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Drop-Weight Impact Test for Measuring the Damage Resistance of Aero Helmets

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Abstract – *This paper represents the performance of aero helmets in a drop-weight impact testing. The potential energy to be used was defined as mass and drop height is to be 4.94 ft-lb (6.7J) multiplied by the specimen thickness. Helmet standards require helmets to be designed only to survive a simple drop test onto an anvil. Two helmets being tested was attached to the test rig in the particular desired impact orientation. The main advantages of this process are the object is attached to the test rig during impact will provides more realistic drop-weight impact and accurate data. Data characterizing from the impact test was collected and analyzed to evaluate the material properties of kenaf and flax. By comparing the peak deformation and absorbed energy, the kenaf aero helmet show a better performance in absorbing energy with less deformation than flax aero helmet.*

Keywords: Bicycle Helmets, Impact Testing, Drop-Weight

1.0 INTRODUCTION

Susceptibility to damage from concentrated out-of-plane impact forces is one of the major design concerns of structures made of advanced composite laminates. Knowledge of the damage resistance properties of a laminated composite plate is useful for product development and material selection. First aim was to establish quantitatively the effects of stacking sequence, fiber surface treatment, variations in fiber volume fraction and processing and environmental variables on the damage resistance of a particular composite laminate to a concentrated drop-weight impact force or energy [1].

Second aim was to compare quantitatively the relative values of the damage resistance parameters for composite materials with different constituents. The damage response parameters can include dent depth, damage dimensions, and through-thickness locations, $F1$, $Fmax$, $E1$ and $Emax$, as well as the force versus time curve. The properties obtained using this test method can provide guidance in regard to the anticipated damage resistance capability of composite structures of similar material, thickness and stacking sequence. However, it must be understood that the damage resistance of a composite structure is highly dependent upon several factors including geometry, thickness, stiffness, mass and support conditions.

Significant differences in the relationships between impact force/energy and the resultant damage state can result due to differences in these parameters. For example, properties

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obtained using this test method would more likely reflect the damage resistance characteristics of an unstiffened monolithic skin or web than that of a skin attached to substructure which resists out-of-plane deformation. Similarly, test specimen properties would be expected to be similar to those of a panel with equivalent length and width dimensions, in comparison to those of a panel significantly larger than the test specimen, which tends to divert a greater proportion of the impact energy into elastic deformation.

1.1 Helmet Design

Bicycle helmet design has changed markedly since 1990 [2-5]. Current helmets have more ventilation holes, are thicker at the rear, and sometimes have a non-smooth external profile. The helmets subjected to oblique impact tests in 2002 [6] had less than ten, large ventilation holes. By 2005, the number of ventilation holes has increased, and their size decreased. Since helmet is a compromise between aerodynamics and ventilation, and since aerodynamics is difficult to test, ventilation perhaps becomes more important than the aerodynamics factor [7-9].

1.2 Testing of Helmet

In this test, 2 different helmets with different material which is kenaf and flax were tested and the specification is shown in table 1. Kenaf Aerohelmet and Flax Aerohelmet is a newly design helmet with new bio-composite material. The top view and side view of the helmet design is shown figure 1 and figure 2. The main purpose for this testing is to compare the data for the newly design material helmet. Every helmet is equipped with different interior pads and foam, attached by Velcro at several sites inside the liner, to bridge the gap with the head. Table 1 gives the specifications of the helmets tested in this experiment.

A drop-weight impact test is performed at the helmet shell. Damage is imparted through out-of-plane, concentrated impact (perpendicular to the plane of the laminated plate) using a drop weight with a hemispherical striker tip. The damage resistance is quantified in terms of the resulting size and type of damage in the specimen. The damage response is a function of the test configuration; comparisons cannot be made between materials unless identical test configurations, test conditions, and so forth are used. Optional procedures for recording impact velocity and applied contact force versus time history data are provided.

Preferred damage states resulting from the impact are located in the center of the helmet, sufficiently far from the helmet edges such that the local states of stress at the edges and at the impact location do not interact during the damage formation event.

