

Impact Strength of Different Weaving Patterns of Woven Kenaf Reinforced Polyester Composites

S.N.A Khalid^a, A.E Ismail^b, M.H Zainulabidin^c

Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Batu Pahat, Johor.

^asitinorazilabintikhalid@yahoo.com, ^bemran@uthm.edu.my, ^chafeez@uthm.edu.my

Abstract. This paper focuses on the effect of weaving patterns and orientations on the energy absorption of woven kenaf reinforced polyester composites. Kenaf fiber in the form of yarn is weaved to produce different weaving patterns such as plain, twill and basket. Three woven mats are stacked together and mixed with polyester resin before it is compressed to squeeze out any excessive resin. There is 9 different orientations are used during stacking processes. The hardened composites are cured for 24 hours before it is shaped according to specific dimensions for impact tests. The composites are perforated with 1m/s blunted projectile. According to the experimental findings, both weaving patterns and orientations have distinct potential effects on the force-displacement diagrams. However, fiber orientations have insignificant effect for plain woven especially in the first stage of deformations. Energy absorption performances for each composite condition are calculated and then plotted against fiber orientations for different weaving patterns. It is found there is no strong relationship between energy absorption and fiber orientations. However for each case of composites, higher energy absorption is found for the composites orientated using $[+40^\circ/-15^\circ/+40^\circ/+75^\circ]$. Based on the fracture observation, both plain and basket-type woven composites reveal large fragmentations occurred indicating lower energy absorption performances. While for twill condition, no obvious fragmentation is observed where the impact damage around the perforated hole is uniformly distributed leading to higher capability of energy absorptions.

1. Introduction

During the recent years, the attentions are given to crashworthiness and energy absorption management on composite structures. The main advantages of fibre reinforced composite material over conventional isotropic materials, however the specific strength and stiffness which can be archived [1]. Nowadays, natural fiber is significantly used to fabricate various parts in automotive applications. Considering the high performance of composite materials in term of cost effectiveness, durability and maintenance, the application of kenaf fiber reinforced composites as construction material has great potential and is important to achieve sustainability. Moreover with composites the designer of fiber, matrix, and fiber orientation are used in produce composite to improved material properties.

Several works had been done on investigating the strength of composite under perforated impact [2,3]. Most of these findings focus on unidirectional, short fiber and little research on woven especially in kenaf natural fiber. The ability of woven fabric is better mechanical properties compare to non-woven [4,5]. Difference of woven and non-woven gives different response on the impact due to the ability to displace and withstand before failure [6]. Therefore, the present work investigates the effect of weaving types and fiber orientation on energy absorption under impact loading. Several



researchers mentioned in their research that orientation of 75° - 15° is recommended for better load capacity and energy absorption [3,7]. Three type of weaving which is plain, twill and basket are reoriented using best angle that are recommended by previous research.

2. Methodology

As-received kenaf yarn with a size of 1mm as shown in Figure 1(a) is used and weaved to form a woven mat as reveal in Figure 1(b). During weaving processes, three different fiber architectures are used such as plain, twill and basket. Woven mats are then stacked (four layers) together using different fiber orientations as listed in Table 1. The stacks are mixed with polyester resin before it is compressed to spread the resin uniformly across the fiber mats. Once the composites hardened and cured for 24 hours (Figure 1(c)), they are shaped into shape and geometry as specified in ASTM D 3763 standard of 100x100x3 mm.

Impact test is performed using HydrosHOT HITS-T10 Shimadzu machine. The samples are positioned and clamped in all-degree of freedom. Before the tests, ASTM D 3763 is properly followed to ensure the results are reliable. The blunted-shaped projectile is used to perforate the samples where the speed of projectile is fixed to 1m/s. During tests, the responses of force-displacement diagrams are recorded. The energy absorptions are determined using the area under the curves of force versus displacement.

