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CHARACTERIZATION OF LOW VELOCITY IMPACT DAMAGE OF GAMMA-IRRADIATED KEVLAR/OIL PALM EMPTY FRUIT BUNCH HYBRID COMPOSITES

SITI MADIHA BINTI MUHAMMAD AMIR

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SITI MADIHA BINTI MUHAMMAD AMIR

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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Chair: Mohamed Thariq bin Hameed Sultan, PhD, PEng, CEng, PTech
Faculty: Engineering

Malaysia, the second world largest exporter of palm oil has generated abundance of oil palm empty fruit bunch (EFB) waste. The oil palm EFB has the potential as the reinforcement in composites for energy absorption applications. In this work, the oil palm EFB were hybridized with Kevlar fabric using hand lay-up technique with different layering patterns. The composites were exposed to gamma radiation dose, i.e. 25 kGy, 50 kGy and 150 kGy. Material characterization were carried out to evaluate the effects of radiation on its mechanical and physical properties of the materials. Low velocity impact and compression after impact tests were performed in this study. Damage propagation were observed using Ultrasonic C-Scan, Computed Thermography and Acoustic Emission methods. The tensile and flexural showed that hybrid composites were 48% and 45% respectively higher in hybrid composites with Kevlar as the skin. The compressive strength was 69% for hybrid composites with oil palm EFB as the skin. The optimum dose for tensile was at 25 kGy and 50 kGy for flexural and compression. At 150 kGy, the degradation of mechanical properties were observed. The density of hybrid composites for Kevlar as the skin was 0.89 g/cm^3. Irradiated composites were observed to have lower water absorption capacity. The impact resistance of the irradiated Kevlar/oil palm EFB hybrid composites was up to 35 J. In damage detection, the images from ultrasonic-C-Scan method did not reflect the actual images observed. Computed tomography and acoustic emission complemented each other in detecting the matrix cracking, delamination and fibre breakage damages in the hybrid composites. From the compression after impact test, it was observed that the compressive residual strength was decreased when the impact energy increased. The optimum radiation dose to withstand the compressive residual strength for 35 J was at 50 kGy. The newly developed hybrid Kevlar/oil palm EFB composites have the potential to be used in energy absorption applications and exposure to gamma radiation is one of the methods to improve its mechanical strength of the hybrid materials for monotonic loading applications.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENCIRIAN KEROSAKAN IMPAK BERKELAJUAN RENDAH TERHADAP KOMPOSIT HIBRID KEVLAR / TANDAN KELAPA SAWIT TERSINAR GAMA

Oleh

SITI MADIHA BINTI MUHAMMAD AMIR

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Malaysia, negara kedua terbesar pengeksport minyak kelapa sawit, telah menghasilkan sisa gentian tandan kelapa sawit yang banyak. Gentian tandan kelapa sawit mempunyai potensi sebagai gentian pengukuh dalam komposit bagi aplikasi yang melibatkan penyerapan tenaga. Dalam kajian ini, gentian tandan kelapa sawit di hibrid bersama gentian Kevlar menggunakan teknik hand lay up dengan susunan berbeza. Hibrid ini didedahkaan dengan sinaran gama dengan dos iaitu 25 kGy, 50 kGy dan 150 kGy. Pencirian bahan dilakukan untuk mengenalpasti kesan radiasi terhadap sifat mekanikal dan fizikal bahan tersebut. Ujian kerosakan impak berkelajuan rendah dan ujian impak selepas mampatan dilakukan pada komposit yang telah dikenakan impak. Kerosakan pada bahan diperiksa menggunakan kaedan Ultrasonik Imbasan-C, Tomografi Berkomputer dan pancaran akustik. Kekuatan tegangan dan lenturan adalah masing-masing 48% dan 45% iaitu lebih tinggi pada komposit Kevlar sebagai lapisan luar. Kekuatan mampatan adalah 69% pada komposit gentian tandan kelapa sawit sebagai lapisan luar. Dos radiasi gama yang optimum untuk meningkatkan kekuatan tegangan adalah pada 25 kGy serta kekuatan lenturan dan mampatan adalah 50 kGy. Dos 150 kGy menunjukkan degradasi pada kekuatan bahan. Ketumpatan hibrid komposit bagi Kevlar sebagai lapisan luar adalah 0.89 g/cm^3. Komposit yang disinari dengan sinaran gama mempunyai kapasiti penyerapan air yang rendah. Kekuatan ketahanan impak bagi hibrid komposit Kevlar/tandan kelapa sawit yang disinari dengan sinaran gama adalah sehingga 35 J. Bagi pengesanan kerosakan, imej menggunakan kaedah Imbasan-C Ultrasonik, tidak menunjukkan imej yang sebenar. Kedua-dua kaedah Tomografi Berkomputer dan Pancaran Akustik saling digunakan untuk mengesan kerosakan peretakan matrik, pelekangan dan pemutusan gentian di dalam struktur komposit hibrid. Ujian impak selepas mampatan, menunjukkan ‘compressive residual strength’ berkurang apabila tenaga impak ditingkatkan. Nilai optimum sinaran dos untuk ‘compressive residual strength’ pada 35 J adalah 50 kGy. Hibrid komposit Kevlar/gentian tandan kelapa sawit