Table 1 : Helmet Specification

Model	**Flax Aerohelmet**	**Kenaf Aerohelmet**
Material	Flax	Kenaf
Total Mass	0.315 kg	0.342 kg
Length	39.5 cm	41.5 cm
Shell Thickness	0.1 cm	0.05 cm
Padding Thickness	2.0 cm	2.0 cm

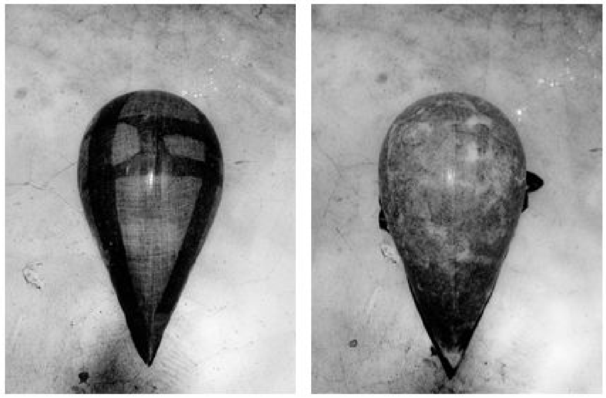

Figure 1: Top view of Helmet Design a) Flax b) Kenaf

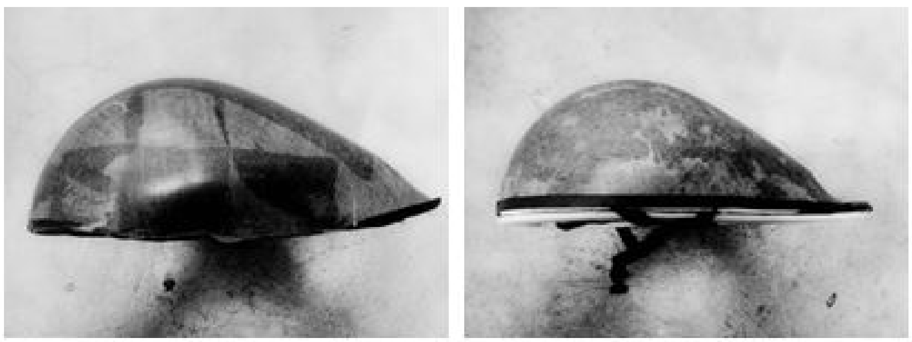

Figure 2: Side View of Helmet Design a) Flax b) Kenaf

2.0 METHODOLOGY

2.1 Low Velocity Impact Testing

This test method determines the damage resistance of a multidirectional composite laminated plate subjected to a drop-weight impact event. The test equipment utilized in this work meets the requirements of the American Society for Testing and Materials outlined in the ASTM D7136 [1]. The helmet is subjected to an out-of-plane concentrated impact (perpendicular to the plane of the laminate) using a drop-weight device with a hemispherical striker tip with a diameter of 16 mm and a hardness of 60 HRC. The incident impact energy corresponds to the potential energy of the drop-weight, defined by the mass (2240 gr) and drop height of the impactor. The damage resistance is quantified in terms of the resulting size and type of damage in the specimen.

The helmet was placed in the rigid support fixture, centered relative to the cut-out and was secured in place using the test rig for helmet, in order to prevent the helmet from rebounding during impact event. Figure 3 shows the drop-weight impact-testing device utilized. The impact device includes a rigid base, a cylindrical drop-weight impactor and a cylindrical guide mechanism. A rebound catcher is used to stop the impactor during its second descent.

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For the testing of plaques that are less than 1 inch (2.42 mm) thick we have optional lightweight crossheads to meet those lower impact energies. To prevent a secondary impact of the falling weight onto the composite plate we employ our anti - rebound device. For larger composite products we offer larger, extended support tables. To fully protect the operator from flying debris we include and offer a selection of interlocked safety enclosures.

