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The Simulation Of Drop-Weight Impact Test On Ramie-Eglass Hybrid Fiber Composite For *Kayoh Jaloe* Wall Material

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Abstract

The purpose of this study is to simulate drop-weight impact tests on hybrid fibre composites made of ramie and Eglass, which are used to make the traditional Acehnese boat wall material for *jaloekayoh*. Using composites of ramie-Eglass fiber hybrid in the construction of *jaloekayoh* wall material will significantly enhance the strength, durability, and sustainability of traditional Acehnese boats. The simulation was carried out using the finite element method approach using the Abaqus software. Three distinct laminate layer configurations—three layers (GRG), five layers (GRGRG), and six layers (GRGGRG)—with alternating Eglass and ramie fibres make up the test specimens. The ends of the specimen are set with fixed support to ensure boundary conditions, which limit all active structural degrees of freedom on all sides of the specimen. According to simulation results, the specimen with six laminate layers, measuring 12.498 mm, had the largest displacement. The specimen with six laminate layers has the highest stress concentration, measured at 560.6 MPa, while the specimen with three layers has the highest strain concentration, measured at 0.023. Its indicating that the lamina variation can influence the structural performance of the *jaloekayoh* material. This research contributes to understanding the potential of ramie-Eglass hybrid fiber composites to enhance the safety and durability of traditional vessels such as *jaloekayoh*. The implications of the results can serve as a foundation for the development of superior structural materials in the future.

Keywords:

Jaloekayoh, hybrid composite, ramie-Eglass fiber, drop-weight impact testing.

1 Introduction

The traditional Acehnese boat, *jaloekayoh*, is very important to the Acehnese community's history and culture. These boats' building and maintenance are vital parts of the indigenous cultural legacy. The careful selection of wall materials that offer strength, lightness, and resilience to survive the various impacts and strains of water is a crucial aspect of the construction of *jaloekayoh*[1]. To fulfill this requirement, fiber composites exhibit considerable potential as a material option. The ramie-Eglass (GRG) hybrid fiber composite is an intriguing amalgamation composed of fibers encased within a robust matrix [2]. As a result of their exceptional mechanical properties, composite fibers have emerged as the preferred material in several maritime and construction applications. The potential benefits of incorporating ramie fiber into composites include enhanced strength and impact resistance [3], [4]. In traditional aquatic settings, such as *jaloekayoh*, wall materials must be able to endure repeated impacts; therefore, hybrid composites can be an appealing alternative[5].

Subsequent literary investigations have uncovered the utilization of coconut fiber, renowned for its water-resistant and robust characteristics, in fortifying the walls of conventional vessels [6]. Pandan fiber has been used to construct traditional boats across several Southeast Asian regions. The flexible qualities of pandan fiber are highly advantageous in boat construction, particularly when shock absorption capabilities are needed [7]. In addition, several studies have also explored the use of wood fibers, such as bamboo, as the main construction material in traditional boat building. Bamboo is known to have good strength and exceptional resistance to environmental elements, making it a popular choice in traditional boat building [8]. In Latin America, some traditional communities use agave fiber in boat making. Agave fiber, obtained from the agave plant, has water-resistant properties and sufficient strength to support the structure of a boat. Thus, the use of agave fiber in traditional Latin American boats has been an important part of maintaining the seafaring culture of the region [9]. A study has been conducted to devise sustainable methods for cultivating and overseeing natural fibers. There is a growing emphasis on enhancing the availability of sustainable natural fiber resources, particularly in the context of boat manufacturing, with a strong commitment to environmental preservation and the betterment of local communities [10]. The utilization of natural fibers in the construction of boats holds significant cultural significance, and safeguarding these methods is crucial to prevent the loss of priceless cultural heritage [11]. Although the use of natural fibers has become a traditional, sustainable practice, there is also a need for innovation in the development of technologies and materials to meet the modern demands of boatbuilding. Research shows that using natural fibers has become an integral part of traditional boats, and research and development are needed to face new challenges and achieve superior results [12].

The application of ramie and Eglass fiber hybrid composites in this study is firmly grounded in developing materials for conventional boats. A combination of ramie and Eglass fibers was utilized in a fiber-based composite approach to enhance the strength and durability of the *jaloekayoh* boat, according to a number of studies [13]. Since then, the construction of boats from composites of natural and synthetic fibers has become a significant trend in the maritime industry.The integration of the distinctive characteristics exhibited by ramie and Eglass fibers presents an appealing resolution for enhancing the functionality of conventional boats [14]. Ramie fiber, nearly as strong as glass fiber, is a highly prospective alternative in boat construction because its strength is nearly equivalent to that of glass fiber [15]. On the other hand, Eglass Fiber has very high strength, and its resistance to various pressures and impacts makes it an irreplaceable material in boat construction [16]. The combination of the strength of ramie fiber with the resilience of Eglass fiber creates an ideal material to withstand various pressures and impacts during rough water travel [17]. In addition to the technical benefits, this approach supports sustainability principles. The use of sustainably sourced ramie fiber and recyclable Eglass fiber supports sustainability aspects in traditional boat construction [4]. Based on this robust research, using composites of ramie-Eglass fiber hybrid in the construction of *jaloekayoh* wall material will significantly enhance the strength, durability, and sustainability of traditional Acehnese boats. Therefore, this research is still very relevant to address the problems faced by traditional Acehnese boats.

