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# The Study of Impact Damage on C-Type and E-Type of Fibreglass Subjected To Low Velocity Impact

N. Razali[1,], S.S. Sazali[2,], M.T.H. Sultan[1,]

[1]*Aerospace Manufacturing Research Centre (AMRC), Level 7, Tower Block, Faculty of Engineering, University Putra Malaysia, 43400 UPM Serdang, Selangor Darul Ehsan, Malaysia.*
[2]*Department of Aerospace Engineering, Faculty of Engineering, University Putra Malaysia, 43400 UPM Serdang, Selangor Darul Ehsan, Malaysia.*

**ABSTRACT**

*This paper presents the results of an experimental study on the low-velocity impact on Fibreglass C-type and E-type of 600 g/m2. The aim of this research is to investigate the dynamic response of composite glass fibre under low velocity impact energy, as well as to analyse the impact damages of composite glass fibre structures and analyze the experimental data from impact testing. Specimens from C-type and E- type fibreglass fabricated in 10 layers with size 150 mm x 100 mm, were subjected to low-velocity impact with circular steel impactor at various energy levels from 10 J to 40 J. This experiment was to examine the impact force, impact energy, impact resistance, penetration behaviour and effect of low impact loading corresponding to different energy and velocity of impact.*

***Keywords:*** *low-velocity impact, impact force, impact energy, energy absorbed*

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## I. INTRODUCTION

Composite materials are employed in several type of applications. In the aviation industry, the composite materials are used as components for aerospace, commercial, pleasure and military aircraft. Doors, skins and other parts of these aircraft are made from composites due to their better performance compared to other materials. Composite materials possess lighter weight and a higher strength to weight ratio, high performance of composites, high resistance and corrosion compared to aluminium and other materials. It is also has low electrical conductivity, wear resistance and high stiffness. Besides that, the composite material is also used in the automotive industry, civil infrastructure, construction and consumer sports and recreational equipment. Impact loading on the composite material, can cause damage to the internal structure and reduce the stiffness and strength of the material. Trowbridge et. al. (2012) mentioned that any materials will be affected by impact loading from either high or low velocity impact, but that different velocities will produce different results [1]. The impact test can be done with many different techniques such as gas gun impact, dropweight tester, pendulum type testers and cantilevered impactor. The high velocity impact is best stimulated using a gas gun. On the other hand, low velocity impact is best stimulated by using a dropweight tester.

Previous researchers have studied the effect of low velocity impact on the behaviour of laminated composite structures. Low velocity impact will affect the strength and performance of composite materials. The compression strength will be reduced and decreases the fatigue strength of the composite. According to Naiket. al., low velocity impact can cause damages beneath the surface, while the surface may appear to be undamaged upon visual inspection. Such damage is called barely visible impact damage (BVID) [2-4].

According to Abrate, during the manufacturing process or during maintenance, tools can be dropped on the structure. In this case, impact velocities are small but the mass of the impact is larger [5]. Low velocity impacts often occur when the aircraft is on the ground, during maintenance or repairing outside or in the aircraft, when some apparatus or tools are accidentally dropped onto the body of the aircraft. Furthermore, when stairs are used to paint the aircraft or to repair some higher part, this can also result in a low velocity impact. Other than that, Natural Gas Vehicle (NGV) tank is also severe low velocity impact. NGV is use as alternative fuel vehicle replacing fossil fuels, and it is more environmental friendly and low cost. However, it has severe vibration because it is located at rear vehicle due to higher reaction of moment, and this can be an example of low velocity impact. From a statically evaluation of Lufthanse during January and February 1994, 67 damages from 168 damages occurred to aircraft, where 70% damages occurred during at ground. Due to the impact, whether high or low velocity impact, this will cause damage and reducing the stiffness and strength of the material. According Trowbridge et. al. (2012), in advanced composite materials impact loading can cause significant internal structural damage, and resulting loss of stiffness and strength [6]. Amit Chib (2003) mentioned damages due to low energy where impactor velocity is less than 40 m /s [7]. In this research, the fibreglass with 10 layers will be impacted by low velocity from 1.5 m/s to 3.0 m/s. Particularly, low-velocity impact can leave very little visible mark onto the impacted surface and it can easily produce even delaminations and matrix cracks that may be invisible on the surface of the laminates [8]. Low velocity impact is considered potentially dangerous mainly because the damage might be left undetected [9].

In this study, the experiment was first conducted by fabricating the test material, which is the fibreglass laminated plate for impact test. The glass fibres specimen was impact tested using the impact test machine. The mechanical properties of fibreglass were determined through impact testing. Before starting the impact test, the thickness of the fabricated specimens was taken. After the thickness for each specimen was taken, the fabricated specimen was tested with low impact velocity for impact test. The mechanical properties of the fabricated specimens were tested by using Drop weight Tester (Test-rig machine), where the impactor was dropped freely from some height or distance. The obtained results were later analysed and compared between C-type and E-type of fibreglass.

In this project, four impact tests were done. The impact energy is in the range of 10 J to 40 J, in increments of 10J. Each impact energy velocity was used on three specimens with size 100 mm x 150 mm. Hence, for each type of glass fibre, 12 specimens were needed. Each specimen consists of 10 layers of fibreglass.

- 10 layers of glass fibre C 600 g/m2 = 12 specimens
- 10 layers of glass fibre E 600 g/m2 = 12 specimens
- Total specimens = 24 specimens for all type glass fibre.

The objectives for this experiment are stated below

i. To examine the impact force, impact energy, impact resistance, penetration behavior and effect of low impact loading corresponding to different energy and velocity of impact loading.
ii. To determine the mechanical properties of C-glass Type 600 g/m2 and E-glass Type 600 g/m2.

## II. EXPERIMENTAL PROCEDURE

**Fabrication.** Each type of fibreglass was cut to a size of 300 mm x 300 mm. The specimens were then tested according to Boeing Testing Standard, BSS 7260. For each type of fibreglass, at least 40 of 300 mm x 300 mm examples were cut. These four specimens, each with 10 layers, were cut into six small specimens with size 100 mm x 150 mm. This is called lay-up process. In this process, 10 layers of woven fibreglass were used tomake a specimen with size 300 mm x 300 mm. Each layer was glued together usingepoxy and hardener. This step was done using traditional and hand lay-up processes. We used hands coveredwith gloves to make a few specimens with size 300 mm x 300 mm, where epoxy andhardener was used at every layer of fibreglass. After the lay-up process ended, thespecimens were left for two days. After two days, the specimen was wrapped withplastic to avoid any damages on the surface.

Procedure:

i. The surface of the glass was cleaned by using a scope.
ii. The resin was rubbed on the plastic that was cut to size 300 mm x 300 mm.
iii. The plastic was placed on the glass.
iv. The epoxy and hardener were prepared with ratio 2:1, and stirred until thesolution became non-viscous.
v. The first layer of fibreglass was placed on the plastic, and the solution was pouredonto the fibreglass.
vi. Step 5 was repeated until all layers were 10 layers. At the last layer, plastic wasplaced and was closed by a glass with size 300 mm x 300 mm.
vii. Weight was placed on the glass to make sure the epoxy had been poured equally.

