International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8 Issue-4, November 2019

Single Edge Notch Bend (SENB) of Kenaf/Fibreglass Hybrid Composites

S. Yunus, Z. Salleh, Y. M. Taib, N. R. N. M. Masdek, K. B. Z. Abidin

Abstract*: Kenaf is known for many years as a typical crop that can be used in various applications such as in automotive, and building structure. Along with the depletion and environmental issues raised nowadays by excessively used of man-made synthetic fibres make the natural fibre to become popular and favourable to be implemented. This paper discusses on the development of long kenaf fibre reinforced polyester matrix composite. Total weight of about 40% fibre fraction was selected. In this study, the addition of about 10% weight fraction of fibreglass in the composite system is needed in order to strengthen the composite material and also to retain its reliability and robustness in their applications. Thus, preparation of two different layer arrangement of kenaf and fibreglass were conducted viz. (i) kenaf at inner layer and fibreglass at outer layer ($[0^o90^o]_K/FG_{2p}/[90^o0^o]_k[0^o90^o]_K$) (ii) kenaf at outer layer and fibreglass at inner layer ($FG/[0^o90^o/90^o0^o]_K/FG$). All configuration samples were fabricated by hand lay-up and cold press technique. Fracture toughness testing was carried out using a single edge notched bend specimen at a loading rate of 10mm/min. All samples were prepared according to ASTM D5045 (Standard Test Methods for Plane-Strain Fracture Toughness and Strain Energy Release Rate of Plastic Materials). Results obtained from SENB test were then evaluated and discussed. It can be used as a guideline or reference for further research on this type of polymer composite.

Keywords* : Kenaf reinforced polyester composite, Kenaf and fibreglass hybrid composite, Single edge notch bend (SENB).

I. INTRODUCTION

Recently, research on new materials which are stronger, stiffer and light weight are gaining major interest in the composite world. Fibre reinforced polymer (FRP) are used in various applications where fibreglass, kevlar, and carbon are among the popular bridging materials used. These materials offer superior performance and strength as compared to the traditional materials used for example wood, plastic and metals. However, nowadays the increase in cost for petroleum resources that are used as feed stocks for these reinforcement materials are the reason why many people are trying to find new materials in order to replace the synthetic fibres. Scientists, researchers and academicians are now facing the challenge on improving the quality of life by reducing the usage of synthetic materials which give bad impact to the environment and human life.

Thus, using natural renewable resource based materials have led to an increase in the study and development of novel bio composite materials. The prices of natural fibres are also much lower when compared to synthetic fibres. Many attempts have been made in using natural fibres as reinforcement materials in polymer matrix as it has resulted in similar or comparable mechanical properties of synthetic fibres [1]–[3]. Natural fibres are also used due to its biodegradability, abundantly, light weight, eco-friendly and nontoxic. The processing of natural fibres is not harmful as compared to synthetic fibres and not abrasive to the processing equipment. However, the usage of natural fibres have some limitations such as low thermal stability, highly flammable, high moisture absorption, strength degradation, variation in mechanical properties and many more [4], [5]. Thus researchers have to find ways to overcome this situation. One of the method is to hybrid it with other reinforcement materials.

The most commonly and favourable synthetic fibre used in composite material is fibreglass. Hybridizing fibreglass together with natural fibres has shown to be promising in many applications. Unidirectional, multidirectional, and woven fibre composite laminates showed excellent properties such as high specific strength, better impact properties and also easy to handle [6]–[8]. More importantly it is much cheaper as compared to other synthetic fibres without sacrificing its mechanical properties.

This study is about the hybridization between kenaf and fibreglass. Layer arrangement becoming is an important thing that needs to be considered when it comes to hybridization materials. The right decision for material position might be helpful to increase the mechanical properties of the whole composite system. Thus, data reported in this study is limited to only the effect of its layer arrangement. There are two types of layer arrangement selected and SENB test was conducted and evaluated to get the fracture toughness values. Few literatures showed the effects of layer arrangement on fracture toughness of these hybrid materials. These types of hybrid materials have great potential to be implemented in high load bearing engineering applications. Thus, the result of fracture toughness from this project can be used as a guideline or reference for further research on hybrid reinforced polymer composites.

Manuscript published on November 30, 2019.
* Correspondence Author

S. Yunus, Mechatronics Section, Electrical Engineering Department, German Malaysian Institute (GMI), Kajang, Selangor, Malaysia.