This study aims to investigate the feasibility of incorporating ramie and Eglass fibers into a hybrid composite for the walls of the *jaloekayoh* canoe, a traditional Acehnese vessel with a significant cultural legacy. This study examined three distinct laminate layer configurations comprised of ramie and Eglass fibers: three laminate layers (GRG), five laminate layers (GRGRG), and six laminate layers (GRGGRG). Laminate layer configuration is one of the important factors that influences the strength of composite materials. In this study, we will outline how each laminate layer configuration can significantly impact the strength of *jaloekayoh* walls and the use of ramie-Eglass fiber-based composites. This understanding is important because choosing the right laminate layer configuration will significantly influence the performance of the *jaloekayoh* wall. It also allows boat builders to adapt boats to different water conditions, creating strong, durable boats as needed.

2 Research Methodology

The simulation was carried out using the finite element method approach using the Abaqus software. Three composite models were fabricated, each consisting of a different number of laminate layers: models with 3, 5, and 6 laminate layers. According to the literature [9], ramie-Eglass fiber composites are regarded as a promising option for boatbuilding due to their ability to endure severe environmental conditions. The test specimen has three laminate layers (GRG) composed of Eglass, ramie, and Eglass fibers. The second test specimen consisted of 5 laminate layers (GRGRG), comprising Eglass, ramie, Eglass, ramie, and Eglass fibers. The third test specimen had six laminate layers, with the fiber sequence Eglass, ramie, Eglass, Eglass, ramie, and Eglass, arranged in the pattern GRGGRG. Fig. 1 illustrates the different fiber changes among the laminate layers.

2.1 Material

The GRG configuration consisting of 3 laminate layers with an Eglass-ramie-Eglass fiber arrangement maintains a balance between strength and weight. Strong ramie fibers provide structural strength in this configuration, while Eglass fibers provide stress resistance. This makes it a good choice for boats that need a balance between performance and lightness. The GRGRG configuration consists of 5 layers of lamina with an Eglass-ramie-Eglass-ramie-Eglass fiber arrangement, increasing the number of lamina layers to increase strength and durability. With increased layers, the boat will have better resistance to shocks and impacts. This configuration is appropriate for rougher water conditions. The GRGGRG configuration is comprised of six laminate layers arranged as follows: Eglass-ramie-Eglass-Eglass-ramie-Eglass, with greater proportions of ramie and Eglass fibers. The outcome is a composite material that exhibits optimal strength, rendering it a highly suitable option for vessels designed to operate in the most severe environmental conditions and necessitate maximum durability. The drop-weight impact test adheres to the ASTM D7136 requirements. Table 1 displays the material properties of Eglass/polyester laminate and ramie/polyester.

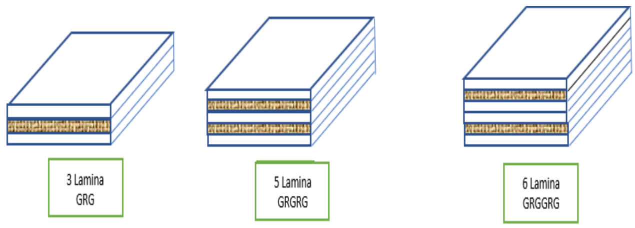

Fig. 1. The appearance of specimen variations in various laminate layer models.

Table 1. Material properties of Eglass/polyester laminate and ramie/polyester

	E_1 (GPa)	$E_2 = E_3$(GPa)	$v_{12} = v_{13}$	v_{23}	$G_{12} = G_{13}$ (GPa)	G_{23} (GPa)
Eglass/polyester [18]	34.7	8.5	0.27	0.5	4.34	2.83
Ramie/polyester, compute by Microscale RVE plug-in [19]	10.5	6.3	0.25	0.31	2.78	2.84

2.2 Load and Boundary Conditions

It is important to note that drop-weight impact testing is a proven method of testing material response to blunt loads [20]. Consequently, calibration and selection of simulation devices are critical. To ensure testing consistency, we employ simulation tools that have undergone rigorous testing and are deemed reliable in this study. This feature enables the test to be replicated using identical parameters, a critical factor in guaranteeing accurate outcomes. In this research, we apply the Finite Element Analysis (FEA) method to evaluate the extent of the strain and displacement values accepted by the *jaloekayoh* structure. The interaction between the specimen and the puncture is carried out using a general explicit contact type, and the simulation step uses a dynamic-explicit approach. At the meshing stage, the impact test specimen consists of 90,000 elements and 1,119 elements for puncture, with a hexahedron mesh type. The ends of the specimen are set to ensure boundary conditions, which limit all active structural degrees of freedom on all sides of the specimen. The shape of the impact simulation test specimen in the form of load, boundary condition, and mesh are shown in Fig. 2.

