Kenaf Fibre Composites as Promising Green-Composites for Automotive Car Door Map Pocket Application

M.Y. Yuhazri[1*], M.H. Amirhafizan[2], A. Abdullah[2], S.H. Yahaya[2], S.T.W. Lau[3], A.M. Kamarul[1]
[1]Faculty of Engineering Technology
[2]Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.
[3]Faculty of Engineering and Technology, Multimedia University, 75450 Jalan Ayer Keroh Lama, Melaka, Malaysia.
Email: *[1]yuhazri@utem.edu.my; [2]amirhafizan@gmail.com; [2]abu@utem.edu.my; [2]saifudin@utem.edu.my
[3]twlau@mmu.edu.my; [1]kamarulamir@utem.edu.my

***Abstract*--** **The utilisation of natural fibres in composite materials is expanding because of an enactment that constrains automotive makers to reuse and recycle materials, leading to an increase in bio-based materials substances in automotive applications. An experimental investigation was conducted to explore car door map pocket for PROTON Saga FL by using non-woven kenaf (N-W) and hybrid from non-woven/ woven fabric kenaf (HN-W/W). The Hand Lay-up Method followed by vacuum bagging process were used. The results revealed that L2 HN-W/W was the reasonable sample for car door map pocket due to its light weight, good tensile strength and flexural strength as compared to PP. It was also found that the tensile strength and flexural strength were improved by utilising woven kenaf fabric in composites. Result implications and future research directions were also presented.**

***Index Term*--** **Natural fibre, kenaf, woven fabric, automotive**

1.0 INTRODUCTION

Today the topic of green material in enclosures is one of the most active areas in automotive part research. With a more prominent worry for ecological security, it is more essential and a challenge for automakers to enhance recyclability of recently created vehicles. As indicated by the *European Guideline 2000/53/EG* regulated by the European Commission, 85 % of the heaviness of a vehicle must be recyclable by 2005. This recyclable rate will be expanded to 95 % by 2015. Vehicles must be built from 95 % recyclable materials, with 85 % recoverable through reuse or mechanical reusing and 10 % through vitality recuperation or warm reusing [1]. This will definitely lead to an increase in natural fibres use, such as kenaf, jute, flax, hemp and etc. The natural fibres reinforced composites have attracted much attention in automotive industry and today research have developed these reinforced composites because natural fibres offer certain benefits, such as light weight, low cost, and renewability [2 – 4].

Environmental issues are motivating researchers to design and develop new materials for the automotive, furniture, construction and packaging industries. To develop new materials, researchers are searching for the utilisation of natural fibres, such as kenaf, jute, flax, hemp and etc. which are available in abundant. Author [5] performed an experimental investigation by replacing glass fibres with natural jute fibres for the structural frontal bonnet of an off-road vehicle (buggy). Results from the investigation revealed the benefits of applying jute fibre composite in buggy enclosures. In another study, author [6] reported on development of fibrous biocomposites made up from nettle and poly (lactic acid) fibres and by using carding and compression-moulding processes. The composites were analysed for tensile, bending and impact properties. By looking at the performance and weight of composites it was suggested that they could have high potential for an automotive dashboard panel application.

Through its benefits of natural fibres can lighten the weight of a car body. There were experimental studies to replace the use of synthetic glass, carbon or aramid fibre. In that sense, natural or renewable fibres as reinforcements were massively used in composites of interior parts for passenger and commercial vehicles. A comprehensive review by author in [7] reported that in 1996, Mercedes-Benz developed door panels by using jute fibres as a reinforcement and epoxy as a matrix in its E-class series vehicles. After 4 years since the development of natural fibres for interior parts by Mercedes-Benz, Audi came out with the door trim panels for A2 midrange car by using polyurethane reinforced hybrid flax/sisal [8 – 9]. Meanwhile, RAUM 2003 model used natural fibre reinforced composite for spare tyre cover [10]. The Toyota car model used 100 % bioplastics which was made up from sugar cane and sweet potato to produce PLA matrix and it was reinforced with kenaf fibres. In the summer of 2008, another Toyota car model of, the RAV4 and Matrix, used soy-based seat foams. Mitsubishi motor was another model which applied natural fibres in the interior part that was made up from a combination of bamboo fibres and polybutylene succinate (PBS) resin the floor mats was made from PLA and nylon fibres. Lately, BMW used prepreg natural fibre mats and thermosetting acrylic copolymer to develop the lower door panel in the 7 series sedan model [11] while Ford designed the storage bin and inner lid by using wheat straw as reinforcement for 2010 Flex crossover [12].

