension, shyness, difficulty, inference, fossilization, language barriers, positive transfer, negative transfer, interlanguage, input hypothesis, output hypothesis, motivation, language classroom, teaching methods, and error analysis. The table presents the number of positive occurrences and negative occurrences for each item, with a tally at the bottom for the overall distribution. This representation overall helped to understand the parameter of relevance of the papers used in this review.

Table I. A tabulation of the relevant lexical items which were selected following the use of the lextutor software in the first stage of analysis

ITEMS	POSITIVE	NEGATIVE
Adaptability	6	4
Interact	7	12
Speaking	4	9
Comprehension	8	6
Shyness	3	10
Difficulty	5	13
Inference	-	8
Fossilization	-	9
Language Barriers	6	11
Positive Transfer	4	8
Negative Transfer	8	4
Interlanguage	9	5
Input Hypothesis	5	13
Output Hypothesis	3	16
Motivation	3	9
Language Classroom	6	11
Teaching Methods	4	9
Error Analysis	5	7
TALLY	**86 (39.72%)**	**164 (75.24%)**

The condensed sources were placed into lextutor, which systematically calculated word frequencies and then it was connected to the research hypothesis. Words matching to challenges or opportunities and having an individual tally over five, were matched for the extraction of the process.

B. *The Second Stage of Analysis*

Althaus, Edy and Phalen [22] state that an aggregation of a large sample of abstracts can disclose significant factors relating to the subject matter being researched. However, there was also a caution of 'imprecise representations' in the fuller body of the researches. That means, the representations can be misinterpreted according to the full research papers; however, in this circumstance, the lexical corpus driven analysis functioned precisely to match the investigation with the general themes emerging from the literature. In Table I, the positive (one-third of the total count) and negative themes (two-thirds of the total count) of the reviewed paper are being displayed, which solely describe the core of tissue rejection in various contexts around the world. With the reflection of the relevant contexts, the advantages and challenges could be located. Till the first stage of analysis, it is vivid that the merits and demerits exist. To dig further, a second stage of analysis was required to find out 'what' are the factors behind to experience such evidences.

As per the framework of Byun *et.al* as being mentioned previously, three areas are needed to be reflected on to find out the causes that create tissue rejection in the mentioned contexts; foreshadowing the similar contexts, tissue rejection can further be explored in the context of Bangladesh [6]. The three areas are: 1) the students' and the instructors' language proficiencies; 2) the varying demands of different academic subjects; and 3) a facilitative body which can support English language teaching and avoid tissue rejection. The sources were manually overviewed to match the context of Bangladesh and relate to the themes from the first stage of analysis. A manual systematic approach was done to increase relevance with data [23]. A much closer observation took place in the second step of analysis, focusing on the opportunities and challenges from each existing information, followed by a three-layered finding based on the archived data. The findings from each arena were then sorted into three different tables (see Results below), summarizing challenges and opportunities as well as the respective contexts and the methods of research.

IV. RESULTS

Each of the tables in results section summarizes the key findings based on the framework of Byun *et al.* [6] which includes mainly the opportunities, challenges and relevant contexts, locations, methods, followed by a discussion of substantive findings from each aable.

Table II. A summary of discoveries from the systematic literature review concerning **the students' and the instructors' language proficiencies**

Authors	Location and Context	Opportunities, challenges/advice	Methods
Chowdhury Patwary [24]	Bangladesh: Classroom interaction in developing speaking skill	**Challenges:** 1) Gaps in students' linguistic knowledge 2) Poor speaking proficiency and confidence among students	Mixed Method
Akhteruzzaman and Sattar [25]	Bangladesh: Struggles of attending introductory English courses in tertiary level	**Challenges:** 1) Low speaking proficiency and teacher quality 2) Challenges in transition to tertiary education	Qualitative

Quyen *et al.* [26]	Teachers' roles in student-autonomy	**Opportunity:** Teachers' roles in autonomy (Western concept of ELT teaching) have been prioritized	Qualitative
Abdul Rhman *et al.*[27]	Namibia: Challenges EFL learners encounter in oral participation	**Opportunity:** 1) Teachers' attitude towards students' speaking affects students' motivation and involvement. 2) Classroom setup and student grouping influence students' use of the target language 3) Students' awareness in fluency encourages them to participate orally 4) Role-play promotes in-class oral participation 5) Students and teachers both claim to avoid using L1 frequently **Challenges /Advice:** 1) Linguistic barriers: vocabulary limitations, pronunciation issues, poor listening skills, lack of preparation, and native language usage. 2) Language anxiety: shyness, demotivation, lack of self-confidence. 3) Students' personal fears and poorly managed class often make students avoid speaking.	Qualitative
Tauhiduz-zaman [28]	Bangladesh: Challenges of CLT in Secondary schools in Southern Bangladesh	**Challenge** Inefficiencies of ELT practitioners	Quantitative
Karavas-Doukas *and* Evdokia [14]	Greece: Teacher-identified factors affect EFL implementation	**Challenges/Advice:** 1) Teachers' attitudes, beliefs and understanding should get modified 2) Insufficient teacher-training 3) Teachers' misjudgment on the possibility and practicality of the innovation	Qualitative
Kang and Su-Ja [29]	Korea: Individual and socio-contextual factors affecting ESL	**Challenges** Sunwoo, a Korean physician's belief regarding teachers' and students' shortcomings	Qualitative
Waters and Alan [30]	Managing innovation in English language education: A research agenda	**Challenges** TESEP-teachers are considered favoring GTM whereas BANA-teachers are considered CLT). As the	Secondary Source
Jimenez, Kanoh [31]	Japan: Searching appropriate method to learn vocabulary to avoid contextual errors	**Challenges** A hassle for larger classes and inexperienced teachers; time-consuming as well	Quantitative

According to the first area of Byun *et al.*'s [6] framework, Table II exhibits several reasons behind tissue rejection of ELT innovations. One of the main barriers is the proficiency level of the students and the teachers. To begin with, Patwary *et al.* [24] talks about this issue by stating how students' lack in language proficiency, especially in speaking ability of English hampers the classroom interaction. As a result, CLT, which is the new innovation of ELT, does not suit

the classroom context of Bangladesh which results in tissue rejection. It is also not possible to have interactive classrooms at tertiary level because of the low English language proficiency of the students and low quality of teachers. As a result, any innovation gets rejected in classroom practice. Moreover, philosophical conflicts between TESEP (Tertiary, Secondary and Primary) countries and BANA (Britain, Australasia and America) countries also cause tissue rejection. TSESP teachers are considered favoring "didactic, content-based pedagogy" whereas BANA teachers are considered as "skills-based, discovery-oriented, collaborative pedagogy" [5]. As the two kinds of teacher foster different philosophies, tissue rejection occurs.