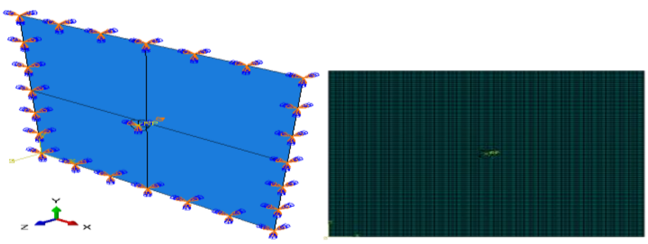

Fig. 2. Load, boundary condition, and mesh.

The method used in this research is the low-velocity impact testing method. This method refers to a low-velocity impact test used to measure a material's response to an impact at a slower speed compared to a high-speed impact. The object tested in this research has a plate shape measuring 300×300 mm and is shaped like a shell. Meanwhile, the tool used as an impactor (an object that hits an object) is semicircular, with a radius of around 10 mm. This signifies that the impactor will strike the test object within a region bounded by a circle measuring 10 mm in radius. The impactor speed utilized in the collision test was roughly 10 meters per second (m/s). This speed is applied to simulate low-velocity collisions. The outcomes of this experiment will yield insights into the behavior and response of the material of the test object when exposed to an impact at the specified speed. This method allows researchers to understand to what extent the ramie-Eglass fiber hybrid composite material is able to withstand and dampen the impact of low-speed impacts, which is very relevant for applications in *jaloekayoh* wall construction and the overall safety of Acehnese traditional boats. Therefore, this study offers significant insights into the material's strength and resistance to impact.

3 Results and Discussion

This study conducted a drop-weight impact test simulation on a ramie-Eglass fiber hybrid composite, which was used as the wall material for the *jaloekayoh*, a traditional Acehnese boat. The material comprises ramie and Eglass fiber arranged in three distinct laminate layer combinations. The drop-weight impact simulation results reveal the maximum displacement data throughout the different laminate layers, as depicted in Fig. 3.

From the drop-weight impact test data, the highest displacement simulation results showed that the highest displacement in the three laminate layers (GRG) reached around 1.129e+01. This provides an initial insight into the material's response to the impact on structures consisting of Eglass, ramie, and Eglass fibers. Then, in the five-layer laminate configuration (GRGRG), the highest displacement reaches around 1.214e+01. Increasing the number of layers in a structure reflects the potential for increased resistance to impact loads. The six-layer laminate configuration (GRGGRG) shows the highest displacement around 1.257e+01. This indicates that adding further layers can improve structural integrity in the face of impact.

3.1 Displacement Contour

As indicated by the high displacement analysis results for the three-laminate layer configuration, the material can effectively absorb impact energy. This factor must be incorporated into the structural design to optimize resistance to impact pressures [21]. Subsequently, the increase in displacement observed in the five-layer laminate specimen suggests that augmenting the material's number of layers can enhance its capacity to absorb and distribute impact energy efficiently [22]. The configuration featuring six laminate layers underscores the material's potential for a more pronounced response to impact loading. This may be considered when designing structures with increased resilience [23].