The prepreg layers that were cut to the required dimensions and orientations are laid on themold. Roller along with hand pressure are used to press the prepregs against the moldstarting form one corner of the prepreg and moving progressively toward the other [10].

**CNC Cutting.** In this step, all specimens were cut by machine CNC. The machine was used to cut sixsmall specimens of size 150 mm x 100 mm. Before the cutting process, the specimenwas held on each side to make the cutter follow the same line during cutting along aneven surface. This will ensure the small specimens all have the same dimensions.After all specimens were cut to size 150 mm x 150 mm, all the specimens werelabeled with a different code. Each type of fibreglass E 600 g/m2and C 600 g/m2was setup to be tested with different energy from 10 J to 40 J. Three specimens of each type willbe impacted by 10 J, another three specimens with 20 J, three specimens with 30 J andthe last three specimens will be impacted with 40 J.

**Impact Test.** In this phase, all specimens will be impacted by a striker, which has size 10 mm, with cylinder cap. The striker mass is 0.787 kg, while the drop mass is 8.892 kg. To complete the impact test, the drop weight testers was used extensively. The impactor was guided by a rail during free fall from a given height. The machine of impact was set for the trigger point and zero height position. The setting of this point required the operator to manually position the striker immediately above the required point of impact on the specimen then, using the trigger controls-mounted on the hand control pendant, position the velocity laser in relation to the velocity target. A sensor was used to activate the mechanical device and prevent multiple impacts after the impactor bounces back up. The machine's name is Imatek, IM10 Drop Weight Impact Tester. It provides higher accuracy, more accurate results, more reliability, and has a high level of safety. IM10 Drop Machine is highly versatile range of drop weight impact testers for performing a wide range of medium energy tests on materials, specimens and the end products of various geometry. This machine is the laboratory grade instrumentation and very rigid construction for highest accuracy test results. Guided mass system was used to ensure the impact geometry was correct throughout the test. IM10 Drop Machine is also highly accurate and reliable, and its very robust construction stands up to the rigours of dynamic testing to provide high reliability with a minimum of downtime [11].

## III. RESULTS AND DISCUSSIONS

**Thickness for Each Specimen**.

To measure the thickness of the specimens, a vernier calliper was used. Three measurements were taken, and the average was used for each case. The Tables below show the thicknesses of fibreglass type C600g/m$^2$ and E600g/m$^2$. From Table 1 below, the range of the average thickness is from 5.68 mm to 6.133 mm (0.453 mm different), while in Table 2 below, the range of the average from 4.873 mm to 5.073 mm (0.2 mm different). The 12 specimens for E-type have the constantly thickness than C-type.

**Table 1: Thickness of specimen type C 600 g/m$^2$**

| Specimen | 1(mm) | 2(mm) | 3(mm) | Average (mm) |
|---|---|---|---|---|
| 10L A1-C600 | 5.80 | 6.10 | 5.80 | 5.90 |
| 10L A2-C600 | 6.48 | 5.64 | 6.28 | 6.13 |
| 10L A3-C600 | 6.38 | 5.78 | 6.20 | 6.12 |
| 10L B1-C600 | 5.78 | 5.64 | 5.92 | 5.78 |
| 10L B2-C600 | 5.56 | 5.78 | 5.70 | 5.68 |
| 10L B3-C600 | 5.80 | 5.72 | 5.66 | 5.73 |
| 10L C1-C600 | 5.66 | 5.82 | 5.78 | 5.75 |
| 10L C2-C600 | 5.78 | 5.58 | 5.72 | 5.69 |
| 10L C3-C600 | 5.60 | 5.70 | 5.88 | 5.77 |
| 10L D1-C600 | 6.24 | 6.10 | 6.18 | 6.04 |
| 10L D2-C600 | 5.72 | 5.54 | 6.00 | 5.75 |
| 10L D3-C600 | 6.04 | 5.90 | 5.90 | 5.95 |

**Table 2: Thickness of specimen type E600 g/m$^2$**

| Specimen | 1(mm) | 2(mm) | 3(mm) | Average (mm) |
|---|---|---|---|---|
| 10L A1-E600 | 5.00 | 5.12 | 5.10 | 5.07 |
| 10L A2-E600 | 5.00 | 5.00 | 5.12 | 5.04 |
| 10L A3-E600 | 5.00 | 5.00 | 5.00 | 5.00 |
| 10L B1-E600 | 4.94 | 4.78 | 4.90 | 4.87 |
| 10L B2-E600 | 4.82 | 5.00 | 5.00 | 4.94 |
| 10L B3-E600 | 5.00 | 5.00 | 4.92 | 4.97 |
| 10L C1-E600 | 5.00 | 5.00 | 5.00 | 5.00 |
| 10L C2-E600 | 5.10 | 5.10 | 5.00 | 5.07 |
| 10L C3-E600 | 5.00 | 5.08 | 5.02 | 5.02 |
| 10L D1-E600 | 5.00 | 5.00 | 5.00 | 5.03 |
| 10L D2-E600 | 5.00 | 4.96 | 4.90 | 4.95 |
| 10L D3-E600 | 4.90 | 4.98 | 4.82 | 4.90 |

**The Result from Drop weight Tester**.

During impact test, energy was the input. From energy input, height or distance of the drop mass for each specimen can be calculated. And from height, the value of velocity will be shown at a computer connected to drop weight machine. Table3 and Table 4 below are an overall view of the result of the impact test:

**Table 3: Result of impact testing on C600 g/m$^2$**

| Energy (J) | Calculated | | Specimen | | | | |
|---|---|---|---|---|---|---|---|
| | Height (m) | Velocity (m/s) | Name | Initial Impact Energy (J) | Initial Impact Velocity (m/s) | Peak Energy (J) | Peak Force (kN) |
| 10 | 0.115 | 1.502 | 10L A1-C600 | 9.51 | 1.46 | 8.68 | 4.31 |
| | | | 10L A2-C600 | 9.42 | 1.46 | 9.04 | 4.80 |
| | | | 10L A3-C600 | 9.42 | 1.46 | 8.72 | 4.80 |
| | | | Average | 9.45 | 1.46 | 8.81 | 4.64 |
| 20 | 0.229 | 2.120 | 10L B1-C600 | 19.24 | 2.08 | 17.51 | 6.22 |
| | | | 10L B2-C600 | 19.27 | 2.08 | 18.18 | 5.45 |
| | | | 10L B3-C600 | 19.27 | 2.08 | 17.81 | 5.64 |
| | | | Average | 19.26 | 2.08 | 17.83 | 5.77 |
| 30 | 0.344 | 2.598 | 10L C1-C600 | 28.95 | 2.55 | 28.88 | 7.49 |
| | | | 10L C2-C600 | 28.94 | 2.55 | 28.28 | 7.35 |
| | | | 10L C3-C600 | 29.00 | 2.55 | 25.88 | 6.89 |
| | | | Average | 28.96 | 2.55 | 27.68 | 7.24 |
| 40 | 0.459 | 3.000 | 10L D1-C600 | 39.18 | 2.97 | 33.81 | 8.40 |
| | | | 10L D2-C600 | 39.25 | 2.97 | 37.4 | 6.97 |
| | | | 10L D3-C600 | 39.21 | 2.97 | 33.89 | 7.82 |
| | | | Average | 39.21 | 2.97 | 35.03 | 7.73 |