Abdulrhman *et al.* [27] depicts that students are reported to face linguistic barriers, including vocabulary limitations, which may impact their language proficiency. This indicates that students may struggle with vocabulary acquisition and may have limited command over the language's lexical resources.

Tauhiduzzaman [28] reflects on the inefficiencies of the English language trainers in Bangladesh; and there are factors such as cultural differences, lack of adaptation, and inadequate teacher training which contribute to this issue. The author also mentions that the transition of Bangladeshi tertiary learners from their previous academic context is also a significant barrier to contribute to this phenomenon.

Karavas-Doukas, Evdokia [14] discusses how teachers' attitudes and beliefs, understanding of the innovation, judgements on the feasibility and practicality of the innovation get rejected which result in tissue rejection in the context of Greece. The same situation can be applicable in Bangladesh where the unheard voices of teachers result in rejection of westernized ELT innovation in the classrooms of Bangladesh [24]. Moreover, factors such as classroom setup, student grouping, and students' awareness of the focus on fluency can also influence their oral participation. On top of that, poorly managed classes, personal fears, and lack of self-confidence are mentioned as factors that often make students avoid oral participation.

Overall, the review findings reveal that students' and teachers' language proficiency levels, particularly in speaking and conducting classes respectively, may vary, with many students struggling in this aspect. Students also face challenges, obstacles, and linguistic barriers that can hinder their language proficiency development.

Table III. A summary of discoveries from the systematic literature review concerning the varying opportunities and challenges of **different academic English language teaching situations**

Author	Location and Context	Opportunities, Challenges/Advice	Methods
Rahman and Pandian [32]	Bangladesh: CLT in EFL Classrooms	**Challenges:** 1) Unclear state of CLT in BD, and Uncontextualized Western content 2) No collaboration between teachers and curriculum designers	Secondary Data
Chowdhury and Kabir [33]	Bangladesh: Tension between Bengali & English	**Challenges:** 1) Friction between Bengali and English due history and identity 2) Considering English as colonial legacy 3) Nationalist and elitist mentalities relating to English	Secondary Research
Biva and Parvin [34]	Global South: Politics of ELT Pedagogy	**Opportunity:** Global politics motivate to accept westernized ELT: Policy does not accept tissue rejection but adopts westernized ELT methods by labeling the native English as authentic English	Quantitative

Kumaravad-ivelu [13]	Previously colonized countries: Post method Pedagogy	**Advice:** In post method era, promoting students' and teachers' methods, instead of borrowing from western ideas	
Ali *et al.* [35]	Bangladesh: Policy regarding ELT	**Challenges:** 1) Curriculum not based on socio-cultural reality. 2) Time and moneywastage for CLT 3) Giving less importance to teachers' beliefs	Qualitative
Tauhiduz-zaman [28]	Bangladesh: Challenges of CLT in secondary schools of southern Bangladesh	**Challenges:** 1) Economic and infrastructural constraints 2) Cultural conflicts 3) Testing (negative backwash effect)	Quantitative
Rahman and Karim [36]	Bangladesh: Problems of CLT in Bangladesh	**Challenges:** 1) Washback effect of university entrance exam 2) Cultural barrier	Mixed Method
Elizabeth *et al.* [37]	Bangladesh: Perceptions of people from two villages about English	**Opportunities:** 1) English and its access to global system, employment, work abroad, local industries 2) English for using technologies 3) English and its culture value/identity **Challenges:** 1) English as a non-Islamic language 2) Concern forBangla	Ethnographic research
Guo and Becktt [7]	China: Hegemony of English: Reclaiming local knowledge and culture in China	**Opportunity:** In China, ESL teaching is being used under the flagship of superiority **Challenges/Advice:** 1) Learners cannot foster critical thinking skill without suitable context 2) Bilingual/local teachers can teach better as they have translation and interpretation skill, unlike foreign experts 3) Glocalization is demanded	
Holliday [38]	Designing a course in intercultural education	**Advice:** Rejection of western culture is a process of domination. Instead, intercultural competence should be fostered.	

According to the second area of Byun *et al.*'s [6] framework, Table III shows the academic setting as a barrier for innovative ELT implementation in Bangladesh. The study of Rahman & Pandian shows the unclear state of CLT in Bangladesh where there is no collaboration between teachers and curriculum designers, as well as the use of uncontextualized Western content [32]. As a result, teachers cannot grasp the western-contextualized ELT practice which is devoid of local cultural sensitivities.

The intriguing research conducted by Chowdhury and Kabir [33] focuses on the tension between the Bengali and English languages in Bangladesh, examining the friction between Bangla and English in terms of independence and identity, the perception of English as a colonial legacy, and the nationalist and elitist mentalities regarding English language education. This majorly results in tissue rejection in English language learning in Bangladesh as learners lack acceptance, reliance and dedication in learning a foreign language,

having suspicion at the back of their mind, which results in insufficient dedication to learn English.

Ali and Walker [35] discuss the policy regarding ELT in Bangladesh, pointing out the lack of connection between the curriculum and the socio-cultural reality of the students. This disconnection leads to a rejection of CLT at the grassroots level, resulting in wasted time and resources, as well as a disregard for teachers' beliefs.

Tauhiduzzaman [28] focuses on the challenges faced in implementing CLT in secondary schools in the southern region of Bangladesh. These challenges include economic constraints, infrastructural limitations, cultural conflicts, seating arrangements in classrooms, class size, testing, and negative backwash effects. The situation is exactly the same in most of the tertiary level institutions in Bangladesh, without any doubt.

Rahman *et al.* [36] discusses the negative washback effect and cultural barriers that become the cause of tissue rejection. As English speaking and listening are not tested in university entrance exams, teachers teach by following traditional methods instead of innovative ELT practices that require speaking and listening.

Elizabeth *et al.* [37] conducted ethnographic research in two villages in Bangladesh, exploring the perceptions of the villagers regarding English. The study revealed positive beliefs about English in terms of access to the global system, employment, working abroad, use of technology, cultural identity; however, they consider English as a non-Islamic language, which can be considered as a major negative aspect of tissue rejection. Though the authors suggest that these beliefs may be naive and not well-informed.

Guo *et al.* [7] conduct a study in Chinese context where they showed that ELT does not consider local context; the local teachers are more informed of the classroom situations than foreign experts. However, the voices of the practitioners are not considered during curriculum design. As a result, ELT innovations get rejected in grassroot levels. Same scenario is observed in the context of Bangladesh. The academic scenario is the same where the foreign experts' opinions are enforced on local teachers without using their local knowledge as resources that results in tissue rejection.