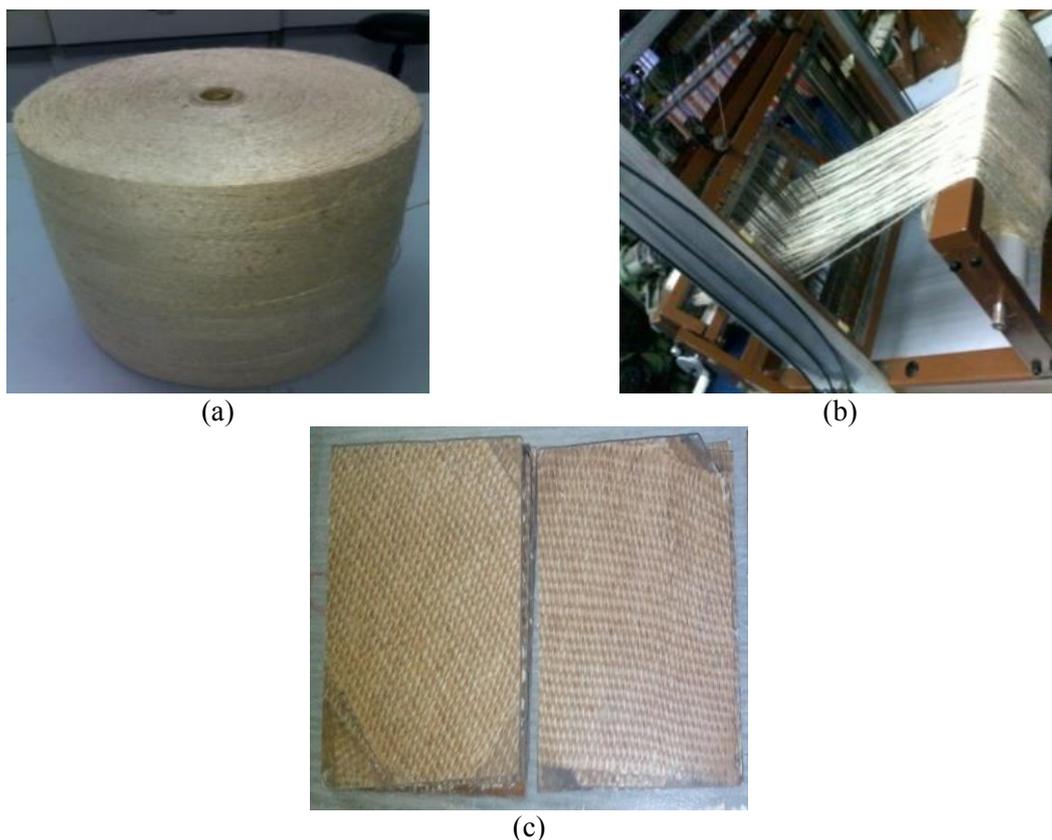


Figure 1: Preparation of composite (a) kenaf yarn (b) weaving process and (c) woven mats

3. Result and Discussion

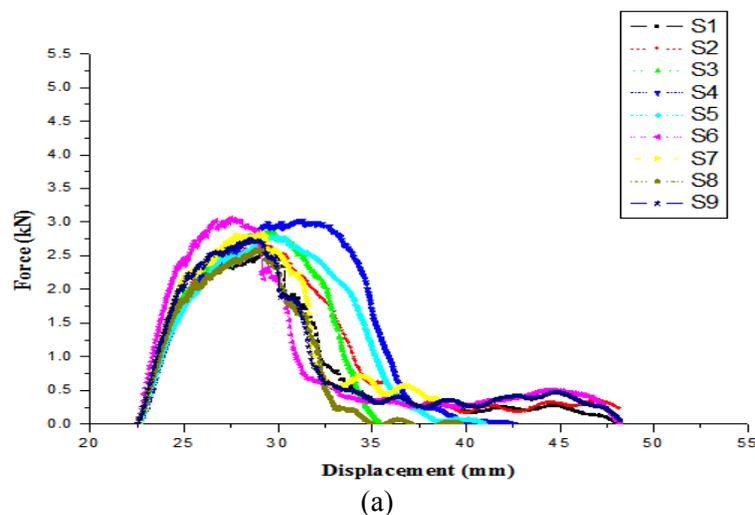
Result from impact test showed the maximum force of penetration, total energy at the maximum penetration and energy absorption. Areas under the graph are analysis to obtain the total energy absorption in composite samples with different orientation and different type of weaving. Total force versus displacement with varying type of weaving as shown in Figure 1. From Figures 1(a),(b) and (c)