Z. Salleh*, Faculty of Mechanical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia.

Y. M. Taib, Faculty of Mechanical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia.

N. R. N. M. Masdek, Faculty of Mechanical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia.

K. B. Z. Abidin, Faculty of Mechanical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia.

II. MATERIALS AND METHOD

A. Materials

In this study, the sample composites were made up from long kenaf fibre and woven fibreglass with reinforcement of polyester as the matrix resin to produce hybrid composite material. About 50% weight fraction of fibre is used in this research. Another 40% weight fraction applied was from kenaf fibre.

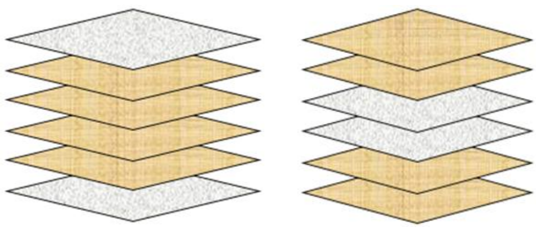
Two layer arrangements were prepared for the long kenaf – fibreglass hybrid composites viz. (i) long kenaf fibre at the outer layer, fibreglass at the inner layer designated as $[0^o90^o]_K/FG_{2p}/[90^o0^o]_k$ and (ii) fibreglass at the outer layer – kenaf at the inner layer designated as $FG/[0^o90^o/90^o0^o]_K/FG$.

B. Production of Composite Materials

The kenaf and fibreglass hybrid composite materials were fabricated by using hand layup and cold press technique for each system configuration as shown in Fig. 1. Long kenaf fibre was initially rolled vertically and horizontally at the inner frame before proceeding with the fabrication process. This is to ensure that the fibre orientation of 0^O and 90^O was achieved.

Polyester resin used in this study are mixed with hardener ratio of 100:1. The manufacturer provides the formula. It takes 30 minutes for the mixture to harden. Thus, it is advised that the pouring process should be done quickly or within the time given. A plastic film is used to cover the soaked kenaf in order to obtain smooth surface finish. The samples are cold pressed in approximately 10kN in room condition. The samples are then leave for 60 minutes for bonding purpose.

Finally the samples are cut out of the mould by using a saw with dimension of 44 mm x 10 mm, that follows standard ASTM D5045 method for Plane – Strain Fracture Toughness and Strain Energy Release Rate of Plastic Materials.



(a) (b)

Fig. 1. Fibre configuration for hybrid composite (a) $FG/[0^o90^o/90^o0^o]_K/FG$ and (b) $[0^o90^o]_K/FG_{2p}/[90^o0^o]_k[0^o90^o]_K$

C. Single Edge Notch Bend Test

The SENB test specimen from each configuration was machined based on the ASTM D5045 standard dimension. The maximum load condition will be obtained in the specimens containing a pre – crack. The dimension of specimens were 44 mm, 40 mm, 10 mm and 6 mm for length (L), span (S), width (W) and thickness (B) respectively which satisfies the condition of 2B < W < 4B require for SENB test. Illustration of specimen configuration is shown in Fig. 2.

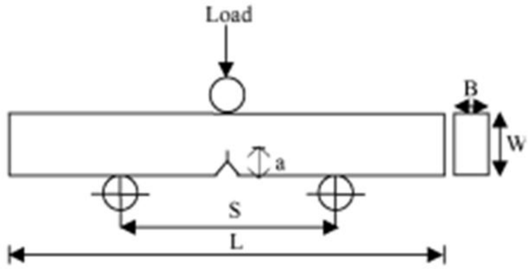


Fig. 2. Standard size for SENB specimen

The initial crack length (a) was 4.5 mm (±0.05). The specimens was initially machined with a V – blade at 4 mm and sharpened with a razor blade before testing.

The test have been done using Universal Testing Machine, that consist of a servo hydraulic loading specimen, support of the specimen, and instruments to record the needed measurement of data. The values of fracture toughness were determined from the load versus deformation curves.

This type of loading ensures that mid-section of the specimen were exposed to pure bending. After testing, crack length caused by fracture of the specimen were extracted and examined using scanning electron microscope (SEM). Fig. 3 shows the set – up of SENB testing. Crosshead speed of about 10 mm/min was implemented in this study.

