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# Computational Analysisof Low Velocity Impacts on Empty Fruit Bunch (EFB) Composite

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**Abstract:**

This paper is to investigate the impact response on peak force behavior of the material at low velocity impact EFB composite. This is because impact damage on EFB composite is not well-known using quasi-static indentation. Series of quasi-static indentation was conducted in experiment to obtain the impact result. However, more experimental results are required to gain an accurate result. Simulation is useful to predict results at a reduced cost and time. Mesh has been created to simulate EFB composite rectangular panel using LS-Dyna. Material properties of EFB composite obtained from three point bending test experiment using Instron 3367. Mesh density on EFB composite rectangular panel is differed, which are 0.5mm, 1mm, 1.5mm, 2mm, and 2.5 mm, and results from the simulation is compared to the experimental results which show the same pattern as the simulation result. From the study, the result proved that the simulation is in good agreement and has the same trend as the experimental result.

***Keywords:*** *Empty Fruit Bunch, Low velocity impact, Quasi-static indentation, Ls-Dyna*

## I. INTRODUCTION

Nowadays, the utilization of composite and its development becomes worldwide as it can be applied in many applications, especially in aerospace, infrastructure and automotive industries. Composite material is a combination of two or more phases which are used due to its high strength and stiffness, low density and non-corrosive property [1]. Synthetic fibers have always been used in composites however natural fiber replacements, known as biocomposites have emerged in a wide spectrum in the area of polymer science. Natural fibers are the product of crops that are renewable resources, which become reinforcement fibers or fillers in composite materialsuch as cotton, flax, hemp, kenaf and non-wood or wood [2]. However, Malaysia hasits own natural fiber that can beused as reinforcementfiberorfiller in composites as it is the second largest producer of palm oil, after Indonesia[3].In palm oil industries, fresh fruit bunch are sterilized after the fruits' oil is removed. However, the empty fruit bunches (EFB) are left as residues. Approximately 70% of empty fruit bunch have turned to waste [4].This waste creates a major disposal problem as they are traditionally burnt, however this creates air pollution and has been discouraged and is recycled to be used in other applications. The mechanical properties of EFB provide insights of fiber tensile strength and low strength but conservative elastic modulus (impact behaviour) which is useful in engineering applications with moderate loading conditions[5].Impact behavior of fiber reinforced composite materials as complicated as compared to conventional metal [6]. Softwares are available as commercial codes to create material models to define the specific failure, post-failure and elastic behavior of the elements. creation of the material models will explain the physical properties of the material in experiments such as strength, modulus and strain-to-failure, however, the addition of specific parameters must be in the software as it cannot be defined

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experimentally[7]. A software that is suitable in solving nonlinear problems including contact and impact problems is LS-DYNA [8]. Furthermore the use of Ls-Dyna is more practical to validate two constitutive models which are to describe the fiber-reinforced composites simulation and the other one is to describe ductile materials [9]. Quasi-static can be treated in low-velocity impact study using LS-DYNA and it depends on impactor mass, stiffness and material properties. Simulation using LS-DYNA requires a mesh for mathematical models to analyze the physical process of simulation [10]. The structural investigation can be done by analyzing the mesh volume or mesh surface that actually gives good impact to obtain numerical results accurately. In this study, mesh quality will represent the desired design mesh criteria. Several of meshing size will gives a simulation graph trend to be compared with the experimental graph. Outcome from the study is to investigate the impact response on peak force behavior of the material. The results was influenced by minor changes in lay-up composite each basic geometry[11].

## II. METHODOLOGY

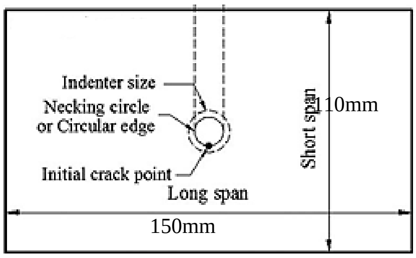
The experiment methodology and the simulation model methodology is described to analyze the impact and impact prediction to the damage by means of finite-element method.

### A. Fabrication of composite

Dry empty fruit bunch (EFB) is obtained from Malaysian Palm Oil Board (MPOB). It considered as short fiber with an approximatelength of 4cm – 8cm. This EFB raw fiber random orientation was coated with polyester resin Reversol P 9565 mixed with 1% methyl ethyl ketone peroxide (MEKP).EFB composite was fabricated using LRTM with EFB volume fractions 10%. The fiber was placed into the LRTM mold of size 304.8mm x 304.8mm in random orientation. The mold was clamped and resin injected into the mold. After the resin has coated all the fiber, the injection is stopped and the EFBcured in room temperature for approximately 3hours.