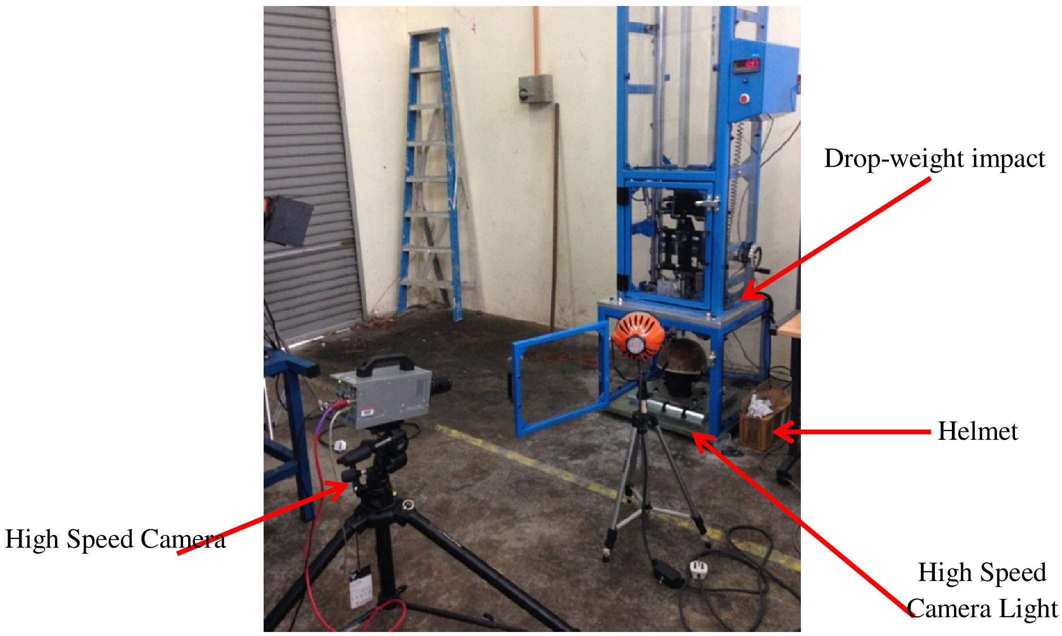

Figure 3 : Drop-Weight Impact Device

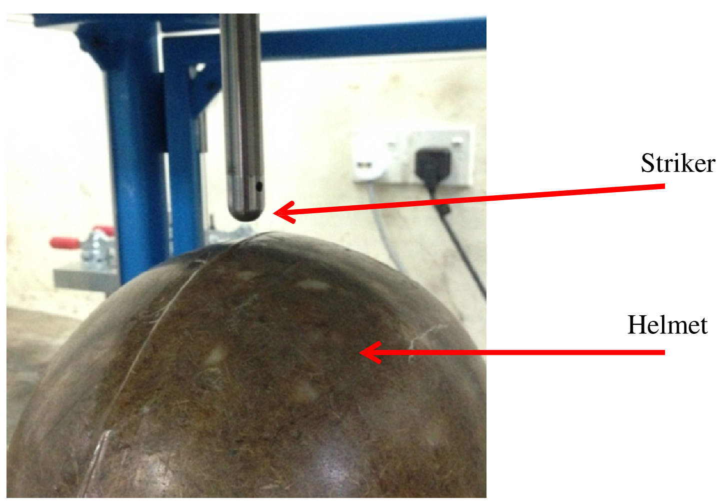

Figure 4 : Impactor Striker and Helmet Shell

3.0 RESULTS AND DISCUSSIONS

Though the test defined in the standard calls for visual inspection and measurements after impact to determine if the specimen has failed, by including instrumentation with our Data

