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Design Improvements in the Inner Shell of a Motorbike Helmet Using Coconut Fiber Composite

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ABSTRACT

Composite materials have penetrated into the manufacturing of many items; from domestic commercialized products to automobile and aerospace industries. It has recently been introduced in the making of the outer shell of the motorbike helmet because of its lightweight, strength and high modulus-to-weight ratio properties. This research aims in design improvements in the inner shell of a motorbike helmet using coconut fiber composite. Modelling of the inner shell of the motorbike helmet is done by using CATIA software. Finite Element Analysis (FEA) is used in analysing its performance by using ANSYS software with the determined properties from a series of mechanical testing. The cost analysis of the coconut fiber composite inner shell of the helmet is conducted in this study with the comparison from the cheapest commercial motorbike helmet. The outcome from the mechanical testing shows that this coconut fiber composite is strong with some properties of elasticity in it. This material has shown to have better stress absorption compared to Expanded Polystyrene Styrofoam (EPS). Therefore, this composite can be used as an alternative material to EPS which is non-biodegradable.

Keywords: Coconut fiber, Biodegradable composite, Inner shell, Motorbike helmet, Finite element analysis.

1. Introduction

Motorbike helmet is a protective headgear used worldwide to protect the head of the rider from serious injuries if any accidents were to occur. Motorbike helmets come in many sizes, shapes and different weights based on the material used to produce it. Motorbike helmets are designed by many layers of materials; starting from the outer parts, to the inner parts of the helmet. The function of the layers is to absorb as many impacts as it can as to reduce the impact on the riders' head. Thus, the selection of the material to produce the helmet is important as to build the quality and comfortable helmet for motorcyclists.

Based on the Arai Helmet which is one of the leading manufacturers of helmet, they use Expanded Polystyrene Styrofoam (EPS) in their helmet. The role of the EPS is to absorb impact from the outer shell; they used to call it shock absorbing liner which protects the head against impacts by functioning as a safety cell which smoothly reduces the impact energy as EPS cells in the liner are compressed and destroyed piece-by-piece extending the time of impact (Inner Shell, 2013). EPS have been used in many absorption applications, one of them as protective gear (Fernandez et al., 2013). The EPS is mostly used as a linen material in motorcycle helmet. According to Afshari and Rajaai (2008), it is assumed that foam section which is EPS has the volumetric crushing behavior that makes it suitable for the inner shell.

The coconut fiber has a bright future in engineering, since it has been invented to be used as fibres for automobile parts; it is also being developed to be used as bed liners, floorboards, sun visors, inside door covers and other equipment for our daily use. Other than lightweight properties, it also easy and cheap to obtained in Malaysia. Thus, manufacturing industry should take this as the advantage of using coconut husk in producing other engineering product that meet the health and safety requirements.

Coconut fibres were investigated by many researchers for different purposes (Hashim, 2005; June et al., 2010; Torabizadeh & Fereidoon, 2013). Researchers have found that the range for density of coconut fiber is around 0.67-1.00 g/cm^3. The preliminary tests have shown that the coconut fiber composites can meet the specifications for industrial tests. The coconuts do not burn very well or give off toxic fumes, which is the key in passing the tests.

This research is carried out with the aim of using coconut fibers to make a composite in order to serve as the inner shell for the helmet as to reduce the usage of the EPS which is widely used in the making of the inner shell of the motorbike helmet. EPS is non-biodegradable and difficult to recycle in Malaysia since there are no recycling centres for the EPS. Nevertheless, coconut husk is biodegradable and more eco-friendly in nature. Cost analysis is also performed to analyse the cost of the inner shell coconut fiber composite.

2. Methodology

2.1. Preparing the EPS Samples

The outer shell of a used helmet was cut into two parts to obtain the Expanded Polystyrene Styrofoam (EPS) which is the inner shell of the helmet as shown in Fig.1. The helmet was cut with an electric grinder (BOSCH). The grinder was used to make the cutting process easier and faster and also to minimize the damage of the inner shell of the helmet during cutting. Then smaller sizes of samples were cut for density measurements.

