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Layering Effect on Mechanical, Thermal & Physical Properties Carbon Fibre Reinforced Polyphenylene Sulfide

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ABSTRACT

The application of thermoplastic composites (TPCs) in aircraft application is expanding. This paper presents a study of the effect of layering thickness of Carbon Fibre Reinforced Polyphenylene Sulfide, CF/PPS. There are 2 thickness of plies which are 6 plies and 8 plies of 1.90 mm and 2.52 mm respectively. To update, the aircraft is now ready to shift from thermoset to thermoplastics composite materials. In parallel to the technology, mechanical, thermal and physical properties of the advanced thermoplastic materials CF/PPS are to be determined. By having towards the behavior and properties, thus the incoming material CF/PPS data could be compared to the current nominal of epoxy thermoset structural for aircraft which is benefit to the aircraft industries purpose. In this study, it was found that, for mechanical properties, Tensile Strength, Flexural Modulus as well as Vickers Hardness recorded 6 plies higher value compared to 8 plies. While, Impact Strength, Interlaminar Shear Strength, (ILSS) and Compressive Strength shown that 8 plies obtained the superior reading compared to 6 plies. For physical properties, the density of 6 plies and 8 plies recorded 1.541 $\mathrm{g/cm^3}$ and 1.547 $\mathrm{g/cm^3}$ respectively. Content as a percentage of the initial mass of fibre, W_f (%) recorded 6 plies was 58.397% while 8 plies was 58.235 %. Fibre content as a percentage of the initial volume, V_f (%) recorded 6 plies was 50.838% while 8 plies was 50.885%. Void content as a percentage of the initial volume, V_c (%) recorded 6 plies was 1.678% while 8 plies was 1.268%. While, for the thermal analysis, both samples of CF/PPS have good thermal stability material in aerospace applications as the weight for both plies CF/PPS are observed as the function of temperature (high heat energy applied). Glass Transition Temperature ($\mathrm{T_g}$) was 93.75°C for 6 plies while 8 plies recorded 93.94°C. Melting Temperature, ($\mathrm{T_m}$) recorded 283.68°C for 6 plies whereas 283.61°C for 8 plies. The morphological analysis under Scanning Electron Microscope (SEM) shows that 6 plies had a lot of fibre pull out compared to 8 plies thus agreed that impact strength was higher on 8 plies over 6 plies.

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1. Introduction

The aerospace industries strive to design structures that are predictable against the fatigue failure because this property of structural aerospace elements is a critical factor in aerospace engineering [1]. Therefore, materials used in aerospace systems such as aircrafts, satellites, missiles and launchers require a combination of a range of properties like strength, stiffness, fracture toughness, fatigue endurance and also corrosion resistance [2].

According to Joshi and Chatterjee [3], it normally costs for €5000-15,000/kg to launch a heavy elevator system into low earth and €28,000/kg to orbits the earth. That is, the industry is calling on composites and designing new materials to address the demands that have led to the main priority of the aerospace industry. Due to the expanding of fibre reinforced polymers composites laminates in many applications, thus composites have increased in demand [4].

Global demand for aircraft is raising drastically because composite production combines product versatility and speedy processing to maximize manufacturing efficiencies with the capability to simplify design while reducing operating charges by reducing its weight [5]. Al-Wandi *et al.,* [4] also mentioned that previous researchers agreed that the composites have contributed to the 50% of its structural weights for both Airbus A350 XWB and Boeing 787.

Thermoplastics Composites (TPCs) can be utilized at greater operating temperatures for good thermal stability and the market is seeing the introduction of new thermoplastic matrices and therefore it have been used in advanced airframes for example on the horizontal tail plane of AW 169, on the weapon bay doors of F-22, on the rudder of Boeing Phantom Eye and also on the rudder and elevators of G650 [6]. Furthermore, Ibren *et al.,* [7] mentioned that some aircraft experienced critical gust load on wing structural from the previous reference, which can be occurred due to the turbulent situation this can be improved by the introducing of composite in the modern aircraft structures due to the lightweight properties.

Thermoplastic is a type of polymer that when heated, it becoming soft or molten and pliable and thus returns to a solid cooling state without altering its intrinsic structures and this activity helps the thermoplastic composite to be recycled [8]. Similarly, according [9], it is relatively straightforward to recycle thermoplastics unlike thermosets it creates a large crosslinked network. Thus, create problem in the recycling process of certain products [10].

The popularity of thermoplastic is due to weight reduction, low cost savings and increased performance thus, becoming the key reasons for the uses of composites for the aircraft parts [11]. Not only that, for machining, thermoplastics can be machined to extremely high tolerances of up to 0.002 mm, which is important in aerospace [12].

While, previous studies stated the benefit of thermoplastic composite is that, it may use in fusion welding, which makes the rib-to-skin bond as strong as the material [13]. Furthermore, the nose leading edge of the A340 and A380-J is composed of thermoplastic advanced composites for impact resistance and weight savings.

Polyphenylene Sulfide (PPS) is a high-performance polymer, which has better comprehensive mechanical properties than common or middle range polymers such as polypropylene, polyamide, and Ultra-High-Molecular-Weight Polyethylene, according to the cost/performance characteristics because of its excellent thermal and physical properties [14]. While Shrivastava [15] stated that, PPS is a semi-crystalline thermoplastic polymer is generally stronger in all direction of molecular arrangement but weaker at perpendicular arrangement because of it amorphous and crystalline phase.

The crystallization behavior of thermoplastic matrix is considered as an important property which can highly affect the mechanical and thermal properties of laminated composite structures [14]. This is due to Shrivastava [15] stated that the crystalline or amorphous play an important role in determining the overall properties of polymer.

Figure 1 illustrates the chemical structure of PPS polymer which is consisting of aromatic rings linked with sulphides [14].

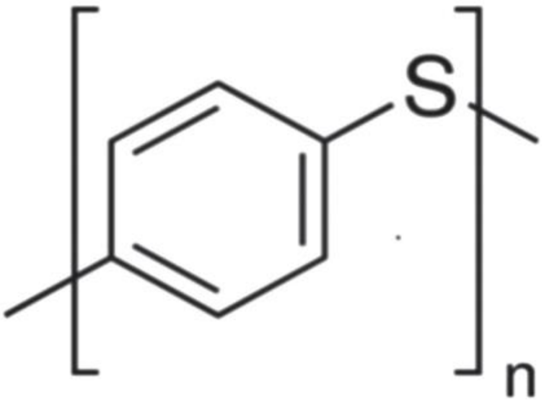


Fig. 1. Chemical structure for Polyphenylene Sulfide, PPS [14]

This semi-crystalline engineering thermoplastic has outstanding thermal stability, superior toughness, inherent flame resistance and excellent chemical resistance due to it has high mechanical strength, impact resistance, and dimensional stability as well as good electrical properties [16]. Therefore, it was found that PPS has possessed excellent on mechanical properties such as tensile behavior, impact, bending or flexural, shear, compressive and fatigue behavior [14].

Khan *et al.,* [17] stated previous researchers found that flexural properties, impact strength and hardness of PPS/CF laminate composites were remarkably enhanced by increasing in reinforcement layers. It was also observed that increase number of layers will reduced the crack propagation and breakage under same load. Less layers showed reduction in fracture resistance. While, previous studies by Yaakob *et al.,* [18] stated that the mechanical properties increase with thickness of facesheet composites of honeycomb laminates composites.