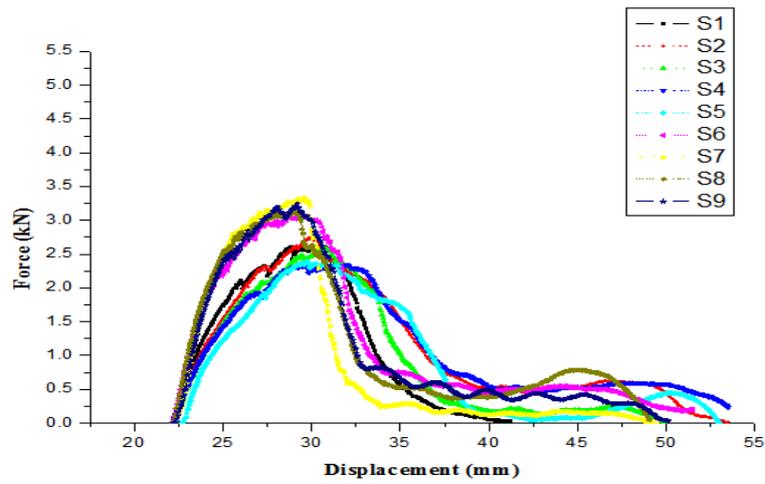
it is shows the similar pattern which is upward and after touching the sample, points of impact are change the curved, but the effect to the force of the sample have a fraction. This situation is almost similar to each other for all samples. From curve that are plotted, there have 4 stages before perforated. At stage 1, there is no damage accusing. As the load increased, matrix cracking occurs at stage 2. The size and extend of the matrix cracking may progress such that interfacial debonding can occurs at stage 3. This in turn, leads to delamination, then fibre breaking, and finally perforation of the impacted specimen at stage 4. The different of each pattern are depending on value of peak force.

Table 1: The orientation arrangement of samples.

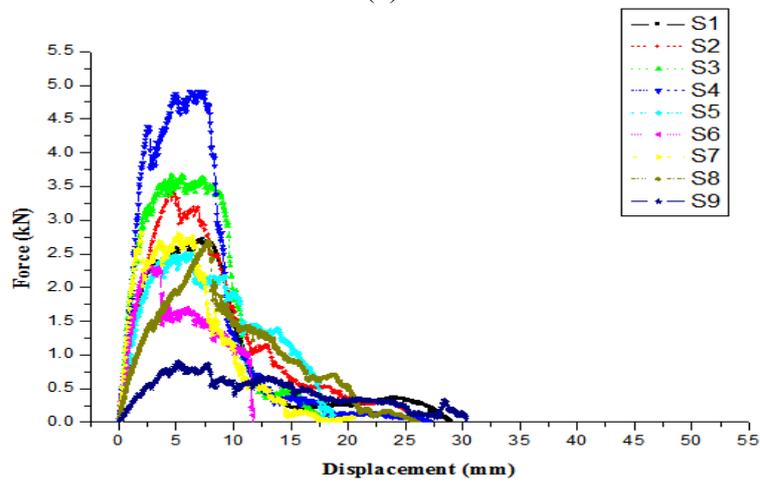
Sample	Orientation (θ°)
S1	-15/-15/-15/-15
S2	-15/+40/+40/+40
S3	-15/+75/+75/+75
S4	+40/-15/+40/+75
S5	+40/+40/+75/-15
S6	+40/+75/-15/+40
S7	+75/-15/+75/+40
S8	+75/+40/-15/+75
S9	+75/+75/+40/-15