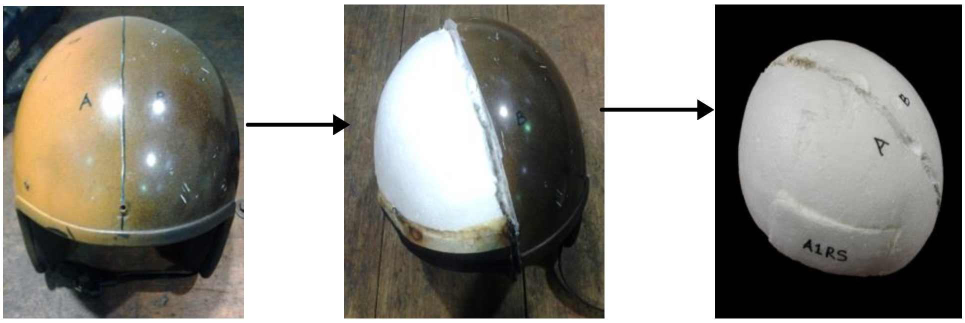


Fig-1. Sequence of removing the outer shell of the helmet

2.2. Preparing the Mould for Mechanical Testing

The samples made from polypropylene were taken as patterns for the tensile and flexural test. Maximum Mold Release Wax (Meguair's) was used as a release agent, and the aluminium foil was used as a working surface as shown in Fig. 2. The release agent was used to prevent the epoxy from getting stuck with the sample and working surface. The modeling clay was used to prevent the excess epoxy from overflowing from the working surface.

Fig-2. Sequence of preparing the mould for the samples for mechanical testing

The mixture of the epoxy resin and the hardener (Multifilla) in the ratio of 2:1 was then poured into the mould carefully. The mould was then left to dry and harden for 24 hours. Then, the samples of epoxy alone without coconut fiber and the coconut fiber composites were prepared by pouring it into the mould. The coconut fiber with a weight of 0.2 g was used for each sample. This was based on the volume fraction of coconut fiber in the samples to be 0.035% from the whole weight. Random orientation of the coconut fiber was used where the fibers were cut into short lengths of 10 mm. 3 pieces for each sample was prepared.

2.3. Mechanical Testing

Density measurements were taken for all the samples; EPS, epoxy alone and the coconut fiber composite using a Densimeter (MD-300S). Then, tensile test was performed using a 10 kN Universal Tensile Machine (LLOYD Instruments LR10K plus). Flexural test for the samples was done with the same Universal Tensile Machine used for tensile test. The maximum deflection of the flexural test was set at 35 mm because it is the maximum distance for the flexural test on the Universal Tensile Machine used.

2.4. Finite Element Analysis (FEA)

The inner shell of the motorbike helmet was drawn using CATIA software based on the dimensions of the existing helmets available. Then, this diagram was used inside ANSYS Mechanical that was generated in Workbench ANSYS, and simulated in ANSYS Mechanical APDL. The helmet was analysed for 500 N and 1000 N force on the targeted area on the helmet. The analysis was then compared between the EPS and the coconut fiber composite.

2.5. Micro Structural Analysis

Sample of the coconut fiber composite was used for the micro structural analysis using Scanning Electron Microscopy (SEM) (JEOL-JSM 5600). The sample was placed inside a resin and polished (Metapol-2 polisher). The sample was coated prior to taking the SEM images using JEOL JFC-1600 Auto Fine Coater Machine.

3. Results and Discussion

3.1. Mechanical Testing

Density measurements for the EPS and the coconut fiber composites were found to be similar; 0.8 g/cm^3 and 0.798 g/cm^3 respectively. The density of the coconut fiber used was around 0.61 g/cm^3. This explains why the density of the composite itself is low. The results for the tensile and flexural test are shown in Fig. 3. The tensile strength for the epoxy alone was only 34.91 MPa while with the addition of the coconut fiber, the tensile strength increased to 44.75 MPa. There has been an increment in tensile strength by 28.2%. Flexural strength on the other hand, has increased from 16.63 MPa to 17.76 MPa with the addition of coconut fiber. This is only a small increment (6.8%), but it shows that the composite is more ductile and has enhanced elasticity characteristic into it.