As a result, natural fibre reinforced composites are seeking into more environmental friendly materials for the automotive interior parts. There is an increasing interest in utilising natural fibres in their interior parts. However, to the best of author's knowledge, no report was found so far in using kenaf fibres for PROTON interior parts. Therefore, this study attempts to develop and investigate car door map pocket for PROTON Saga FL by using non-woven and hybrid non-woven/ woven fabric kenaf. The finding of this study will help PROTON to reduce the final weight and usage of petroleum-based materials.

2.0 EXPERIMENTAL

2.1 Materials

The materials used in this study were non-woven kenaf, woven fabric kenaf and epoxy resin. Kenaf fibres were supplied by the Lembaga Kenaf dan Tembakau Negara Malaysia (LKTN). Figure 1 (b) shows non-woven kenaf fibres and Figure 1 (a) shows woven kenaf fibres. The epoxy auto-fix 1345-A and auto-fix 1345-B was obtained from Chemibond Enterprise Sdn. Bhd. The XTR mould sealer and XTEND 19RSS mould release were supplied by AXEL Plastics Research Laboratories, INC.

(a) (b)

Fig. 1. (a) woven kenaf fabric, (b) non-woven kenaf

2.2 Composite preparation

Woven kenaf fibres were produced manually by using kenaf yarn. The non-woven and woven kenaf were cut according to mould size. The layup sequences of composite are shown in Table 1. Figure 2 (a) shows examples of layup sequences of hybrid non-woven/ woven (HN-W/W) kenaf fabric and Figure 2 (b) shows examples of layup sequences of non-woven (N-W) composites. The arrangement of composites fabrication is as shown in Figure 3. Figure 4 shows the sample of car door map pocket from hybrid kenaf fibres and polypropylene (existing product). The purpose of using the woven kenaf fabric is to improve the mechanical behaviour of composites. Hand lay-up method followed by vacuum bagging process was used to produce composites laminates. Vacuum pump RA 0100 F 503 with brand BUSCH was used with capacity V_{max} 100 m^3/h and P_{abs} 0.1 hPa (mbar).

Table I
Layup sequences of composites

Samples	Hybrid composites (HN-W/W)	Non-woven composites (N-W)
L1	N/W	N
L2	NN/W	NN
L3	NNN/W	NNN
L4	NNNN/W	NNNN
L5	NNNNN/W	NNNNN
L6	NNNNNN/W	NNNNNN

Note: Non-woven (N); woven fabric (W)

For the production of composite, the mould should apply the XTR mould sealer and XTEND 19RSS mould release to avoid the composite from being attached and for easy removal from the mould. Table 2 shows typical properties of XTR mould sealer. Before applying the XTR mould sealer, the mould surfaces should be clean and free of previously used sacrificial mould releases (like paste waxes, fluoropolymer releases etc.) and other surface contaminants, like dust, dirt, polishes, and residue from polishing or compounding. Apply two coats of XTR and allow approximately 15 – 20 minutes between each coat. Allow a minimum of 30 minutes before applying mould release.

Table II
Typical properties of XTR mold sealer

Effective ingredients	< 2 %
Color	Clear/ Pale Yellow
Specific Gravity	0.774 @ 25°C
Flash Point	< 73°F/ <23°C (C.O.C)
Shelf Life	12 months in original unopened container
Solvents	Aliphatic Hydrocarbons
Odor	Paraffinic

Then, apply the XTEND 19RSS mould release. Table III shows typical properties of XTEND 19RSS mould release. Before applying to the mould surface, mould surfaces should be clean and free of previously used mould releases and other surface contaminants.