However, the composite fibres with twill woven shows higher energy absorption compare to plain and basket. Figure 3 shows the energy absorption of plain, twill and woven using nine type of orientation referring to Table 1. From the result that are obtain, the higher energy for three type of woven indicate on sample four which is using orientation [40/-15/40/75]. Due to the result, it demonstrated that a fiber orientation for each layers is significantly affected to value of energy absorption.



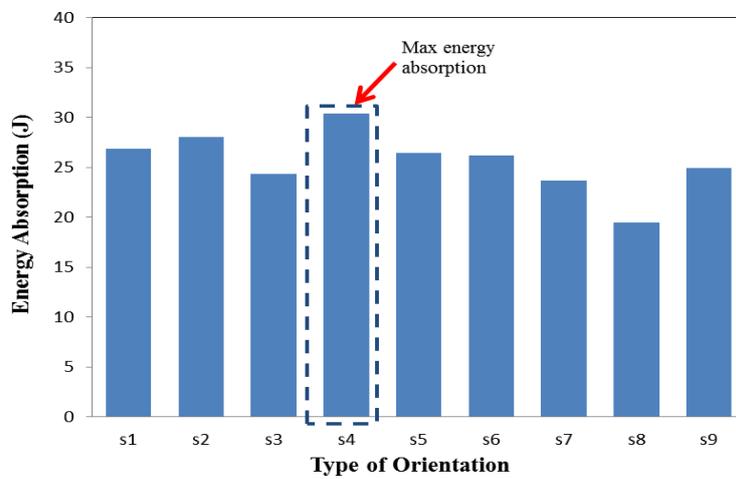


(b)

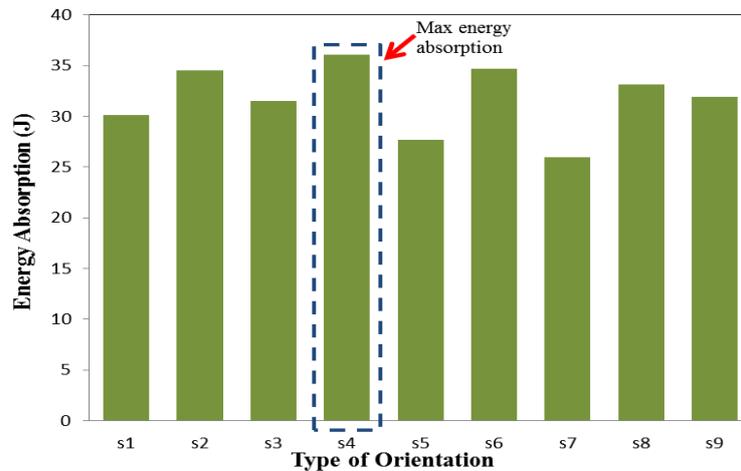


(c)

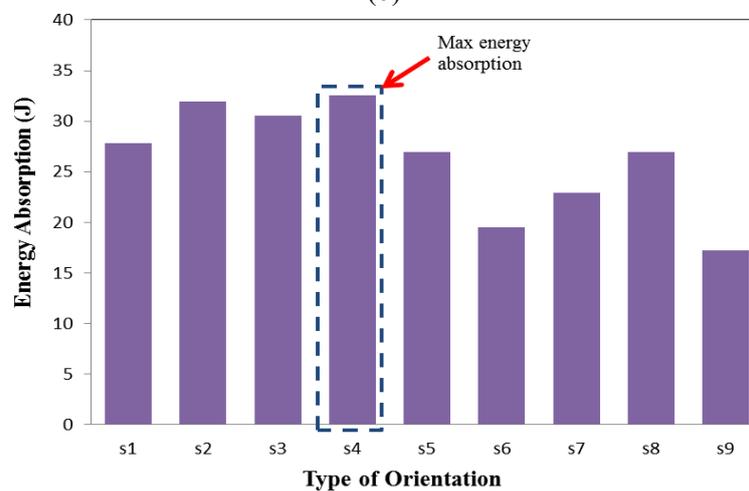
Figure 2: Force-displacement on (a) Plain (b) Twill and (c) Basket