**Table 4: Result of impact testing on E600 g/m$^2$**

| Energy (J) | Calculated | | Specimen | | | | |
|---|---|---|---|---|---|---|---|
| | Height (m) | Velocity (m/s) | Name | Initial Impact Energy (J) | Initial Impact Velocity (m/s) | Peak Energy (J) | Peak Force (kN) |
| 10 | 0.115 | 1.502 | 10L A1-E600 | 9.41 | 1.45 | 9.66 | 4.65 |
| | | | 10L A2-E600 | 9.50 | 1.46 | 9.63 | 4.87 |
| | | | 10L A3-E600 | 9.48 | 1.46 | 9.37 | 4.90 |
| | | | Average | 9.46 | 1.46 | 9.55 | 4.81 |
| 20 | 0.229 | 2.120 | 10L B1-E600 | 19.16 | 2.08 | 19.38 | 6.50 |
| | | | 10L B2-E600 | 19.27 | 2.08 | 18.09 | 6.67 |
| | | | 10L B3-E600 | 19.22 | 2.08 | 18.05 | 6.84 |
| | | | Average | 19.22 | 2.08 | 18.51 | 6.67 |
| 30 | 0.344 | 2.598 | 10L C1-E600 | 29.01 | 2.55 | 28.61 | 8.21 |
| | | | 10L C2-E600 | 28.96 | 2.55 | 27.53 | 8.03 |
| | | | 10L C3-E600 | 29.89 | 2.55 | 26.42 | 8.32 |
| | | | Average | 28.95 | 2.55 | 27.52 | 8.19 |
| 40 | 0.459 | 3.000 | 10L D1-E600 | 39.22 | 2.97 | 33.74 | 9.18 |
| | | | 10L D2-E600 | 39.18 | 2.97 | 38.67 | 9.21 |
| | | | 10L D3-E600 | 39.18 | 2.97 | 38.40 | 9.71 |
| | | | Average | 39.19 | 2.97 | 36.94 | 9.37 |

**Combination Result of C-type and E-type**

This section was an overall result from impact test on specimens.

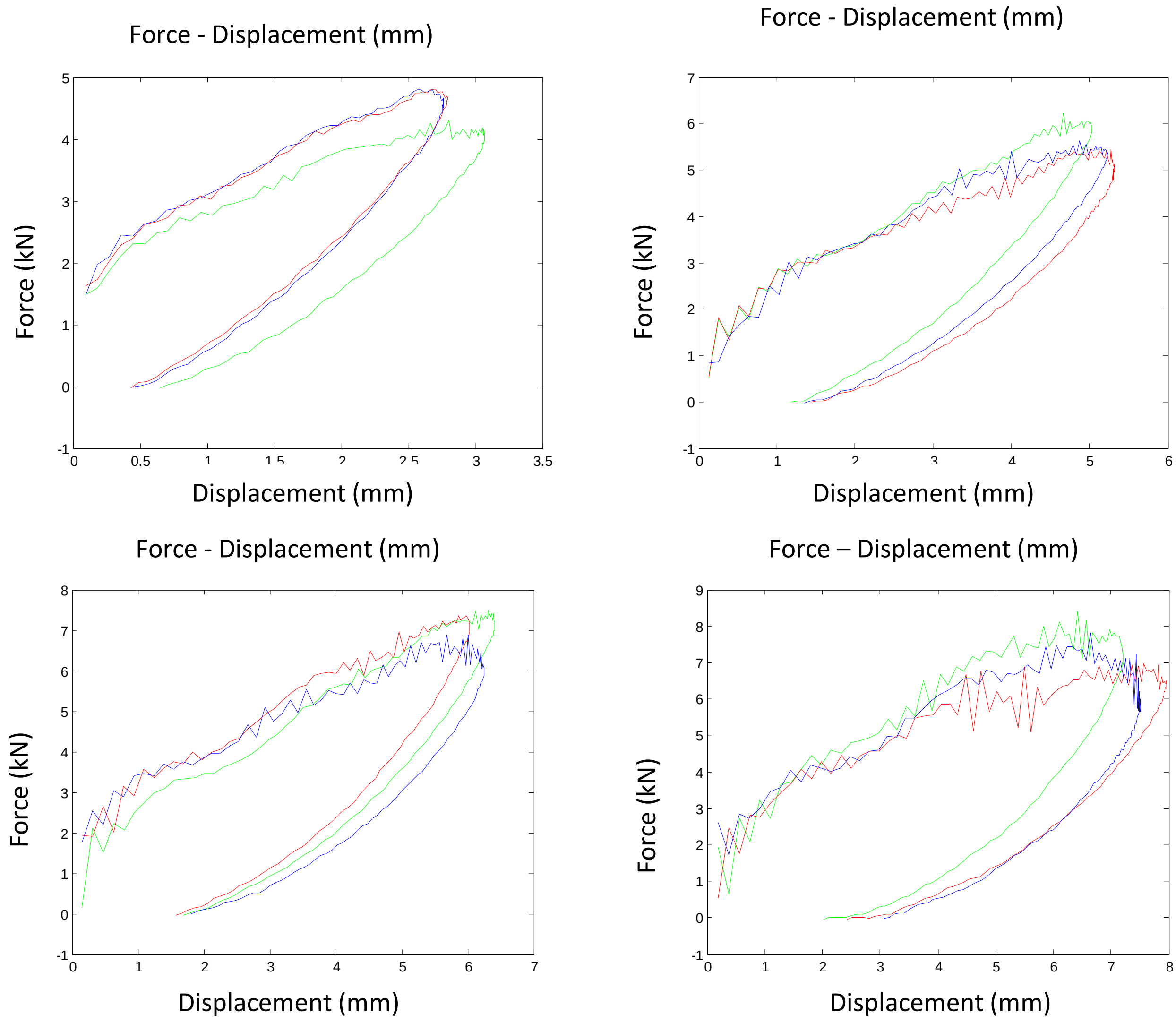
**Table 5: Full results from impact testing**

