The Effect of Weight Percentage on the Tensile Properties of Glass/ Kenaf Hybrid Composites

M. F. Ismail, M. T. H. Sultan, A. Hamdan, A. U. M. Shah, S.N.A. Safri

Abstract*: Nowadays, hybridisation between synthetic fibre and natural fibre is common due to environmental concerns and financial problem. This research was conducted to examine the effects of different glass fibre (GF) composition on the tensile properties of glass/kenaf hybrid composites. For this study, epoxy resin was used as matrix and woven glass fibres type E600 and woven kenaf fibres (KF) were used as the reinforcements. Hybrid composites fabricated by hand lay-up technique while maintaining 10 number of layers for each sample. An investigation of tensile properties of glass/kenaf hybrid composites with different weight composition of GF; 0%, 25%, 30%, 50%, 70%, 75% and 100% were carried out. The composites were tested and the results shows that sample HS5 that consists of hybridized 75% GF and 25% KF is having characteristics almost approaching the performance of sample made from 100% GF.

Index Terms: Hybrid Composites, Kenaf fibre, Tensile Properties, Glass fibre.

I. INTRODUCTION

Natural fibres have been utilized more than 3000 years ago as reinforcement for materials by many countries [1] [2]. It has plays an important role in developing the industry towards a green concept, environmental friendly and economic efficiency. Synthetic fibres come from organic synthetic compound in high-molecular state and mixture of petroleum oil that are used to improve naturally existing animal and plant fibres. Natural fibres promising many advantages and may slightly replace synthetic fibres in the material industry as in Table 1 [2-3]. The tensile strength and the Young's modulus of natural fibres is lower than that of fibres used in synthetic materials but will be higher when the cellulose content increases [4]. The physical properties of natural fibres having significance effect on the composite product's properties [2] [5-6].

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Table 1: Comparison between natural fibre and synthetic fibre [6].

Natural Fibre	Synthetic Fibre
Renewable	Non-renewable
Biodegradable	Non-biodegradable
Cheap	Expensive
Lightweight	Heavier than NF
Less pollution	High pollution

Currently KF is one of the natural fibres that have fascinated researchers to discover their potential as a reinforcement element. Kenaf is one of the most common natural fibre studied by researchers focusing on the hybridization with synthetic fibres [7-9]. From previous studies, KF is a promising materialfor structural performance applications [10-12]. GF is classified among the most compliance synthetic fibre materials in industry for a wide range of application [13-16]. Glass may possible to transform in continuous filament of smaller diameter as fibre due to its viscosity-temperature relationship [17-19]. GF alone having both stiffness and strong due to tension, but vice versa in compression due to buckling of long and narrow typical fibre [20-22]. However, this disadvantages can be solved by selecting the best configurations of GF based on the manufacturer suggestions [23-26].

Most research nowadays put a strain on the development of new natural fibre composites and focusing their work on green materials [27-30]. The research involves on their mechanical properties involving tensile, impact and after impact [31-33]. Natural fibre composites are emerging as acceptable alternatives to replace or reinforced synthetic fibre composites. The trends for such development is likely because of the attractive property of the natural composites fibre itself as being mentioned previously. Hybrid compostieshas been started to receive recognition in industry [34-38]. Therefore, tensile properties obtained in this study will help to increase the fundamental knowledge on the effect of weight composition between synthetic fibre and natural fibre, specifically between GF and KF.

II. METHODOLOGY

A. Sample Preparation

The research started with the fabrication of the sample, with 10th-layers fibre per each sample using kenaf and E600 glass fiber [39] [40]. The matrix used was epoxy Zeepoxy HL002TA with Zeepoxy HL002TB hardener. The mixture were prepared with ratio 2(epoxy):1(hardener). Hand lay-up technique were used for sample preparation and left to cure for 24 hours before being cut into standard size required for tensile testing. The samples are prepared and presented in seven different types denoted with symbol labelled GS, KS, HS1, HS2, HS3, HS4, and HS5 that are exhibited in Table 2.

Table 2: The samples involved in the testing and discussion of the mechanical properties.