Not only that, Lee and Soutis [19] mentioned that the compressive strength does influenced by the thickness of the materials and almost 35% reduction of the strength as the thickness is increased due load transmitted to the end which increasing the chances of premature failure. While, impact force found to be increase with composite thickness [20]. Similarly, previous studies by Padmanabhan [21] stated that ILSS specimen of 5 mm laminate shows higher marginally value compared to 3 mm thickness laminate due to increase in elasticity which arises from layer as the ply is increases.

According to the previous researchers, effect of thickness and resin system will influenced the tensile properties of composite materials [22]. While Yadav and Srivastava [23] stated that increase in thickness of laminate will decrease the tensile strength. Not only that, delamination can be observed with increase of thickness. The delamination, fibre matrix debonding and fibre failures can be experienced by the composites and as the results, all these damaging problems will lead to the reduction performance on strength properties [24].

2. Methodology

The materials of composite CF/PPS panels were imported from The Netherlands with 2 different thickness for 6 plies and 8 plies of 1.90 mm ± 0.06 and 2.52 mm ± 0.08 respectively. The woven type of 5 Harness Satin with the orientation for 6 plies was [(0,90)/ (±45)/ (0,90)] s while 8 plies was [[(0,90)/ (±45)]2] s as shown in Figure 2 and Figure 3.

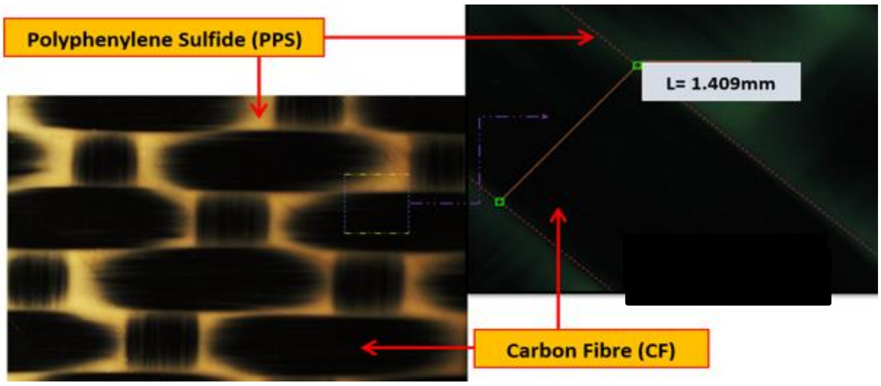
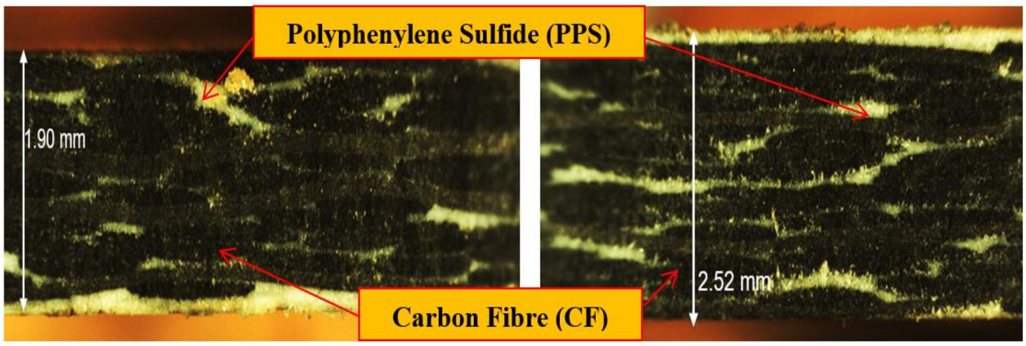


Fig. 2. Surface view of CF/PPS panels



(a) (b)

Fig. 3. Lateral view of CF/PPS panels for (a) 6 plies and (b) 8 plies

The incoming materials has been cut into the specific dimensions according to the testing standard by using Waterjet Cutting Machine Flow Mach 2 with abrasive mesh garnet #80 and trimmed by using mitre saw and grinder. Then, all the specimens will be used for the material characterization on mechanical, thermal and physical properties according to the respective standards.

2.1 Mechanical Properties
2.1.1 Tensile test (ASTM D3039)

Tensile Test was obtained by using Instron® 5585 with load cell 150kN. The testing standard for ASTM D3039 is used in tensile test to determine the force that is required to break the specimen with the dimension of 150 mm x 22 mm at speed 2 mm/min (0.05 in/min).

2.1.2 Izod unnotched impact test (ASTM D256)

Izod Unnotched Impact Test was obtained by using Motorized Pendulum Impact Tester CEAST 9050 with the pendulum hammers of 22 J at impact speed of 3.46m/s with a starting angle of 150° of a length of 326.8 mm based on ASTM D256 with the dimension sample of 64 x 12.7 mm.

2.1.3 Interlaminar shear strength, ILSS (EN 2563)

The ILSS test was determined by using a Universal Testing Machine 5 (UTM5)/Instron 5967 according to the EN 2563 standard with the dimension of 20 mm x 10 mm with 10 mm span length and 1mm/min speed. The loading nose radius and support radius is 3mm.

2.1.4 Flexural test (EN 2562)

Flexural test was conducted by using Instron® 5585 Floor Model Testing with a load cell 150 kN according to EN 2562 standard. This experiment is set to 5 mm/min of displacement rate with the dimension of 10 mm x 100 mm. The support span is at 80 mm for the sample.

2.1.5 Compression test (ASTM D6641)

For compression test, Universal Testing Machine UTM 3/ INSTRON 8852 was used to conduct the experiment at rate 1.3 mm/min. The standard used was ASTM D6641. The dimension of sample was 140 mm x 25 mm and with gauge length 10 mm.

2.1.6 Vickers hardness test (ASTM E384)

Micro Hardness tester with an indenter of pyramid shape at an angle of 136° was used. The Vickers hardness is a measure of the hardness of a material that could be computed from the size of the impression produced under load by a pyramid-shaped diamond indenter. The specimens were subjected to a load of 50 g during 15 s under controlled ambient conditions. The diagonals of each indentation were measured 3 times to obtain average values [25].

2.2 Thermal Characterization

2.2.1 Thermogravimetric analysis (TGA) (ASTM E1131)

For TGA, the machine used was TGA Perkin Elmer STA 6000 (USA). The sample size was 10 milligrams (mg). 10 mg of the samples were heated from 30°C to 992°C at heating rate of 10°C /min under nitrogen atmosphere with flow rate of 100 mL/min according to the test standard of ASTM E1131.

2.2.2 Differential scanning calorimetry (DSC) (ASTM 3418)

The procedure for DSC is given by the standards ASTM D3418. TA Instruments Q2000 (USA) is used to conduct this test. The sample size of 10 to 15 mg from the sample was crimped in an aluminum pan and tested over a temperature range 30°C to 330°C at scanning rate of 10 °C /min under nitrogen atmosphere.

2.3 Physical Characterization
2.3.1 Water absorption (ASTM D570)

This test was conducted according to ASTM D570. The specimen of CF/PPS were immersed in distilled water at room temperature and weighed every 24 hours using Industry Electronic Balance until saturation is noticed (144 hours).

2.3.2 Determination of the fibre, resin and void contents (EN 2564)

The determination of fibre, resin and void content was conducted by referring to the EN 2564 standards according to method B. The objective of this work is to determine the fibre, resin and void contents. The sample sizes of 1-5g is used in this test. The data can be obtained by using acid digestion test.

2.4 Morphological Analysis, Scanning electron microscopy (SEM)

For morphological observation, SEM machine type JEOL6010PLUS with elemental analysis EDS is used. The specimen was coated by using platinum at 3nm thickness.