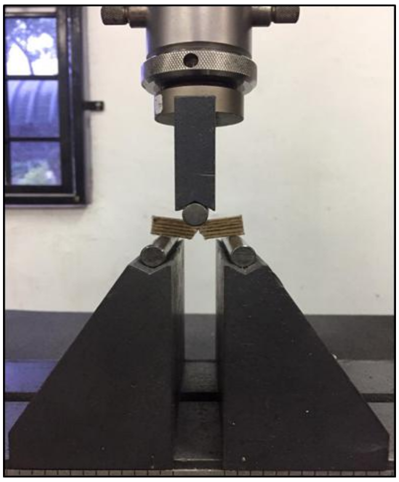


Fig. 3. Set – up of SENB testing

Fracture toughness is an indication of the amount of stress required to propagate a preexisting flaw. It is a very important material property for damage tolerance design. Mode I critical stress intensity factor, (K_{IC}) is used to determine the fracture toughness of most materials. Based on ASTM D5045 standard, it is calculated with the following relations:

$$K_{IC} = \frac{6YP}{BW^{1/2}} \qquad (1)$$

$$Y = 1.93\left(\frac{a}{W}\right)^{\frac{1}{2}} - 3.07\left(\frac{a}{W}\right)^{\frac{3}{2}} + 14.53\left(\frac{a}{W}\right)^{\frac{5}{2}} - 25.11\left(\frac{a}{W}\right)^{\frac{7}{2}} + 25.80\left(\frac{a}{W}\right)^{\frac{9}{2}} \qquad (2)$$

where Y, P, B, a, and W represent geometrical factor, rupture forces, thickness of sample, pre-crack length, and witdh of sample respectively.

Retrieval Number: D5186118419/2019©BEIESP
DOI:10.35940/ijrteD5186.118419
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

D. Scanning Electron Microscopy (SEM)

The electron microscope was used for surface fracture observation. The samples are first cut leaving only the surface fracture for observation only. This is done to fit the specimen in the electron microscope. For composite specimen it is important to coat the specimen with gold dust to avoid image blur during observation by using coating machine. The sample was then taped on top of the stage by using carbon tap and this is important to discharge the electron. To observe the surface fracture it is important to zoom in at the right area where fractured area is shown. Another way to improve the image was by adjusting the brightness and contrast of the image.

III. RESULTS AND DISCUSSION

A. Single Edge Notch Bend Properties

Fracture toughness test was conducted for both $[0^o90^o]_K/FG_{2p}/[90^o0^o]_k$ and $FG/[0^o90^o/90^o0^o]_K/FG$ hybrid composites. Fig. 4 show typical load – displacement curve under loading rate of 10 mm/min as mentioned in respective standard. As can be seen the curve started with linear deformation before the non – linear deformation. The non – linear deformation is preceding to the attainment of maximum load. After it reaches the maximum load, gradual decrement on the curve was observed. This might be due to the cracking of material that happened together with limited plastic deformation. Similar trend was also reported by previous researchers [9], [10].

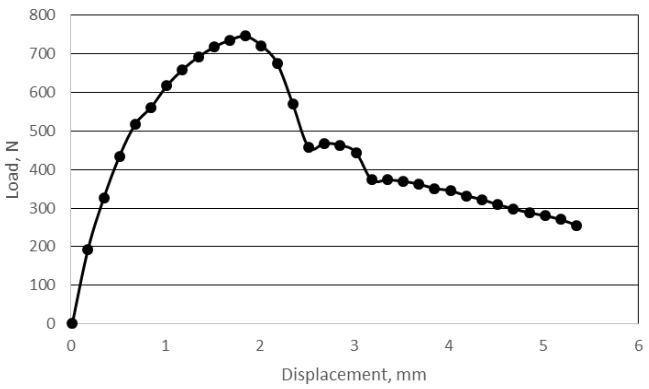


Fig. 4. Typical load – displacement curve of SENB for hybrid composite

Table 1 shows K_Q (trial K_{IC}) result obtain for both type of hybrid composites material used in this study. The calculation to obtain K_Q values can be refer from equation (1) and (2). It can be clearly seen that the material to resist fracture at pre – cracking area for $FG/[0^o90^o/90^o0^o]_K/FG$ is higher compare to $[0^o90^o]_K/FG_{2p}/[90^o0^o]_k$ hybrid composites. Almost 65% higher values can be seen when fibreglass placed at outer layer compare to kenaf at outer layer.