Table IV. A summary of discoveries from the systematic literature review concerning **support systems** to aviod tissue rejection

Author	Location and context	Opportunities, challenges/advice	Methods
Rahman and Pandian [32]	Bangladesh: CLT in EFL Classrooms	Challenges: 1) Lack of teacher training infrastructure 2) No collaboration between teachers and curriculum designers	Secondary Data
Patwary and Chowdhury [24]	Bangladesh: Classroom interaction as a way of students' developing speaking skill	Challenge: Lack of supportive academic environment and motivation	Mixed Method
Akhteruz-zaman and Sattar [25]	Bangladesh: Struggles of attending introductory English courses in tertiary level	Challenge: Discrepancy between policy and practice (not enough infrastructural support)	Mixed Method
Kabir [16]	Bangladesh: Challenges of speaking English in classroom	Challenge: Lack of resources provided by the institution	Mixed Method

Tsui [17]	China: Conflict of novice teacher regarding CLT vs. Traditional Method	Challenge: Schools took several initiatives for integrating CLT; however, there was no training on integrating ELT in the context of China	Qualitative
Tauhiduz-zaman, [28]	Bangladesh: Challenges of CLT in secondary schools of southern Bangladesh	Challenge: Inadequacies in administrative and Infrastructural set-up.	Quantitative
Bax [39]	Roles for teacher educator in context-sensitive teacher education	Advice: Nourishing context-sensitivity in teacher education to help teachers reflect on their works and increase productivity.	Qualitative

According to the third area of Byun *et al.*'s [6] framework, table 4 shows insufficient teaching support as a major reason for tissue rejection. To begin, Rahman & Pandian [32] discuss the general lack of teacher training infrastructure. Since teachers do not get the chance to understand underlying philosophies of ELT innovations and cannot share their own opinions regarding the compatibility of certain ELT innovations, tissue rejection occurs. Because of a lack of supportive academic environment and motivation, interaction in the classroom cannot take place. As a result, in recent ELT innovations where the philosophy entails classroom interaction gets rejected as the classroom environment is not appropriate.

Patwary and Chowdhury [24] explored classroom interaction as a mean of developing students' speaking skills; however, they discovered lack of a supportive academic environment and motivation, which are major challenges and are catalysts for tissue rejection. Similarly, Akhteruzzaman and Sattar [25] focused on the struggles faced by students attending introductory English courses in tertiary education in Bangladesh and identified a discrepancy between policy and practice, with inadequate infrastructural support. Kabir [16] examined the challenges of speaking English in the classroom in Bangladesh. The lack of resources provided by institutions was identified as a major challenge; the innovations which easily suit in the western context do not suit in a developing country like Bangladesh.

Tauhiduzzaman [28] also talks on inadequacies in administrative set-up, infrastructural limitations, seating arrangements in classrooms etc. in the high schools of southern Bangladesh. Needless to say, the scenario is similar for tertiary level educational institutions of Bangladesh as well.

V. A HOLISTIC PERSPECTIVE

The metaphorical concept-tissue rejection, refers to challenges and barriers of learning English language, specifically among Bangladeshi tertiary level-students. The challenges emerged from the findings of tissue rejection basically shade light on two aspects-lack of planning and manpower to implement proper curriculum and students' inadequate proficiency to learn English as the second/global language of the world. A holistic overview includes factors such as: socioeconomic challenges, limited exposure to English, unplanned curriculum and pedagogy, incompetency of English instructors, language anxiety, cultural, economic and linguistic differences, difficulty in code-switching from Bangla to English, lack of motivation, limited resources, standardized testing pressure, exam-fever etc.

The main reason in the expanded horizon reflects on the complexity between traditional GTM and CLT method, to teach English as a second language in Bangladeshi tertiary level education. Above all, curriculum design should be localized and the facilitators should be well-trained to

manage diverse situations. If having a sustainable and contextualized policy, the students as well as the teachers will feel at home in advancing their level of learning and teaching English at tertiary level education. Rather than adopting a 'rapid implementation' of ELT, a step-by-step plan of curriculum should be there beside the teachers and the students as a blueprint, to avoid tissue rejection and implement effective policies in the context of Bangladesh.

VI. CONCLUSION

In conclusion, this systematic review highlights the critical issues, contextual factors, and drawbacks of 'tissue rejection' among Bangladeshi ESL learners at the tertiary level. The study specifically aimed at understanding the extent to which 'tissue rejection' can occur due to the failure of contextualization in English language teaching scenario in Bangladesh. The findings of this study also address the challenges, shortcomings, and strategies of Bangladeshi English language education by calling for a comprehensive reform of policies and practices to improve students' language proficiency as well as enhance their educational experiences. This study again emphasizes the importance of addressing these contextual issues for achieving the country's developmental goals; it cautions against blindly adopting western teaching methodologies without considering the local context and teacher readiness as well, to avoid policy-practice discrepancy, curriculum and resource limitations, and administrative and infrastructural constraints.

Importantly, this review has highlighted the role of teachers, policymakers and stakeholders, to have a comprehensive and collaborative effort in addressing tissue rejection. Though this review reflects on some important aspects of tissue rejection among tertiary level learners in Bangladesh, it has certain limitations. As this is a qualitative study purely based on secondary data, the data of this study is very limited and may have a gap in the information. Therefore, it is difficult to consider these sample as representative of whole Bangladesh. Moreover, the research is a context-specific study as the data is drawn from a single field of study (tertiary level students). Further large-scale studies and exploration of diverse background in different contexts will help to produce more accurate findings and enhance the quality of ESL education in Bangladesh largely. However, the present study will offer a promising input in the quest for the causes and effects of 'tissue rejection' in English language Education in Bangladesh.

As English is the Lingua Franca of the present world, it is a dire need to recognize the contextual challenges of English, and pave the way for an inclusive and effective approach of learning this language. By doing so, we can aspire to reduce the phenomenon of tissue rejection, empower Bangladeshi ESL learners, and enable them to fully embrace English as a valuable tool for academic, professional, and personal growth.

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REFERENCES

[1] World Bank. 2016. 'GDP growth (annual %).' Online at <http://data.worldbank.org/indicator/NY.GDP.MKTP. KD. ZG?

[2] G.H. Beckett, S. MacPherson, "Researching the impact of English on minority and indigenous languages in non-'Western' contexts", TESOL Quarterly, vol. 39, pp. 299-307, 2005.

[3] R. Phillipson, "Linguistic imperialism", Oxford: Oxford University Press, 1992.

