

Mechanical Characterization of Sugarcane-based Natural Fiber Composites Using Machine Learning and Experimental Techniques

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Abstract

This study presents the manufacturing process of biocomposite materials using lignocellulosic fibers extracted from sugarcane bagasse combined with epoxy matrix and a comprehensive analysis to predict the strength using experimental, machine learning, and analytical frameworks. Chemical treatment of the sugarcane bagasse was performed using a 5% sodium hydroxide (NaOH) solution to enhance fiber-matrix adhesion by removing non-cellulosic components and reducing hydrophilicity. Biocomposites were manufactured using a rectangular mold of 19 in × 15 in × 0.7 in volume with a fiber volume fraction of 0.3, followed by hot pressing the suspension and controlled curing. Mechanical characterization, including tensile, flexural, and impact strength, was conducted in accordance with ASTM standards. Multiple analytical models, including Rule of Mixture (ROM), Inverse ROM, Modified ROM, Halpin-Tsai, and Hirsch model were employed to predict the modulus of elasticity (MoE) and strength. Supervised machine learning models such as linear regression (LR), decision tree regression (DTR), extreme gradient boosting (XGBoost), random forest regression (RFR), and support vector regression (SVR) were adopted to predict the MoE and strength. Finally, the mechanical properties predicted from the machine learning models were validated and verified using experimental and analytical results. The results demonstrate the significant potential of sugarcane bagasse as a sustainable reinforcement material.

Keywords

Sugarcane bagasse, machine learning, NaOH treatment, biocomposite, and mechanical characterization.

Biographies

Farhan Sadik is an undergraduate student pursuing a Bachelor of Science in Industrial and Production Engineering at American International University–Bangladesh (AIUB). His academic focus includes production planning, operations management, quality control, and supply chain management. Farhan has actively participated in seminars on Industrial Engineering and Operations Management, expanding his knowledge of process optimization and

manufacturing efficiency. He is also a general member of the IEOM Club at AIUB, contributing to event organization and visual communication. His technical expertise includes proficiency in AutoCAD, SolidWorks, and statistical process control. Farhan has earned Dean's List Honors multiple times in recognition of his academic excellence. With strong analytical, teamwork, and leadership skills, he aims to build a career in industrial process optimization and sustainable production system development.

Md Rois Uddin is currently completing his final semester in the Department of Industrial and Production Engineering (IPE) at American International University-Bangladesh (AIUB). As part of his academic experience, he successfully completed an industrial training program under BKMEA in the Ready-Made Garment (RMG) sector of Bangladesh where he gained practical exposure to production systems, lean manufacturing and industrial process management. Rois is an active member of the AIUB Oratory Club (AOC) and the Industrial Engineering and Operations Management (IEOM) Society. Through which he has participated in several seminars and workshops on sustainability, supply chain management (SCM) and Industry 4.0. He has also developed technical proficiency in AutoCAD, SolidWorks and 3D design and simulation showcasing his ability to integrate design tools with industrial engineering concepts. Rois is passionate about innovation, productivity improvement and sustainable industrial growth in Bangladesh, aiming to contribute meaningfully to the country's evolving manufacturing sector.

Arif Raogir is a final-semester student in the Department of Industrial and Production Engineering (IPE) at American International University-Bangladesh (AIUB). He has augmented his academic studies with a practical industrial training program under BKMEA within Bangladesh's Ready-Made Garment (RMG) sector, gaining hands-on experience in production systems, lean manufacturing, and industrial process management. His academic development is further supported by his active membership in the Industrial Engineering and Operations Management (IEOM) Society, through which he has engaged in seminars and workshops focused on sustainability, supply chain management, and Industry 4.0. He has also cultivated strong technical proficiency in design software such as AutoCAD and SolidWorks, demonstrating a capacity to integrate these tools with core industrial engineering principles effectively. His research interests are centered on innovation, productivity improvement, and fostering sustainable industrial growth, with a dedicated aim to contribute to the advancement of Bangladesh's manufacturing sector.

Shrish Taazwar Khan is an undergraduate student pursuing a Bachelor of Science in Industrial and Production Engineering at American International University – Bangladesh (AIUB). He specializes in Operations Management, Material Handling, Supply Chain Management, Human Factors Engineering, and Production Planning & Control in the terms of his academic focus. He is well-known as a team leader and has successfully led various types of events. He currently serves as the General Secretary of the IEOM AIUB Student Chapter. He has also volunteered at several international conferences, including the 7th IEOM Conference Bangladesh, held at AIUB last December. His strong verbal communication skills enable him to effectively manage and complete assigned tasks. He has completed his industrial training under BKMEA and possesses technical proficiency in AutoCAD, SolidWorks, Arena Simulation, and Microsoft Office. As an Industrial Engineer, he is recognized for his expertise in optimization and project management. He is dedicated to work on projects that contribute for achieving the United Nations Sustainable Development Goals (SDGs) and to the betterment of both society and industry, while aligning with the principles of Industry 4.0 and 5.0.

Mohammad Tauhiduzzaman is an Assistant Professor in the Department of Industrial and Production Engineering at American International University–Bangladesh. Prior to this, he served as an Assistant Professor in the Department of Textile Engineering at Daffodil International University. He also worked as a Postdoctoral Researcher at the University of Maine in the School of Forest Resources and the Advanced Structures and Composites Center from 2020 to 2023.

Dr. Tauhiduzzaman completed his PhD in Mechanical Engineering at Florida Atlantic University in 2019 and earned his MSc in 2016 from the University of Texas at El Paso. He received his BSc in Mechanical Engineering from Khulna University of Engineering and Technology in 2011. He has worked in diverse research environments under various sponsored projects. His research interests focus on identifying the root causes of fracture and failure using multiscale modeling approaches, including finite element analysis, molecular dynamics, density functional theory, and machine learning. Major highlights of his completed research projects include sponsorship from the United States Department of Agriculture (USDA), Federal Aviation Administration (FAA), Office of Naval Research (ONR), and the National Science Foundation (NSF).