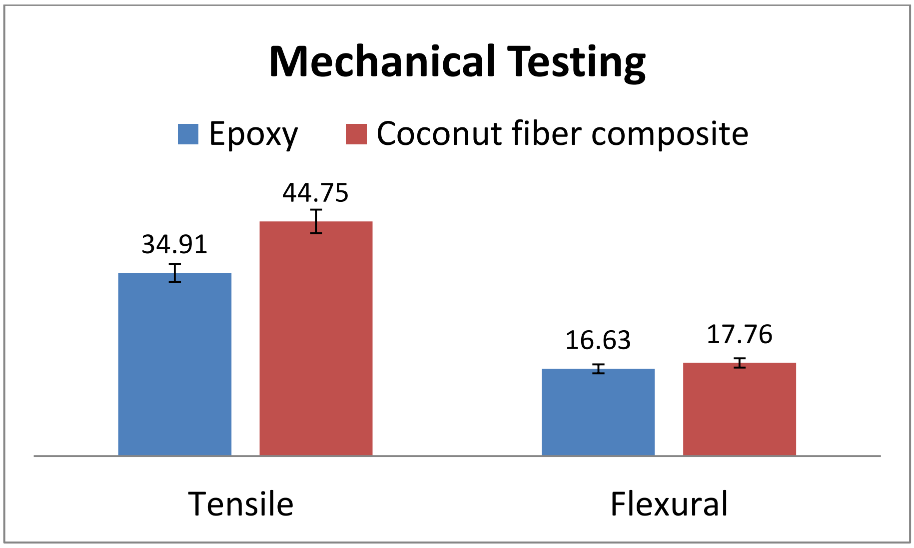


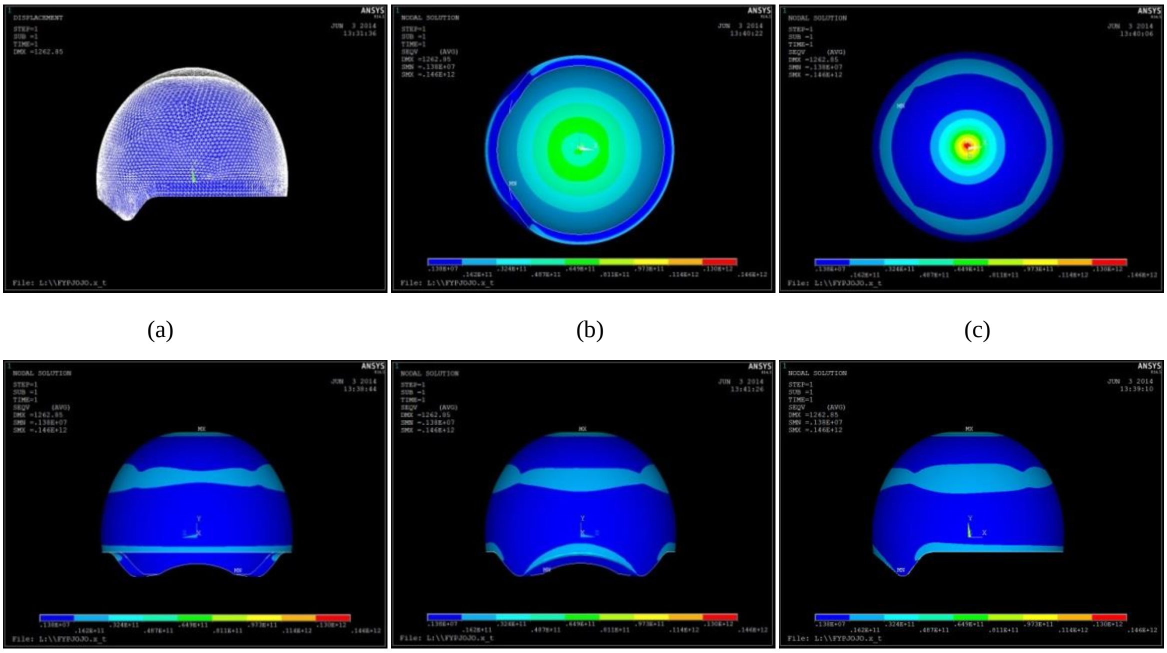
Fig-3. Results of Tensile and Flexural Strength Testing for the Epoxy and Coconut Fiber

3.2. Finite Element Analysis

The same analysis was performed for the EPS and coconut composite fibre material for the inner shell of the motorbike helmet. Both materials were analysed with 500 N and 1000 N force at the top part of the helmet; it is because the top part of the helmet can represent the differences of the both analysis (composite and EPS) and the stress distribution can be clearly seen in Figs 4-7. Fig. 4 shows that the inner shell of the helmet deflected after 500 N of force being applied on top of it, the maximum deformation of it was recorded at 1262.85 mm while the maximum deformation for 1000 N is 2519.16 mm. This value indicates the deformation of the whole shape in volume; it is not the displacement in length.