yang baru dibangunkan berpotensi untuk diaplikasikan dalam bidang penyerapan tenaga dan pendedahan dengan sinaran gama menjadi salah satu cara untuk meningkatkan kekuatan mekanikal bahan hibrid tersebut bagi aplikasi beban ‘monotonic’.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

ABS	Acrylonitrile-butadiene-styrene
AE	Acoustic Emission
ASTM	American Society for Testing Materials
BG	Between group
CAI	Compression after impact
CR	Computed radiography
CT	Computed tomography
DIC	Digital image correlation
DR	Digital radiography
EFB	Empty fruit bunch
ET	Electromagnetic testing
FESEM	Field emission scanning electron microscope
FFT	Fast fourier transform
FRPC	Fibre reinforced polymer composite
GLS	Glass
GRFP	Glass fibre plastic
IR	Infrared
KJK	Kevlar-Jute-Kevlar
K/OP/K	Kevlar/Oil palm EFB/Kevlar
LAD	Linear Array Detector
NDT	Non Destructive Testing
NIJ	National Institute of Justice
NIRR	Near infrared reflectography
OH	Hydroxyl group
OPEFB	Oil palm empty fruit bunch
OP/K/OP	Oil palm EFB /Kevlar/ Oil palm EFB
PAT	Plant Assessment Technology
PBO	Poly p-phenylene benzobiosoxazole

PC	Polycarbonate
PLA	Polylactid acid
PMC	Polymer matrix composites
PP	Polypropylene
RT	Radiography testing
SEM	Scanning Electron Microscope
UT	Ultrasonic testing
VT	Visual testing
WG	Within group
WPC	Wood plastic composite

CHAPTER 1

INTRODUCTION

1.1 Background

Composite materials is defined as a material made of two or more constituent materials with different physical or chemical properties in which when combined, it produces a material with different characteristics from the individual components. It is made up of matrix and a reinforcement in which the combination gives superior properties of the individual components. In the composite materials, the reinforcements which comprise strong load carrying material is embedded in a weaker material which is known as the matrix (Taj, Munawar, & Khan, 2007). The function of matrix is to transfer stress between the fibres, to provide barrier against harmful environment and to protect the surface of the fibres from any mechanical scratch. The matrix plays an important role in the tensile load carrying capacity of a composites structure. The fibre reinforcement function is to improve the strength, stiffness and creep resistance of the materials particularly its strength-to-weight and stiffness-to-weight ratios (Kalpakjian & Schmid, 2006). Examples of fibre material are glass, aramids or also known as Kevlar, carbon and examples of matrix materials are polymers, metals and ceramics (Kalpakjian & Schmid, 2006). There are also other types of composites which are the metal matrix composites and ceramic matrix composites. However, most of the composites used in the industry today are based on polymer matrices.

In the current scenario, hybrid composites have great demand and are widely used with many applications (Gururaja & Hari Rao, 2012). Currently, most hybrid composites are made of only synthetic fibres such as Kevlar with carbon, Kevlar with fibreglass, carbon with fibreglass (Randjbaran, Zahari, Jalil, & Majid, 2014; Dorey, Sidey, & Hutchings, 1978).