| Name | Velocity kph (km/h) | Peak Displacement (mm) | Peak acceleration (g) | End Energy (J) | End Displacement (mm) | Impact Energy (J) |
|---|---|---|---|---|---|---|
| 10L A1-C600 | 5.27 | 2.80 | 48.44 | 4.020 | 510.87 | 9.51 |
| 10L A2-C600 | 5.24 | 2.66 | 54.05 | 4.05 | 399.63 | 9.42 |
| 10L A3-C600 | 5.24 | 2.57 | 54.01 | 3.96 | 443.28 | 9.42 |
| 10L B1-C600 | 7.49 | 4.66 | 70.34 | 10.47 | -54.01 | 19.24 |
| 10L B2-C600 | 7.50 | 5.02 | 61.56 | 11.39 | 220.94 | 19.27 |
| 10L B3-C600 | 7.50 | 4.87 | 63.71 | 10.89 | 16.35 | 19.27 |
| 10L C1-C600 | 9.19 | 6.32 | 84.86 | 17.08 | -50.85 | 28.95 |
| 10L C2-C600 | 9.19 | 5.87 | 83.35 | 17.39 | -39.84 | 28.94 |
| 10L C3-C600 | 9.19 | 5.68 | 78.04 | 19.54 | -43.37 | 29.00 |
| 10L D1-C600 | 10.69 | 6.43 | 95.37 | 27.59 | -52.42 | 39.18 |
| 10L D2-C600 | 10.70 | 7.57 | 78.91 | 28.09 | -21.80 | 39.25 |
| 10L D3-C600 | 10.69 | 6.65 | 88.71 | 30.34 | -34.34 | 39.21 |
| 10L A1-E600 | 5.24 | 3.39 | 52.28 | 3.19 | 351.83 | 9.41 |
| 10L A2-E600 | 5.26 | 2.82 | 54.83 | 2.69 | 380.65 | 9.50 |
| 10L A3-E600 | 5.26 | 2.65 | 55.21 | 3.62 | 371.23 | 9.48 |
| 10L B1-E600 | 7.47 | 4.76 | 73.60 | 9.43 | -40.61 | 19.16 |
| 10L B2-E600 | 7.50 | 4.56 | 75.54 | 9.52 | -56.46 | 19.27 |
| 10L B3-E600 | 7.49 | 4.20 | 77.50 | 9.80 | -49.57 | 19.22 |
| 10L C1-E600 | 9.20 | 5.49 | 93.15 | 16.03 | -30.44 | 29.01 |
| 10L C2-E600 | 9.19 | 5.61 | 91.10 | 16.31 | -41.10 | 28.96 |
| 10L C3-E600 | 9.18 | 5.20 | 94.45 | 15.10 | -29.70 | 28.89 |
| 10L D1-E600 | 10.69 | 6.56 | 104.29 | 24.39 | -29.35 | 39.22 |
| 10L D2-E600 | 10.69 | 6.83 | 104.65 | 21.85 | -11.08 | 39.18 |
| 10L D3-E600 | 10.69 | 6.82 | 110.36 | 23.18 | -49.68 | 39.18 |

**Calculation of Energy absorbs**

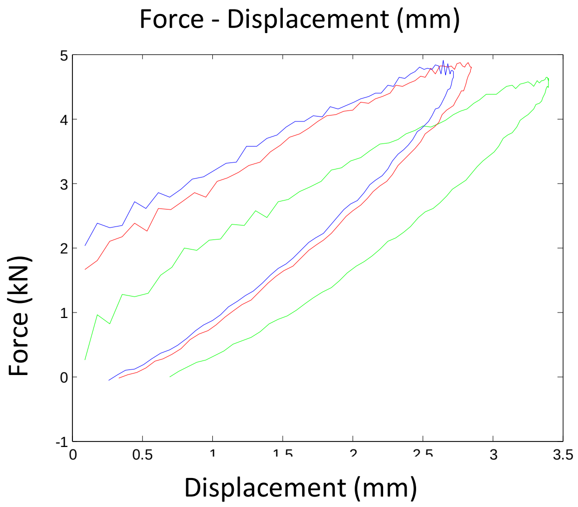
From the graph we can see Force against Displacement for each specimen. The area under the graph shows the results of the energy absorption. The graph of Force (KN) against Displacement (mm) represents the energy absorbed during the impact test. Once the mass impacted the specimen, the specimen absorbed some power or weight impact to show it has the capability to withstand to any impact with some power impact.

i. Green line represents the first test on first specimen.
ii. Red line represents a second specimen.
iii. Blue line represents a third specimen.

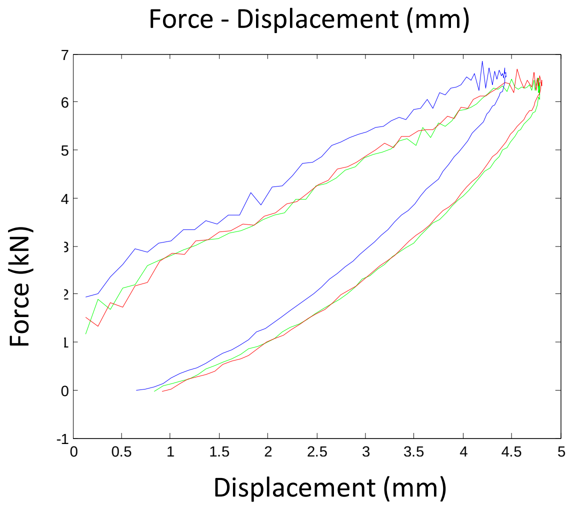



**(c) 30 J impact energy** **(d) 40 J impact energy**

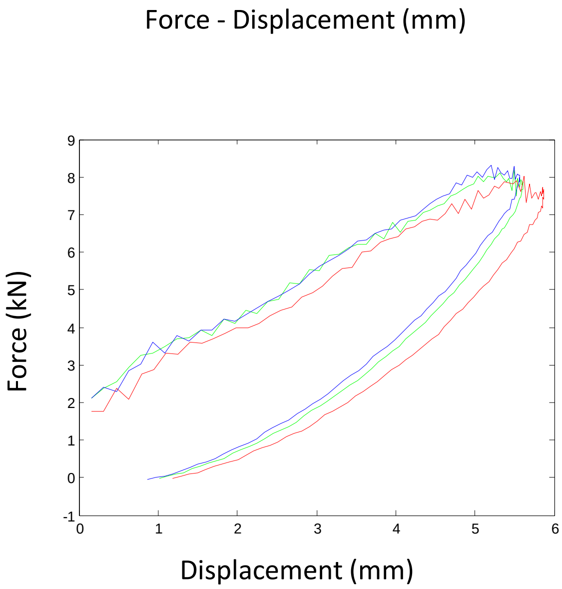
**Figure 1: Force-Displacement Graph for 10 layers of C600g/m²**



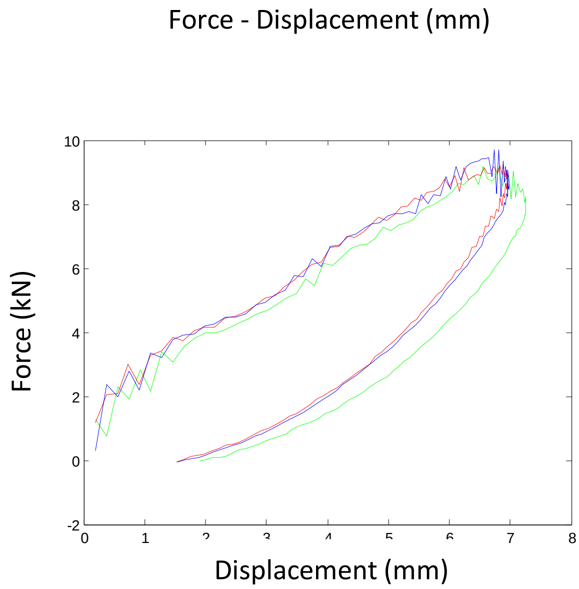

**(a) 10 J impact energy**




**(b) 20 J impact energy**




**(a) 30 J impact energy**




**(b) 40 J impact energy**

**Figure 2: Force-Displacement Graph for10 layers of E 600g/m$^2$**

By using Matlab software, the area under the graph of force and displacement is calculated and it represent energy absorb of specimen during impact by drop mass.