The Fig. 4 (b) – (f) and Fig. 5 (b) - (f) show the Von Misses stress distribution on the different part of the EPS inner shell for the 500 N and 1000 N respectively. The stress distribution on the EPS is clearly different. It can be clearly seen that for the 500 N and 1000 N, different readings of minimum and maximum stress are plotted on the EPS inner shell. For the 500 N, the minimum result value plotted is

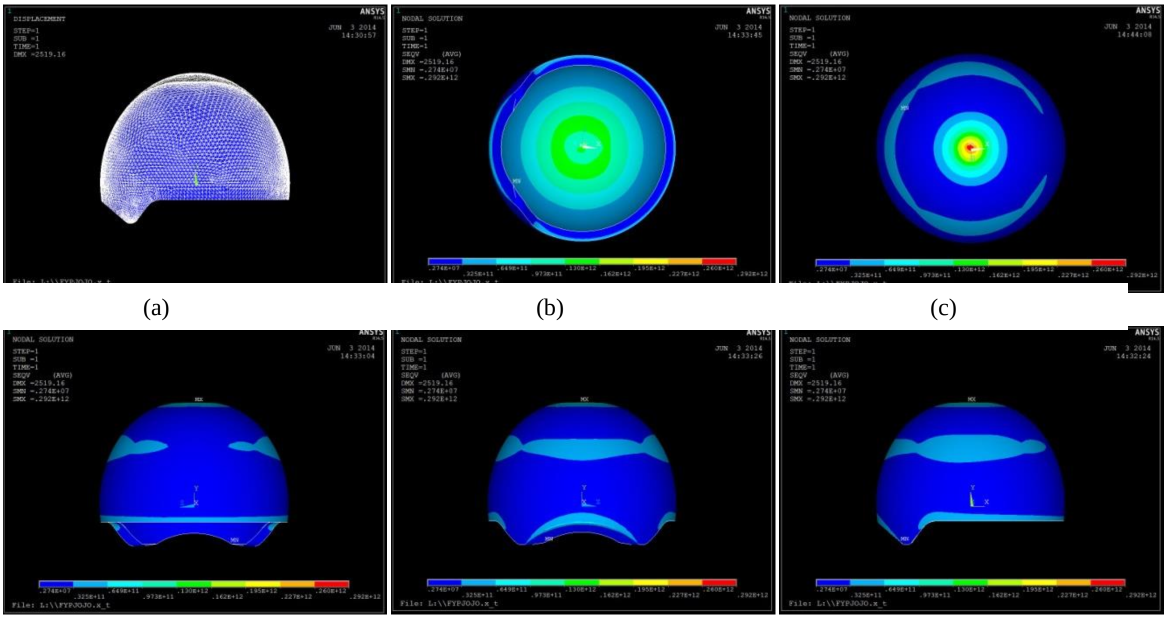
1.38 MPa and the maximum result value plotted is about 146 GPa. Meanwhile, stress distribution for the 1000 N resulted in a maximum value of about 2.74 MPa, while the minimum result plotted is 292 GPa. The value plotted on the EPS inner shell between these two forces is clearly different.



(a) (b) (c)

(d) (e) (f)

Fig.4. Von Misses stress distribution for the 500 N load for the EPS (a) undeformed (b) bottom view (c) top view (d) front view (e) rear view (f) side view



(a) (b) (c)

(d) (e) (f)