[4] G. Braine, "Non-native educators in English language teaching", Mahwah, NJ: Lawrence Erlbau, 1999.

[5] A. Holliday, Appropriate Methodology and Social Context. Cambridge: Cambridge University Press, 1994.

[6] K. Byun, H. Chu, M. Kim, I. Park, S. Kim, & J. Jung, "English-medium teaching in Korean higher education: policy debates and reality", Higher Education, vol. 62, pp. 431-449, 2011.

[7] Y. Guo, & G.H. Beckett, "The hegemony of English as a global language: Reclaiming local knowledge and culture in China". Convergence, vol. XL, pp. 1-2, 2007.

[8] E. Hoyle, "Planning organizational change in education". Research in Education, pp. 1-22, May, 1970.

[9] M. O. Hamid, & R. B. Baldauf, "Will CLT bail out the bogged down ELT in Bangladesh?" English Today, vol. 24, pp. 16–24, 2008.

[10] National Curriculum and Textbook Board (NCTB). Online at <http://www.nctb.gov.bd/>

[11] C. J. Marsh, & G. Willis, "Curriculum: Alternative Approaches, Ongoing Issues", New Jersey: Prentice Hall, vol. 4th ed, 2007.

[12] M. Fullan, "The New Meaning of Educational Change", London & New York: Routledge, vol. 4th ed, 2007.

[13] B. Kumaravadivelu, "Toward a Post-method Pedagogy", Teachers of English to Speakers of Other Languages, Inc. (TESOL), vol. 35, pp. 537-560, 2001.

[14] E. Karavas-Doukas, "Teachers identified factors affecting the implementation of an EFL innovation in Greek public secondary schools", Center for English Language Teacher Education, University of Warwick, Coventry, CV4 7AL, England, 2009.

[15] S. Mehtab, "Difficulties and challenges in implementing CLT in Bangladesh", BRAC University, 2012. Retrieved from http://hdl.handle.net/10361/1894

[16] U. S. Kabir, "Challenges of Speaking English in Bangladeshi Classrooms", 2014.

[17] Tsui, B.M. Amy, "Complexities of Identity Formation: A Narrative Inquiry of an EFL Teacher", TESOL Quarterly, vol. 41, December 2007.

[18] M. M. Ali, & A. L. Walker, "Bogged Down' ELT in Bangladesh: Problems and Policy", Cambridge University Press, United Kingdom, vol. 30, 2014.

[19] D. Riffe, S. Lacy, & F. Fico, "Analyzing Media Messages: Using Quantitative Analysis in Research", Mahwah, NJ: Lawrence Erlbaum Associates, 2005.

[20] O.R. Holsti, "Content Analysis for the Social Sciences and Humanities", Reading, MA: Addison-Wesley, 1969.

[21] K. Krippendorff, "Content Analysis: An Introduction to its Methodology", 3rd ed, New York: Sage, 2012.

[22] S. L. Althaus, J. A. Edy & P. F. Phalen, "Using the Vanderbilt Television Abstracts to Track Broadcast News Content: Possibilities and Pitfall", Journal of Broadcasting & Electronic Media - J BROADCAST ELECTRON MEDIA, vol. 46, pp. 473-492, 2002.

[23] N. Bergen, "Narrative depictions of working with language interpreters in cross-language qualitative research", International Journal of Qualitative Methods, vol. 17, 2018.

[24] M. N. Patwary, & S. Chowdhury, "Classroom Interaction as a Way of Developing Students' Speaking Skill at the Tertiary Level EFL Classroom: An Empirical Investigation", Crossings: A Journal of English Studies, vol. 12, pp. 220–250, 2021.

[25] M. Akteruzzaman, & S. B. Sattar, "The Struggles of Attending Introductory English Courses in Bangladeshi Universities", International Journal of Linguistics, Literature and Translation, vol. 3, pp. 223–234, 2020.

[26] Q. H. T. Le, T. T. Dang, & Q. T. T. Bui, "Tertiary EFL Students' Learner Autonomy: The Roles of Teachers in the Classroom. Theory and Practice in Language Studies", vol. 13, pp. 1880-1887, 2023.

[27] A. Musabal, & M. Abdalgane, "Exploring the Obstacles EFL Learners Encounter in Classroom Oral Participation from the Perspective of Tertiary Level Instructors", Journal of Namibian Studies: History Politics Culture, vol. 33, pp. 1121 - 1141, 2023.

[28] M. Tauhiduzzman, "Exploring the challenges to implement CLT at the secondary level in the Southern region of Bangladesh", 2010.

[29] S. Kang, "Individual and Social-Contextual Factors Affecting the Learning and Use of ESL: A Case Study of a Visiting Korean physician", TESL Canada Journal, vol. 24, 2006.

[30] A. Waters, "Managing Innovation in English language education", Cambridge University Press. Language Teaching, vol. 47, pp. 92 - 110, 2009.

[31] F. Jimnez, & M. Kanoh, "Change in Learning Ability Using Scaffolding in EFL Vocabulary Learning System", 8SCIS-ISIS 2012, Kobe, Japan, November 20-24, 2012.

[32] M. Rahman, & A. Pandian, "A Critical Investigation of English Language Teaching in Bangladesh: Unfulfilled expectations after two decades of Communicative Language Teaching", English Today, vol. 34, pp. 43-49, 2018.

[33] R. Chowdhury, A. H. Kabir, "Language wars: English education policy and practice in Bangladesh", Multiling, Ed. 4, 21, 2014.

[34] T. P. Biva, "Politics of ELT Pedagogy in the Global South. Daffodil International University's DSpace repository", 2020. http://dspace.daffodilvarsity.edu.bd:8080/handle/123456789/7286

[35] M. S. Rahman, S. M. S. Karim, "Problems of CLT in Bangladesh: Ways to Improve", International Journal of Education Learning and Development, vol. 3, pp. 75-87, April 2015.

[36] E. Erling, P. Seargeant, M. Solly, Q. H. Chowdhury, & S. Rahman, "Attitudes to English as a language for international development in rural Bangladesh", British Council, London., 2012.

[37] A. Holliday, "Designing a course in intercultural education. Intercultural Communication Education", vol. 1, pp. 4-11, 2018.

[38] S. Bax, "Roles for a teacher educator in context-sensitive teacher education", ELT Journal, vol. 51, pp. 232–241, July 1997.