Table I: K_Q values for kenaf – fibreglass hybrid composites

Configuration	K_Q (MPa$\sqrt{m}$)
$[0^o90^o]_K/FG_{2p}/[90^o0^o]_k[0^o90^o]_K$	20.35 (1.63)
$FG/[0^o90^o/90^o0^o]_K/FG$	32.54 (2.82)

Fracture toughness is strongly related with the maximum forces where a high maximum force will produce higher toughness values. Thus, the comparison between two different layers of these hybrid composites shows that $FG/[0^o90^o/90^o0^o]_K/FG$ exhibit higher values due to the position of fibreglass at outer layer which give advantage as its support by fibre - bridging the crack lead to enhanced the crack propagation resistance before its failure.

Fig. 5 shows SENB specimen for $[0^o90^o]_K/FG_{2p}/[90^o0^o]_k$ hybrid composites. Close – up crack length is in between 0.5 ±0.05. Meanwhile Fig. 6 shows the fracture surface of tested specimen. Similar specimen for $FG/[0^o90^o/90^o0^o]_K/FG$ hybrid composites is shown in Fig. 7 and fracture surface in Fig. 8.

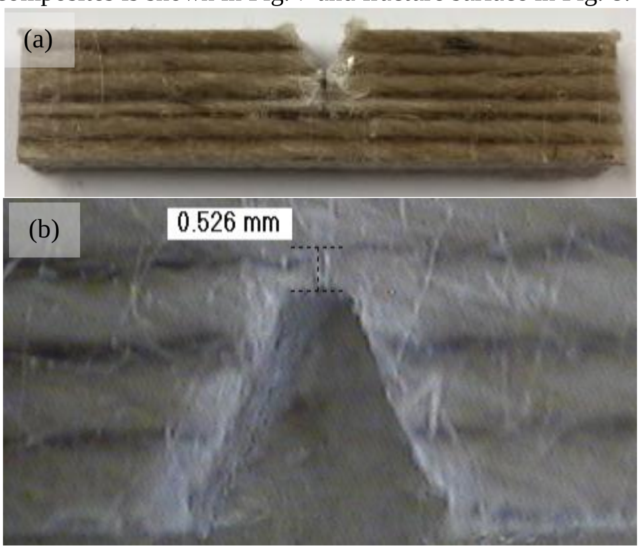


Fig. 5. (a) SENB specimen for $[0^o90^o]_K/FG_{2p}/[90^o0^o]_k$ hybrid composites; (b) Close – up crack length

Fig. 6. Fracture surface of SENB specimen for $[0^o90^o]_K/FG_{2p}/[90^o0^o]_k$ hybrid composites

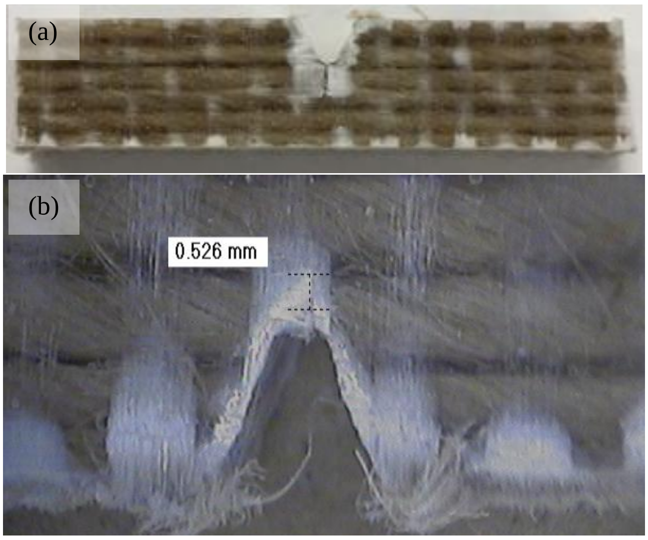


Fig. 7. (a) SENB specimen for FG/[$0^o90^o/90^o0^o$]$_K$/FG hybrid composites; (b) Close – up crack length

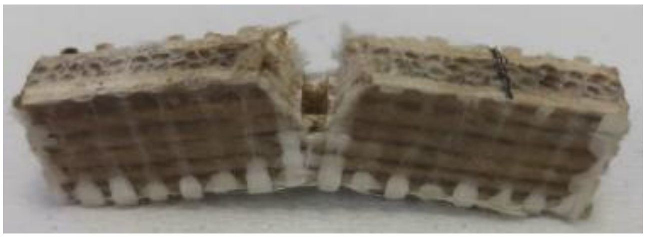


Fig. 8. Fracture surface of SENB specimen for FG/[$0^o90^o/90^o0^o$]$_K$/FG hybrid composites