Kevlar is a type of polymeric fibre with many usage. It is used in the aircraft industry and the military such as the body armour, vehicle spall liner (Yahaya R. , Sapuan, Jawaid, Leman, & Zainudin, 2015) and more. Kevlar fabric has high tensile strength and modulus. However, production of Kevlar fabric involve complex process, thus the price of Kevlar fabric is relatively expensive. According to Begum et al. (Begum & Islam, 2013), fibre reinforced polymer composite (FRPC) developed using synthetic fibre have many advantages such as high strength, high stiffness, long fatigue life, adaptability to the function of the structure, corrosion resistance and environmental stability. There are also drawbacks on this type of material which are high cost, high density, poor recycling and non-biodegradable. As for that reason, the use of synthetic fibre has moved to natural plant fibre reinforced polymer composites where by the material with natural fibre have satisfactorily high specific strength and modulus, light weight, low cost and biodegradability. Various plant fibres used in composites are oil palm empty fruit bunch (EFB), kenaf, jute, flax, etc.

Oil palm EFB natural fibre are waste from palm oil industry. Malaysia, being the world second largest exporter of palm oil after Indonesia, has generated abundance of waste from the industry due to insufficiently utilized. This scenario raised environmental concerns and problems in replanting operations. It is reported that in the year 2017, the oil palm plantation area in Peninsular Malaysia is accounted for 2.71 million hectares or 46.6% of the total planted area. Sabah is the highest plantation area covering 89.1% of the total oil palm planted area in the state. Sarawak recorded total matured area of 86.3% (Kushairi & Nambiappan, 2017).

In overcoming the environmental issues, many efforts have been done to overcome the problems such as turning the oil palm industry waste to food packaging materials (Oluwalana, Oluwamukomi, Toriola, & Karim, 2015), briquette (Nasrin, et al., 2008), composites (Shinoj, Visvanathan, Panigrahi, & Kochubabu, 2011) and as the fuel for biomass energy production (Shuit, Tan, Lee, & Kamaruddin, 2009). The oil palm EFB has gained interest to the researches in producing composites made from the oil palm EFB (Rozman, et al., 2001) especially in hybridising the oil palm EFB with different fibres. Jawaid et al. in his work hybridized the oil palm EFB with other natural fibre such as jute fibre (Jawaid, Abdul Khalil, & Abu Bakar, 2010).

Besides hybridizing the fibres to enhance the properties, exposure to gamma radiation is one of the methods to improve the mechanical strength of the composites. Gamma radiation, also known as ionising radiation, is a form of electromagnetic radiation with a very short wavelength. Due to its short wavelength, it has the capability to penetrate a wide range of materials. Gamma radiation is emitted from the disintegration or decay process from an unstable atomic nucleus to become a more stable nucleus. Examples of radioactive materials that produce gamma radiation are Iridium-192 and Cobalt-60, which are manmade radioactive materials.

There are profound effects in materials when it is exposed with the adequate absorbed dose. Application of gamma radiation can be applied to composites, plastic, textile, wood, and rubber industries. These exposures are usually performed in a radiation processing plant.

1.2 Problem statement

Recently the world has gained wide interest in hybrid composite between synthetic and natural fibre (Begum & Islam, 2013). Studies on the environmental aspects, socio economic impact and potential of South East Asia for contribution in natural fibre reinforced polymer composite production such as jute, rice husk, bamboo, coconut, banana, flax, hemp, pineapple, sisal and wheat husk has been conducted by Begum et al. (Begum & Islam, 2013). Examples of natural fibre used as reinforcement are coir, jute, flax, kenaf, oil palm empty fruit bunch (EFB) etc.

Oil palm fibres are in abundance in Malaysia since it is one of the largest exporter in oil palm industry in the country. Hence, various studies have been conducted to produce products from oil palm fibres and this includes studies of hybrid composites with oil palm fibres. Currently, there have been research conducted in hybrid between oil palm and other fibres.

Kevlar is a type of synthetic fibre which is used as reinforcement in composites. Kevlar is known as fibre with high tensile strength properties, however, it is non-biodegradable and expensive as compared to natural fibre. Kevlar is also known to have good impact properties. While oil palm EFB is believed to have potential as the reinforcing fibre in polymer composites for energy absorption applications especially in low velocity impact (Faizi, et al., 2017). Thus, by hybridizing Kevlar and oil palm EFB, a new class of hybrid material can be developed. By adding oil palm EFB to Kevlar, this might have influence on the impact resistance. Thus, the impact performance of Kevlar/oil palm EFFB hybrid composites need to be investigated.