(a)



(b)



(c)

Figure 3: Energy absorption (a) Plain woven (b) Twill woven (c) Basket woven

In general, the fracture mechanisms are almost similar where the surfaces are perforated after impacted. Figure 4 shows fragmentation of three type of woven such as plain, twill and basket. For the plain woven it can be seen that fragmentation that happen at the back is around distance 2.5 cm to 3.0 cm. Besides, for twill woven the fragmentation of fracture surface with distance 2.0 cm to 2.4 cm and for basket woven, fragmentation is 3 cm to 6 cm. Whether the size of perforated on basket woven is greater than plain woven, but still have higher capability to absorb energy absorption. From the result it can see that the highest energy absorption is on twill woven. It can be explained that when fabric is stretched in one direction which is load direction, it amplifies in the reverse direction. Owing to the crimp, the fabric strength is less than the strength of twisted yarns, because of the twisted yarns; the yarn strength is less than the strength of fibres [8].

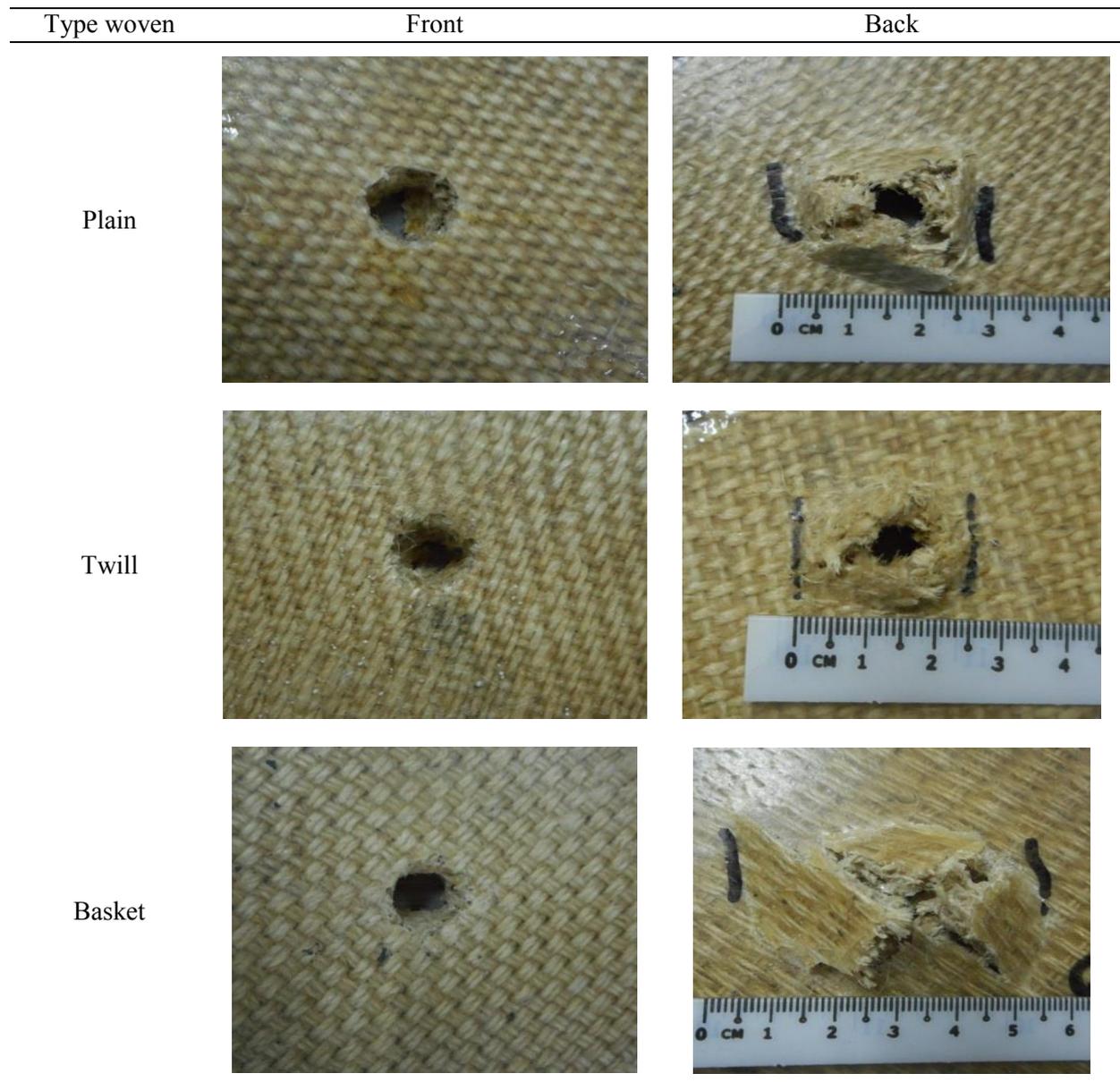


Figure 4: Fragmentation of composite after impacted

4. Conclusion

The present study is carried out on the behaviour of composite with different type of woven and orientation. The result presents the perforated impact performance on deformation, peak force, mechanical strength and energy absorption. Following conclusions are drawn;

- i. Energy absorbed of twill woven was higher than those of plain and basket. The best orientation for three type of woven is [+40/-15/+40/+75].