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VALIDATION OF PCTRAN FOR SIMULATING LARGE BREAK LOSS OF COOLANT ACCIDENT (LBLOCA) IN VVER NUCLEAR REACTOR

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***Abstract*— The accident simulator, PCTRAN plays an important role in the training and education of nuclear power professionals. It has the prospect in leading many training resources in nuclear power plants. In this study the accuracy of PCTRAN used for simulating major accident scenarios in VVER reactors is discussed. The simulation is done considering a large break loss of coolant accident (LBLOCA) in the cold leg of 200 % of 100 cm^2 guillotine break and thermal hydraulic responses of VVER-1200 reactor is monitored. The accuracy of PCTRAN is further justified by comparing with the responses of various components of RELAP5 code-based data. It has been observed that, PCTRAN is being able to simulate most of the data with good agreement with RELAP5 code-based data. PCTRAN may smoothen the dataset for leaked mass flow rate and maximum cladding temperature. This leads to the high accuracy of PCTRAN in long time run, however it lacks in sensitivity during transient study.**

Keywords—PCTRAN, LBLOCA, thermal hydraulics, VVER-1200

I. INTRODUCTION

In order to maintain the security and reliability of the nuclear power plant, it is essential to analyze the large break loss of coolant accident (LBLOCA) in the VVER-1200 reactor [1]. In this analysis, the behavior of the reactor core and its constituent parts is examined in the case of a significant coolant system rupture [2]. This includes assessing the impact of the accident on fuel cladding, analyzing thermal hydraulic parameters, and investigating the effects of control rod withdrawal. Furthermore, it is important to examine the subcooled boiling phenomena in the reactor downcomer during a LBLOCA scenario [3].

Understanding these phenomena and their consequences is essential in developing strategies to mitigate the effects of a LBLOCA and prevent severe accidents like the Chernobyl accident. These studies provide insights into the thermal hydraulic properties of the reactor core components and help in developing advanced analysis tools to predict and control the effects of a large break loss of coolant accident in the VVER-1200 reactor.

The drop in water temperature that occurs during emergency core cooling system injection is one of the important factors to take into account while analyzing an LBLOCA in a VVER-1200 reactor [4]. The water temperature reduction in the event of a large break loss of coolant accident is approximately 120-150 ℃ [3]. This reduction

in temperature is critical for maintaining the integrity of the reactor core and preventing fuel cladding failure. Furthermore, it is important to simulate and analyze the behavior of the coolant system during a LBLOCA in a VVER-1200 reactor [3].

PCTRAN is a widely used computer code for simulating and analyzing accidents in light-water reactors, including loss of coolant accidents. This code has been utilized in numerous studies to investigate various aspects of loss of coolant accidents and their effects on thermal-hydraulic parameters in different reactor types [4, 5]. For instance, Hadad and Esmaeili-Sanjavanmareh used PCTRAN to assess LBLOCA for a nuclear power station of the VVER-1000 type [6]. They focused on understanding the behavior of the reactor during such accidents and assessing the potential consequences. In addition, Chiang et al used PCTRAN in conjunction with other nuclear thermal hydraulic models to model incidents similar to the one at Fukushima for a Chinshan BWR/4 NPP. Their aim was to better understand the dynamics of the accidents and develop strategies for mitigating their consequences [6]. The use of PCTRAN in simulating loss of coolant accidents has also been demonstrated in studies on specific reactor types. For example, Qi, Ben *et al.* [7] used PCTRAN to simulate the behavior of an Indonesian conceptual HTR reactor during a loss of coolant accident. Other simulation packages also are available. For example, Hossain MK combined two accident scenarios to test the effectiveness of the ECCS during major BDBA scenarios [8].

II. PCTRAN SIMULATOR

PCTRAN is a thermal hydraulic model-based software that has been used in various studies to simulate different scenarios in nuclear power plants. PCTRAN was used in one work by Che *et al*. [9] to model the behavior of Cr_2O_3-doped UO_2 fuel under a limited LBLOCA scenario. The study entailed exposing the fuel under specific conditions and then feeding PCTRAN with the results as input. During the LOCA progression, the findings showed the normalized reactor power, coolant pressure, and cladding outer surface temperature.

In a different study by Ibrahim and Atia, thermal hydraulic conditions in a PWR nuclear power plant were simulated using PCTRAN under steady state, station blackout (SBO), and loss of coolant accident (LOCA) scenarios [10]. The researchers found that PCTRAN provided good accuracy in simulating these conditions. By using PCTRAN (Personal Computer Transient Analyzer) and an air dispersion algorithm, Cheng was able to analyze a nuclear power station accident and its off-site dosage impacts [11].

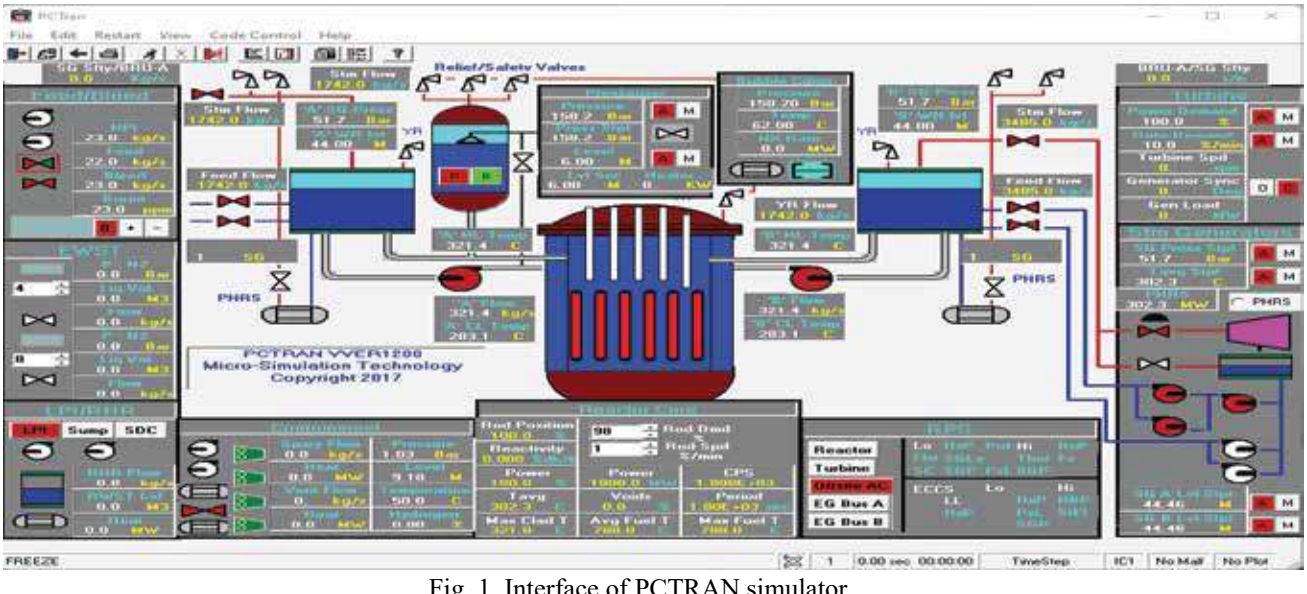

Fig. 1. Interface of PCTRAN simulator

In addition, PCTRAN has been used in other studies to simulate different types of accidents and scenarios. For instance, Khan *et al.* [12] suggested the usage of PCTRAN in simulating a nuclear power plant catastrophe similar to the one that occurred at Fukushima. The thermal hydraulic effects of a coolant loss accident with and without an emergency core cooling system were examined by Nath *et al.* using PCTRAN [13].