Fig. 9. and Fig. 10 shows the morphological analysis of the fractured area for both [0^o90^o]$_K$/FG_{2p}/[90^o0^o]$_k$ and FG/[$0^o90^o/90^o0^o$]$_K$/FG hybrid composites respectively. It can be seen that catastrophic failure of [0^o90^o]$_K$/FG_{2p}/[90^o0^o]$_k$ hybrid composites has larger crack area during propagation is one of the major damage mechanism. Besides that, fibre delamination was created from 0^O fibre direction. Fibre pull – out of fibreglass can also be observed. Similar damage mechanism can be seen for FG/[$0^o90^o/90^o0^o$]$_K$/FG hybrid composites. Fibre fracture and fibre pull – out of kenaf fiber might be due to the failure that happened right after breakage of fibre – bridging fibreglass.

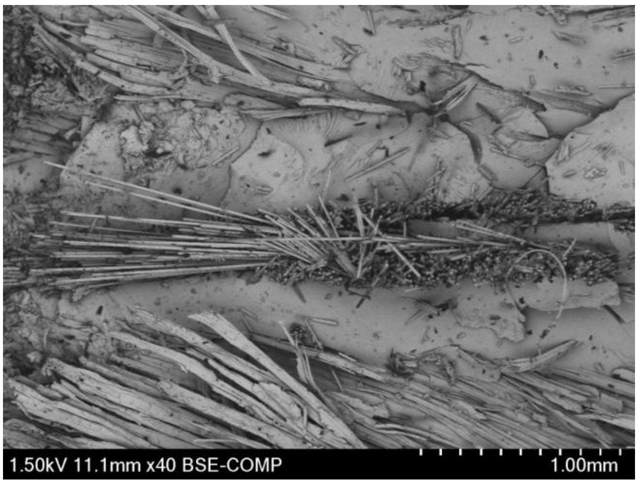


Fig. 9. SEM micrographs of SENB specimen for [0^o90^o]$_K$/FG_{2p}/[90^o0^o]$_k$ hybrid composite

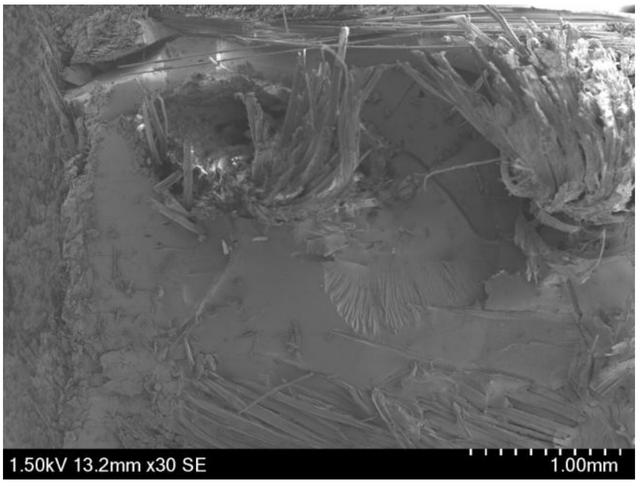


Fig. 10. SEM micrographs of SENB specimen for FG/[$0^o90^o/90^o0^o$]$_K$/FG hybrid composite

IV. CONCLUSION

In this work, the effect of layer arrangement of long kenaf and fibreglass reinforced polyester hybrid composites was successfully investigated. The primary results suggest that layer arrangement of fibreglass at outer layer give better fracture toughness as compared to position of kenaf at outer layer. Fracture surface analysis showed good bridging fibreglass which hold the material well before its rupture.

ACKNOWLEDGMENT

Thanks Allah for His mercy. Thanks to Ministry of Higher Education (MOHE) of Malaysia for the financial support through grant awards, Faculty of Mechanical Engineering (UiTM) and MyBrain PhD, final year student, Mohamad Noorshahmi Bin Noordin and Faris Che Hassan, and also to Institute of Research Management & Innovation (IRMI) of Universiti Teknologi MARA, Malaysia for facilitating this project.