**Table 6: Energy absorb for each impact energy**

| Type | Energy (J) | Energy Absorb | | | Average |
|---|---|---|---|---|---|
| C 600 g/m$^2$ | 10 | 5.60 | 5.17 | 5.46 | 5.54 |
| | 20 | 11.20 | 12.91 | 12.28 | 12.13 |
| | 30 | 17.56 | 18.10 | 20.13 | 18.60 |
| | 40 | 28.13 | 28.60 | 30.87 | 29.20 |
| E 600 g/m$^2$ | 10 | 4.62 | 4.82 | 4.97 | 4.80 |
| | 20 | 10.20 | 10.23 | 10.15 | 10.19 |
| | 30 | 16.72 | 16.97 | 16.01 | 16.57 |
| | 40 | 25.51 | 23.54 | 24.07 | 24.38 |

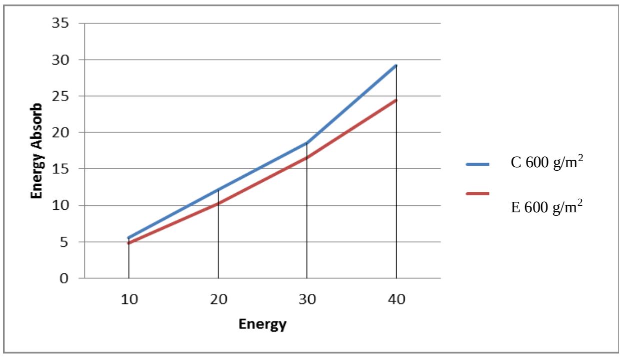



**Figure 3: The graph line between energy absorb- energy between each type of specimen**

The graph in Figure 3 represents the relationship between energy absorption and impact energy. From the graph, we can see that fibreglass type C has higher energy absorption compared to fibreglass type E. When the impact energy increases, the absorbed energy also increases.

When we compare the materials due to thickness, the fibreglass type E has lower thickness. So, the energy absorption should be higher compared to C-type fibreglass, but the results show opposite. This is because the E-type has been fabricated in smaller thickness, but also has great strength, which will reduce the absorption of energy.

**Variation of Maximum Peak Force**

**Table 7: Specimen materials with max peak force**

| Name | Velocity kph (km/h) | Initial velocity (m/s) | Peak force (kN) | Peak energy (J) | Impact Energy (J) |
|---|---|---|---|---|---|
| 10L A1-C600 | 5.27 | 1.50 | 4.31 | 8.68 | 9.51 |
| 10L A2-C600 | 5.24 | 1.50 | 4.80 | 9.04 | 9.42 |
| 10L A3-C600 | 5.24 | 1.50 | 4.80 | 8.72 | 9.42 |
| 10L B1-C600 | 7.49 | 2.10 | 6.22 | 17.51 | 19.24 |
| 10L B2-C600 | 7.50 | 2.10 | 5.45 | 18.18 | 19.27 |
| 10L B3-C600 | 7.50 | 2.10 | 5.64 | 17.81 | 19.27 |
| 10L C1-C600 | 9.19 | 2.60 | 7.49 | 28.88 | 28.95 |
| 10L C2-C600 | 9.19 | 2.60 | 7.35 | 28.28 | 28.94 |
| 10L C3-C600 | 9.19 | 2.60 | 6.89 | 25.88 | 29.00 |
| 10L D1-C600 | 10.69 | 3.00 | 8.40 | 33.81 | 39.18 |
| 10L D2-C600 | 10.70 | 3.00 | 6.97 | 37.40 | 39.25 |
| 10L D3-C600 | 10.69 | 3.00 | 7.82 | 33.89 | 39.21 |
| 10L A1-E600 | 5.24 | 1.50 | 4.65 | 9.66 | 9.41 |
| 10L A2-E600 | 5.26 | 1.50 | 4.87 | 9.63 | 9.50 |
| 10L A3-E600 | 5.26 | 1.50 | 4.90 | 9.37 | 9.48 |
| 10L B1-E600 | 7.47 | 2.10 | 6.50 | 19.38 | 19.16 |
| 10L B2-E600 | 7.50 | 2.10 | 6.67 | 18.09 | 19.27 |
| 10L B3-E600 | 7.49 | 2.10 | 6.84 | 18.05 | 19.22 |
| 10L C1-E600 | 9.20 | 2.60 | 8.21 | 28.61 | 29.01 |
| 10L C2-E600 | 9.19 | 2.60 | 8.03 | 27.53 | 28.96 |
| 10L C3-E600 | 9.18 | 2.60 | 8.32 | 26.42 | 28.89 |
| 10L D1-E600 | 10.69 | 3.00 | 9.18 | 33.74 | 39.22 |
| 10L D2-E600 | 10.69 | 3.00 | 9.21 | 38.67 | 39.18 |
| 10L D3-E600 | 10.69 | 3.00 | 9.71 | 38.40 | 39.18 |

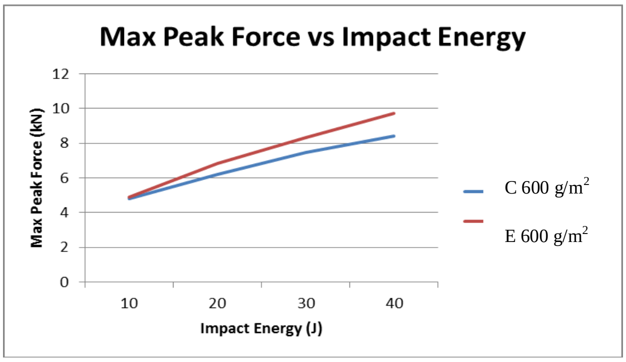



**Figure 4: Graph of max peak force-Impact energy**

Figure 4 shows the relationship between peak force and impact energy. The different types of fibreglass show different results, which was that the E600 g/m$^2$ type has the highest max peak force compared to the C600g/m$^2$. At lower impact energy, both types have the same value of maximum peak force, but this change when impact energy increases.