It is important to note that while PCTRAN has been used in various studies, the accuracy of its simulations may vary depending on the specific scenario and the input data used. Therefore, it is recommended to validate the results of PCTRAN simulations with experimental data or other validated models.

A. Reactor Core Kinetics model

A point kinetics model was developed with one delayed neutron group, external reactivity control (such as control rods and boron injection). The point kinetics equation is expressed by

$$\frac{dn}{dt} = \frac{\rho-\beta}{\iota} n + \lambda C \quad (1)$$

$$\frac{dC}{dt} = \frac{\beta}{\iota} n - \lambda C \quad (2)$$

where

n = neutron density
ρ = reactivity
β = delayed neutron fraction
ι = neutron life time
λ = decay constant
C = precursor concentration

B. Break Discharge Model

When a break occurs in the subcooled zone and the water level is higher than the break, the choking orifice flow by Zaloudek as follows [15],

$$W_{LR} = A_1 \left[\frac{2g_c}{v_f}(P - 0.81P_{sat})\right]^{1/2} \quad (3)$$

If the break occurs in the liquid phase of the saturated region, Moody's liquid critical flow will be applied. It will employ the vapor critical flow if it is located in the vapor phase [16].

C. Reactor Coolant Flow Model

For reactor coolant flow, PCTRAN/VVER employs a semi-empirical approach that takes into account both forced and natural circulation patterns. Full (volumetric) rated flow is taken into account for forced circulation when the reactor coolant pumps are operating. If the pumps continue to run while the system is flashing, the flow is decreased by the space taken up by the void. The flow coasts down exponentially once the pumps are tripped until stable natural circulation is established.

The heat balance from the reactor core and removal rate by the steam generators at a specified loop flow rate are used to compute the reactor hot and cold leg temperatures for a PWR. The flow rate can be expressed as

$$\Delta T = \frac{Q_{SG}}{W_{RC}C_p} T_H = T_{Avg} + \frac{\Delta T}{2} T_C = T_{Avg} - \frac{\Delta T}{2} \quad (4)$$

Where, T_{avg} is the RC average temperature.

D. Fuel Temperature and Degraded Core

In PCTRAN/VVER, a simplified model that takes into consideration the temperatures of the fuel and cladding has been developed. In contrast to nuclear power produced by the core during normal operation, this model can mimic 1) thermal power delivered into the coolant; and 2) fuel and cladding heat up under accident conditions.

Core thermal power Q_{MWT} is represented by

$$Q_{MWT} = UF \times (T_F - T_{avg}) \quad (5)$$

Where, T_F is the known average fuel temperature at 100 % rated power. The heat transfer coefficient UF is then calculated such that the core thermal power is equal to the neutron power from the kinetics equation at steady state.

E. Emergency Core Cooling System

The accumulator tanks are filled with nitrogen gas. The adiabatic expansion equation

$$PV^{1.3} = constant \quad (6)$$

is used for calculating the gas transient pressure.

III. METHOD OF SIMULATION

At the beginning of the simulation process, 100% BOC (beginning of cycle of fuel) is considered. The initial conditions of the reactor are summarized below with RELAP5.

Table I. Initial conditions of the simulator [13]

Parameters	PCTRAN (VVER-1200)	RELAP5 (VVER-1000)	% Error
Total reactor power, MW	3200	3120	2.56
Primary side pressure, MPa	16.2	15.7	3.18
Cold leg temp, ºC	298	284	4.93
Hot leg temp, ºC	329	316	4.11
Core flow rate, m^3/h	86000	84800	1.42
Steam generator pressure, MPa	7.4	6.3	17.46
PRZ level, m	8.17	7.8	4.74
Maximum cladding temperature, ºC	411	350	17.43

It is worth mentioning that PCTRAN VVER-1200 simulated data is compared to RELAP5 VVER-1000 parameters with the mentioned error percentage in Table I. VVER-1000 is an earlier generation reactor model where the total energy generation is lesser than VVER-1200, thermal hydraulic parameter values also lower as shown in the Table I. As a result, some deviations are expected during the comparison of the simulated data.

Table II. Reactor scram setpoints

Description	Set Point in Basic Data
Short neutron fluxperiod	< TRPD = 10 second
High neutron flux	> HIFX = 107 % Nom
Low Rx pressure	< PSCRAM =147 bar and power > 75 %
High T-hot	> THOT = 330 ºC and P < 137.2 bar
Low primary sub-cooling	< TSCM = 10 ºC
Low SG pressure	< PSGL = 49 bar
Low core flow	1 of 4 MCP's tripped and power > 75 %
High SG pressure	> PSGH = 78.4 bar
Low SG level	< SGLL = 0.65 M
High Rx pressure	> PHIGH = 176 bar
Low pressurizer level	< LPZL = 4.6 M

Table II shows the reactor shutdown set points below or above which the reactor SCRAM action will be performed by the reactor.

Table III. Chronological sequence of events for the case of lbloca.

Time (s)	Events
20.5	Initiation of LBLOCA cold leg of 200 % of 100 cm^2
28	Scram Low Primary Pressure 14.7 MPa
28.5	Scram Low PRZ Level 4.6 m
32	Reactor Scram
32	Turbine trip
32.5	60.0 % Load rejection malfunction
41.5	Containment Spray Starts at 0.13 MPa
221	Actuation of HA-1
328	Actuation of HA-2

For the simulation process, the simulator was let to run for 20 sec for reaching the steady state nominal operation. The malfunction of LBLOCA in the cold leg was considered with break size equal to 200 % of 100 cm^2. The transient report shows the initiation time and parameter changes with time in TABLE III.