3. Results and Discussions
3.1 Mechanical Properties

For tensile properties, tensile strength gives the in-plane mechanical behavior of composite materials [26]. Table 1 shows the result of the tensile test.

Table 1
Tensile test data for 6 plies and 8 plies CF/PPS

CF/PPS	Maximum Load (kN)	Tensile Stress (MPa)	Extension at maximum load (mm)	Young's Modulus (MPa)
6 plies	26.48	626.98	4.90783	14879.369
8 plies	29.74	536.42	4.76282	12124.020

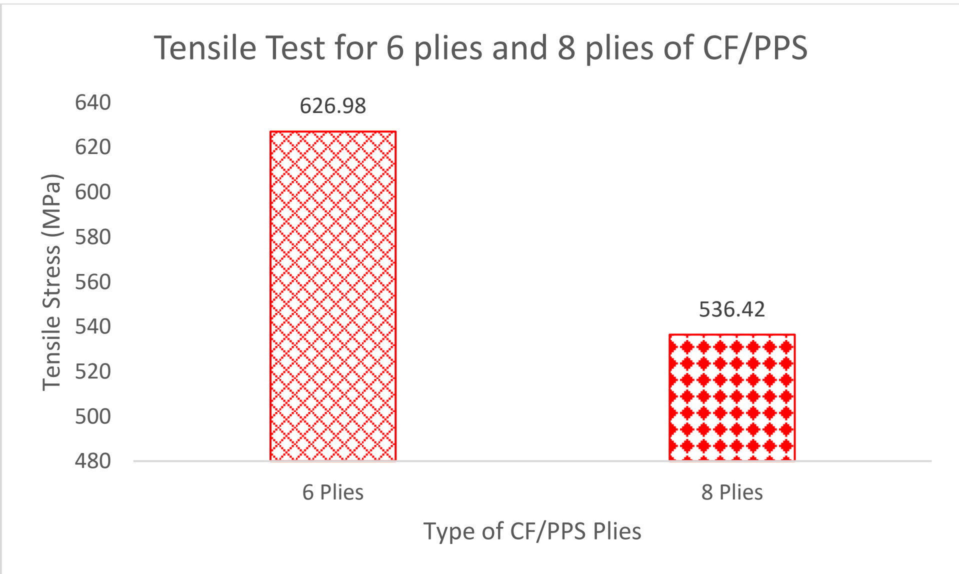


Fig. 4. Comparison between tensile stress of 6 plies and 8 plies of CF/PPS

Figure 4 shows the bar graph for tensile stress. In this research, it was found that 6 plies CF/PPS shows relatively superior in tensile properties which was recorded 626.98 MPa compared to 8 plies which was 536.82 MPa. This can be attributed to relatively higher Young's Modulus of 6 plies and 8 plies which were recorded 14879.37 MPa and 12124.020 MPa respectively. It was found that the layer thickness of the composite is another factor to determine the mechanical strength of the materials [27]. In this research, it was found that increase thickness gives a low tensile strength value. Similarly, this statement was in parallel with [28] which stated that, increase in thickness of laminates tends to decrease the tensile strength. In this research, it was obtained that the maximum load recorded was higher at 8 plies which was 29.74 kN compared to 6 plies which was 26.48 kN. Thus, authors [22] proved that the load increases sharply in thick specimen compared to the thin laminates.

Motorized Pendulum Impact Tester CEAST 9050 was used to conduct the Izod unnotched impact test. Table 2 shows the result of the Impact test data.

Table 2
Impact data for 6 plies and 8 plies CF/PPS

CF/PPS	Width (mm)	Thickness (mm)	Impact strength (J/m)	Impact strength (kJ/m^2)
6 plies	12.70	1.90	2308.07	181.74
8 plies	12.70	2.52	3070.87	241.47

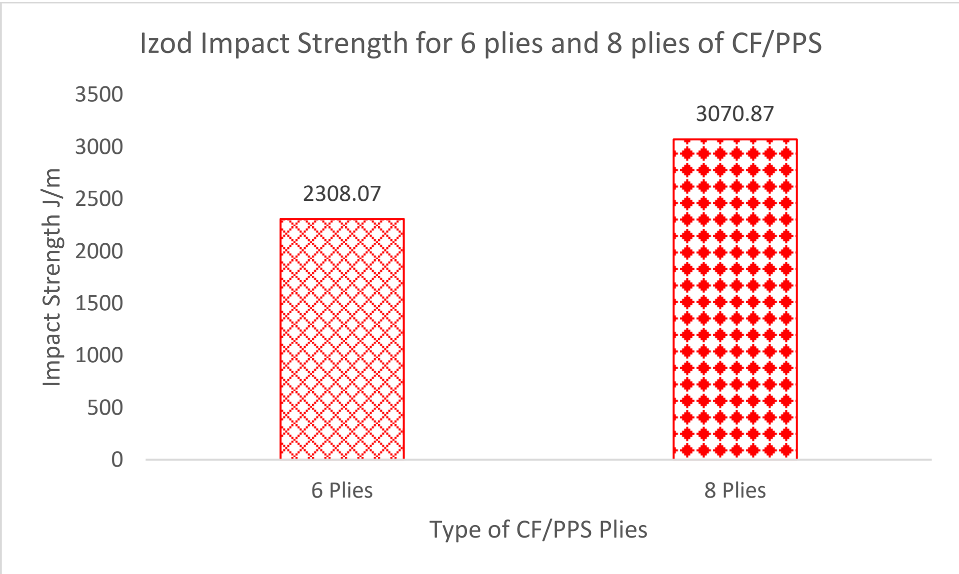
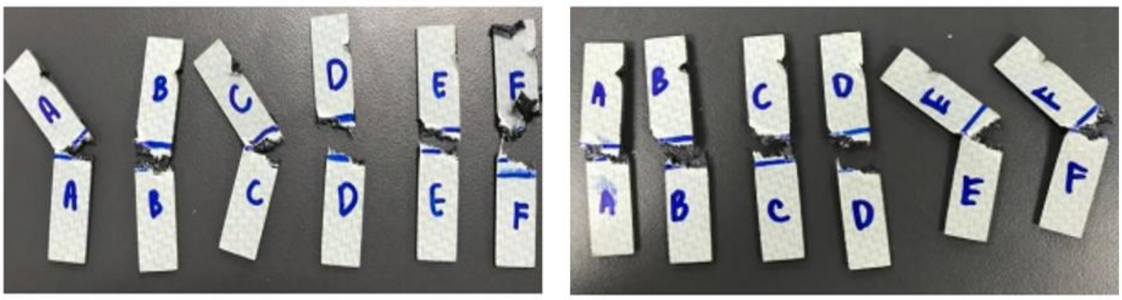


Fig. 5. Comparison between Izod impact strength for 6 plies and 8 plies CF/PPS



(a) (b)

Fig. 6. Impact fracture for (a) 6 plies and (b) 8 plies CF/PPS

Impact strength of CF/PPS for 8 plies was higher than 6 plies as in Figure 5 which was recorded 3070.87 J/m and 2308.07 J/m respectively. In this research, it was found that 6 plies had lower impact resistance compared to 8 plies. Similarly, Wang *et al.,* [20] found that the impact resistance of the composite was increased with thickness. Not only that, Yadav and Srivastava [23] also agreed that, specimen with maximum number of layers absorbed more energy. As a result, in this research, the impact strength value of 8 plies absorbed higher energy to fail the material. Therefore, Wang *et al.,* [29] stated that, this is mainly attributed to the impact energy absorbed by the material. This increment in impact strength was attributed to more energy absorption in laminates during impact because of the toughness on the material was enhanced as the layers were increased [17]. As in Figure 6, the results of fracture show that unnotched samples in 6 plies had a complete break of failure mode, while 8 plies had two failure modes: complete break and hinge break.