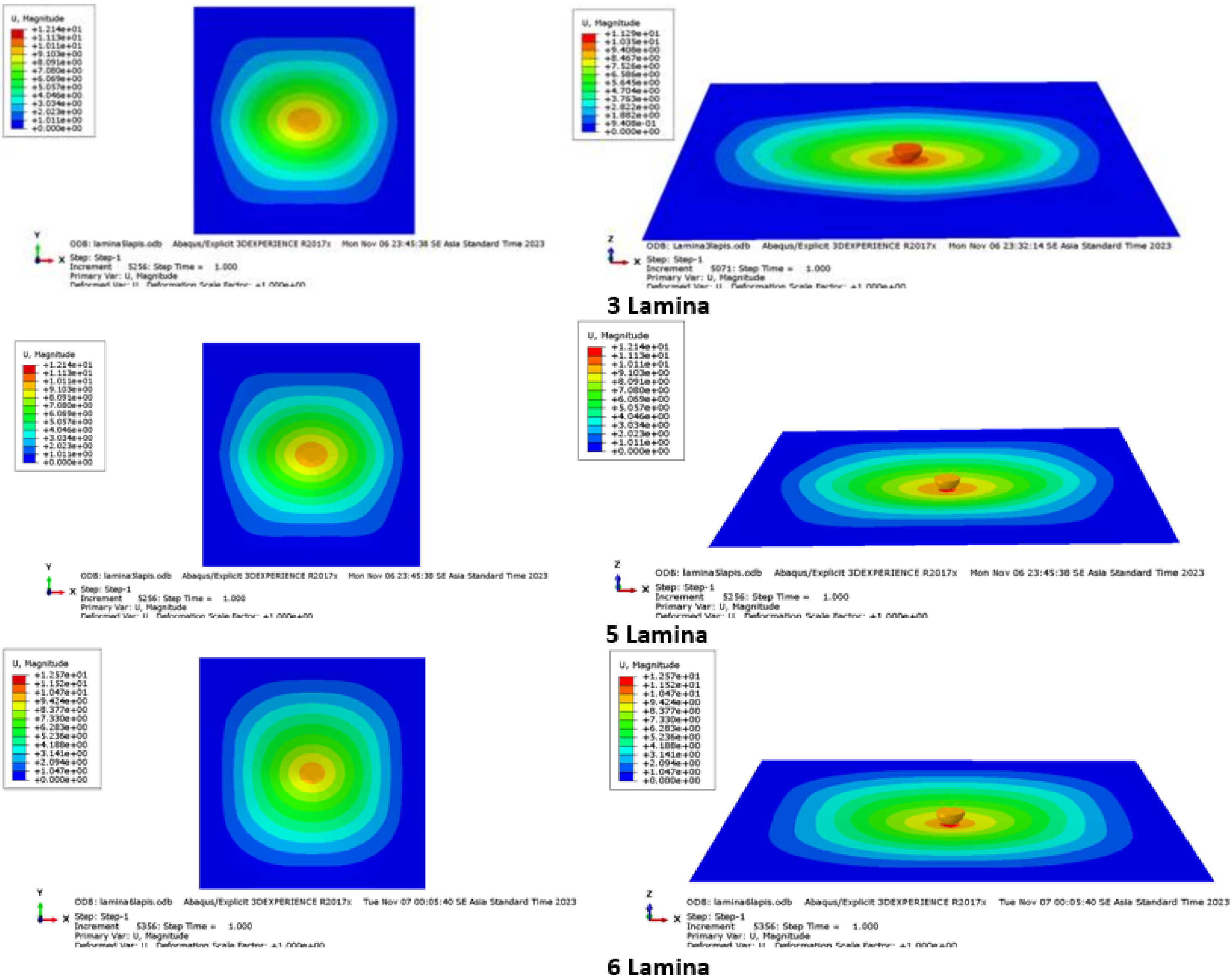

Fig. 3. Displacement of test specimens for several variations of laminate.

The outcomes of displacement contour analysis offer an in-depth understanding of the deformation distribution within the test specimen, specifically concerning deformation patterns. This is because pattern analysis identifies how deformation propagates across the specimen, thereby aiding designers in identifying critical zones. Identifying critical zones via high displacement zones makes it possible to ascertain which areas necessitate particular focus in structural design enhancements [24]. Consequently, this simulation comprehensively comprehends the material's reaction to impact pressures across various laminate layer configurations. By identifying critical areas, displacement contours direct design enhancements that increase the *jaloekayoh's* structural resilience [25]. Achieving this comprehension constitutes a critical stride towards confronting the adversities of the hostile marine milieu and safeguarding the long-term viability of Aceh's traditional boats.

The test specimen configurations were made in three different configurations, including variations in the number and sequence of laminate layers. Data from displacement testing results along the highest specimen in various laminate layers can be seen as in Fig. 4. Displacement along the three laminate layers (GRG) specimen shows that the simulation results show that the highest displacement in the three laminate layers configuration reaches around 11,290 mm. The rise in performance can be ascribed to the specific combination of fibers used, demonstrating the material's capacity to withstand impact stresses [26]. Subsequently, the presence of the five laminate layers (GRGRG) becomes apparent. The specimen consisting of five laminate layers exhibited a maximum displacement of approximately 12,073 mm. The higher structural endurance of this structure is demonstrated by the superior response to impact loads, which is attributed to the more complicated fiber combination [27]. Six laminate layers (GRGGRG) generate an equivalent displacement of approximately 12,498 mm. The material's capacity to absorb impact energy is enhanced as the number of layers increases, thereby generating the possibility for more substantial improvements in structural durability [28]. These simulations offer an in-depth comprehension of how the material reacts to impact loads in different combinations of laminate layers. The significant displacement observed in the given configuration suggests the possibility of enhancing *jaloekayoh's* structural resilience. This understanding can be used to develop stronger materials and make more effective design improvements.

3.2 Stress Concentration Contour

An essential factor to consider when assessing the strength and impact resistance of the ramie-Eglass fiber hybrid composite material is the level of stress concentration. This study involved conducting drop-weight impact tests on composites with different numbers of laminate layers, specifically 3, 5, and 6 layers. The laminate layers were composed of Eglass-ramie-Eglass (GRG), Eglass-ramie-Eglass-ramie-Eglass (GRGRG), and Eglass-ramie-Eglass-Eglass-ramie-Eglass (GRGGRG). The test results data for the most intense stress concentration contours in different laminate layers can be observed in Fig. 5.