The different thickness between both types will influence the result of maximum peak force. Although both consist of 10 layers, the thickness of E type is smaller than C type. The lower thickness will result in higher force during impact testing.

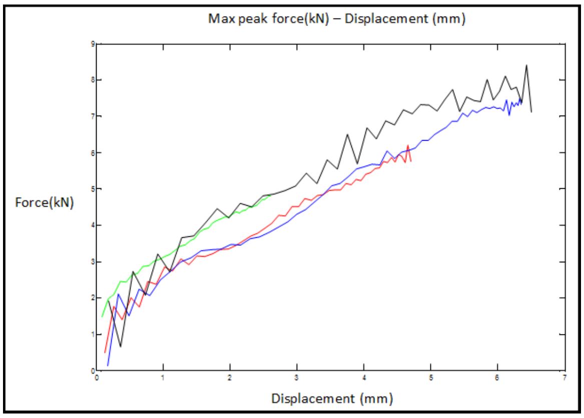



**Figure 5: Graph of max peak force-Displacement for C-type**

From Figure 5, we can see the relation of maximum peak force against displacement for C-type for all impact energy. The green line in the graph represents the force under impact of 10 J, the red line represents the force under impact of 20 J, the blue line represents the force under impact of 30 J while the black one represent the force under impact of 40 J.

For line green (10 J) and black (40 J), we can see the same points at first displacement. The red line (20 J) and blue (30 J), at initial displacement, show the same increment and points until it reaches maximum peak force.

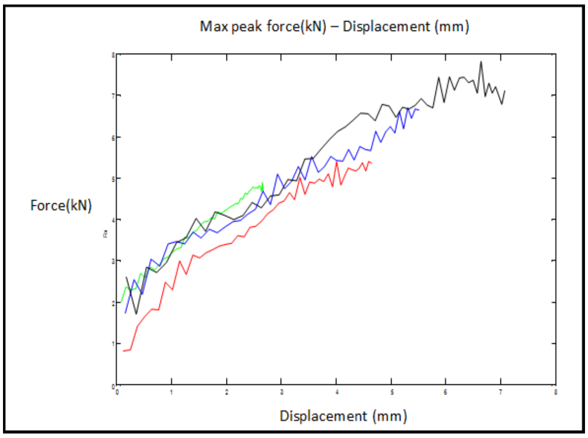



**Figure 6: Graph of max peak force-Displacement for E-type**

From Figure 6, we can see the relation of maximum peak force against displacement for C-type for all impact energy. The green line in the graph represent the force that under impact of 10 J, the red line represent the force under impact of 20 J, the blue line represent the force under impact of 30 J while the black one represent the force under impact of 40 J.

For line green (10 J), blue (30 J) and black (40 J), it shows the same points mostly at all incidences of displacement. However the red line (20 J), shows smaller force at displacement, until we reach maximum peak force.

**Variation of Energy and Time**

Energy-time curve for 10 layer C 600 g/m$^2$

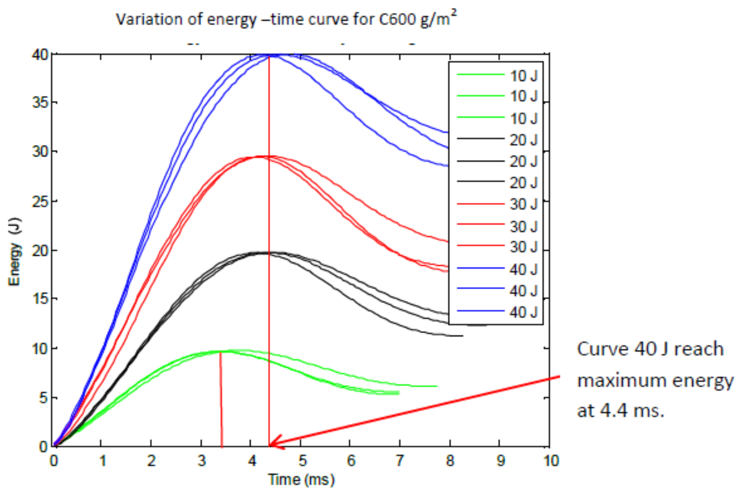



**Figure 7: Energy – Time curve for 10 layers C600 g/m$^2$**

The curve variation of energy and time show a smooth curve. The less impact energy at 10 J reach maximum at 3.4 ms. While for higher impact energy at 40 J, it reach maximum at 4.4ms.

Energy-time curve for 10 layers E600 g/m2

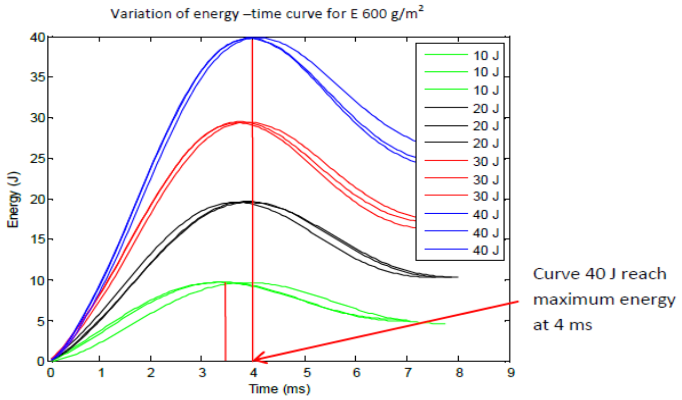



**Figure 8: Energy – Time curve for 10 layers E600 g/m$^2$**

The energy time curve shows the decay of force over time. The following graph shows the energy time curves from the first time of impact until the energy reaches zero again. From Figure 7 and Figure 8 above, the E-type shows faster decay than C-type at 4 ms. The different material have different decay times due to thickness and strength of structure. Time of travel of energy after impact is smaller at E-type compared to C-type material.

**Variation of Force and Time**

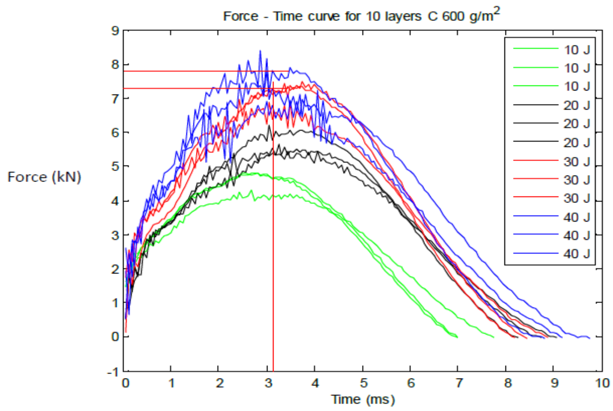



**Figure 9: Force–Time curve for 10 layers C 600 g/m$^2$**

Curves are not smooth and irregular, and reach maximum force at different time for each impact energy. The 40 J impact energy curve show, it reach maximum force with 7.9 kN at 3.1 ms.