To find the interlaminar shear strength, Universal Testing Machine 5(UTM5)/Instron 5967 was used to determine the data for both plies. Table 3 shows the data for ILSS.

Table 3
ILSS data for 6 plies and 8 plies CF/PPS

Sample	Width (mm)	Thickness (mm)	Maximum Load (N)	Interlaminar Shear Strength (MPa)
6 Plies	10.22	1.90	1970.79	75
8 Plies	10.23	2.52	2738.00	79

Figure 7 shows the results of the ILSS test. According to Azam *et al.,* [26], ILSS is used to evaluate the influence of fibre–matrix bonding on the interlaminar shear strength (ILSS) at a laminate level. In this research, it can be seen that the 8 plies of CF/PPS show relatively high ILSS properties which was recorded 79 MPa compared to 6 plies which was 75 MPa. Similarly, according to Padmanabhan [21], it was found that, the interlaminar shear strength increased as the material is tend to be more elastic in the thick material.

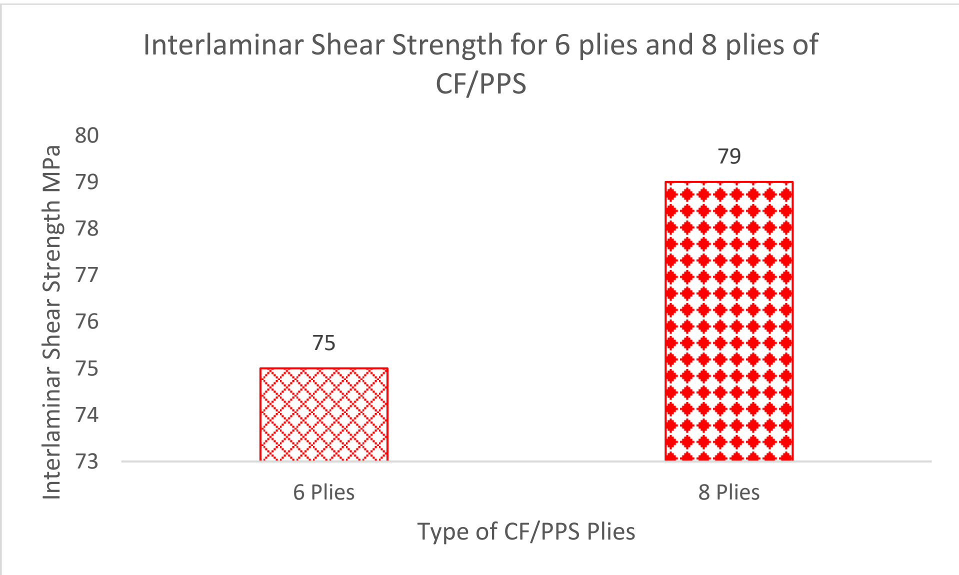


Fig. 7. Comparison between ILSS for 6 plies and 8 plies CF/PPS

To find the flexural properties, The Instron® 5585 Floor was used to determine the flexural strength and flexural modulus. Table 4 shows the flexural data for the testing.

Table 4
Flexural data for 6 plies and 8 plies CF/PPS

CF/PPS	Maximum Load (N)	Flexural Stress (MPa)	Flexural Strain (mm)	Modulus (MPa)
6 plies	236.60	786.46	0.02	50442.22
8 plies	427.08	807.03	0.02	49139.70

From Figure 8, the flexural modulus of 6 plies was higher which was 50442.22 MPa compared to 8 plies which was 49139.7 MPa. From the results, it can be observed that higher thickness produced the lower flexural modulus data. Thus, adding layers to the composite material will reduce the stress at the interface between the outer and inner CF/PPS. In addition to that, lower bending modulus might affected by the fibre-matrix interactions to provide a great pressure resistance during bending [30].

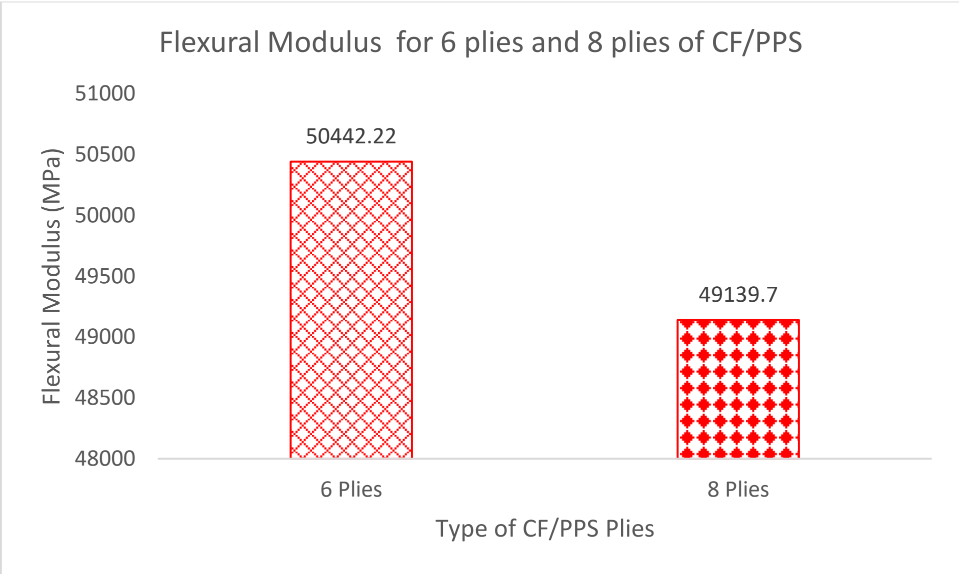
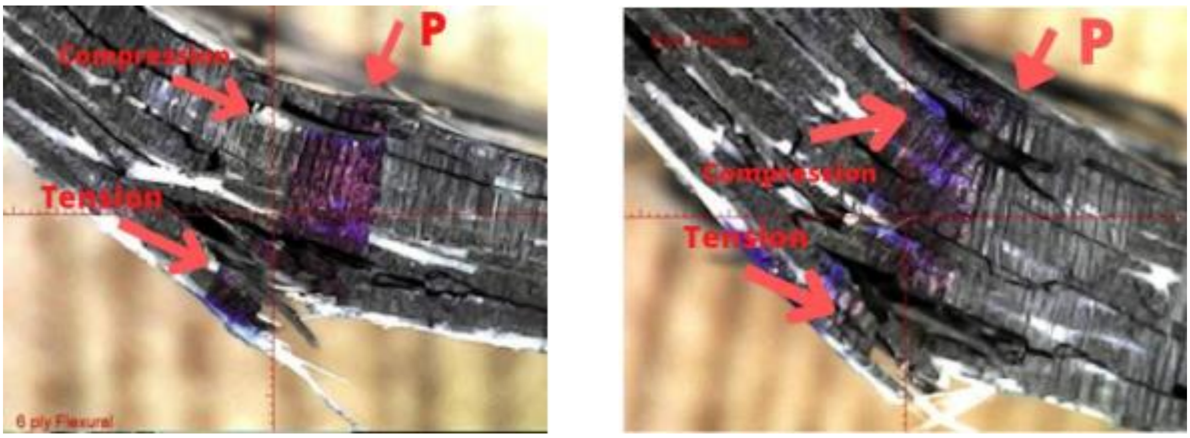


Fig. 8. Comparison between flexural modulus for 6 plies and 8 plies CF/PPS

Figure 9(a) and (b) show the tension and compression in 6 and 8 plies CF/ PPS respectively. In this research, two main cracks could be identified, which were tension and compression that had propagated from each of the composite flat faces.



