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Tensile and Flexural Properties of Aramid Fiber Composite Laminates

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Abstract

Composite laminates are a type of materials that being develop currently as for their lightweight, strength and renewable compared to traditional materials which is steel. These materials are being used widely in automotive and aerospace industry because if their benefits. This study focus on developing strong composite laminates materials from aramid fiber. The objectives of the study are to fabricate the composite laminates of aramid fiber and to evaluate the mechanical properties of the composite laminates which are tensile and flexural strength. The fabrication method used in this research was vacuum assisted infusion molding with infusion of 2:1 epoxy resin to hardener ratio. There are two types of samples with different layer of aramid fiber which are 4 and 6 layers. The composite laminates are then cut using vertical bandsaw machine into desired shape and size required for the testing. The tensile and flexural strength is obtained by testing the material using universal testing machine. Tensile test referred to ASTM D3039 standard and flexural test referred to ASTM D790 standard. The mechanical properties of the composite laminates fabricated using this method tend to be superior to another research which use compression molding and polyester resin. The maximum load of the tensile properties for both 4- and 6-layer composite laminates sample were 6.01 kN and 8.12 kN respectively. The maximum load for the flexural properties of both 4- and 6-layers composite laminates were 156.875 N and 461.458 N respectively.

1. Introduction

This research project aims to investigate the use of composite laminates made from aramid fiber as an alternative material for automotive manufacturing. The study focuses on evaluating the mechanical properties, including tensile strength, flexural strength, and hardness, of composite laminates with varying numbers of wall layers. The main objective is to design and fabricate composite laminate panels using vacuum infusion molding and assess their performance through experimental testing. The significance of the study lies in the potential benefits of composite laminates, such as reduced weight, improved performance, and better fuel efficiency, which can contribute to lightweight and cost-effective automotive production. The results of this research can provide valuable insights for the automotive industry in considering the adoption of composite laminates as a viable alternative to traditional materials like steel alloy. The introduction should describe general information on the subject matter area of study. It is usually arranged in such a manner to gradually bring to focus the specific motivations of the current study, the research questions, the problem statements, the hypotheses, the objectives, as well as the expected outcome.

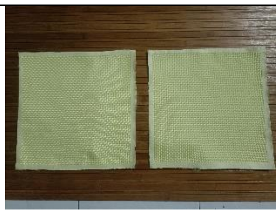
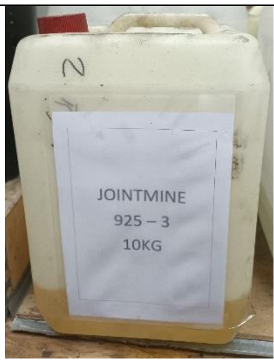
2. Materials and Methods

2.1 Materials

The materials used in this research include aramid fiber and epoxy resin. Aramid fiber is renowned for its exceptional strength-to-weight ratio and impact resistance, making it an ideal reinforcement material for composite laminates. For material preparation, the woven aramid fiber used in the research is cut into 30 cm × 30 cm to be arrange in the mold.

Epoxy resin, when combined with an appropriate hardener, acts as the matrix material in the composite. The resin provides excellent adhesion, enhances the mechanical properties of the laminate, and ensures a strong bond between the fibers. The mixture of the resin and hardener ratio used is 2:1 epoxy to hardener.

Table 1 *Materials used in the research*

<table>
<tr><td>Woven Aramid Fiber</td><td></td></tr>
<tr><td>Epoxy</td><td>
</td></tr>
<tr><td>Hardener</td><td>
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2.2 Methods

The fabrication process for the Kevlar aramid composite laminates employs the vacuum-assisted infusion molding technique. This method involves placing the aramid fiber in a mold and applying a permeable release fabric over the fibers. The mold is then sealed with a vacuum bag, and a vacuum is applied to draw the resin through the fibers, saturating them completely. The resin impregnated laminate is allowed to cure under ambient conditions, resulting in a consolidated composite laminate with uniform fiber distribution and enhanced mechanical characteristics.