Table III
Typical properties of XTEND 19RSS mold release

Effective ingredients	1 – 3 %
Color	Clear/ Pale Yellow
Specific Gravity	0.73 @ 25°C
Flash Point	< 73°F/ < 23°C (C.O.C)
Shelf Life	12 months in original unopened container
Solvents	Aliphatic Hydrocarbons

2.3 Tensile test

Mechanical properties were tested as per ASTM Standards with cross head speed of 2 mm/min by using Shimadzu Universal Testing Machine. The sample was cut with dimension 25 x 250 mm^2. Loads were applied until the sample was broken. Five tests were conducted for each type of sample and the average values were reported.

2.4 Flexural test

The flexural test was carried out on a Shimadzu Universal Testing Machine according to ASTM Standard with cross head speed of 2 mm/min. The sample was cut with dimension 15 x 100 mm^2. Loads were applied until the sample was broken. Five tests were conducted for each type of sample and the average values were reported. The flexural strength was calculated according to the formula described below:

$$\delta_{fm} = \frac{3PL}{2bd^2} \quad (1)$$

where δ_{fm} is flexural strength (MPa), P is load at a given point on the load-deflection curve (N), L is the length of the support span (mm), b is width of the specimen (mm) and d is thickness of specimen (mm).

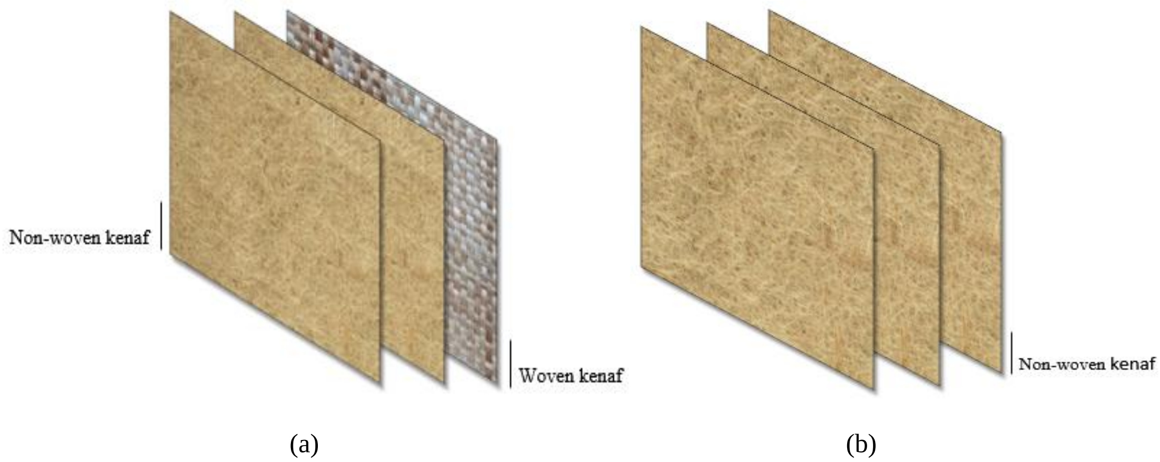

Fig. 2: Example of layup sequences of hybrid composites

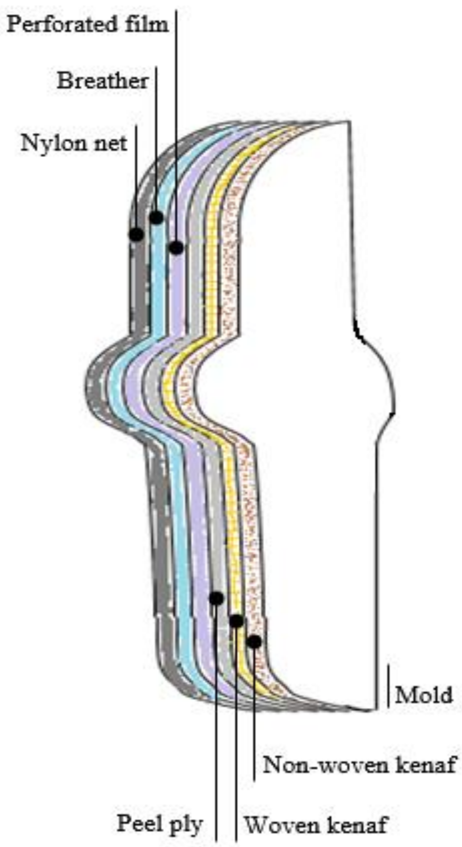

Fig. 3. Arrangement of composites fabrication.