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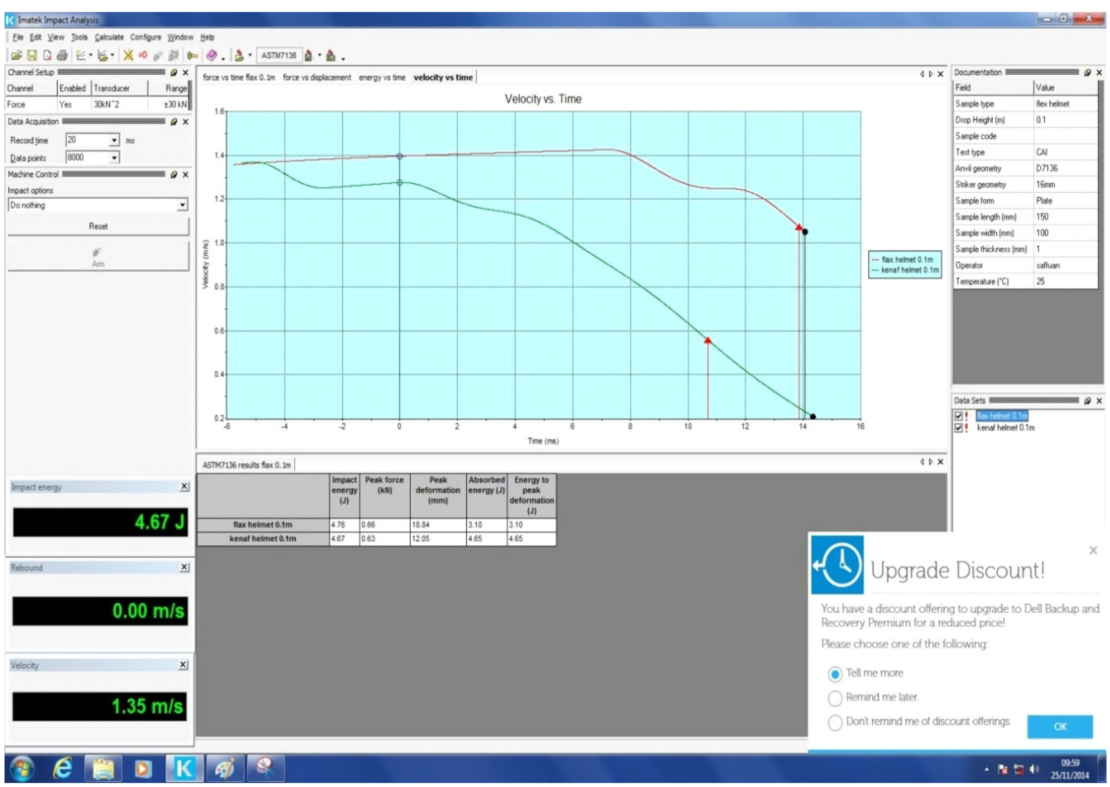
Acquisition System complete with Visual Impact and a strain gauged tup failure points/modes that may remain hidden under normal test conditions can be found. One piece of information that may not be found without the use of instrumentation is the first crack or incipient damage point.

The impact device may be instrumented to measure the velocity of the impactor at a given point before impact, such that the impact velocity may be calculated. Commonly, such systems use a double-pronged flag, which obstruct a light beam between a photo-diode emitter and detector. The leading edges of the flag prongs are typically separated by 3.0 to 10.0 mm [0.125 to 0.400 in.]. The flag prongs shall be positioned such that velocity measurement is completed between 3 to 6 mm [0.13 to 0.25 in.] vertically above the surface of the specimen. The impact velocity is calculated using the measured time the light beam is obstructed by each prong, as well as the time that an impact force is first detected. Velocity measurement shall be accurate to within 5 mm/s [0.20 in./s]. Table 2 gives the result for drop-weight impact test for Flax Aerohelmet and Kenaf Aerohelmet.

Table 2: Data from Impact Test.