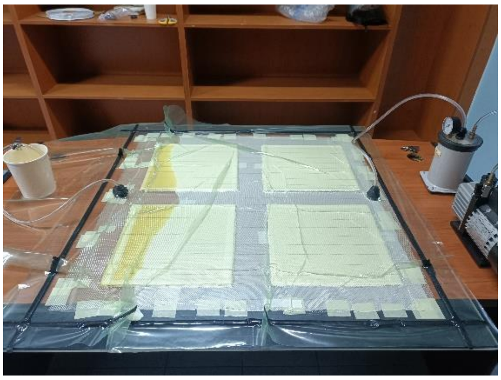

Fig. 1 *Complete set up of vacuum assisted infusion method*

The composite laminates are precisely cut into standardized sizes for testing purposes. A vertical bandsaw machine is employed for this purpose. The laminate specimens are securely positioned and aligned on the bandsaw table, ensuring accuracy and consistency. The vertical bandsaw machine with its vertically oriented blade and controlled cutting motion allows for clean and accurate cuts. This process ensures that the specimens meet the required dimensions for subsequent testing

Fig. 2 *Vertical bandsaw machine*

To evaluate the mechanical properties of the composite laminates, two types of tests are performed: tensile testing and three-point bending testing. Tensile testing is conducted using a universal testing machine (UTM) in accordance with the ASTM D3039 standard. Specimens of the composite laminate are prepared with standardized dimensions and securely gripped in the UTM. A tensile load is applied to the specimen, and the UTM measures the applied load and the resulting elongation or displacement, allowing for the determination of parameters such as tensile strength, modulus of elasticity, and elongation at break.

Three-point bending testing is also carried out using the UTM to find out the flexural strength, following the ASTM D790 standard. Composite laminate specimens are placed on supports with a 60 mm span length, and a load is applied at the center of the specimen. The UTM records the load and the deflection of the specimen during the bending test. These measurements enable the calculation of parameters such as flexural strength and flexural modulus, which provide insights into the laminate's resistance to bending forces.

3. Results and Discussion

The research successfully demonstrated the strength-enhancing effects of the vacuum-assisted infusion method and the use of epoxy resin in aramid fiber composite laminates. The results indicate the potential of these materials and fabrication techniques for various industrial applications.

3.1 Tensile Test

In the tensile testing of the composite laminates, both the 4-layer and 6-layer aramid fiber samples exhibited higher maximum loads compared to a referenced journal, which employed compression molding. The average maximum load for the 4-layer laminates was 6.01 kN, while for the 6-layer laminates, it was 8.12 kN. The epoxy resin and the vacuum-assisted infusion method used in this research were found to enhance the strength properties of the aramid fiber composite laminates.

Table 2 *Data obtained from tensile test of 4-layer sample*

Sample	Max Load (kN)	Elongation at Max (mm)	Elongation at Break (mm)	E. Modulus (MPa)	Yield Strength (kN/m^2)	Max Stress (MPa)	Max Strain (%)	Stress at Break (MPa)
1	6.33	5.46	5.91	2484.88	83275.655	84.38	3.209	58.985
2	5.27	6.41	7.06	1634.70	59968.364	70.20	3.770	49.112
3	6.42	5.12	5.43	2738.76	84512.746	86.12	3.058	61.792
Average	6.01	5.66	6.13	2286.11	75918.923	80.23	3.346	56.630

Table 3 *Data obtained from tensile test of 6-layer sample*

Sample	Max Load (kN)	Elongation at Max (mm)	Elongation at Break (mm)	E. Modulus (MPa)	Yield Strength (kN/m^2)	Max Stress (MPa)	Max Strain (%)	Stress at Break (MPa)
1	7.52	3.92	4.54	2568.85	56195.405	60.20	2.307	42.124
2	6.46	3.54	4.21	2828.16	41440.293	51.68	2.081	36.171
3	10.38	5.89	6.20	2902.66	57075.945	83.00	3.464	57.563
Average	8.12	4.45	4.98	2766.56	51570.548	64.96	2.617	45.286

3.2 Flexural Test

Similarly, in the flexural testing, the 6-layer aramid fiber composite laminates demonstrated higher maximum loads compared to the referenced journal's sample, which was 461.458 N in this research. The 4-layer laminates had an average maximum load of 156.875 N. The number of layers significantly influenced the flexural properties, with the 6-layer laminates exhibiting greater strength.