Sample	Weight percentage ratio
GS	100% GF
KS	100% KF
HS1	25% GF + 75% KF
HS2	30% GF + 70% KF
HS3	50% GF + 50% KF
HS4	70% GF + 30% KF
HS5	75% GF + 25% KF

III. RESULTS AND DISCUSSION

The tensile test results are illustrated in Fig 1 to Fig 7, while Fig 8 represent overall results which had been compared with one another. Each of the following graphical representation is obtained from various tensile testing. The figures represented by the graph exhibits the maximum load resisted by the material before it breaks. The best performance of specimen will be selected amongst those seven samples. Several factors will be considerable, such as the highest (or uniformly constant) force the samples can withstand and also the longest (or uniformly constant) elongation it experiences before any fractures or failures.

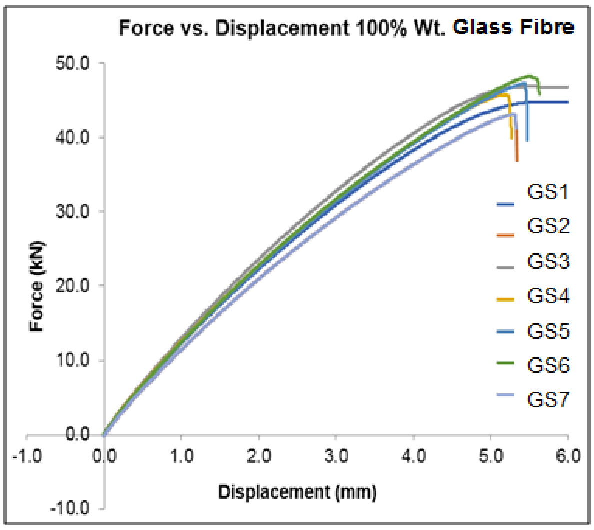

Fig 1. Graph of tensile - force displacement curves for 100% wt. GF

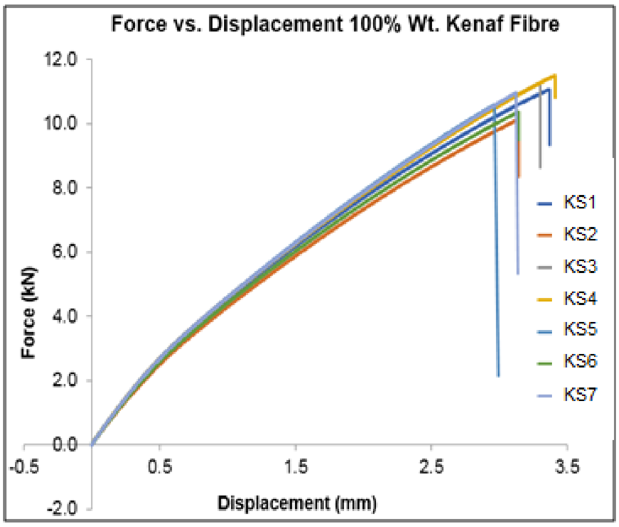

Fig 2. Graph of tensile - force displacement curves for100% wt. KF

From the graph represented by Fig 1, sample GS6 showing highest force resistance followed by samples GS5, GS3, GS1, GS4, and GS7 similar with GS2. The values for tensile force are 48.30kN, 47.37kN, 46.91kN, 44.79kN, 45.80kN and 43.15kN respectively. Sample GS3 and GS1 showing longest tensile displacement followed by samples GS6, GS5, GS7 and GS2. The shortest displacement is GS4 sample. The values for tensile displacement are 6.06mm, 6.02mm, 5.63mm, 5.48mm, 5.32mm, 5.25mm and 5.17mm respectively.

From the graph represented by Fig 2, KS4 shows the highest force and longest displacement resistance before failures. Tensile strength for all the same type of samples represents in force versus displacement graph are showing similar trends. Sample KS4 showing highest force resistance followed by samples KS3, KS1, KS7, KS5, KS6 and KS2. The values for tensile force are 11.50kN, 11.26kN, 11.07kN, 10.96kN, 10.59kN, 10.37kN and 10.14kN respectively.Sample KS4 also showing the longest tensile displacement followed by samples KS1, KS3, KS6, KS2, KS7 and KS5. The values for tensile displacement are 3.40mm, 3.37mm, 3.15mm, 3.14mm, 3.13mm and 2.97mm respectively.