	Impact energy (J)	Peak force (kN)	Peak deformation (mm)	Absorbed energy (J)	Energy to peak deformation (J)
Flax Aerohelmet	4.76	0.66	18.84	3.10	3.10
Kenaf Aerohelmet	4.67	0.63	12.05	4.65	4.65



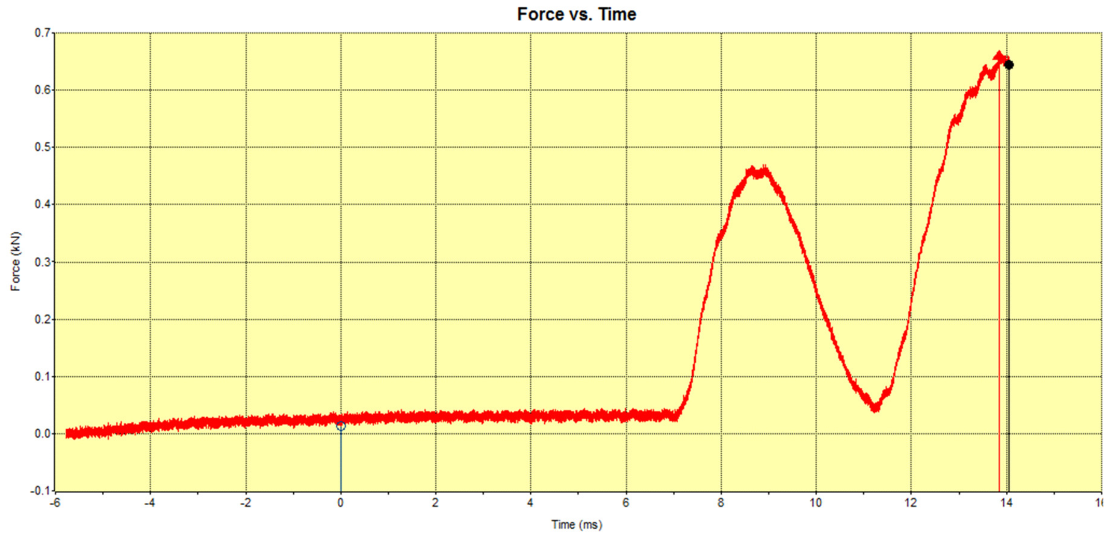


Figure 6 : Force vs. Time for Flax Helmet

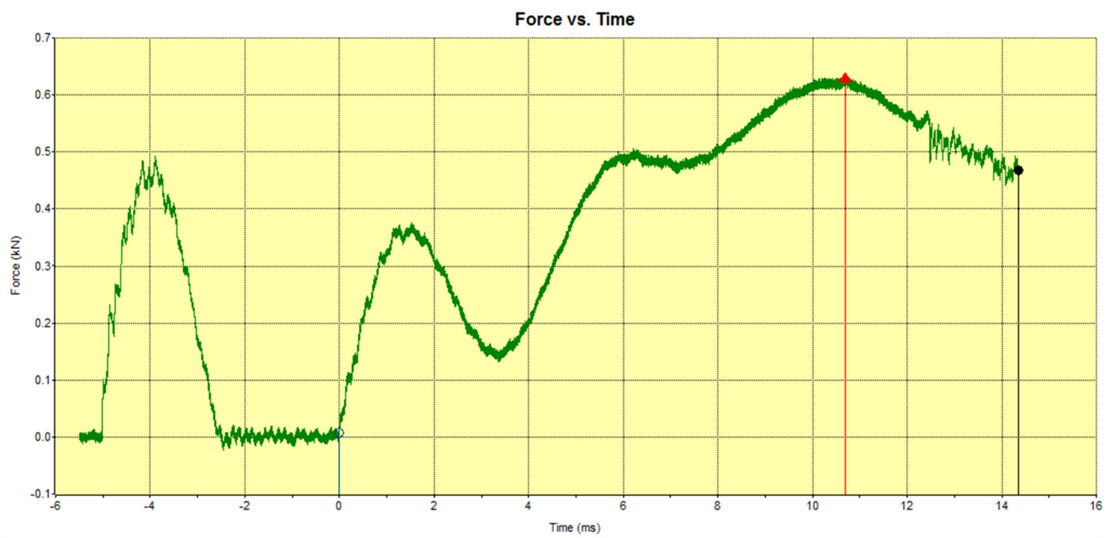


Figure 7: Force vs. Time for Kenaf Helmet

Figure 10 shows the peak deformation for flax aerohelmet and kenaf aerohelmet. For flax aerohelmet, it has shown 18.84 mm deformation after the impact. Meanwhile, kenaf aerohelmet has shown 12.05 mm of deformation. By comparing both of the material, flax has deformed more than kenaf and show the flexibility deformation of the material. The less deformation by kenaf shown the strength of the material even though the thickness of the kenaf aerohelmet shell was less than flax aerohelmet shell.