Table 4 *Data obtained from flexural test of 4-layer sample*

Sample	Max Force (N)	Max Displacement (mm)	Max Stress (N/mm^2)	Max Strain (%)
1	170.938	11.5710	113.9580	5.78550
2	164.063	8.59650	109.3750	4.29825
3	135.625	8.27250	90.4167	4.13625
Average	156.875	9.48	104.5832	4.74

Table 5 *Data obtained from flexural test of 6-layer sample*

Sample	Max Force (N)	Max Displacement (mm)	Max Stress (N/mm^2)	Max Strain (%)
1	416.250	9.12350	99.9000	7.60292
2	481.875	8.01300	115.6500	6.67750
3	486.250	7.98100	116.7000	6.65083
Average	461.458	8.37250	110.7500	6.97708

3.3 Discussions

The results of the research showed that the 4-layer and 6-layer aramid fiber composite laminates fabricated using the vacuum-assisted infusion method and epoxy resin exhibited higher maximum loads in both tensile and flexural testing compared to a referenced journal that used compression molding and polyester resin. The average maximum load for the 4-layer laminates in tensile testing was 6.01 kN, while for the 6-layer laminates, it was 8.12 kN.

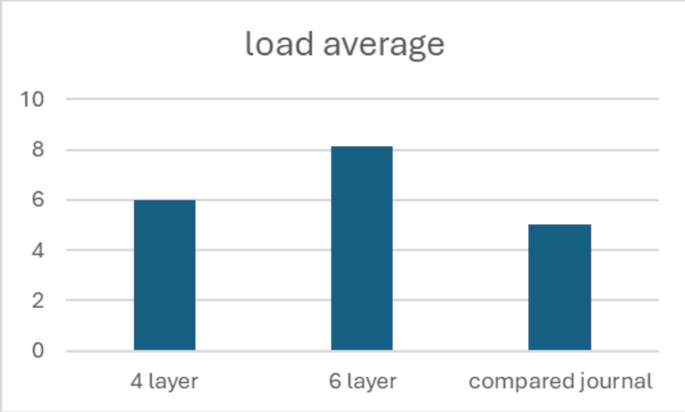

Fig. 3 *Comparison for tensile result*

In flexural testing, the 4-layer laminates had an average maximum load of 156.875 N, while the 6-layer laminates recorded an average maximum load of 461.458 N. The superior performance of the samples in this research can be attributed to the use of the vacuum-assisted infusion method and epoxy resin, which enhanced the strength properties of the aramid fiber composite laminates. These findings demonstrate the potential of this fabrication approach and resin selection for producing strong and durable composite laminates.

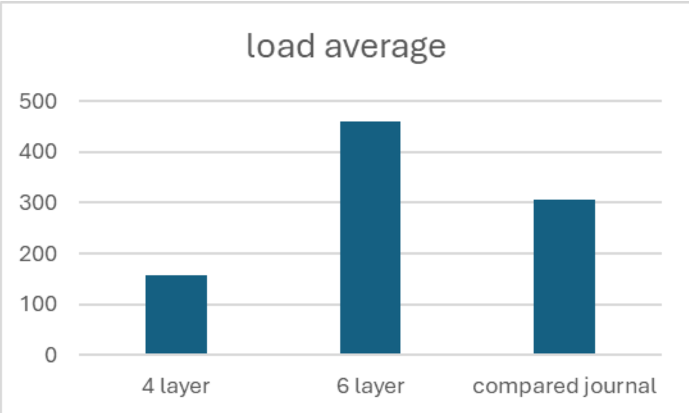

Fig. 4 *Comparison for flexural result*

4. Conclusions

In conclusion, the research successfully achieved its first objective of designing and fabricating composite laminates panels from aramid fiber using the vacuum-assisted infusion method. The use of this advanced fabrication method and epoxy resin resulted in high-quality laminates with improved properties compared to traditional methods such as hand layup or compression molding. The second objective, which focused on evaluating the mechanical properties of the laminates, was also successfully accomplished. The tensile and flexural testing showed that both the 4-layer and 6-layer laminates exhibited higher maximum loads compared to a referenced journal, indicating superior strength. The study demonstrated the influence of the number of layers and resin selection on the mechanical properties, highlighting the benefits of the vacuum-assisted infusion method and epoxy resin in enhancing the strength of aramid fiber composite laminates.

Moving on to recommendations, future studies could explore additional parameters that can further optimize the mechanical properties of aramid fiber composite laminates. Investigating the effect of different fiber orientations, such as unidirectional, woven, or randomly oriented fibers, would provide valuable insights into anisotropic behavior and load-bearing capabilities. Additionally, incorporating additives into the epoxy resin, such as toughening agents, nanofillers, or coupling agents, could significantly impact the mechanical properties and expand the application range of the laminates. Lastly, exploring the influence of post-curing treatments, such as elevated temperature or extended curing durations, could optimize the resin's crosslinking and improve the long-term performance of the laminates. These recommendations would contribute to further enhancing the strength, durability, and application potential of aramid fiber composite laminates.

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