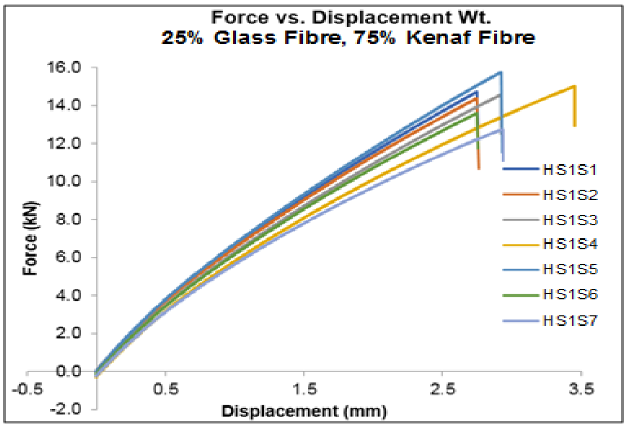

Fig 3. Graph of tensile - force displacement curves for 25% wt. GF, 75% wt. KF

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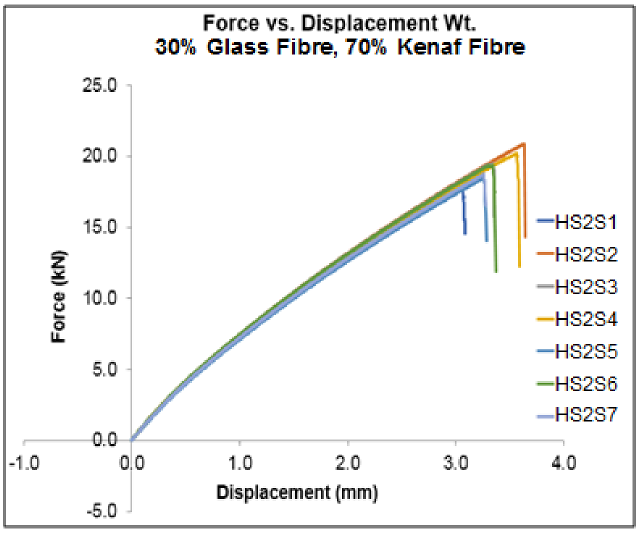

Fig 4. Graph of tensile - force displacement curves for 30% wt. GF, 70% wt. KF

From the graph represented by Fig 3, sample HS1S5 shows the highest force resistance, while sample HS1S4 shows longest dis-placement elongation resistance before failures.Sample HS1S5 showing highest force resistance followed by samples HS1S4, HS1S1, HS1S3, HS1S2, HS1S6 and HS1S7. The values for tensile force are 15.69kN,14.99kN, 14.63kN, 14.56kN, 14.37kN, 13.51kN and 12.75kN respective-ly. Sample HS1S4 showing highest tensile displacement followed by samples HS1S7, HS1S5, HS1S3, HS1S2, HS1S6 and HS1S1. The values for tensile displacement are 3.45mm, 2.93mm, 2.92mm, 2.91mm, 2.74mm, 2.73mm and 2.72mm respectively.

From the graph represented by Fig 4, sample HS2S2 shows the highest force and longest displacement elongation resistance before failures. Sample HS2S2 showing highest force resistance followed by samples HS2S4, HS2S3, HS2S6, HS2S7, HS2S5, and HS2S1. The values for tensile force are 20.71kN, 20.12kN, 19.43kN, 19.14kN, 18.61kN, 18.40kN and 18.01kN respectively.Sample HS2S2 showing longest tensile displacement followed by samples HS2S4, HS2S6, HS2S3, HS2S7, HS2S5 and HS2S1. The values for tensile displacement are 3.63mm, 3.57mm, 3.35mm, 3.33mm, 3.27mm, 3.26mm, and 3.05mm respectively.