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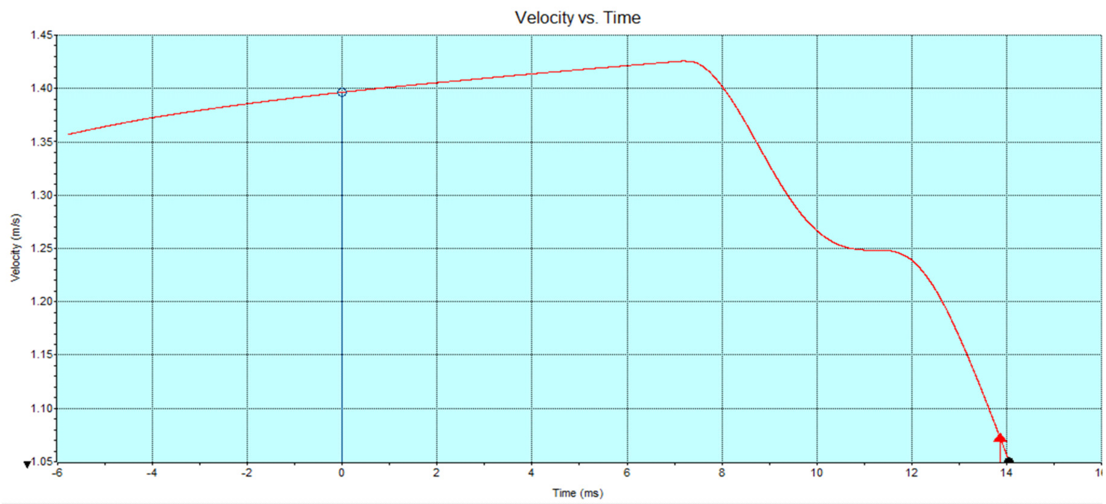