Secondly, focusing on the enhancement on the properties of the hybrid composites using green technology that is radiation method. In producing hybrid composites, the biggest concern is to improve its strength as compared when the natural fibre is used alone as the reinforcement for the composites. Besides with only hybridizing the materials, there are different methods in enhancing the mechanical properties of the composites. Chemical treatment is one of the methods to improve the mechanical strength (Asim, Jawaid, Abdan, & Nasir, 2018). Rozman et al. (Rozman , Saad, & Mohd Ishak, 2003) studied the effect of maleic anhydride chemical modification on the flexural and impact properties of oil palm empty fruit bunch (EFB). Radiation technique is also one of the techniques in improving the mechanical properties. Ionising radiation, especially from the gamma source origin, offers several benefits such as a continuous operation, less atmospheric pollution, minimal time requirement, and more (Shubhra & Alam, 2011). Besides, the processing steps are reduced using gamma radiation technique as compared to chemical treatment. Irradiation of gamma radiation is a relatively new technique in hybrid composites. There are limited studies on the effect of gamma radiation on the mechanical and impact strength after low velocity impact to the hybrid composites. Hence, the studies on the impact properties of Kevlar / oil palm EFB hybrid composites before and after gamma radiation has not been explored.

The effect of exposure to radiation may improve the mechanical properties of the materials due to the cross linking process. In contrast, it is known that polymer matrices are usually radiation sensitive, which can be significantly affected by certain amounts of radiation exposure (Wu, Li, Huang, Huang , & Li, 2013). As a result, excessive radiation dose might lead to the degradation of properties such as poor mechanical strength and this cause serious engineering problems. Consequently, the investigation of radiation's effect on the performance of the composites is essential when developing any new hybrid combination.

Low velocity impact will produce damage due to the impact. However, the internal damage from low velocity impact event is not visible or sometimes barely visible at the impacted surface. The defects that are not visible at the impacted surface is very hazardous in structural engineering applications. To overcome this problem, Non-Destructive Testing (NDT) is used to detect internal defects such as delamination, crack or fibre breakage.

There are many NDT methods such as Radiography, Eddy Current, Liquid Penetrant, Ultrasonic, Magnetic Particle, Acoustic Emission and more. However, not all NDT methods can be applied for hybrid composites. This is due to the characteristics of the material such as the difference of material density and material structure especially when it is hybridizes. Hence, detection of internal defects due to impact event using suitable NDT methods is important especially for newly developed hybrid composites such as Kevlar/ oil palm EFB hybrid composites.

Due to the reasons stated above, this has attracted the author to explore the hybrid composites between oil palm empty fruit bunch (EFB) / Kevlar fibres for various potential applications. Adding the Kevlar fibres to the oil palm EFB fibres with the exposure to gamma radiation is a step forward as a tool to enhance the properties of the hybrid composites. The statement of the problems can be illustrated as follows:

i. What is the best layering pattern for oil palm EFB fibre and Kevlar so that improve mechanical properties achieved in terms of tensile, flexural and compression?

ii. Is the irradiation with gamma radiation to the hybrid composites improves the performance of the mechanical properties of the hybrid composites?

iii. Is the irradiation with gamma radiation bring significant improvement to the impact strength of the hybrid composites or vice versa?

iv. What is the maximum radiation dosage for the hybrid composites to experience degradation process?

All of these issues are being investigated in this work. Experimental methodologies were conducted in this work to achieve the research objectives. Density, water absorption and thickness swelling were employed to investigate the physical properties of the hybrid composites with different radiation dose. Tensile, flexural and compression tests were employed to investigate the mechanical properties when applied various radiation dose with different layering pattern. Gel content analysis was performed to measure the percentage of the crosslinking due to radiation exposure to the hybrid composites. Further analysis on the microstructure is also conducted using scanning electron microscope (SEM) and field emission scanning electron microscopy (FESEM).

Further investigation on impact properties of the hybrid composites with different radiation dose are investigated. Low velocity impact damage and compression after

impact tests are performed to understand the impact properties of the hybrid composites with radiation dose. Non-Destructive Testing (NDT) are performed to study the damage mechanism of the hybrid composites after underwent low velocity impact test. Ultimately, this research is targeted to improve the hybrid composites between oil palm EFB and Kevlar with the usage of gamma radiation in terms of mechanical properties.