(a) (b)

Fig. 9. Tension and compression for (a) 6 plies and (b) 8 plies CF/PPS

Compression test will be tested to find the compressive strength by using Universal Testing Machine UTM 3/ INSTRON 8852. Table 5 shows the result of the compressive strength.

Table 5
Compressive strength data for 6 plies and 8 plies CF/PPS

Plies CF/PPS	Compressive Strength (MPa)
6	410.721
8	439.012

Figure 10 shows the compressive strength for both 6 and 8 plies of CF/PPS. In this figure, the 6 plies recorded the lower compressive strength which was 410.721 MPa compared to 8 plies which was 439.012 MPa. According to Lee and Soutis [19], the compressive strength specimens increased with increasing thickness due to the specimen stability of Euler Buckling theory. The result of compression strength shows an acceptable failure mode in category of Brooming Gage Middle (BGM) accordingly to the testing standard as shown in Figure 11.

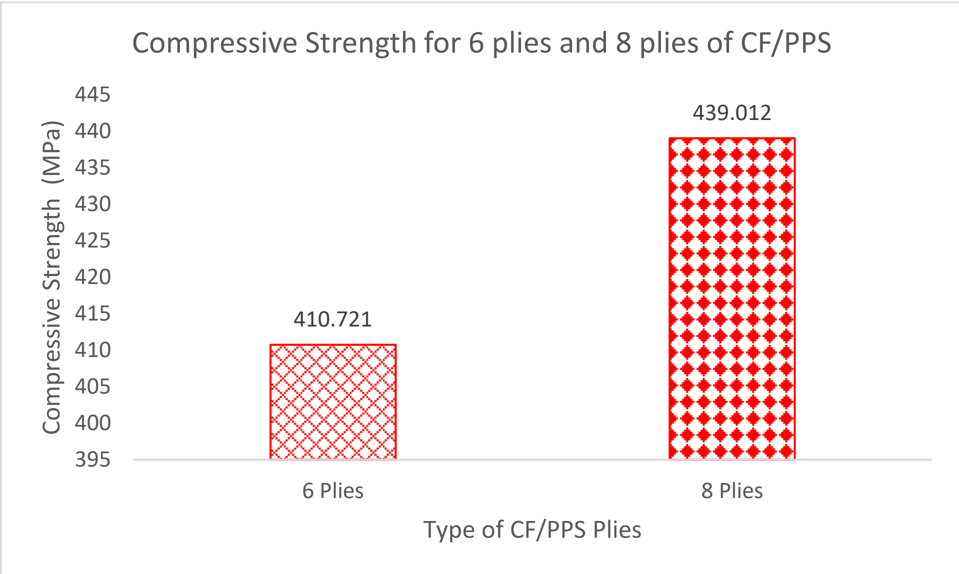


Fig. 10. Comparison between compressive strength for 6 plies and 8 plies CF/PPS

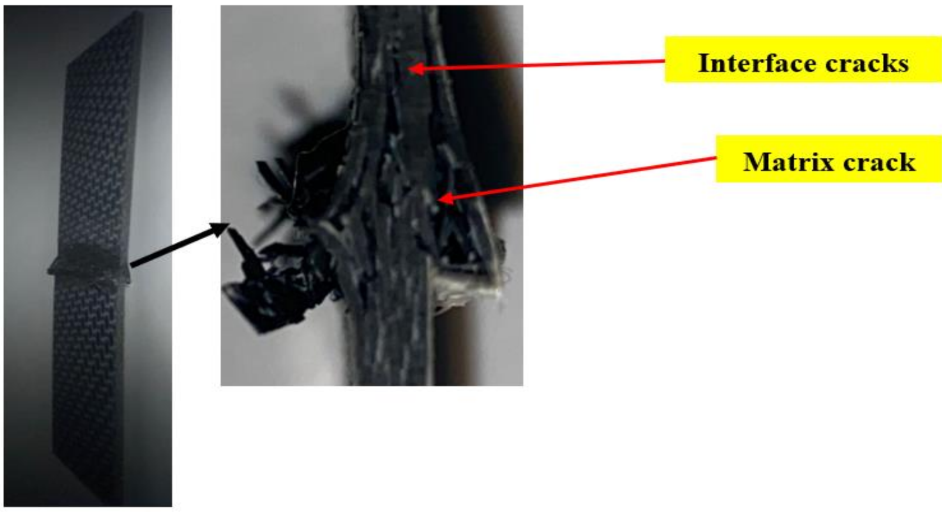


Fig. 11. Acceptable failure mode and areas of BGM for compression specimen

Vickers hardness is used to determine the hardness of the specimens. Figure 12 shows a pyramid shape indenter was exerted on the surface of CF/PPS. For each specimen, three measurement points were recorded for both 6 plies and 8 plies and the values are averaged as suggested by Yovanovich [31]. Table 6 shows the hardness properties both 6 plies and 8 plies CF/PPS and the unit is Vickers Pyramid Number (HV).

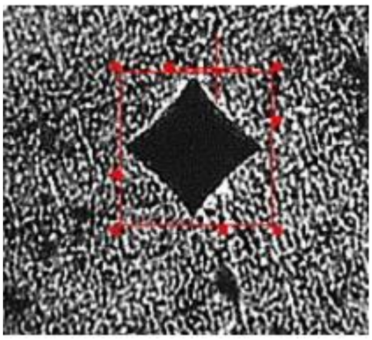


Fig. 12. Pyramid shape indenter on CF/PPS surface

Table 6
Hardness reading for 6 plies and 8 plies CF/PPS

Reading	Hardness 6 plies CF/PPS (HV)	Hardness 8 plies CF/PPS (HV)
Average	22.2394	21.1460

Figure 13 shows that hardness value of 6 plies CF/PPS was higher than 8 plies which were recorded 22.2394 HV and 21.1460 HV respectively. This is true due to the fact that the modulus of elasticity of 6 plies is much higher than 8 plies which is turn to relate the resistance of the material plies is deform due to indentation [32]. Hardness of CF/PPS composite decrease gradually with decreasing plies of reinforcement. This significant enhancement in hardness was ascribed to the distribution of the test load on fibres which decreased the penetration of the test ball into the surface of the composite material [17]. The findings revealed that CF/PPS has an exceptional ability to withstand plastic deformation. Decreasing the number of layers increased the wettability or bonding between the polymer matrix and the fibres, which improved indentation resistance. The hardness results were in good agreement with the flexural test results, indicating that the mechanical properties of PPS laminates improved as the number of layers decreased. On the other hand, the range of hardness for both plies is valid due to the previous studies expecting the value should be around 16 HV to 24 HV [33].