### B. Experimental Test

An EFB composite rectangular panel size of 150mm x 110mm x 6mm, as in Figure 1a, underwent experimental tests followed by finite element analysis simulation. This EFB composite rectangular panel was clamped using four grips to undergo quasi-static compression loadingprocess using instron 3367 machine, as in Figure 1b and 1c. The bottom plate is fixed but has a small hole to ensure the impactor can perforate the panel. The force acting on the rectangular panel created the graph force-displacement curve which was measured by the load cell. Rate displacement for the load cell was 1.25mm/min as referred to Li, Xuefeng and Xiaosu in 2012 who used ASTM standard D6264-98 test method to measure the damage resistance of a fiber-reinforced polymer-matrix composite to a concentrated quasi-static indentation force [12].




(a)

(b) (c)

Fig 1. (a) Measurement of EFB composite specimen (b) quasi-static indentation test using instron 3367 (c) Impactor adjusted on the plane.

### C. Numerical Simulation

Impact analysis normally used are implicit and explicit, however using non-linear explicit finite element program in Ls-Dyna is preferable to analyze transient dynamic to model fiber composite [13]. Newton-Raphson is a method used to solve problems related to impact and contact in Ls-Dyna.

### C.1 Geometrical Model

Ls-Dyna software has been selected to simulate the EFB composite rectangular panel. Geometrical model of rectangular panel EFB composite in Ls-Dyna uses the same measurement as the experiment and thickness is 6 mm. Table 1 shows the parameter

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and units for the geometry and figure 2 shows the point to create the EFB composite rectangular panel. The impactor has been created with a radius of 10 mm. This rectangular panel has been setup as shell and the impactor as rigid. A shell-solid-shell model is suitable for modeling the crash box [14]. Impactor position is in the middle on the top of the rectangular panel. There is no distance between the rectangular panel and the impactor, similar to the experimental setup which uses quasi-static indentation force as shown in figure 3.

Table 1 : Parameters and units

| Parameters | Units |
|---|---|
| Length | Milimeter (mm) |
| Time | Sec |
| Mass | Kilogram |
| Force | Newton |
| Young's Modulus | Giga Pascal (Gpa) |
| Density | $Kg/mm^3$ |
| Velocity | mm/msec |

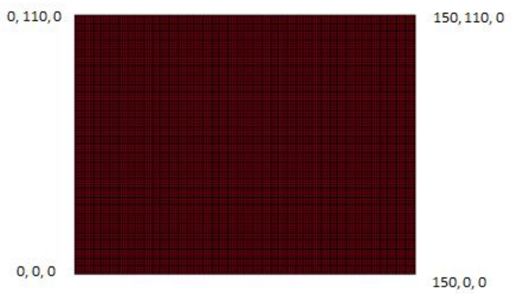


Fig 2: Plate (EFB composite rectangular panel) coordinate

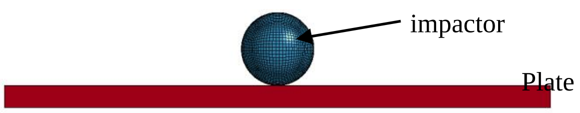


Fig 3: Position Plate (EFB composite rectangular panel) and the impactor

## C.2Meshing

Mesh generation for the rectangular panel uses hypermesh with hexahedral elements which is suitable for meshing shell element [15]. There are five different size mesh applied which are 0.5mm, 1mm, 1.5mm, 2mm and 2.5mm. These mesh sizes is to observe which graph pattern is a suitable match to the graph pattern of experimental results. However, it is different for the impactor which only applies auto mesh as a simple mesh to be analyzed.

## C.3 Material Model

MAT_003 PLASTIC KINEMATIC has been selected to model EFB composite rectangular panel which is suitable to model isotropic material in shell element. The short and random oriented EFB fiber used in the fabrication of EFB composite rectangular plate can be characterized as having isotropic material properties [16]. This material model uses Hughes-Liu as its method. Furthermore, the impactoris assigned as MAT_20 RIGID which belongs to a rigid body or solid body. The value in Table 2 is from the flexural test EFB composite specimen and is considered as isotropic with poisson's ratio equal to 0.3 [17]. Thevalue in Table 3 is taken from the previous researcher who used the same material for impactor [8].