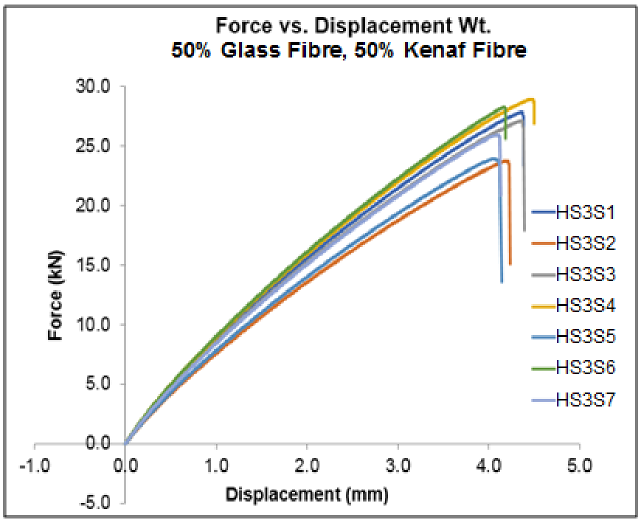

Fig 5. Graph of tensile – force displacement curves for 50% wt. GF, 50% wt. KF

From the graph represented by Fig 5, sample HS3S4 shows the highest force and longest displacement elongation resistance before failures. Sample HS3S4 showing highest force resistance followed by samples HS3S6, HS3S1, HS3S3, HS3S7, HS3S5 and HS3S2.The values for tensile force are 28.79kN, 28.05kN, 27.68kN, 27.08kN, 25.64kN, 23.83kN and 23.71kN respectively. Sam-ple HS3S4 showing longest tensile displacement followed by samples HS3S1, HS3S3, HS3S2, HS3S6, HS3S7 and HS3S5. The values for tensile displacement are 4.50mm, 4.38mm, 4.37mm, 4.21mm, 4.18mm, 4.12mm and 4.10mm respectively.

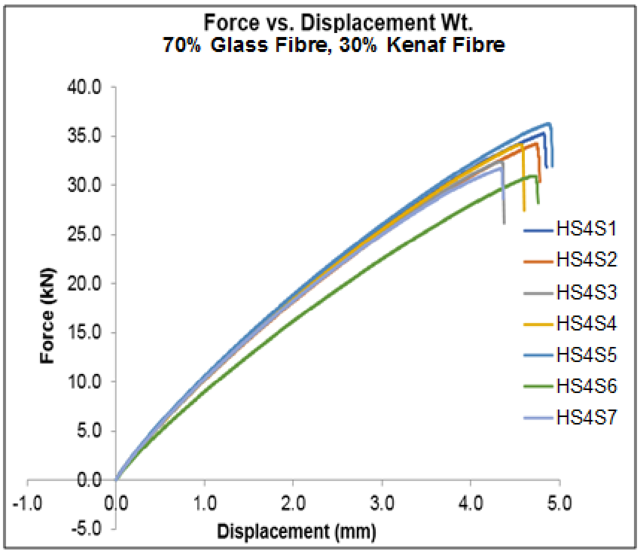

Fig 6. Graph of tensile - force displacement curves for 70% wt. GF, 30% wt. KF

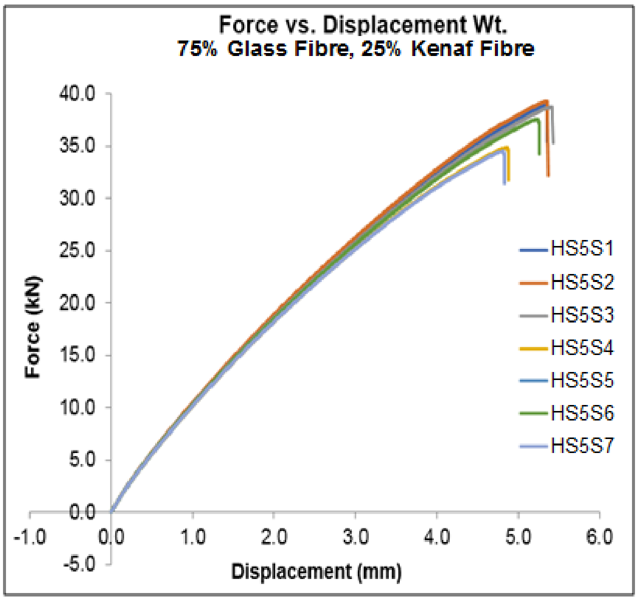

Fig 7. Graph of tensile - force displacement curves for 75% wt. GF, 25% wt. KF

From the graph represented by Fig 6, sample HS4S5 shows the highest force and longest displacement elongation resistance before failures. Sample HS4S5 showing highest force resistance followed by samples HS4S1, HS4S2, HS4S4, HS4S3, HS4S7 and HS4S6.The values for tensile force are 36.23kN, 35.01kN, 34.17kN, 34.06kN, 32.38kN, 31.55kN and 30.69kN respectively. Sam-ple HS4S5 showing longest tensile displacement followed by samples HS4S1, HS4S2, HS4S6, HS4S4, HS4S7 and HS4S3. The values for tensile displacement are 4.89mm, 4.83mm, 4.74mm, 4.73mm, 4.56mm, 4.35mm and 4.33mm respectively.