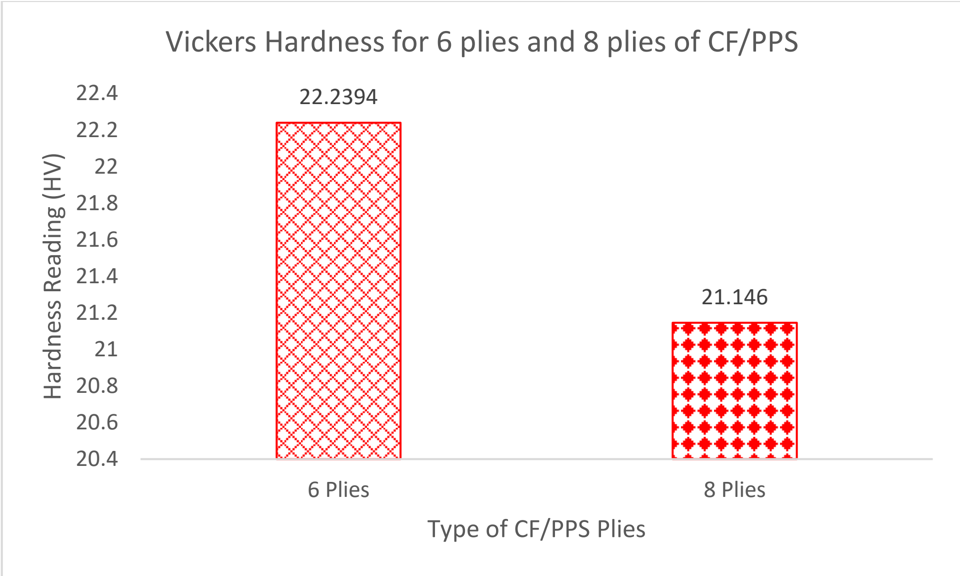


Fig. 13. Comparison between Vickers hardness reading for both 6 plies and 8 plies CF/PPS

3.2 Thermal Properties

TGA properties was done and shown in Figure 14 for thermal degradation curve for both 6 plies and 8 plies CF/PPS. The weight changes of CF/PPS samples were measured as a function temperature.

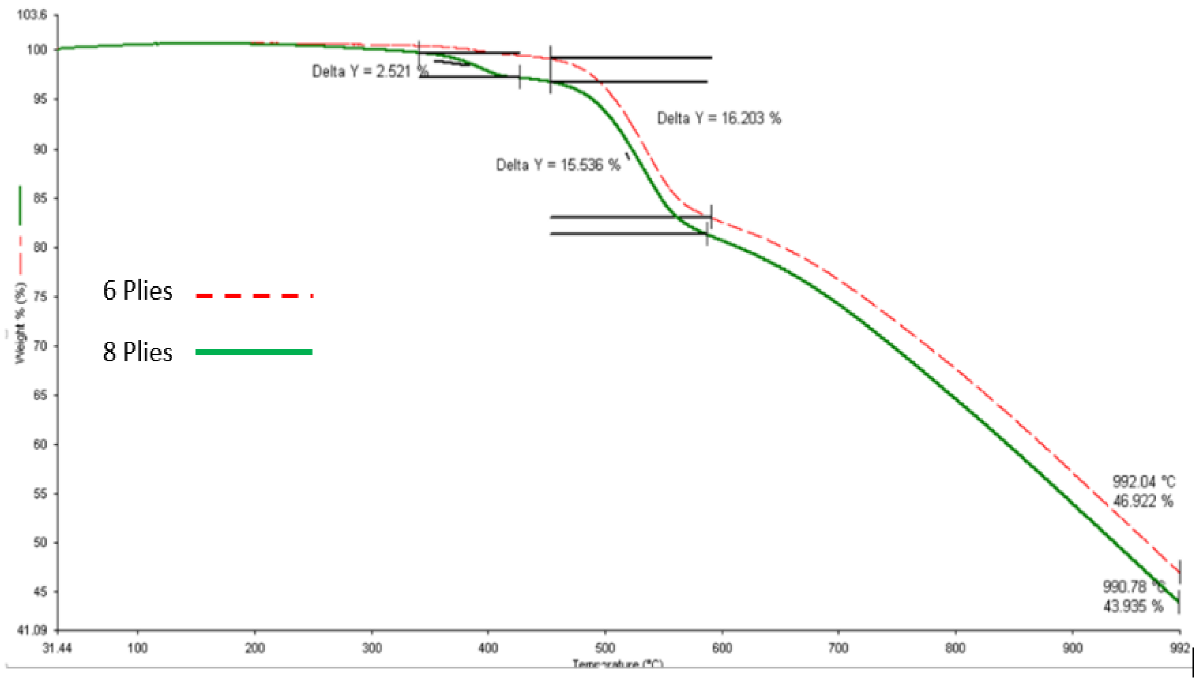


Fig. 14. Comparison between TGA Curve for 6 plies and 8 Plies CF/PPS

Figure 14 shows the thermal degradation curve of CF/PPS for 6 plies and 8 plies. It is clearly shown that there was no significant difference in thermal degradation between these 2 different plies due to the composite exhibit a single decomposition stage in a nitrogen environment. It clearly seen that 6 plies of CF/PPS had a stable chemical bond of its molecular structure which imparts a high degree of molecular stability compare to 8 plies. Initial Decomposition Temperature (IDT) or onset is the point where the material starts degrades and measures of thermal stability of CF/PPS. IDT for 6 plies and 8 plies were 453.20°C and 347.95°C respectively. The results indicate the 6 plies have higher IDT compare to 8 plies. According to Table 7, 6 plies CF/PPS residual weight was recorded 46.92% while the residual weight for 8 plies was 43.93%. For both plies, it is shown that thermal stability is good. This is due to PPS exhibits good dimensional and thermal stability because of its ordered alternating arrangement of phenylene and sulfide atoms [14].

Table 7
TGA values for both CF/PPS

CF/PPS Plies	IDT (°C)	Residue (%)
6	453.2	46.92
8	347.95	43.93

For glass transition temperature (T_g), melting temperature (T_m), as well as thermal stability of the materials can be evaluated by using DSC [9]. According to Hasan [34], thermal analysis is the general term given to a group of analytical techniques that measure the properties of a material as it is heated or cooled. The DSC curve can also determine the enthalpy, ΔH of the material in exothermic and endothermic reaction as the heat energy applied to it in heating condition or heat released in cooling condition.

Figure 15 and 16 show the DSC curve for both 6 plies and 8 plies CF/PPS respectively. It can be found that the Glass Transition Temperature, T_g was 93.75°C for 6 plies while 93.94°C for 8 plies. Melting Temperature, T_m recorded 283.68°C for 6 plies whereas 283.61°C for 8 plies. The value of the T_g and T_m data was near according to the previous researchers on DSC whether it is neat PPS or CF/PPS. According to Spruiell [35], the T_g of PPS was 89°C and T_m of PPS was 280.48°C. While Ste-Marie [36], found T_m to be in between ~278°C and ~283°C whereas [37], obtained 290°C for the T_m.