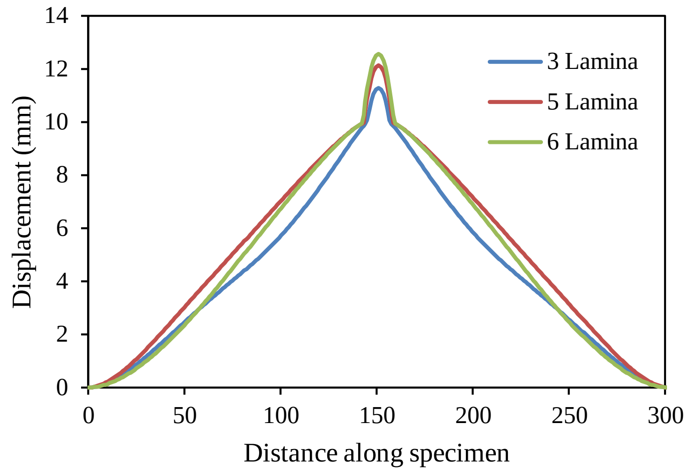

Fig. 4. Displacement graph along the test specimens for several laminate variations.

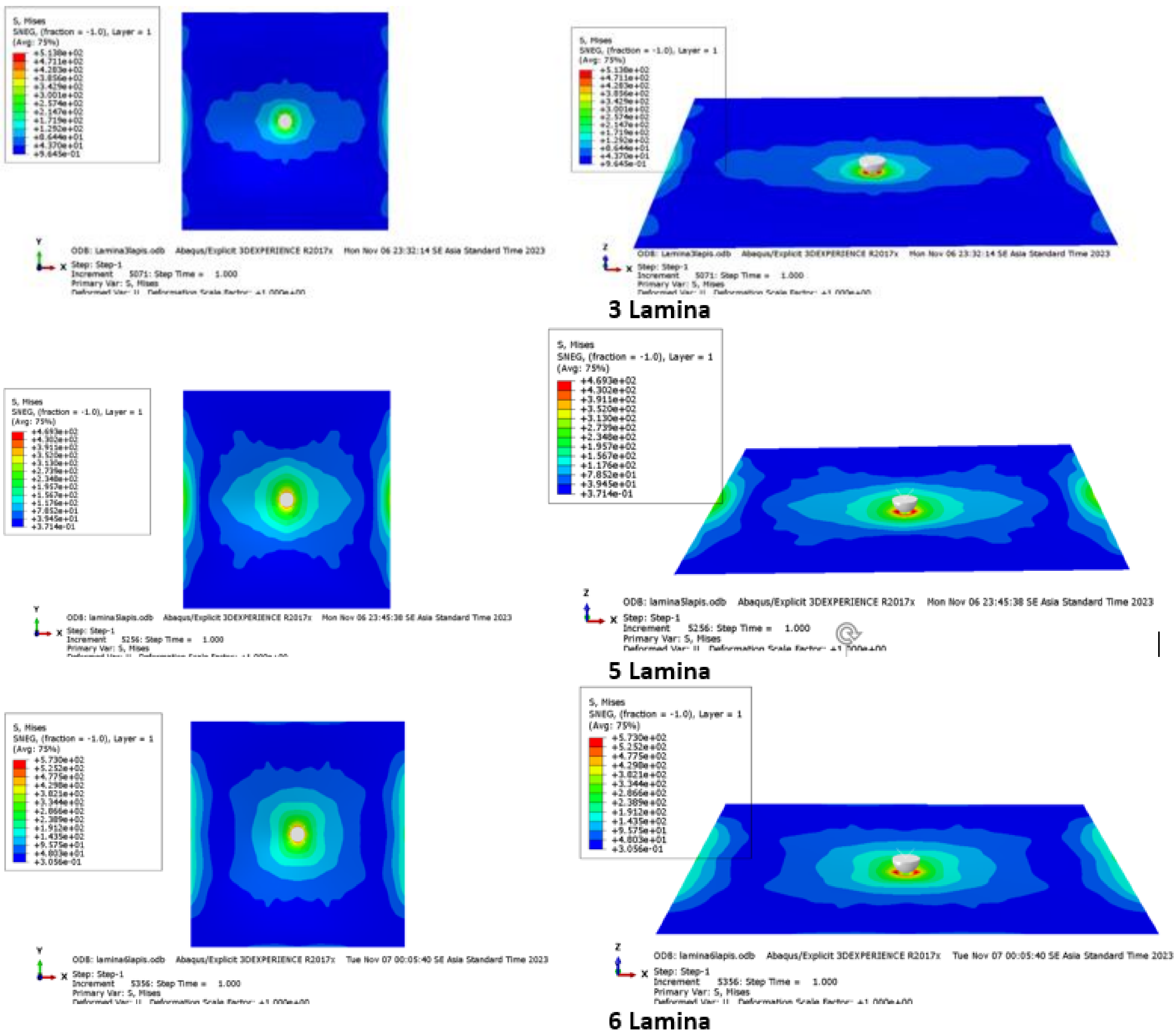

Fig. 5. Stress concentration contours in test specimens for several laminate variations.