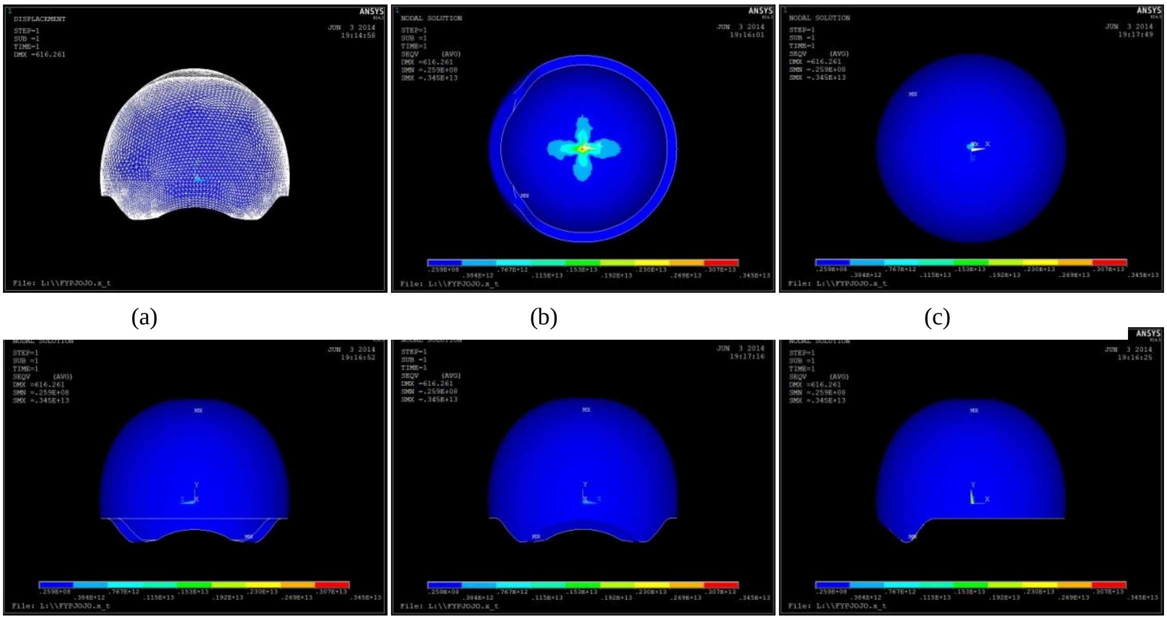
Fig-5. Von Misses stress distribution for the 1000 N load for the EPS (a) undeformed (b) bottom view (c) top view (d) front view (e) rear view (f) side view

Fig. 4(d) and Fig. 5(d) show the stress distribution which can be seen clearly. They represent the front view of the inner shell of the helmet. For the 500 N load, the stress distribution continues from the left side to the right side while for the 1000 N load, the stress distribution disconnected on the front side of the inner shell.

The composite material behaviour is totally different with the EPS since it is the orthotropic material models which consist of many parameters to be determined and set it before running the programme for analysis.

The composite material is totally different in terms of the stress distribution shape on the inner shell. The shape that produced from the composite analysis turned out like a shape of a four leaf clover plant (Fig. 6 (b)). The deflection of the composite inner shell with 500 N is recorded as 616.26 while for the 1000 N it is recorded as 1232.88. It can be seen that the value of the deflection is twice for the 1000 N force (Fig. 7(b)).

The minimum stress value plotted on the inner shell is 25.9 MPa while the maximum stress value plotted on the inner shell is 3450 GPa. For the 1000 N of force, the value of the minimum stress value is 0.62 MPa and the maximum stress value is 6740 GPa. The stress distributions are parallel with each other, where it cannot be seen clearly where the different is. The minimum and maximum nodal point are also the same.



(a) (b) (c)

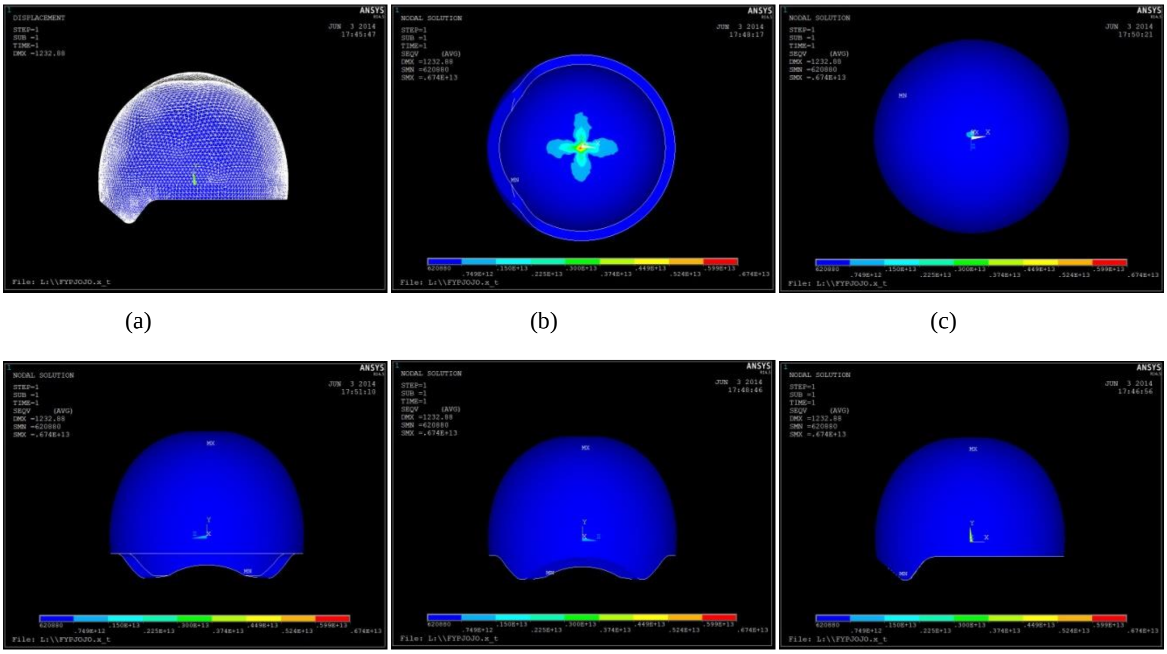
(d) (e) (f)