IV. RESULTS AND DISCUSSION

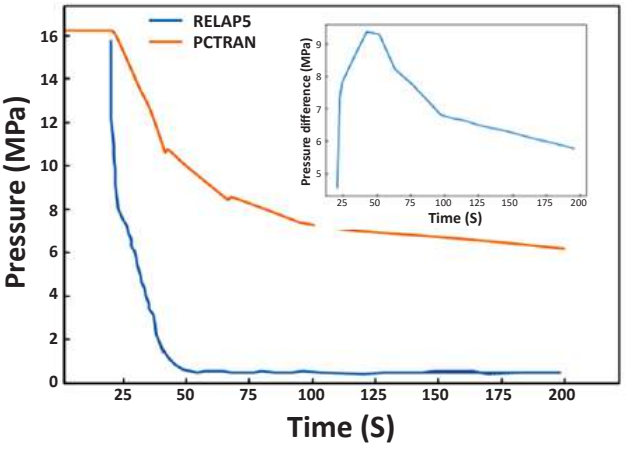

Fig. 2. Change in PRZ Pressure (MPa) with time. Inset shows the pressure difference with time.

The malfunction of LBLOCA was initiated after 20.5 sec of nominal operation. After the malfunction there was a break in the cold leg. As a result, coolant was lost from the reactor pressure vessel (RPV). Reactor shuts down due to low primary pressure and low pressurizer level signal. Fig. 2 shows the rapid decrease in primary pressure. The huge deviation in two data may have occurred due to the model difference between VVER-1200 and VVER-1000. The difference between PCTRAN and RELAP5 based predictions are shown in the inset. All the parameter values found in the simulation were all below the safety margin prescribed by IAEA [17]. Based on the initial condition, maximum pressure difference was 8.5 MPa which tends to decrease over time.

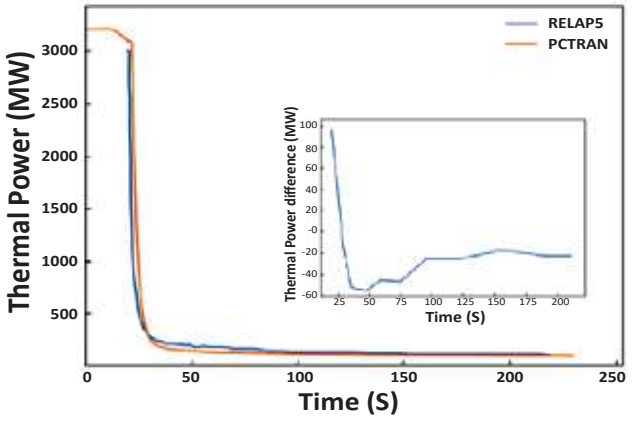

Fig. 3. Change in thermal Power (MW) and data difference with time in the inset.

Thermal power is expected to decrease rapidly after the safe shutdown of the reactor indicated by Fig. 3. Both the PCTRAN and RELAP5 data is in good agreement with minimal difference which can be seen from the inset. The data difference is well below the acceptable error margin.

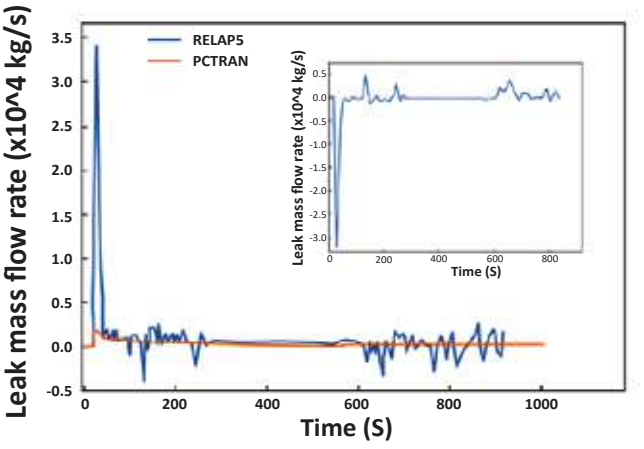

Fig. 4. Leaked mass flow rate and difference in data with time in the inset.

Huge amount of mass is lost due to the cold leg break. The leaked mass flow rate is shown in Fig. 4. The difference between two predictions shows, PCTRAN tends to smoothen the data indicated in the inset. As a result, the sensitivity of the data may be low and PCTRAN is unable to demonstrate the peak or sharp changes in value with time. However, the average value over time has very good agreement for both the predictions.

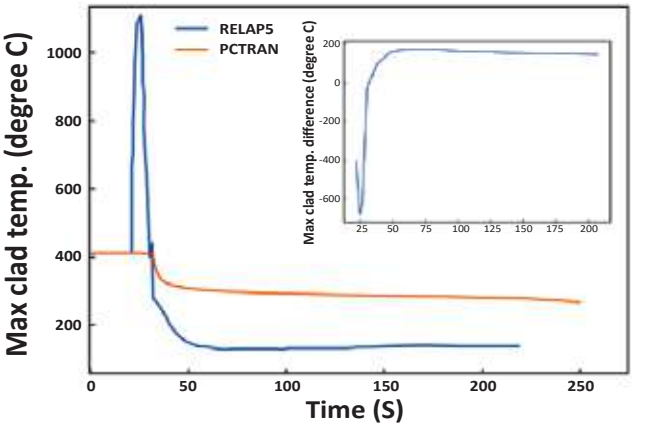

Fig. 5. Change in max cladding temperature and data difference with time in the inset.

Just after the malfunction initiation, there was a significant amount of difference between both approximations which tends to decrease with time as shown in Fig. 5. The change in max cladding temperature for two different simulation methods are shown in the inset. The initial difference is a result of lack of sensitivity of PCTRAN during transient events. PCTRAN is unable to detect the huge sudden transient change in data.

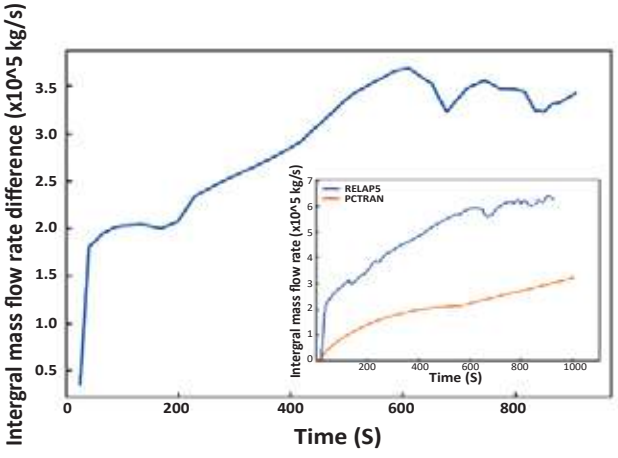

Fig. 6. Data difference with time and change in integral mass flow rate in the inset.