Table 2 : Materials properties of EFB composite rectangular panel

| Material properties | Symbol (Unit) | Value |
|---|---|---|
| Young Modulus, E | (Gpa) | 4.556 |
| Poisson's Ratio | γ | 0.3 |
| Density | P ($kg/mm^3$) | 1.53e-6 |
| Yield Stress | $F_y$ (Gpa) | 0.039 |
| Failure Strain | | 0.008 |

Table 3: Material properties on steel solid ball (Impactor)

| Material properties | Symbol (Unit) | Value |
|---|---|---|
| Young Modulus, E | (Gpa) | 207 |
| Poisson's Ratio | γ | 0.3 |
| Density | P ($kg/mm^3$) | 7.85e-6 |
| Radius | R mm | 10 |

## C.4Initial and Boundary Condition

Data for EFB composite rectangular panel and impactor part has been selected using fixed node (fixed node at the end of rectangular panel) and plate (select all the nodes at the panel). The boundary condition of the EFB composite rectangular panel is fixed on the sides and the rest of the nodes as plate, whereas the impactor isa whole solid ball,as shown in Figure 4. The defining curve is to set the impactor velocity curve on abscissa values A1= 300 m/s and Ordinate (function) values Q1= - 6 mm as the impactor penetrates the EFB composite rectangular panel. These two are loaded in XY data curve. The next step on the boundary interface include two sections which is to setup PRESCRIBED_MOTION_RIGID for rigid part (impactor) and Spc_Set for impactor, fixed node and plate (EFB composite rectangular panel). According to table 5, movements on fixed node is constrained, no movement, and then on the plate and impactor only z-direction motion. This to ensure the impactor hits the plate in a vertical direction and with no rotational movement.

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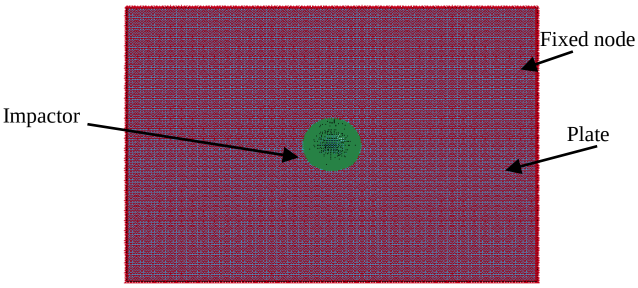


Fig 4: Boundary selection on fixed node, plate, impactor

Table 5: Spc_Set

| Part | DOF X | DOF Y | DOF Z | DOFR X | DOFR Y | DOFR Z |
|---|---|---|---|---|---|---|
| Fixed node | 1 | 1 | 1 | 1 | 1 | 1 |
| Plate (EFB Panel) | 1 | 1 | 0 | 1 | 1 | 1 |
| Impact or | 1 | 1 | 0 | 1 | 1 | 1 |

**C.5Boundary Condition**

Setup on the boundary condition gives information in terms of defining the contacts, constraints etc. It is also able to reduce the problem size [18]. The contact used is CONTACT_AUTOMATIC_SURFACE_TO_SURFACE asit is suitable for impact purpose. In the contact, the potential penetration location has to be identifiedand checked which part to be a 'slave' node through a 'master' segment. Moreover this contact explains which surface is the master surface and which is the slave. Generally, this contact-impact algorithm input has defined the slave node surface to be checked each time step to ensure it can penetrate the surface similar to the experiment. Master is the surface part that undergoes penetration, which is the EFB composite rectangular panel (plate), and the slave part which impacts the surface, is the steel solid ball (impactor), identified according to the internal logic. Force has been included in the master part to observe its behavior during the penetration and to find the peak force at the end of the simulation.

**C.6Define Control**

Define control is to investigate the explicit analysis on solution control and output parameters. CONTROL_TERMINATION is used to identify termination time problems. Termination time that has been selected is 300 m/s, whereby the impactor is able to penetrate the EFB composite rectangular panel at approximately – 6 mm and above 300 m/s.

**C.7DefineDatabase_Binary_Option**

There is a file that is important in plotting data information over three dimensional geometry model which is D3PLOT. Database has been found can be plotted using LS-PREPOST in Ls-Dyna. **ASCII**. This database file is necessary to obtain output results at the end of the simulation. Information written in this file is default on serial and shares the computer's memory. There are certain files also included under ASCII file such as GLSTAT, MATSUM, RCFORCE, NODOUT as shown in table 6. Setup on binary in ASCII is necessary to investigate the time interval between outputs, however the value cannot be zero. The data is written based on memory sharing computers and series default.