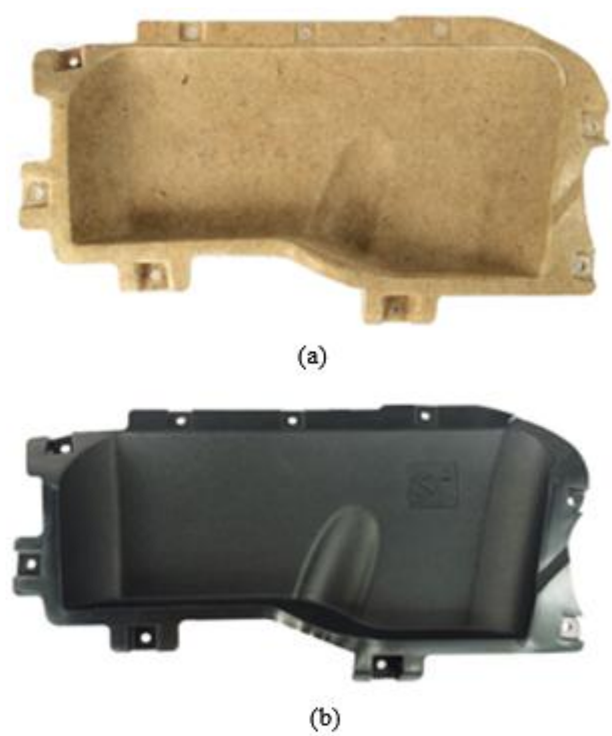

Fig. 4. Sample of door map pocket made from (a) hybrid kenaf (b) polypropylene (PP)

3.0 RESULT AND DISCUSSION

3.1 Tensile performance

Figure 5 presents results of tensile test for HN-W/W, N-W and PP. Result of PP is as a benchmark due to the existing product. The samples were prepared with their layers increased until six layers. As illustrated in Figure 5, the most striking observation to emerge from the data comparison is that the HN-W/W is higher than N-W. It proves that by utilising woven fabric in composite it can improve the mechanical properties and open a new avenue for woven kenaf fabric for commercialisation in automotive sector. In addition, the finding provides evidence that the tensile properties increasewith increasing thickness or layers in both composites. However, it was surprisingly found that L5 HN-W/W was lower as compared to L4, about 1.8 %. From the observation, it was due to the thickness of L5 was lower as compared to L4.

On the other hand, the present findings also suggested that the tensile properties in both composites were higher as compared to PP except L1 N-W. From the results obtained, it has high potential to use kenaf fibre composite in automotive car door map pocket application. In this context, it is clearly shown in Figure 5 and Table 4, L2 HN-W/W is the most appropriate for car door map pocket where high tensile properties and dimensional stability coupled with low weight as compared to PP. Among the plausible explanations for these findings is that hybrid kenaf shows they can be used successfully in car door map pocket in order to realise reduction of weight and cost. Concurrently, L2 HN-W/W composites can contribute to car door map pocket weight with a reduction of 1.62 %.