1.3 Research objectives

The main objective of this work is to study the mechanical properties and low velocity impact damage of hybrid composites Kevlar/oil palm EFB when it is irradiated with gamma radiation. Below are the specific objectives of the present work:

i. To investigate the influence of irradiation dose on mechanical and physical properties of Kevlar/ oil palm EFB hybrid composites.

ii. To analyse the effect of gamma radiation on low velocity impact properties of Kevlar/ oil palm EFB hybrid composites.

iii. To evaluate the internal damage due to low velocity impact event using NDT methods such as ultrasonic test (UT), computed tomography (CT) and acoustic emission (AE) methods.

iv. To determine the compressive residual strength of post-impact Kevlar/ oil palm EFB hybrid composites.

1.4 Scope and Limitations of the study

The scope of this work is to characterize the hybrid between Kevlar/ oil palm EFB composites when it is irradiated with gamma radiation. In this work, different layering pattern were fabricated. The first layering pattern were oil palm EFB as the interior and Kevlar as the exterior and the second layering pattern were oil palm EFB as the skin and Kevlar as the core. The characterization included were the physical properties and mechanical properties. The physical properties involved were the density, water absorption and thickness swelling. In mechanical properties, the testing conducted were tensile, flexural and compression testing.

This work was further continued with low velocity impact damage test. The investigation on the impact properties was only limited to energy level 35 J because at energy level 35 J, the impactor was able to penetrate the irradiated materials. Characterisation of low velocity impact damage to the material were studied. Compression after impact were investigated in this work. Evaluation on the damage defect were carried out using non detective testing method such as computed tomography, ultrasonic and acoustic emission.

There were various defects in composites such as voids, delamination, matrix cracking and fibre breakage. However, in this work the detection of defects were only limited to delamination, matrix cracking and fibre breakage because these defects were the major

defects that contribute to the failure of the composites. Detection of voids in the internal damage of composites were not included in the studies.

1.5 Thesis outline

There are five chapters in this thesis that describes the whole research of the work.

i. Chapter 1 provides the introduction and background to the research and followed by Chapter 2.

ii. Chapter 2 discusses the literature review. The literature review for this chapter includes the discussion on the hybrid composites that have been developed. The literature survey also include the various non – destructive testing methods currently used on the detection of damage in the hybrid composites. This chapter also includes the literature survey on radiation effect on the composites.

iii. Chapter 3 delves on methodology of the development of different layering pattern and characterisation of the gamma irradiated hybrid composites involving physical and mechanical testing. From the results of the physical and mechanical testing, the best layering pattern were chosen for low velocity impact damage test using the drop rig test. Methodology on low velocity impact damage included in this chapter. Methodology on compression after impact test were discussed and followed by non-destructive testing methods; acoustic emission, ultrasonic C-scan and Computed Tomography.

iv. Chapter 4 deals with the results and discussion of the physical and mechanical testing. The discussion included on the different layering sequence; Kevlar/oil palm EFB/Kevlar (K/OP/K) and oil palm EFB/Kevlar/oil palm EFB (OP/K/OP) on the effect of radiation onto the physical and mechanical properties of the developed material. In this chapter, discussion on the low velocity impact damage and compression after impact damage are discussed. The last part in this chapter is the results and discussion on non-destructive testing on the evaluation of the damage due to low velocity impact.

v. Chapter 5 provides the conclusion of the research work and recommendation for further study.

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In her career, she is currently attached in the Leading Edge Non Destructive Testing Group under Industrial Technology Division as a Research Officer in Malaysian Nuclear Agency. Her research is focus in Digital Industrial Radiography. She was also appointed as the Quality Manager for ISO 17020. She was the project leader for Technical Corperation (TC), International Atomic Energy Agency (IAEA) with project title 'Developing Efficient Non-Destructive Testing (NDT) Data Management Through Integrated NDT Modalities (2012-2014). She was also appointed as the project leader for Scifund with project title 'Development of Mobile Radioscopy System for Industrial Inspection (2010-2012). She is one of the co-authors in book title 'Keselamatan Sinaran Dalam Radiografi Industri' published by Dewan Bahasa dan Pustaka.