Table 6 : File under ASCII

| FILE | Description |
|---|---|
| GLSTAT | Function of this file is to deliver the global data. It is include internal energy kinetic energy, total energy, stone-wall energy spring and damper energy, hourglass energy, ratio, sliding interface energy, external work and X, Y, Z- velocities direction. |
| MATSUM: | This file is more to investigate energy of individual materials. Output results using this file appear the momentum and rigid body velocities of X, Y, Z- direction. Moreover it capable to deliver the result of components total kinetic energy totals hourglass energy and total internal energy. |
| NODOUT | File that contain nodal point data. Output results in this file appear the acceleration, displacement and velocities of X, Y, Z- direction in-term of rotational direction, rotational acceleration and rotational velocities. |
| RCFORC: | This file related resultant contact forces in X, Y, Z directions. It actually used for impact purpose or problem. The resultant interface force is nothing compared with contact force. |

## III. RESULT AND DISCUSSION

Analyzing low velocity impacts on empty fruit bunch (EFB) composite compares experiment and simulation results. The limitation is to investigate impact response based on the peak force gained from the impact between impactor (solid rigid ball) and plate (EFB composite rectangular panel) with different mesh sizes and number of elements. Figure 5 (a) and (b) shows the data differential between simulation and experimental results. Among all mesh sizes only 0.5 mm mesh size (66000mm elements) has been chosen because its peak force point recorded is closest to the experimental peak force point which is 1668N and 1731N respectivelyas in Figure 5 (a). Experimental peak force is higher than simulation peak force but the trend of both graphsare almost the

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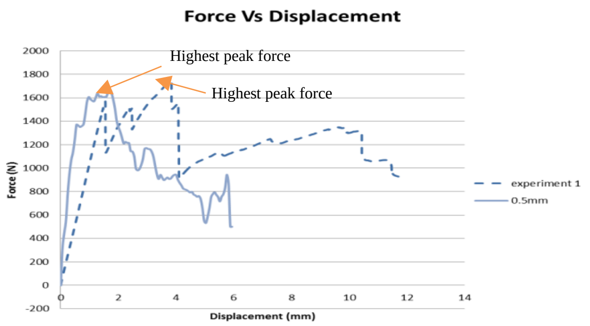
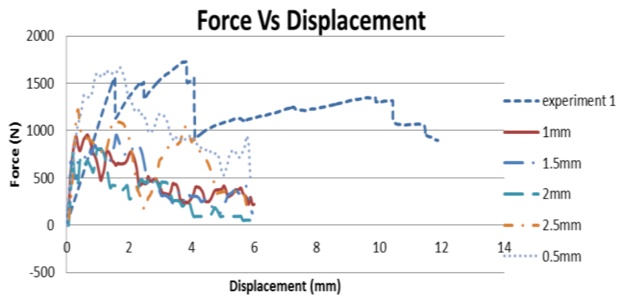
same whereby peak force increases at the early displacement and then reduce, which is similar to the results by Nayeemudin in 2013 [8]. The end of the graph indicates that the impactor penetrated the whole plate depth and then stopped. The experimental trend is not the same as simulation even though both plates are 6 mm, because in the experiment the impactor has resistance when penetrating the plate whereas in simulation the impactor moves automatically through with no resistance [19]. Figure 5 (b) also shows the simulation results for all the mesh sizes and it is clear that 0.5mm mesh size has the highest point among all mesh sizes.




(a)




(b)

Fig 5: The graph of force againts the displacement (a) Comparison graph simulation and experiment (b) Graph for all the mesh sizes compared with the experiment

## IV. CONCLUSION

A low-velocity impact numerical analysis on EFB composite rectangular panel is studied using Ls-Dyna software finite element codes. The results have been successfully delivered with five different mesh sizes and to find the closest peak force point compared to experimental peak force. The trend of simulation peak forces and that obtained from experiment shows almost the same trend, with apercentage difference of 3.77 % which is found to be a fair agreement. The smaller mesh size is found to increase accuracy. It can be concluded that Ls-Dyna software is capable in calculating the transient responses and provides the stress distributions and displacements for impactor and plate (EFB composite rectangular panel).

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