From the drop-weight impact test data, the simulation results for the greatest stress concentration suggest that the highest stress concentration in the three laminate layers (GRG) is around 5.138e+02. It describes the material response to impact loads in a configuration with three fiber layers. Then, in the five laminate layers (GRGRG), the highest stress concentration reaches around 4.693e+02. This variation shows the difference in stress distribution in the material by adding two additional layers. Furthermore, the configuration with six laminate layers (GRGGRG) produces the highest stress concentration of around 5.730e+02. This offers a further understanding of the impact of incorporating an extra layer on the distribution of stress inside the structure. The examination of variations in stress concentration among different laminate configurations reveals the impact of material structure and the interactions between ramie-Eglass fibers inside it. The increase in the number of layers is pivotal in stress dispersion [29]. High stress concentrations can indicate places in the material that are likely to face higher loads. This aspect becomes the primary area of interest for further structural design or required reinforcement [30]. Comprehending stress concentration is crucial for assessing the strength and resilience of a material against impact loads. The optimization of the laminate arrangement might be focused on minimizing the most severe stress concentrations and enhancing the overall structural performance [31].

Stress concentration contours comprehensively depict the stress dispersion within the material across several layers of the laminate. Examining these contours might offer a further understanding of regions that may necessitate additional focus in structural engineering. It is crucial to highlight the significance of validating simulation results by comparing them with experimental and theoretical data. Subsequent stages in the advancement of simulation models and experiments will enhance the assurance and dependability of these findings. The simulation findings indicate that the stress concentration fluctuates based on the arrangement of the laminate layer. Hence, conducting additional research is imperative to comprehend the means of optimizing the material structure for minimizing the most significant stress concentrations. Ensuring the strength and longevity of the material used in Aceh's traditional boat, the *jaloekayoh*, is crucial for withstanding challenging operational conditions. The three test specimen configurations were selected to encompass various alterations in the quantity and arrangement of laminate layers. Fig. 6 displays the data regarding stress testing outcomes on the top specimens in different laminate layers.

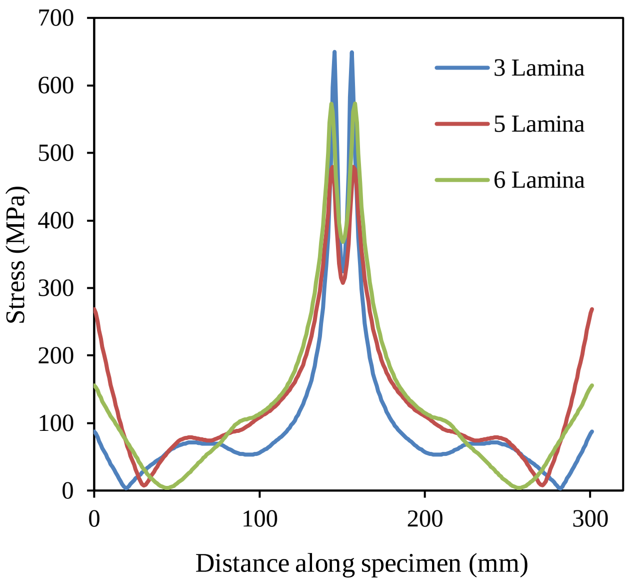

Fig. 6. Stress graph along test specimens for several laminate variations.

As a result, the stress exerted on the specimen against the three laminate layers (GRG) resulted in a maximum stress concentration of approximately 649.3 MPa in the configuration of the three laminate layers. This approach emphasizes the inherent robustness of the content in this comparatively uncomplicated arrangement [32]. The laminate consisting of five laminate layers (GRGRG) exhibits a maximum stress concentration of around 465.1 MPa. The incorporation of increased intricacy in the arrangement of the laminate layer signifies a substantial alteration in stress concentration, underscoring the significance of a more comprehensive structural design [33]. In addition, applying six laminate layers (GRGGRG) resulted in the maximum level of stress concentration, measuring around 560.6 MPa.The results offer a more profound understanding of how including layers impacts stress distribution and its correlation with enhanced structural durability [34]. These simulations deeply understand the material's response to impact loads in various laminate layer configurations. High stress concentrations in specific configurations provide a signal for the potential for increased structural resistance in *jaloekayoh*. This analysis can be the basis for developing more resilient materials and more effective design improvements for traditional Acehnese boats.

3.3 Strain Concentration Contours

Strain concentration analysis is a crucial component in comprehending the behavior of ramie-Eglass fiber hybrid composite materials under impact conditions. This study involved conducting drop-weight impact tests on composites with different configurations of laminate layers, specifically 3, 5, and 6 laminate layers, consisting of Eglass-ramie-Eglass (GRG), Eglass-ramie-Eglass-ramie-Eglass (GRGRG), and Eglass-ramie-Eglass-Eglass-ramie-Eglass (GRGGRG)—test result data. The highest stress concentration contours in the various laminate layers can be seen in Fig. 7.