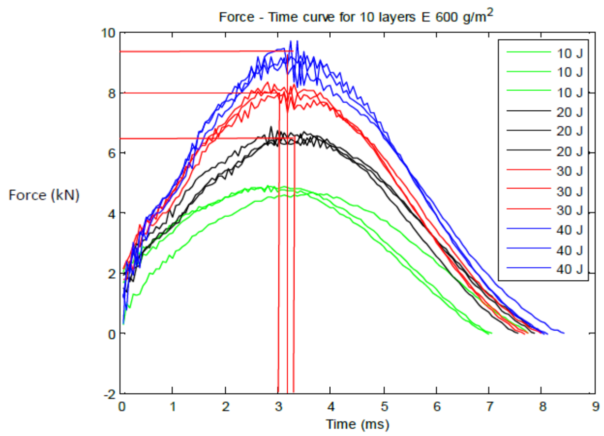



**Figure 10: Force– Time curve for 10 layers E600 g/m$^2$**

The curve of force against time in a Figure 10 show smooth curve and has maximum force around 3 ms to 3.5 ms. At curve 40 J impact energy, it reach maximum force at 9 kN.

Variation of force and time in a graph demonstrates the change of momentum due to impact on the specimen. From Matlab coordinates, the results of the momentum change are shown in the Table 8 and Table 9 below:

**Table 8: Change of momentum for 10 layers C 600 g/m$^2$**

| Specimen | Impact energy(J) | Change of the momentum (kgms$^{-1}$) |
|---|---|---|
| 10LA1-C600 | 10 | 21.43 |
| 10LA2-C600 | 10 | 22.08 |
| 10LA3-C600 | 10 | 21.76 |
| 10LB1-C600 | 20 | 31.13 |
| 10LB2-C600 | 20 | 29.90 |
| 10LB3-C600 | 20 | 30.41 |
| 10LC1-C600 | 30 | 37.63 |
| 10LC2-C600 | 30 | 37.14 |
| 10LC3-C600 | 30 | 35.81 |
| 10LD1-C600 | 40 | 41.12 |
| 10LD2-C600 | 40 | 40.97 |
| 10LD3-C600 | 40 | 39.30 |

**Table 9: Change of momentum for 10 layers E600 g/m$^2$**

| Specimen | Impact energy(J) | Change of the momentum (kgms$^{-1}$) |
|---|---|---|
| 10LA1-E600 | 10 | 22.87 |
| 10LA2-E600 | 10 | 22.56 |
| 10LA3-E600 | 10 | 22.26 |
| 10LB1-E600 | 20 | 31.64 |
| 10LB2-E600 | 20 | 31.83 |
| 10LB3-E600 | 20 | 31.64 |
| 10LC1-E600 | 30 | 37.94 |
| 10LC2-E600 | 30 | 37.88 |
| 10LC3-E600 | 30 | 38.27 |
| 10LD1-E600 | 40 | 42.69 |
| 10LD2-E600 | 40 | 43.68 |
| 10LD3-E600 | 40 | 43.42 |

Both Tables 8 and Table 9 show that the E-type material has higher change of momentum compared to the C-type. This can be related to the value of the energy absorbed. From the previous, the E-type material shows lower value of energy absorption compared to the C- type.