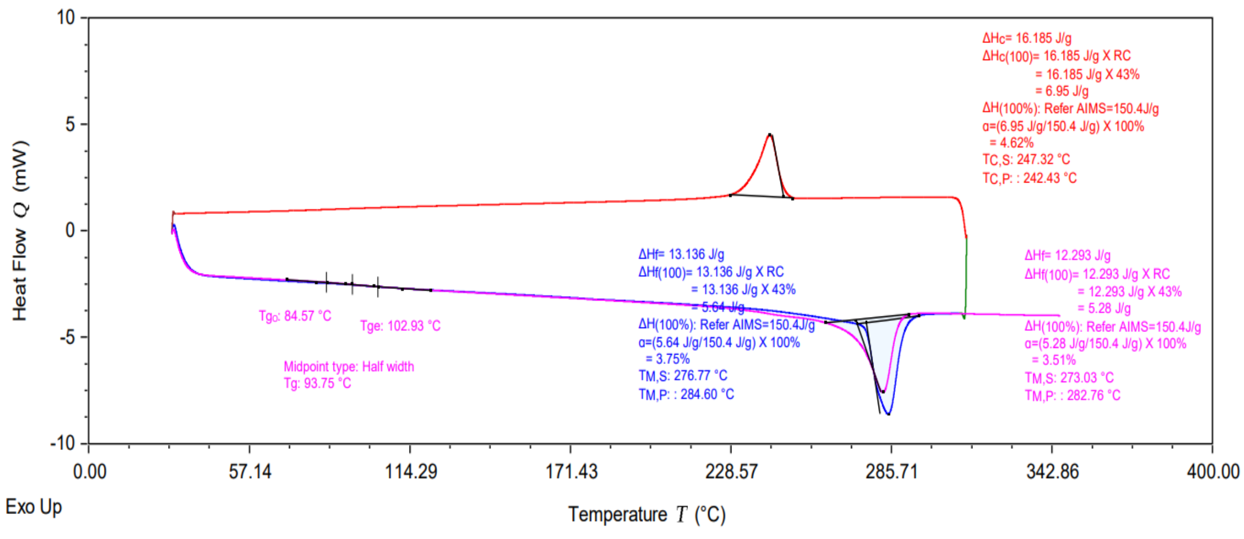


Fig. 15. DSC curve for 6 plies CF/PPS

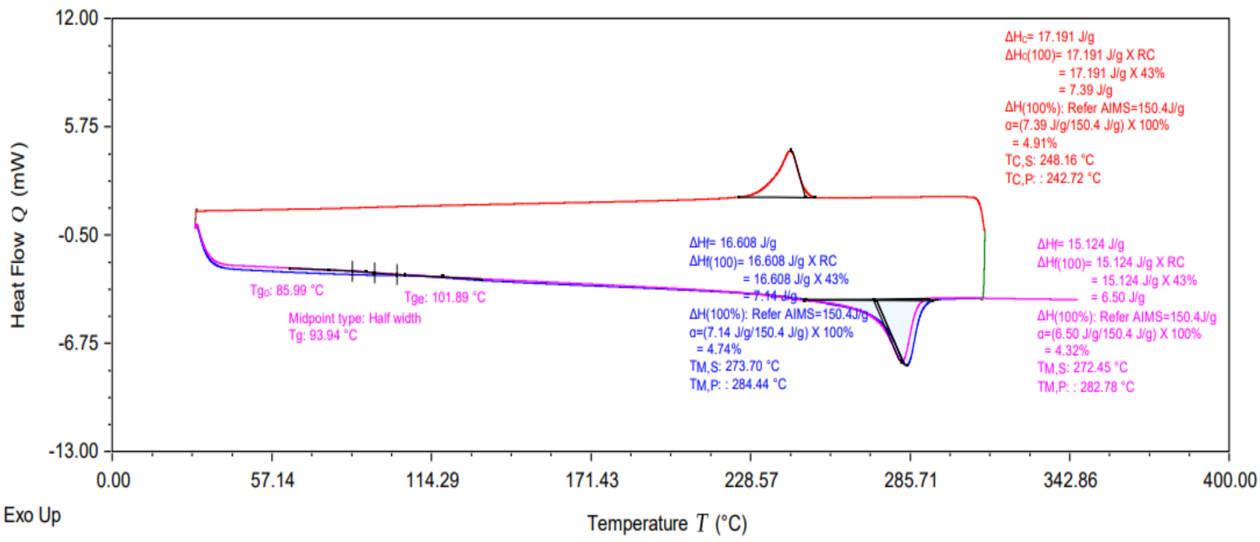


Fig. 16. DSC curve for 8 plies CF/PPS

3.3 Physical Properties

Water absorption was conducted and presented as shown in Table 8.

Table 8
Water absorption data for 6 plies and 8 plies CF/PPS

Time (hour)	Mass for 6 Plies, CF/PPS (g)	Water Absorption 6 Plies, CF/PPS (%)	Mass (g) for 8 Plies, CF/PPS (g)	Water Absorption 8 Plies, CF/PPS (%)
2	1.1793	-	1.5422	-
4	1.1793	0	1.5422	0
6	1.1793	0	1.5422	0
8	1.1793	0	1.5422	0
10	1.1793	0	1.5422	0
12	1.1793	0	1.5422	0
14	1.1793	0	1.5422	0
16	1.1793	0	1.5422	0
18	1.1793	0	1.5422	0
20	1.1793	0	1.5422	0
22	1.1793	0	1.5422	0
24	1.1793	0	1.5422	0
48	1.1793	0	1.5422	0
72	1.1793	0	1.5422	0
96	1.1793	0	1.5422	0
120	1.1793	0	1.5422	0
144	1.1793	0	1.5422	0

Figure 17 shows the graph of CF/PPS on water absorption testing based on result of Table 8. The water absorption remains constant over 144 hours as there is no significant difference. In contrast, Ma and Shih-Wen [38] stated that water absorption recorded for CF/PPS is 0.059%, thus this may due to parallax error or human error while taking the reading even though it still shows in 0% range. Thus, proved that PPS has low water absorption [39].

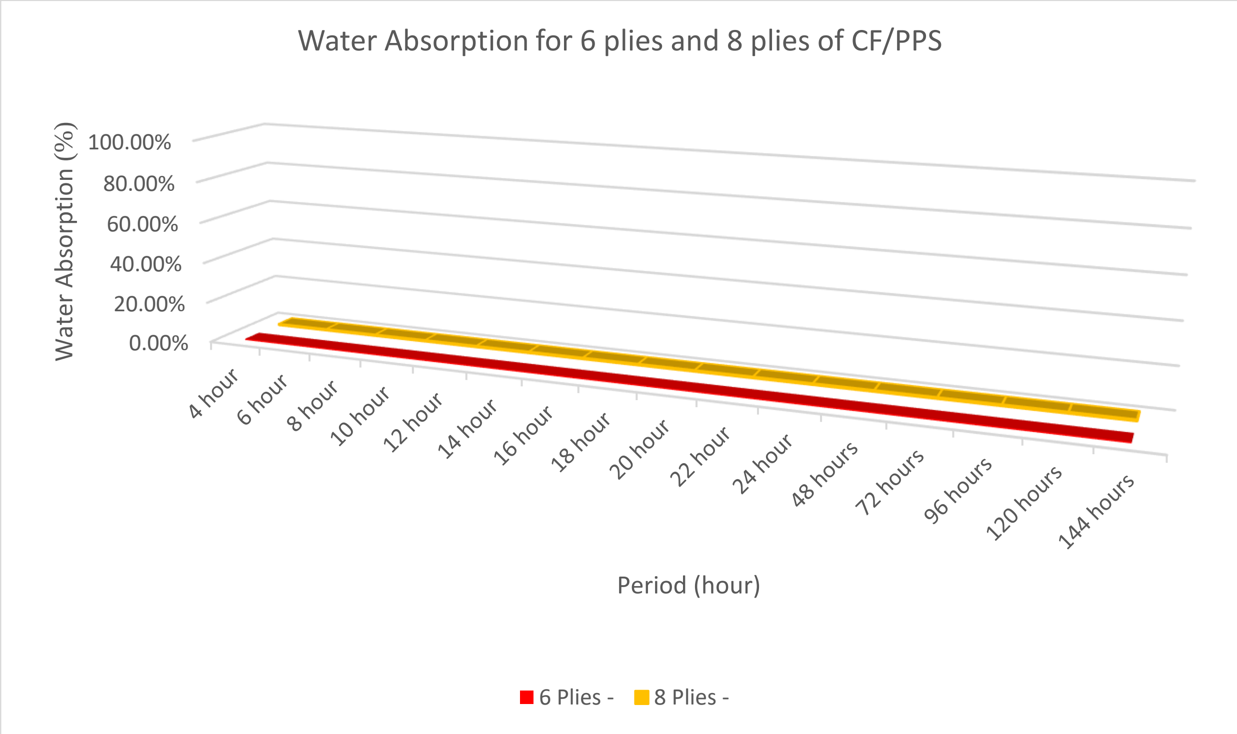


Fig. 17. Water absorption curve based on period

Determination of the fibre, resin and void contents were done for both plies. In this section, fibre, resin and void content were determined by using acid digestion test according to method B of EN 2564. The results are shown in Table 9.