From the drop-weight impact test data, the simulation results of the highest strain concentration in the various laminate layers show that the highest strain concentration in the three laminate layers (GRG) is around 3.786e-02. These data provide an initial picture of the material's response to impact loads in configurations with three fiber layers. Within the five laminate layers (GRGRG), the maximum strain concentration reached approximately 3.004e-02. The observed fluctuation suggests a disparity in the strain distribution inside the material due to the two extra layers. The configuration comprising six laminate layers (GRGGRG) has the most pronounced strain concentration at around 4.693e+02. This further elucidates the impact of incorporating an extra layer on the strain distribution inside the structure.

The analysis results show that differences in strain concentrations between laminate configurations indicate different material responses to impact loads. This variability is significantly impacted by the ramie-Eglass fiber interactions and material structure within each laminate layer [35]. Then, the high strain concentrations in the three and five laminate layers may indicate that the strain distribution is more even throughout the structure. However, in six layers of lamina, the significant increase can be a focus of attention in further structural design [36]. Subsequently, the strain concentration contours provide a more comprehensive insight into the strain distribution across various laminate layers within the material. These contours offer additional insight into regions that may necessitate particular consideration in the design of structures.

Emphasizing the validation of simulation results with practical and theoretical data is crucial. Further steps in developing simulation models and experiments will provide certainty and reliability to these findings. The simulation results show that the strain concentration varies depending on the configuration of the lamina layer. Therefore, further research must be carried out to understand how to optimize the material structure, especially in the six laminate layers, to reduce the highest strain concentrations. In the context of the traditional Acehnese boat, *jaloekayoh*, it is crucial to prioritize the strength and durability of the material when dealing with impact loads. The three test specimen configurations were selected to encompass various alterations in the quantity and arrangement of laminate layers. The data regarding the outcomes of strain testing on the topmost samples in different laminate layers is displayed in Fig. 8.