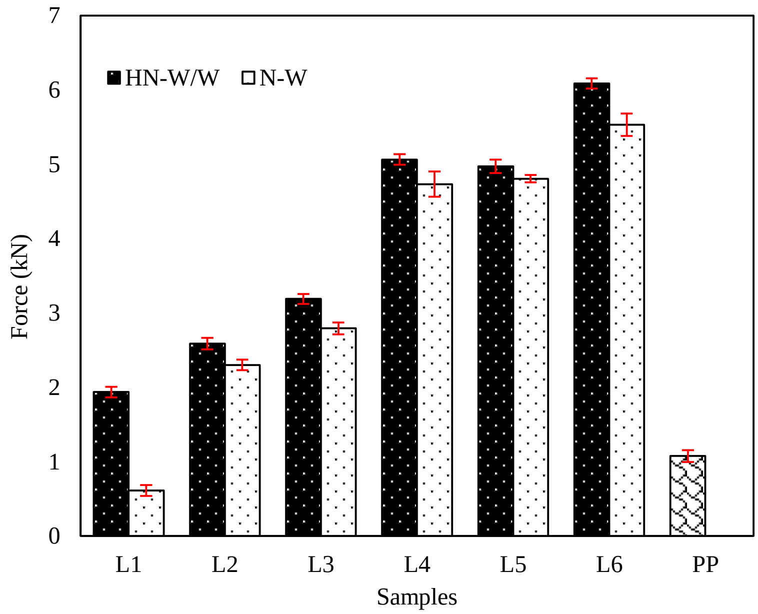

Fig. 5. Tensile strength of composites

3.2 Flexural performance

Figure 6 demonstrates the results of flexural strength or bending properties of HN-W/W, N-W composites and PP. Result of PP is as a benchmark due to the current product. Figure 6 shows a similar trend with Figure 5, where the flexural strength increases with increasing thickness or layers in both composites. On the other hand, what is interesting in Figure 6 is that HN-W/W is enhanced in flexural strength as compared to N-W and PP. The finding provides evidence that when woven fabric in composites are applied it can improve the flexural properties to withstand bending before reaching breaking point.

In addition, as illustrated in Figure 6, L2 HN-W/W, in which one layer is non-woven kenaf and one layer woven fabric kenaf is the reasonable sample for car door map pocket due to its light weight and higher in flexural properties of about 28.6 % as compared to PP. The finding is consistent with findings of past studies by author [13 – 15], which mentioned that good mechanical properties and light weight has improved fuel efficiency and reduced emissions during the use-phase of the component.

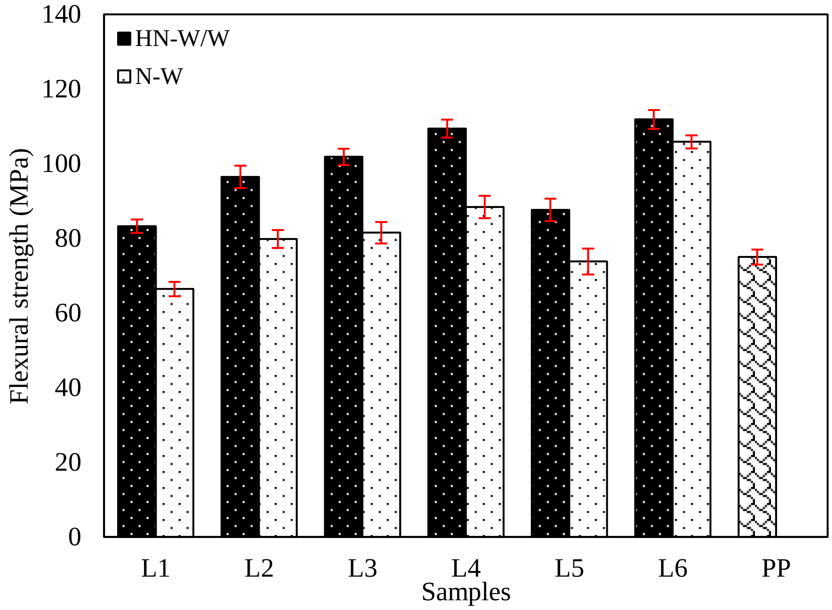

Fig. 6. Flexural strength of composite.

Table IV

Mechanical properties of HN-W/W composite

Samples	Areal density (Kg/m^2)	Thickness (mm)	Tensile strength (kN)	Flexural strength (MPa)
L1	2.45	2.50	1.93	83.29
L2	2.47	2.88	2.58	96.45
L3	4.61	6.06	3.18	101.84
L4	6.38	8.53	5.06	109.39
L5	6.14	8.28	4.97	87.662
L6	8.83	10.78	6.08	111.87
PP	2.51	3.00	1.07	75.00

Table V

Mechanical properties of N-W composite

Samples	Areal density (Kg/m^2)	Thickness (mm)	Tensile strength (kN)	Flexural strength (MPa)
L1	1.77	1.94	0.16	66.43
L2	2.81	3.86	2.30	79.86
L3	3.66	5.86	2.79	81.53
L4	5.89	8.38	4.73	88.43
L5	5.21	7.94	4.80	73.81
L6	7.74	9.22	5.53	105.87
PP	2.51	3.00	1.07	75.00