From the graph represented by Fig 7, sample HS5S2 shows the highest force while sample HS5S3 shows the longest displacement elongation resistance before failures. Sample HS5S2 showing highest force resistance followed by samples HS5S1, HS5S3, HS5S6, HS5S5, HS5S4 and HS5S7. The values for tensile force are 39.08kN, 38.71kN, 38.49kN, 37.33kN, 37.04kN, 34.76kN and 34.33kN respectively.Sample HS5S3 showing longest tensile displacement followed by samples HS5S1, HS5S2, HS5S6, HS5S5, HS5S4, and HS5S7. The values for tensile displacement are 5.41mm, 5.35mm, 5.36mm, 5.25mm, 5.09mm, 4.87mm and 4.82mm respectively.

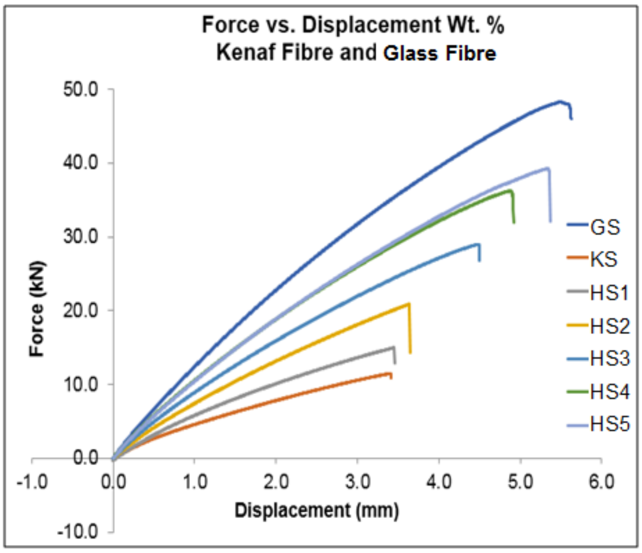

Fig 8. Graph of tensile - force displacement curves comparison for all types of samples

All the results are compared and summarised in Fig 8 for all types of samples. Sample GS shows the highest force and longest displacement elongation resistance. Vice versa to sample K that shows the lowest force and shortest displacement elongation resistance before failures. Tensile strength for all the same type of samples that represents in force versus dis-placement graph are showing similar trends that ends up to certain pivot point before its failures. In addition, the perfor-mance of sample HS5 that consists of hybridized 75% GF and 25% KF being compared to other hybrid composites weight percentage is having characteristics almost approaching the performance of tensile test for the 100% weight percentage of GF.

IV. CONCLUSION

Generally, from the preliminary experiment for the hybrid composite of GF and KF, it was observed that the optimum weight percentage that approaching almost similar mechanical and physical properties of 100% fibreglass weight percentage are the combination of 75% GF and 25% KF, represented by sample HS5. According to the results of the research, it is concluded that sample HS5 gives a better performance for its tensile properties compared to the other combination of hybrid composite weight percentage denoted by HS1, HS2, HS3, and HS4 which the weight per-centage of fibre composition may varies. The results show that those samples of the material manufactured from different weight percentage of fibres may influence the performance. Hence, it is suggested that sample HS5 with the combination of 75% GF and 25% kenaf weight percentage is a significant alternative method for manufacturing aerospace structure. The improvement of energy absorption in the hybrid composites are determined by the plastic deformation. The hybrid composite concept increases the fundamental of the composite material, due to the enhancement of adhesion be-tween the fibre and the matrix for both woven GF and woven KF.These results indicate the potential of glass/ kenaf fibre hybrid composites as an alternative to existing materials. Hence, further research must be carried out in future to fully utilized kenaf fibres to be part of development.

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REFERENCES

[1] S. Taj, M.A. Munawar, S. Khan, “Natural fibre-reinforced polymer composites”, In Proceedings Pakistan Academy Science.

[2] R. Nadlene, S.M. Sapuan, M. Jawaid, M.R. Ishak, and L. Yusriah, “Material characterization of roselle fibre (Hibiscus sabdariffa L.)as potential reinforcement material for polymer composite,” Fibres and textiles in Eastern Europe, 2015.

[3] S.N.A. Safri, M.T.H. Sultan, M. Jawaid, and K. Jayakrishna, “Impact behaviour of hybrid composites for structural appli-cations: A review,” Composites Part B: Engineering, 2018.