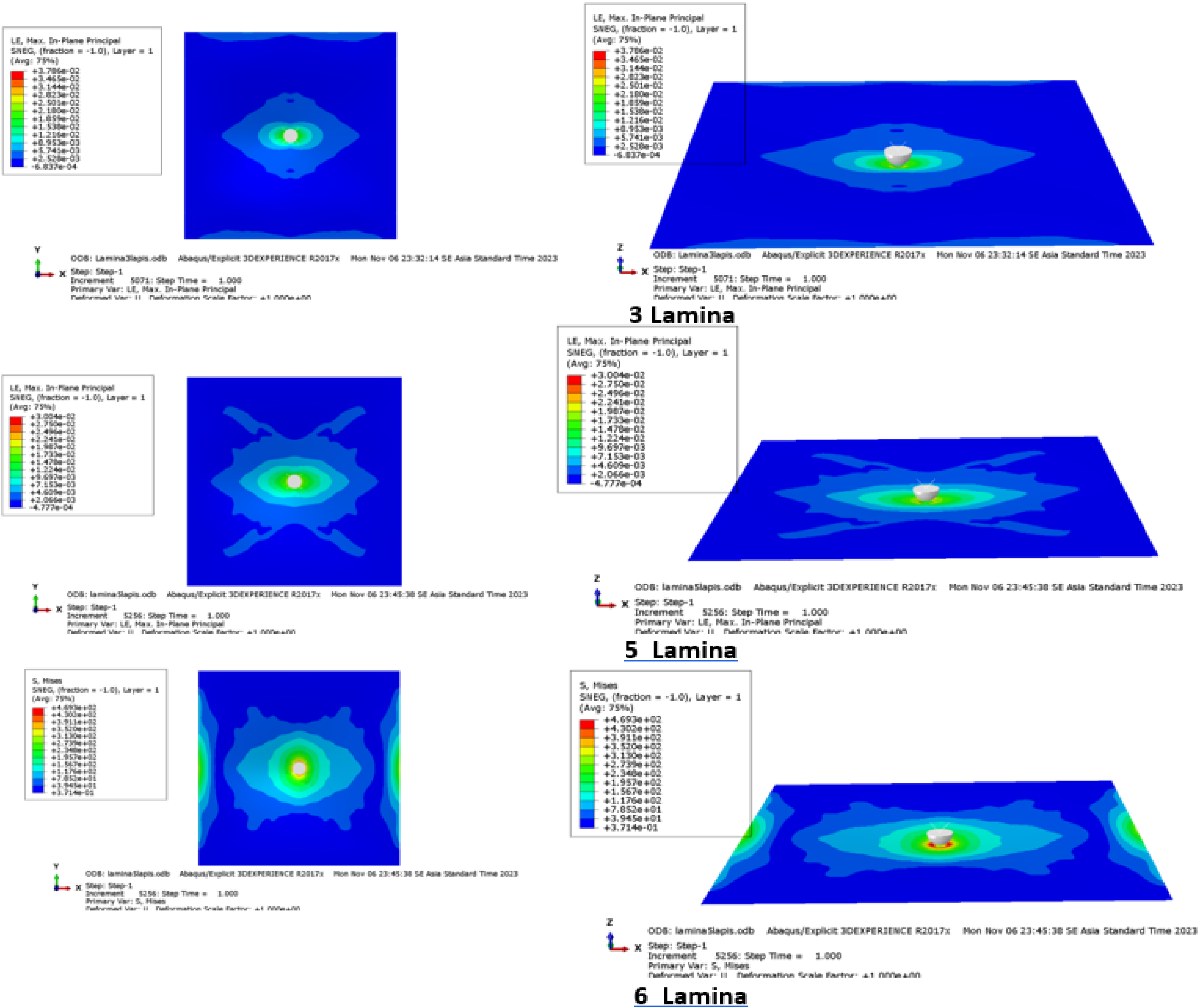

Fig. 7. Strain concentration contours in test specimens for several laminate variations.

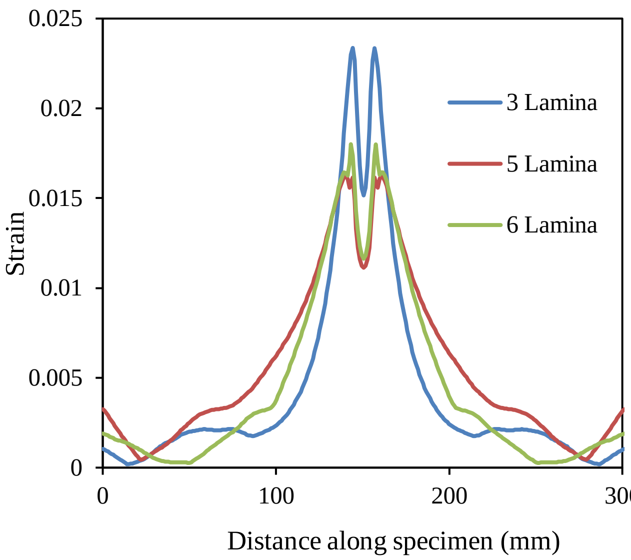

Fig. 8. Strain graph along test specimens for several laminate variations.

The simulation results indicate that the configuration consisting of three laminate layers (GRG) induces the greatest strain concentration along the specimen, approximately 0.023. This analysis describes the material's ability to absorb impact energy and the strain distribution in the three-layer laminate. Then, for the five laminate layers (GRGRG), the highest strain concentration is around 0.017. Variations in the number of laminate layers provide a further understanding of how configuration influences deformation and the material's ability to respond to external stresses in 5 laminate layers. In addition, when six laminate layers (GRGGRG) are used, the maximum level of strain concentration is approximately 0.016. The inclusion of extra layers in this example results in enhanced material ductility and a more uniform distribution of strain across the 6-layer laminate. This analysis is corroborated by reference [37], which establishes a theoretical foundation for the simulation model, and reference [38], which enhances the comprehension of the material properties of ramie-Eglass fiber composites. These simulations provide deep insight into how the material reacts to impact loads on various laminate layer configurations. The recorded strain concentrations provide insight into the potential for increased structural strength in *jaloekayoh*. This analysis can be the basis for developing more effective materials and more robust designs. This research was only conducted on drop-weight impact test specimens. To determine the performance of *jaloekayoh* material, further simulations need to be carried out by modeling *jaloekayoh* with a configuration that is consistent with the original shape.

4 Conclusion

Drop-weight impact testing on the ramie-Eglass fiber hybrid composite for *jaloekayoh* wall material has been carried out with conclusions. The specimen comprising 6 laminate layers (GRGGRG) exhibited the most significant displacement at 12,498 mm, suggesting an enhancement in structural stability. The increase in displacement during the addition of the laminate layer suggests the possibility of enhanced structural strength and durability. The highest stress concentration that occurred in the specimen with 6 laminate layers (GRGGRG) was 560.6 MPaindicating an increase in the material's ability to absorb impact loads. The decrease in stress concentration in specimens with 5 laminate layers (GRGRG) shows the positive influence of variations in layer configuration on stress distribution. The highest strain concentration was recorded in the specimen with 3 laminate layers (GRG) at 0.023, signifying a commendable capacity to diminish impact energy. The decrease in strain concentration with the addition of the laminate layer indicates an increase in the strength and durability of the material.The outcomes of this simulation may serve as a foundation for the advancement of structural materials of superior quality. Physical testing to validate simulation results and additional investigation of variations in laminate layer configuration and fiber type are suggested for future research. Therefore, this study makes a significant scholarly contribution by examining the potential of composite materials to enhance the safety and durability of traditional Acehnese boats, with a particular focus on the *jaloekayoh*, when subjected to impact pressures of sea waves.

Declaration of Competing Interest

The authors declare that the work reported in this study was not affected by any conflicting financial interests or personal connections.

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