Fig-6. Von Misses stress distribution for the 500 N load for the coconut fiber composite
(a) undeformed (b) bottom view (c) top view (d) front view (e) rear view (f) side view

The result for the DMX which is the displacement of deformed material for both materials can be seen in the Fig. 4 (b), Fig.5 (b), Fig. 6 (b) and Fig. 7(b). The DMX result in this analysis recorded was so high in displacement which is 1262.85 mm, 2519.16 mm, 616.26 mm, 1232.88 mm which are basically volumetric displacement sin the whole shape and not linear length. The DMX here in ANSYS means relative displacement where it determining the change in distances as a function of time between points A and B; in example the plane surface of a body during dynamic test (Baker and Farrar, 1992).

It can be seen on the distribution of the Von Misses stress on the inner shell of the helmet, for the composite material, the stress distribution is lower in term of volume compared to the EPS material stress distribution. Besides that, the EPS material stress distribution also can be seen in Fig. 4.7 where it recorded large area of red coloured stress that represents maximum stress applied on it. It is in contrast with the stress distribution of the composite material where the red coloured area is small. Based on the EPS result, it is also can be seen where the force affected all area of the helmet, while composite result, showed that it only affect the part where the forces are applied on it.

Based on the result of the analysis, it can be said that the composite material has the advantage. It is because; the value of the DMX for the composite recorded at a lower value compared to the EPS DMX. This can be clearly seen that the displacement area of the composite DMX deformed is very small in height. The stress distribution for the composite material on the inner shell also resulted in very minimal red coloured stress area; which is the maximum stress compared to the EPS material which the stress distribution covered all area of the inner shell and leave little part of blue coloured stress area; which is the minimal stress applied on it. These data represent the nodal number where one point on the material bears minimal or maximum stress from the force applied.



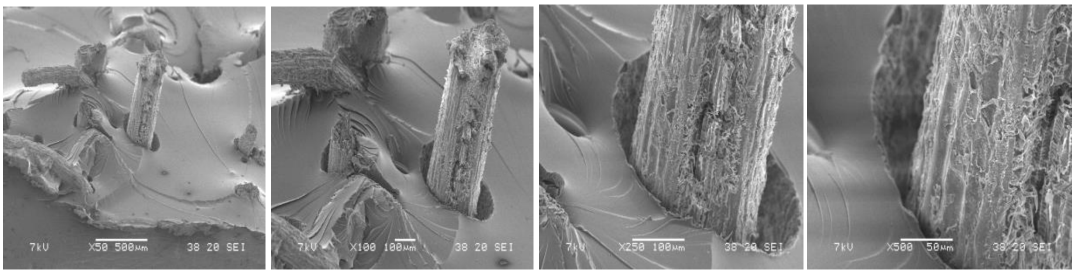
(a) (b) (c)

(d) (e) (f)

Fig-7. Von Misses stress distribution for the 1000 N load for the coconut fiber composite (a) undeformed (b) bottom view (c) top view (d) front view (e) rear view (f) side view

3.3. Micro Structural Analysis

Fig. 8 shows the micro image of the sample from tensile test experiment. It is a part which was obtained from the point where the sample is broken. It clearly shows that the sample has a void between the fiber and the epoxy. The mixture of these two materials are hand made and may have the possibility to have generated the void between the fibre and the epoxy.



(a) (b) (c) (d)

Fig-8.SEM images of the coconut fiber composite

4. Conclusion

The composite material which is made from coconut fiber is biodegradable, stronger and more ductile than the EPS material. The weight of the coconut fiber composite is similar compared to the EPS. Furthermore, it has similar shock and stress absorbent characteristics as the EPS. Thus, this composite can be used as an alternative material to build the inner shell of the helmet because of its properties.

4. Acknowledgement

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