Fig. 6. shows the change in integral mass flow and difference between two simulated results. The difference has been observed to increase over time. Again, the peaks have been smoothened in PCTRAN which indicates the low sensitivity of the data.

The change in steam generator water level was in good agreement compared to other parameters indicated in Fig. 7.

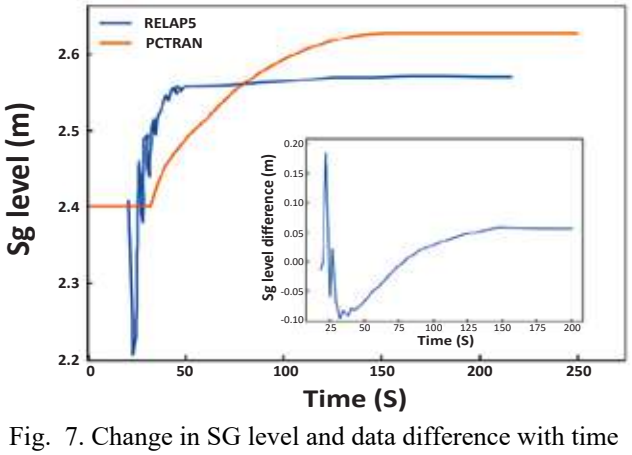

Fig. 7. Change in SG level and data difference with time in the inset.

V. CONCLUSION

The nuclear power plant simulation software, PCTRAN, has become a promising way to efficiently evaluate a nuclear power plant accident and its off-site dose consequences. Therefore, we used PCTRAN to monitor the thermal hydraulic responses considering the condition of a large break LOCA in a VVER-1200 reactor. Our simulated results show good agreement with RELAP5 code generated data based on VVER-1000 with a minimal error margin. The thermal hydraulic responses determined by this simulation are found to be well within the prescribed safety design values which enhance the applicability of this software in aforementioned reactor. However, high level of deviations has been found for the primary side pressure and integral mass flow rate as PCTRAN smoothens the data of the peaks values of leaked mass flow rate and max cladding temperature, which may result in less sensitivity. In summary, PCTRAN has been observed to show excellent prediction of the parameter behaviors for a longer period observation, however, the sensitivity level decrease for transient analysis. To ensure the application of PCTRAN in simulating accident scenario in VVER-1200 reactor further sensitivity analysis and uncertainty qualification is required.

REFERENCES

[1] Salauddin Omar & Mohammad Nasim Hasan, “A PCTRAN Based Analysis On The Effect Of Breaksize And Comparative Study Between Hot and Cold Leg Loss of Coolant Accidents In VVER 1200 Power Reactor,” Acta Mechanica Malaysia (AMM), Zibeline International Publishing, vol. 5, pp. 31-34, Jul. 2022.

[2] Dreganov OI, Shulimov VN, Kiselyova IV, Alekseev AV, “Measurement of the spent fuel rod cladding temperature during the in-pile testing at 500–900 °C,” Nuclear Energy and Technology, vol. 4, pp. 21-26, Oct. 2018.

[3] Li, Dong-hao, “Study on hydraulic characteristics of reactor coolant pump shutdown transition process based on primary

circuit closed system," Frontiers in Energy Research Vol. 9, Feb. 2022.

[4] Ibrahim SM, Atia SI,"Thermal hydraulic simulations of a PWR nuclear power plant," International Journal of Nuclear Safety and Security, vol. 1, pp. 31-52, 2019.

[5] Hossen, Muhammed Mufazzal, Mohammad Khalaquzzaman, and SK Anisur Rahman, "Analysis of Steam Line Break Accident Using PCTRAN Model of VVER-1200 NPP," Applications of Modelling and Simulation, vol. 7, pp. 8-15, 2023.

[6] Hadad, Kamal, and Mansour Esmaeili-Sanjavanmareh,"PCTRAN enhancement for large break loss of coolant accident concurrent with loss of offsite power in VVER-1000 simulation," Kerntechnik, vol. 82, pp. 176-183, 2022.

[7] Qi, Ben, Xingyu Xiao, Jingang Liang, Li-chi Cliff Po, Liguo Zhang, and Jiejuan Tong,"An open time-series simulated dataset covering various accidents for nuclear power plants," Scientific Data, vol. 9, pp. 766, 2022.

[8] Hossain MK, Asaduzzaman MD, Faruk MO, Hassan MM, Rumi KMJU, "Comparative Transient Analysis of Large Break Loss of Coolant Accident (LBLOCA) with Subsequent Loss of Offsite Power and all AC power in VVER-1200 Reactor using PC Based VVER-1200 NPP Simulator," J Nucl Ene Sci Power Generat Technol, vol. 11, 2022.

[9] Y. Che, G. Pastore, J. Hales, & K. Shirvan, "Modeling of Cr_2O_3-doped UO_2 as a near-term accident tolerant fuel for LWRs using the bison code," Nuclear Engineering and Design," vol. 337, pp. 271-278, 2018.

[10] S. Ibrahim and S. Atia, "Thermal hydraulic simulations of a pwr nuclear power plant," International Journal of Nuclear Safety and Security, vol. 1, pp. 1, 2019.

[11] Yi-Hsiang Cheng, Chunkuan Shih, Show-Chyuan Chiang, Tung-Li Weng, "Introducing PCTRAN as an evaluation tool for nuclear power plant emergency responses," Annals of Nuclear Energy, vol. 40, pp. 122-129, 2012.

[12] A. Khan, A. Ghosh, M. Rahman, S. Ahmed, & C. Karmaker, "An investigation on the possible radioactive contamination of environment during a steam-line break accident in a vver-1200 nuclear power plant," Current World Environment, vol. 14, pp. 299-311, 2019.

[13] P. Nath, K. Rahman, & A. Bari, "Thermal hydraulic analysis of a nuclear reactor due to loss of coolant accident with and without emergency core cooling system," JEA, vol. 01, pp. 53-60, 2020.

[14] Mousavian, S. & D'Auria, Francesco & Giorgio, Galassi & Petruzzi, A & Salehi, Mahmoud, "Uncertainty Analysis of LB-LOCA in VVER-1000 Geometry," 2003.

[15] L. S. Tong and J. D. Young, "A Phenomenogical Transition and Film Boiling Heat Transfer Correlation," International Heat Transfer Conference Digital Library, Begel House Inc., 1974.

[16] F. J. Moody, "Maximum Flow Rate of a Single Component, Two Phase Mixture," Transactions of ASME, Ser C, vol. 87, pp. 134-142, 1965.

[17] Status report 108—VVER-1200 (V-491), IAEA/ARIS, International Atomic Energy Agency (IAEA), 2013.

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