Figure 8 : Velocity vs. Time for Flax Helmet

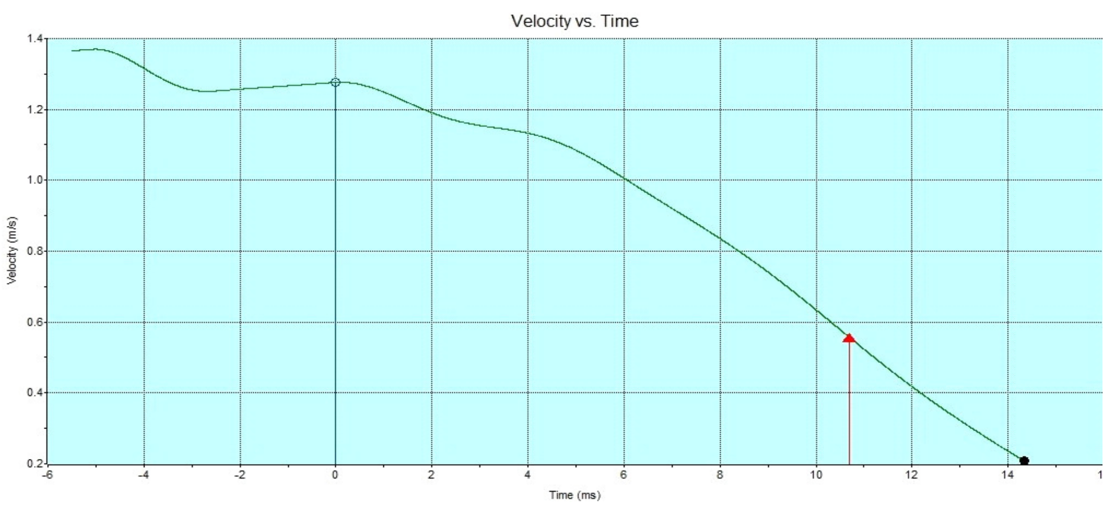

Figure 9 : Velocity vs. Time for Kenaf Helmet

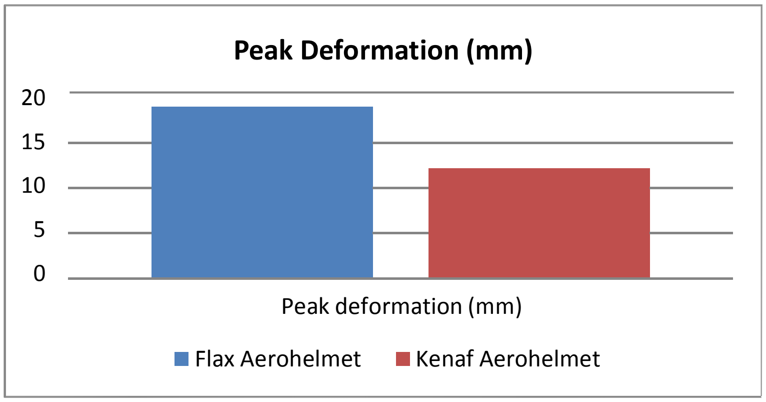

Figure 10: Peak Deformation (mm) for Flax Aerohelmet and Kenaf Aerohelmet

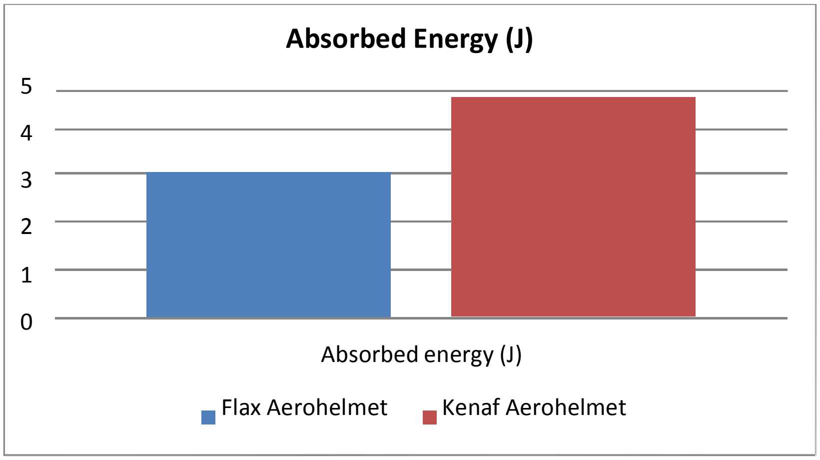

Figure 11: Absorbed Energy (J) for Flax Aerohelmet and Kenaf Aerohelmet

Figure 11 shows the absorbed energy for flax aerohelmet and kenaf aerohelmet. Even though flax aerohelmet show more deformation after the impact, it shows less absorbed energy after the impact. It shows the kenaf materials properties are better which is less deformation and more absorbed energy than flax material. The deformation mechanisms and energy absorption capability of flax and kenaf shells for helmets are experimentally studied with the aim of developing a comprehensive constitutive law to be implemented for real application and also for impact analysis for future research.

2.0 CONCLUSION

Creating a drop-weight impact event is a proven way to obtain the absorbed energy during an impact test. Drop-weight impact tests were done on a helmet impact test rig which best replicates to attach the helmet during impact event. To reduce the impact force of the helmet, material that used for the shell of the helmet play an important role because the higher it absorbed energy from the impact event, less deformation will happen to the helmet. Thus, a good material for the helmet shell is important to be highlighted because the absorbing energy could reduce the risk of injury to the cyclist.

ACKNOWLEDGEMENT

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