[4] R. Nadlene, S.M. Sapuan, M. Jawaid, M.R. Ishak, and L. Yusriah, “A review on roselle fibre and its composites,” Journal of NaturalFibres, 2016.

[5] T. Sathishkumar, P. Navaneenthakrishnan, S. Shankar, R. Rajasekar, and N. Rajini,“Characterization of natural fibre and composites – A review,” Journal of Reinforced Plastics and Composites, 2013.

[6] A. Hamdan, F. Mustapha, K.A. Ahmad, M.R. Ishak, and A.E. Ismail, “The effect of customized woven and stacked layer orientation on tensile and flexural properties of woven kenaf fibre reinforced epoxy composites,” International Journal of Polymer Science, 2016.

[7] S. H. Aziz, and M.P. Ansell, “The effect of alkalization and fibre alignment on the mechanical and thermal proper-ties of kenaf and hempbast fibre composites: Part 1 - Polyester resin matrix,” Composite ScienceTechnology, 2006.

[8] S. Shibata, Y. Cao, and I. Fukumoto. “Flexural modulus of the unidirectional and random composites made from biodegradable resin and bamboo and kenaf fibres,” Composites Part A: Applied Science and Manufacturing, 2008.

[9] M. Davoodi, S.M. Sapuan, D. Ahmad, A. Ali, A. Khalina and M. Jonoobi, “Mechanical properties of hybrid kenaf/glass reinforced epoxy composite for passenger car bumper beam. Materials and Design.