**Variation of Energy and Displacement**

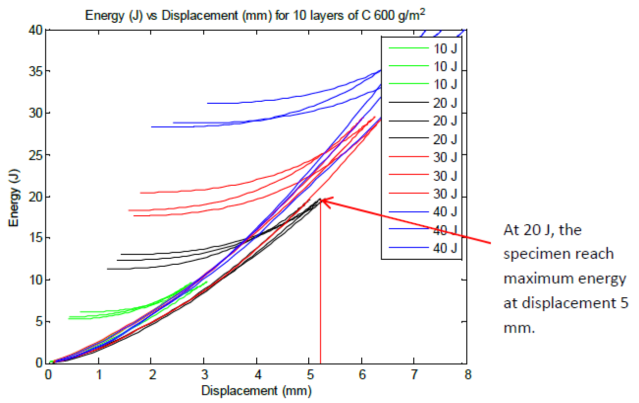



**Figure 11: Energy–Displacement curve for 10 layers C600 g/m$^2$**

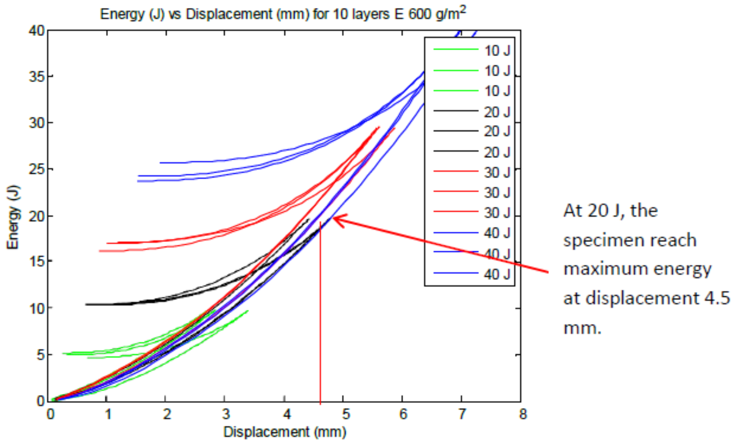



**Figure 12: Energy–Displacement curve for 10 layers E600 g/m$^2$ Variation of Displacement and Time**

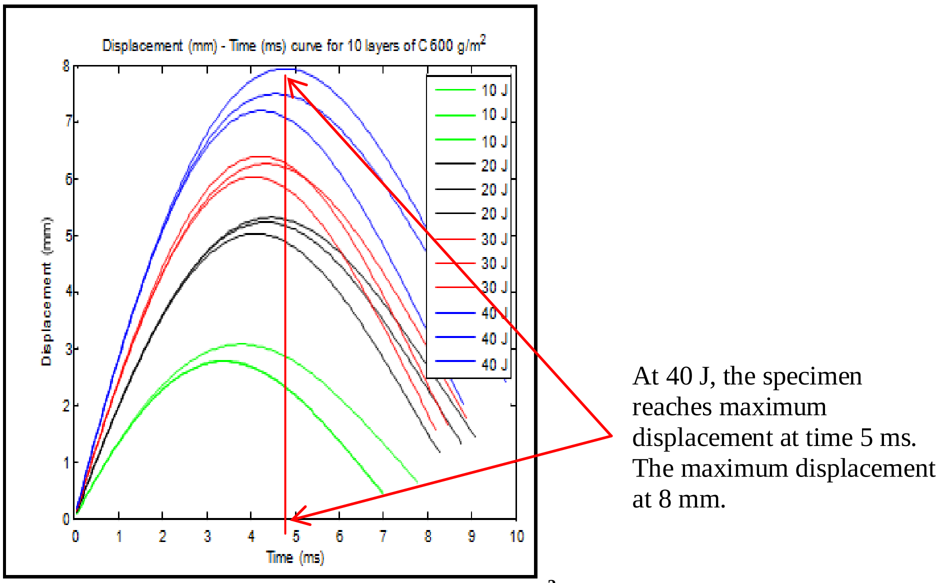



**Figure 13: Displacement-Time curve for 10 layers C600 g/m$^2$**

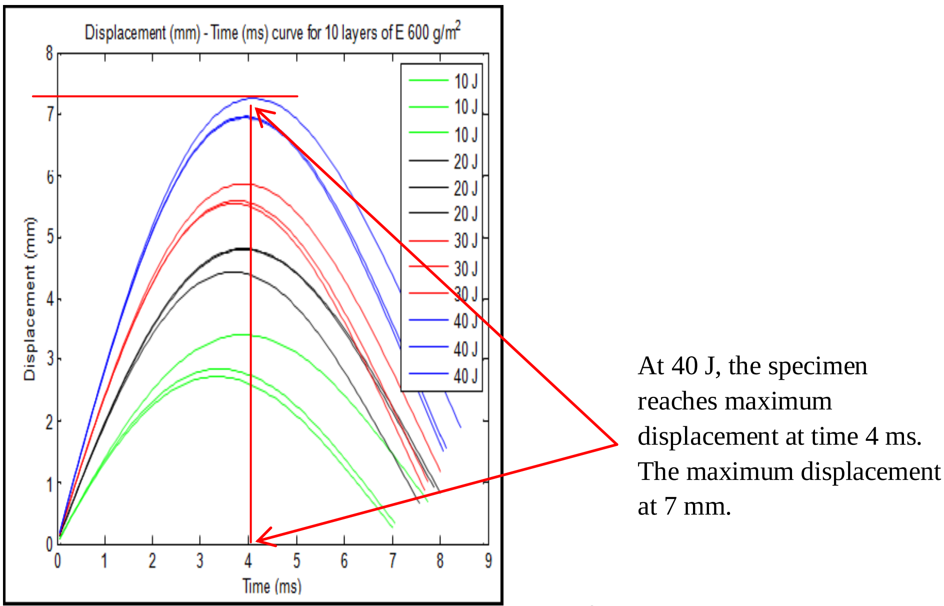



**Figure 14: Displacement-Time curve for 10 layers E600 g/m$^2$**

A displacement-time graph shows the positions of a moving object at different times. Figure 13 and Figure 14 show the displacement-time graph of a specimen after impact. From time t=0 to t=8 ms, the displacement of specimens keeps changing. When the impact energy increases, the displacement also increases.

The velocity of motion can be determined from the slope of the displacement-time graph. From the graph above, around t=0 to t=4 ms, the slope is positive, meaning that the velocity is both positive and different for each impact energy. From the C-type and E-type graph, we can see that the E-type material reaches maximum peak displacement faster than C-type. The E-type material has a lower peak displacement than C-type. On this displacement-time graph, the slope equals velocity, when two curves coincide, the two specimens have the same displacement at that time.

**Variation curve between Peak Force and Peak Energy with Impact Energy for both types of materials**

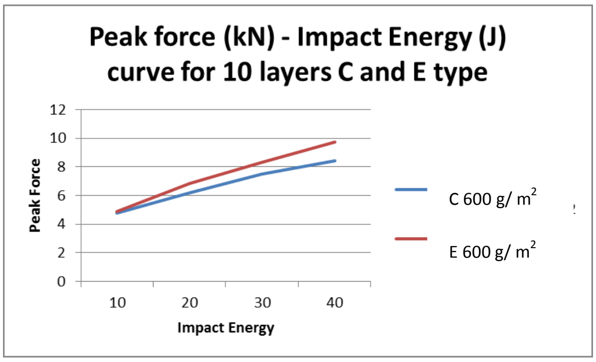



**Figure 15: Peak force– Impact energy curve for 10 layers C and E600 g/m$^2$**

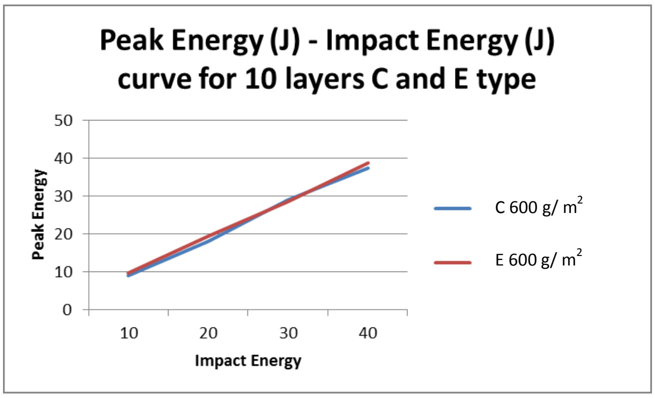



**Figure 16: Peak energy –Energy impact curve for10 layers C and E600 g/m$^2$**

The variation curve for Figure 15 shows the E-type materials have higher peak force compared to the C-type. At lower impact energy of 10J, both types have the same peak force, but when impact energy increases, the peak forces become different. Figure 16 shows the variation of curve between peak energy and impact energy. Both types have the same line and value of peak energy.

## IV. CONCLUSION

From this analysis, we can see that the different types of material will have different results at low velocity impact. The material properties will affect the stiffness of the structure and the contact stiffness will have a significant effect on the dynamic response of the structure. The thickness of the specimens will also influence the impact dynamics. The different impact energy will result in different damages and errors. The thickness for C-type and E-type are different. E-type has a smaller thickness compared to C-type fibreglass. From variation curve of force and displacement, the area under the graph represent energy absorb by specimen. The energy absorbed during impact testing shows the C-type of fibreglass is higher than E-glass. The maximum peak force of E-type material show higher results compare than C- type material. The fibreglass E 600 g/m2 shows excellent results compared to C600 g/m$^2$. It has high strength, good impact resistance, and a small damage area. Although it has thinner thickness, the absorption of energy is smaller because the structure restores it.

Although the C-type of fibreglass has higher thickness, it should have smaller absorption energy, but this is not the case. The E type fibreglass show it just need to do little work to resist and sustain the impact force, compare than C type that need to do more work. It can be seen at data energy absorb where C type fibreglass has higher absorption of impact to restore the pressure on specimen. The E type fibreglass has higher change of momentum mean it has higher residual strength to resist the impaction of drop mass. E600 $g/m^2$ has higher peak load, lower energy absorption, slower damage progression, and less severe failure mode. Different of thickness between two types of materials, this is because of errors or mistakes during the fabrication process. At earlier fabrication phases mistakes may have occurred, more bubbles and air traps forming at each layer of the fibreglass. By using hand lay-up or traditional technique, without vacuum bagging and hot bonder machine, so the success of fabrication process is mostly based on traditional hand lay-up technique. With most low velocity impacts, small amounts of damage are introduced in a small zone surrounding the impact point, and the dynamic properties of the structures are not affected by the presence of damage.

**ACKNOWLEDGEMENT**

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