REFERENCES

1. M. Z. R. Khan, S. K. Srivastava, and M. K. Gupta, “Tensile and flexural properties of natural fiber reinforced polymer composites: A review,” J. Reinf. Plast. Compos., vol. 37, no. 24, pp. 1435–1455, 2018.
2. S. Yunus, A. H. Abdullah, N. H. A. Halim, Z. Salleh, and Y. M. Taib, “Low energy impact on the short kenaf fibre reinforced epoxy composites: Effect to the residual strength and modulus,” J. Mech. Eng., vol. 12, no. 2, pp. 72-83, 2015.
3. Y. Wu, C. Xia, L. Cai, A. C. Garcia, and S. Q. Shi, “Development of natural fiber-reinforced composite with comparable mechanical properties and reduced energy consumption and environmental impacts for replacing automotive glass-fiber sheet molding compound,” J. Clean. Prod., vol. 184, pp. 92-100, 2018.
4. C. Elanchezhian, B. V. Ramnath, G. Ramakrishnan, M. Rajendrakumar, V. Naveenkumar, and M. K. Saravanakumar, “Review on mechanical properties of natural fiber composites.,” Mater. Today Proc., vol. 5, no. 1, pp. 1785–1790, 2018.
5. M. Ramesh, “Kenaf (Hibiscus cannabinus L.) fibre based bio-materials: A review on processing and properties,” Prog. Mater. Sci., vol. 78–79, pp. 1–92, 2016.
6. S. Yunus, Z. Salleh, N. R. N. M. Masdek, Y. M. Taib, I. I. S. Azhar, and K. M. Hyie, “Post-Impact and Open Hole Tensile of Kenaf Hybrid Composites,” in IOP Conference Series: Materials Science and Engineering, vol. 328, Art. no. 012017, 2018.

7. Z. Salleh, S. Yunus, N. R. N. M. Masdek, Y. M. Taib, I. I. S. Azhar, and K. M. Hyie, “Tensile and Flexural Test on Kenaf Hybrid Composites,” in IOP Conference Series: Materials Science and Engineering, vol. 328, Art. no. 012018, 2018,.
8. M. J. Sharba, Z. Leman, M. T. H. Sultan, M. R. Ishak, and M. A. Azmah Hanim, “Effects of kenaf fiber orientation on mechanical properties and fatigue life of glass/kenaf hybrid composites,” BioResources, vol. 11, no. 1, pp. 1448–1465, 2016.
9. A. Ismail et al., “Fracture toughness of woven kenaf fibre reinforced composites,” Int. Eng. Res. Innov. Symp., vol. 160, Art. no. 012020, 2016.
10. Z. Salleh, Y. M. Taib, K. M. Hyie, M. Mihat, M. N. Berhan, and M. A. A. Ghani, “Fracture Toughness Investigation on Long Kenaf / Woven Glass Hybrid Composite Due To Water Absorption Effect,” Proc. Eng., vol. 41, pp. 1667–1673, 2012.

AUTHORS PROFILE

Syarifah Yunus is Technical Training Officer in Mechatronics Section, Electrical Engineering Department, German Malaysian Institute (GMI), Kajang, Selangor. She received her Bachelor Degree and MSc in Mechanical Engineering from Universiti Teknologi MARA. Her research interests include natural fibre composites and fracture mechanics of engineering materials.

Zuraidah Salleh is currently a Senior Lecturer at Faculty of Mechanical Engineering, Universiti Teknologi MARA. She received her Bachelor Degree in Mechanical Engineering from Universiti Teknologi MARA and her MSc. from Universiti Sains Malaysia (USM). Her research interests include composites, coating and welding.

Nik Rozlin Nik Mohd Masdek is currently serving as Senior Lecturer at the Faculty of Mechanical Engineering, Universiti Teknologi MARA. She received her Bachelor Degree in Biomaterial Engineering and MSc in Mechanical and Materials Engineering from University Malaya. She obtained her Ph.D from the University of British Columbia. Her research interests include corrosion, nanocrystalline coating and electrochemical processes.

Ya’kub Md Taib is currently an Associate Professor at the Faculty of Mechanical Engineering, Univerity Teknologi MARA. He received his Bachelor Degree in Mechanical Engineering from ITM, Malaysia and his M. Phil from Swansea University, Wales, U.K. His research interests include composites and fracture mechanics of engineering materials.

Zainal Abidin Kamarul Baharin is currently a Senior Lecturer at the Faculty of Mechanical Engineering, Universiti Teknologi MARA. He received his Bachelor Degree in Mechanical Engineering from Louisiana State University, USA and his MSc. from Fachhochschule Karlsruhe, Germany. He is a licensed professional engineer in the USA and a registered professional engineer in Malaysia. His research interests include solar still, solar pond and biofuel.