[10] Food and Agriculture Organization of United Nations (FAO) (2013). Application of Natural Fibre Composites in the Develop-ment of Rural Societies.
[11] M.J. Sharba, Z. Leman, M.T.H. Sultan, M.R. Ishak, and M.A.A. Hanim, "Tensile and compressive properties of woven kenaf/glass sandwich hybrid composites," International Journal of Polymer Science, 2016.
[12] S.D. Salman, Z. Leman, M.T.H. Sultan, M.R. Ishak, and F. Cardona, "Influence of Fiber Content on Mechanical and Morphological Properties of Woven Kenaf Reinforced PVB Film Produced Using a Hot Press Technique," International Journal of Polymer Science, 2016.
[13] S.S. Sanchez, E. Barbero, R. Zaera, and C. Navarro "Compression after impact of thin composites laminates," Composite Science and Technology, 2005.
[14] A.U.M. Shah, M.T.H. Sultan, M.Jawaid, F. Cardonaand A.R.A. Talib, "A review on the tensile properties of bamboo fibre reinforced polymer composites," Bioresources, 2016.
[15] H.J. Nadaf, and A.M. Naniwadekar, "Analysis of anti-roll bar of passenger car using alternative material," International Journal of Advanced Technology in Engineering and Science, 2015.
[16] Boeing. "AERO - Boeing 787 from the ground up," 2010.
[17] F. Chowdury, and S. Jeelani, "Low velocity impact response and ultrasonic NDE of nanoclay nanocomposites," Journal of Composite Materials, 2007.
[18] A.U.M Shah, M.T.H. Sultan, F. Cardona, M. Jawaid, A.R.A. Talib andN. Yidris, "Thermal analysis of bamboo fibre and its com-posites", BioResources, 2017.
[19] S.D. Salman, M.J. Sharba, Z. Leman, M.T.H. Sultan, M.R. Ishak &F. Cardona, "Tension-Compression Fatigue Be-havior of Plain Woven Kenaf/Kevlar Hybrid Composites", BioResources, 2016.
[20] S.D. Salman, Z. Leman, M.T.H. Sultan, M.R. Ishak, and F. Cardona, "Influence of Fiber Content on Mechanical and Morphological Properties of Woven Kenaf Reinforced PVB Film Produced Using a Hot Press Technique", International Journal of Polymer Science, 2016.
[21] N.H. Mostafa, Z.N. Ismarrubie, S.M. Sapuan, and M.T.H. Sultan, "Effect of equibiaxially fabric prestressing on the tensile performance of woven E-glass/polyester reinforced composites," Journal of Reinforced Plastics and Composites, 2016.
[22] J.M. Duell, "Impact Testing of Advanced Composites", Advanced Topics in Characterization of Composites, 2004.
[23] U. Farooq, and P. Myler,"Prediction of barely visible impact damage in composite panels subjected to blunt nose impact," Research and Innovation Conference, 2009.
[24] A.C.J. Glover, "Non-Destructive Testing Techniques for Aerospace Applications C-Scan B-Scan D-Scan,".
[25] B. Nikfar, and J. Njuguna, "Compression-after-impact (CAI) performance of epoxycarbon fibre-reinforced nano-composites using nanosilica and rubber particle enhancement," In 2nd International Conference on Structural Nano Composites (NANOSTRUC 2014), IOP Conference Series: Material Science and Engineering, 2004.
[26] V. Dhawan, S. Singh, and I. Singh,"Effect of natural fillers on mechanical properties of GFRP composites," Journal of Composites 2013.
[27] A.F.M. Nor, M.T.H. Sultan, M.Jawaid, A.M.R. Azmi, andA.U.M. Shah, "Analysing impact properties of CNT filled bamboo/glass hybrid nanocomposites through drop-weight impact testing, UWPI and compression-after-impact behaviour," Composite Part B Engineering, 2019.
[28] S.D. Salman, Z. Leman, M.T.H. Sultan, M.R. Ishak, andF. Cardona, "Effect of kenaf fibers on trauma penetration depth and ballistic impact resistance for laminated compo-sites", Textile Research Journal, 2016.
[29] K.I. Ismail, M.T.H. Sultan, A.U.M. Shah, M. Jawaid, S.N.A. Safri, "Low velocity impact and compression after impact properties of hybrid bio-composites modified with multi-walled carbon nanotubes", Composite Part B Engineering, 2019.
[30] S.D. Salman, Z. Leman, M.T.H Sultan, M.R. Ishak, andF. Cardona, "Ballistic impact resistance of plain woven ke-naf/aramid rein-forced polyvinyl butyral laminated hybrid composite", BioResources, 2016.
[31] M.T.H. Sultan, K. Worden, W.J. Staszewski, S.G Pierce, J.M. Duliue-Barton, A. Hodzic, "Impact damage detection and quantification in CFRP laminates; A precursor to ma-chine learning", 7th International Workshop on Structural Health Monitoring, 2009.
[32] M.J. Sharba, Z. Leman, M.T.H. Sultan, M.R. Ishak, andM.A. AzmahHanim, "Partial replacement of glass fiber by woven kenaf in hy-brid composites and its effect on monotonic and fatigue properties", BioResources, 2016.
[33] P. Zakikhani, R. Zahari, M.T.H. Sultan, D.L. Abang Abdul Majid, "Morphological, mechanical, and physical properties of four bam-boo species", Bioresources, 2017.
[34] P. Vimalanathan, N. Venkateshwaran, and V. Santhanam, "Mechanical, dynamic mechanical, and thermal analysis of Shorearobusta -dispersed polyester composite," International Journal of Polymer Analysis and Characterization, 2016.
[35] J. Zhang, B.L. Fox, D. Gao, and A.W. Stevenson, "Inspection of Drop-weight Impact Damage in Woven CFRP Laminates Fabricated by Different Processes," Journal of Composite Materials, 2009.
[36] F. Mustapha, K.D. Mohd Aris, N.A. Wardi, M.T.H. Sultan, A. Shahrjerdi, "Structural health monitoring (SHM) for composite structure undergoing tensile and thermal testing", Journal of Vibroengineering, 2012.
[37] N.H. Mostafa,Z.N. Ismarrubie, S.M. Sapuan, M.T.H. Sultan, "Fibre prestressed polymer-matrix composites: A review", Journal of Composite Materials, 2016.
[38] C. Soutis, "Carbon fibre reinforced plastics in aircraft construction," Materials Science and Engineering, 2005.
[39] S.S. Suhaily, A.H.P.S. Khalil, W.O.W. Nadirah, and M. Jawaid, "Bamboo based biocompositesmateral, design and applications," Material Science, 2013.
[40] A.U.M. Shah, M.T.H. Sultan, M. Jawaid, F. Cardona, andA.R.A. Talib, "A review on the tensile properties of bamboo fiber rein-forced polymer composites," BioResources, 2016.
[41] N.H. Mostafa,Z.N. Ismarrubie, S.M. Sapuan, and M.T.H. Sultan, "Fibre prestressed composites: Theoretical and numerical modelling of unidirectional and plain-weave fi-bre reinforcement forms", Composite Structures, 2017.
[42] P. Zakikhani, R. Zahari, M.T.H Sultan, D.L. Majid, "Thermal degradation of four bamboo species," BioResources, 2016.

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