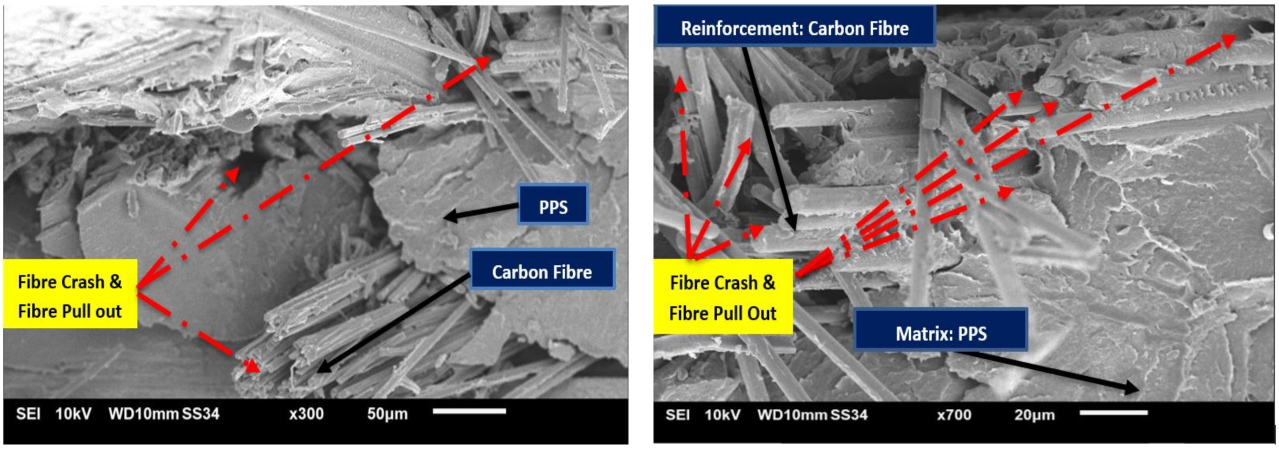
Based on Table 9, it can be seen that, 8 plies of CF/PPS recorded higher fibre content compared to 6 plies which were 50.885% and 50.838% respectively. Meanwhile, the void content as percentage of initial volume was high for 6 plies compared to the 8 plies which were 1.678 % and 1.268 % respectively. It also can be observed that the density of 6 plies was lower than 8 plies which were1.541 g/cm^3 and 1.547 g/cm^3 respectively. Therefore, it is easy to conclude that due to the lack of PPS impregnation in 6 plies, this zone had more pores between the matrix and the reinforcement. In addition to that, the density values were also similar with the supplier.

Table 9
Determination of fibre, resin and void content

Sample (CF/PPS)	Weight of specimen (g)	Density of specimen (g/cm^3)	Fibre content as a percentage of initial mass, W_f (%)	Fibre content as a percentage of initial volume, V_f (%)	Void content as a percentage of initial volume, V_c (%)
6 Plies	0.9837	1.541	58.397	50.838	1.678
8 Plies	1.3178	1.547	58.235	50.885	1.268

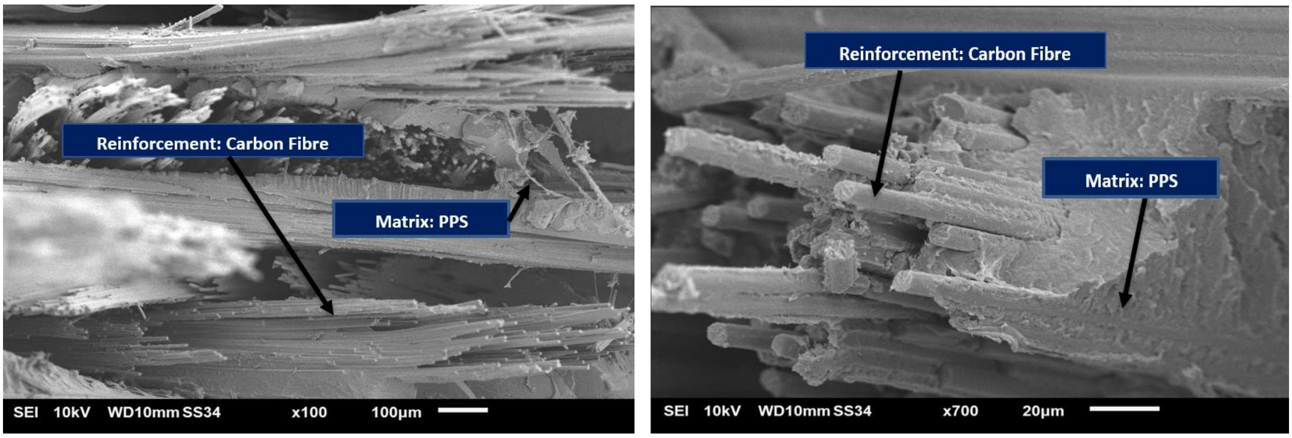
3.4 Morphological Analysis, Scanning Electron Microscope, SEM

According to the SEM results of CF/PPS for both 6 plies and 8 plies after Impact Tests as shown in Figure 18 and 19, it can be observed that 6 plies shown greater on fibre pull out. In definitions, the bonding between the matrix of resin and fibre is not strong. In terms of fibre crash, it is obviously shown that more crush was observed in 6 plies of CF/PPS compared to 8 plies. Therefore, it proved that 8 plies absorbed more energy compared to 6 plies CF/PPS which recorded 3070.87 J/m and 2308.07 J/m respectively.



(a) (b)

Fig. 18. SEM Observation under magnification (a) x 300 and (b) x 700 for 6 plies CF/PPS



(a) (b)

Fig. 19. SEM Observation under magnification (a) x 100 and (b) x 700 for 8 plies CF/PPS

4. Conclusions

In parallel to the technology for aircraft to shift from thermoset to advanced thermoplastic structural parts, the incoming materials for CF/PPS composites in terms of mechanical, thermal and physical properties are determined. From the result of CF/PPS with different layering of 6 plies and 8 plies, it was found that, the physical properties for CF/PPS is very stable, no water absorption, and very light in weight which is low density materials. For mechanical properties, the Tensile Strength, Flexural Modulus as well as Vickers Hardness (HV) recorded 6 plies reading is higher compared to 8 plies. While, Impact Strength, Interlaminar Shear Strength and Compressive Strength shown that 8 plies obtained the superior reading compared to 6 plies. For the thermal analysis, both sample of CF/PPS has good thermal stability material which shows the good potential in aerospace applications service.

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