CONCLUSION

The present study was designed to develop and investigate car door map pocket for PROTON Saga FL by using non-woven kenaf (N-W) and hybrid non-woven/ woven fabric kenaf (HN-W/W). Generally these findings suggest that kenaf fibres can be successfully used in car door map pocket application. One of the most significant findings from this study is that the tensile strength and flexural strength improved by utilising woven kenaf fabric in composites. L2 HN-W/W is the reasonable sample for car door map pocket due to its light weight, good tensile strength and flexural strength as compared to PP. The findings from this study make a contribution to PROTON and automotive sector because kenaf fibres have the functional capability to substitute petroleum-based materials, such as PP that are currently being used in the industry. This research has raised many questions that need further investigation. Further work needs to be done to establish the right process for commercialisation.

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REFERENCES

[1] Peijs, T., 2003. Composites for recyclability. *Materials today*, *6*(4), pp.30-35.

[2] Mohanty, A.K., Misra, M. and Hinrichsen, G., 2000. Biofibers, biodegradable polymers and biocomposites: an overview. *Macromolecular materials and Engineering*, *276*(1), pp.1-24.

[3] Yang, H.S., Kim, H.J., Park, H.J., Lee, B.J. and Hwang, T.S., 2007. Effect of compatibilizing agents on rice-husk flour reinforced polypropylene composites. *Composite Structures*, *77*(1), pp.45-55.

[4] Kim, H.S., Yang, H.S. and Kim, H.J., 2005. Biodegradability and mechanical properties of agro-flour–filled polybutylene succinate biocomposites. *Journal of Applied Polymer Science*, *97*(4), pp.1513-1521.

[5] Alves, C., Silva, A.J., Reis, L.G., Freitas, M., Rodrigues, L.B. and Alves, D.E., 2010. Ecodesign of automotive components making use of natural jute fiber composites. *Journal of Cleaner Production*, *18*(4), pp.313-327.

[6] Kumar, N. and Das, D., 2017. Fibrous biocomposites from nettle (Girardinia diversifolia) and poly (lactic acid) fibers for automotive dashboard panel application. *Composites Part B: Engineering*, *130*, pp.54-63.

[7] Koronis, G., Silva, A. and Fontul, M., 2013. Green composites: a review of adequate materials for automotive applications. *Composites Part B: Engineering*, *44*(1), pp.120-127.

[8] Akampumuza, O., Wambua, P., Ahmed, A., Li, W. and Qin, X.H., 2017. Review of the applications of biocomposites in the automotive industry. *Polymer Composites*, *38*(11), pp.2553-2569.

[9] Barbosa, R., Lima, A.G. and Pereira, A.L., 2013. *Natural Fibers Contribution to Sustainability in Inovar-Auto Program* (No. 2013-36-0576). SAE Technical Paper.

[10] Graupner, N., Herrmann, A.S. and Müssig, J., 2009. Natural and man-made cellulose fibre-reinforced poly (lactic acid)(PLA) composites: An overview about mechanical characteristics and application areas. *Composites Part A: Applied Science and Manufacturing*, *40*(6), pp.810-821.

[11] Stewart, R., 2010. Automotive composites offer lighter solutions. *Reinforced Plastics*, *54*(2), pp.22-28.

[12] Andresen, C., Demuth, C., Lange, A., Stoick, P. and Pruszko, R., 2012. Biobased automobile parts investigation. *A Report Developed for the USDA Office of Energy Policy and New Uses*.

[13] Muessig, J., 2002, April. Influence of fiber fineness on the properties of natural fiber composites. In *Proceedings, 4th International Wood and Natural Fiber Composites Symposium Kassel/Germany*.

[14] Joshi, S.V., Drzal, L.T., Mohanty, A.K. and Arora, S., 2004. Are natural fiber composites environmentally superior to glass fiber reinforced composites?. *Composites Part A: Applied science and manufacturing*, *35*(3), pp.371-376.

[15] Yuhazri, M.Y., Amirhafizan, M.H., Abdullah, A., Yahaya, S.H. and Lau, S.T.W., 2017. Potentiality of Utilising Non-Woven Kenaf Fibre Composite for Car Door Map Pocket. *Journal of Advanced Manufacturing Technology (JAMT)*, *11*(2), pp.129-138.