LIST OF PUBLICATIONS

Journals

Siti Madiha Muhammad Amir, Mohamed Thariq Hameed Sultan, Mohammad Jawaid, Ahmad Hamdan Ariffin, Mohamad Ridzwan Ishak, Mohd Reusmazzran Yusof, Shukri Mohd and Khairul Anuar – Effect of Gamma Radiation on Compressive Properties of Kevlar/Oil Palm Empty Fruit Bunch Hybrid Composites : BioResources 13(4), pp 7628-7639, 2018. **Published**

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Siti Madiha Muhammad Amir, Mohamed Thariq Hameed Sultan, Mohammad Jawaid, J Naveen, Syafiqah Nur Azrie Safri, Shukri Mohd and Khairul Anuar Mohd Salleh – Low Velocity Impact and Compression After Impact Properties on Gamma Irradiated Hybrid Kevlar/ Oil Palm EFB Composites : Industrial Crop and Product Journal. **Submitted**

Siti Madiha Muhammad Amir, Mohamed Thariq Hameed Sultan, Mohammad Jawaid, Mohamad Ridzwan Ishak, Mohamad Ridzuan Ahmad, Muhamad Noor Izwan Ishak, Suhairy Sani,Syafiqah Nur Azrie Safri, Shukri Mohd and Khairul Anuar Mohd Salleh – Evaluation on Low Velocity Impact Defects on Gamma Irradiated Oil Palm EFB/ Kevlar hybrid Composites using NDT Methods : MDPI Journal **Submitted**

Book Chapters

Siti Madiha Muhammad Amir, M.T.H.Sultan, Mohammad Jawaid, Ahmad Hamdan Ariffin, Shukri Mohd, Khairul Anuar Mohd Salleh, Mohamad Ridzwan Ishak, Ain Umaira Md Shah (2019) – Nondestructive testing method for Kevlar and natural fiber and their hybrid composites in book

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Conference Proceedings

1. **S.M.M.Amir,** M.T.H.Sultan, M.Jawaid, F.Cardona, M.R.Ishak and M.R.Yusof – Effect of Kevlar and Carbon Fibres on Tensile Properties of Oil Palm/Epoxy Composites, AIP Conference Proceedings 1901, 030021 (2017). **Published**

Conferences Attended

1. 3rd Advanced Materials Conference 2016 (AMC2016), 28 – 29 November 2016, Bayview Hotel, Langkawi Island, Kedah, Malaysia,
   Presenter
2. 1st International Conference on Safe Biodegradable Packaging Technology (SafeBioPack 2018), 24th – 25th July 2018, Malaysian Industry Government Group for High Technology (MIGHT), Cyberjaya, Malaysia.
   Presenter and Poster Presenter

Workshops and Seminars

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2. Technical visit Airbus Helicopters Malaysia (AHM), Aerospace Manufacturing Research Centre (AMRC) UPM, The Institute of Engineers Malaysia (IEM),3rd May 2017 **Participant**
3. Introduction to Taguchi Method, Aerospace Manufacturing Research Centre (AMRC) UPM, Universiti Kebangsaan Malaysia (UKM), The Institute of Engineers Malaysia (IEM), 26th April 2017 **Participant**
4. Global Aerospace Industry Outlook and Insight into Malaysia's Aerospace Initiatives, Aerospace Manufacturing Research Centre (AMRC) UPM, STRAND Aerospace Malaysia, 2nd March 2017 **Participant**
5. TVET, A Case for Transformation, Aerospace Manufacturing Research Centre (AMRC) UPM, 5th November 2016 **Participant**
6. Workshop on Thermal Mechanical Analyzer, Laboratory of Biocomposite Technology Institute Tropical Forestry and Forest Product (INTROP), 1st June 2016 **Participant**
7. Seminar on The Route To Become a Certified Engineer (CEng) and Professional Engineer (PEng), Aerospace Manufacturing Research Centre (AMRC) UPM, Institute of Mechanical Engineers Malaysia Branch (IMechE)

The Institute of Engineers Malaysia (IEM), Board of Engineers Malaysia (BEM), Malaysia Society of Structural Health Monitoring (MSSHM), MySET, 1st April 2016 **Participant**

8. Clean Sky Green Sky by Prof Ric Parker (Director of Research And Technology Rolls Royce), Aerospace Manufacturing Research Centre (AMRC) UPM, 3rd September 2015 **Participant**

9. High Impact Journal Writing and Publishing Workshop – Institute Tropical Forestry and Forest Product (INTROP), 3rd to 4th June 2015 **Participant**

10. Dynamic Mechanical Analysis of Polymeric Material, Laboratory of Biocomposite Technology Institute Tropical Forestry and Forest Product (INTROP), 11th March 2015 **Participant**

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