- ii. Value of peak force of basket woven is higher compare to other weaving which is reach 5.0 kN.
- iii. The fragmentation of basket produces greater distance which is 3 cm to 6 cm of absolute penetration. Referring to energy absorption result, whether have greater fragmentation but still have higher capability to absorbed energy compare to plain woven.

5. Acknowledgements

Authors acknowledged Universiti Tun Hussein Onn Malaysia (UTHM), MyBrain15 Scholarship (MyPhd), Office for Research, Innovation, Commercialization and Consultancy Management (ORICC) through RAGS Vot. R019, Center for Graduate Studies UTHM.

6. References

- [1] Mamalis AG, Robinson M, Manolakos DE, Demosthenous GA, Ioannidis MB, Carruthers J. 1997 *Composite Structures* 37 109-134
- [2] Roslan MN, Ismail AE, Hashim M.Y, Zainulabidin MH, Khalid SNA 2014 *Applied Mechanics and Materials* 465 1324-1328
- [3] Mahdi E, Hamouda AMS, Sedaey TA 2014 *Material and Design* 56 923-928
- [4] Khalid SNA, Jamaluddin MR, Roslan MN, Ismail AE, Zainulabidin MH 2015 *Journal of Applied Science and Agriculture* 10(7)
- [5] Khalid SNA, Ismail AE and Zainulabidin MH 2015 *Applied Mechanics and Materials* 773-774 149-153
- [6] GM Khan Arifuzzaman, M Terano, MA Gafur, Alam Shamsul M 2013 *Engineering Science*
- [7] Ismail AE, Hassan MA, Kamaruddin K.A 2014 Vol. 1, no. c, pp. 1-5
- [8] Ferdousa Nasrin, Sadiqur Md, Rahman b, Kabir Reashad, Arif Eftekhari Ahmed. 2014 *International Journal of Scientific Research Engineering & Technology (IJSRET)*, ISSN 2278 – 0882, Volume 3, Issue 9