Finite Modelling of Impact Behaviour of Sandwich Panel with Bagasse Composite Core

Samyukta More[1]

University of New South Wales at the Australian Defence Force Academy

Over the last two decades, the use of natural fibres for reinforcement material has increased in combination with plastics in order to produce high strength materials for use in aircraft structures and construction industry. Bagasse is one such source of natural fibres; a by-product from the widespread sugarcane industry in Australia. The aim of this project is to investigate the use of sugarcane bagasse as the composite core of a sandwich panel structure and establish its compression and impact resistance properties. Low velocity impact numerical test results, obtained from a finite element model (FEM) analysis, can be used to determine the structure's potential application as a crash barrier for highways and other energy absorption applications. This report presents the results of quasi-static bagasse composite compression tests and low velocity impact tests of cylindrical bagasse samples. This report also investigates the significance of sandwich panels with bagasse as a composite core using the commercial FEM software, LS-DYNA.

Contents

Nomenclature

σ	= Stress	(Pa)
ε	= Strain	
E	= Young's Modulus	(MPa)
v	= Velocity	(ms^{-1})

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[1] PLTOFF, School of Engineering and Information Technology. ZEIT4500

m	= Mass	(kg)
σ_{ys}	= Yield Stress	(MPa)
KE	= Kinetic Energy	(J)
F	= Force	(N)
δ	= Displacement	(mm)
VF	= Volume fraction	
E_{abs}	= Energy Absorbed	(J)

I. Introduction

Composites are composed of two or more constituent materials that when combined, produce a material with characteristics distinct from the individual constituents. Over the last two decades, the use of natural fibres for reinforcement material within composites has increased in combination with plastics in order to produce high strength materials with a low weight and cost. Composites often have an impressive strength-to-weight ratio which has led to their increased application in sandwich panel constructs for the transport and aviation industry as well as a substitute for conventional metal materials in the fields of transportation, construction and in the manufacture of a range of consumer products. Bagasse; a by-product from the prevalent sugarcane industry in Australia, is a source of natural fibre which could be utilized in composite construction. The University of New South Wales is currently studying the compression and impact resistance properties of sugarcane bagasse as the composite core of a sandwich panel structure for eventual use as highway crash barriers.

Bagasse is the fibrous by-product of sugarcane that is harvested and crushed for sugar production. About 54 million tonnes of sugarcane bagasse is produced around the world annually [4]. The fibres are currently used in the production of paper, feedstock and mainly as an additional energy source for sugar mills. There is a wide range of studies on the use of natural fibres such as flax, hemp, jute, sisal and coir however less focus has been placed upon investigating bagasse fibres and its potential applications. Bagasse asserts its suitability as a reinforcement fibre for composite materials because of its wide availability and biodegradable characteristics while concurrently meeting the modern demand for environmental friendly products [6].

Within a part-fibre composite, the bagasse reinforcement would be the principal load-bearing component that provides strength and stiffness to the matrix. The matrix material holds the composite together and any load applied is transferred to the fibres. The mechanical properties of natural fibre composites are dependent on variables such as fibre content, fibre orientation, filler and additive type/content and the methods of loading [3]. The use of appropriate composite constituents per application enables composites to generally sustain large compression/tensile loads, flexural and shear forces [1]. Bagasse is a plausible fibre reinforcement for energy absorption sandwich panel applications as its low cellulose content results in a low density and thus, positively affects its energy absorption capabilities [5].

Sandwich panels use has also increased in recent years to support the consistent demand for high strength/low weight requirements on almost any structure. Composite sandwich panels are composed of two stiff facesheets with a thick, lightweight core of low elastic modulus. The resultant structure is relatively lightweight and able to carry transverse load efficiently. Facesheets comprising of light alloys such as aluminium or fibre-reinforced composites are commonly used with a variety of core materials including; honeycomb cores made of fibreglass-reinforced thermoplastic, nomex, aluminium or foam. The specific energy absorption characteristics of composite sandwich panels surpass those of metals and offer many advantages over single material structures [8,9]. Unfortunately, composite sandwich panels are extremely susceptible to low velocity impact damage [10]. Therefore, in order to produce a structure that has effective energy absorption capabilities, appropriate choices of lightweight and high impact resistant materials are crucial. The potential of bagasse fibres as a sandwich panel core for the application of impact barriers is thus explored in this project.

II. Project Objective

The objective of this project is to investigate, model and validate the compression and impact resistance characteristics of bagasse as a composite core incorporated into a sandwich panel. The dynamic modelling will be performed using numerical simulations and the commercial finite element software, ANSYS and LS-DYNA.

III. Background

The two major factors limiting the high scale production of natural fibre composites are strength and water absorption characteristics. The use of sugarcane bagasse as a composite material is still a relatively new concept, meaning there is little evidence of experimentally tested bagasse energy absorption characteristics. Thus, this short literature review discusses the findings of past research conducted on impact testing of sandwich panels.

A range of physical phenomena such as shock, elastic and plastic wave propagation, perforation, fracture and fragmentation occur as a result of an impact [11]. Damage in sandwich panels occurs in the form of fibre breakage, matrix cracking and delamination [12]. As impact testing generally causes destruction of materials, the cost of manufacture of the material and the time consuming nature of the manufacture make physical testing a very expensive process to conduct. With the advancement of finite element technology and the ability to build accurate numerical models, impact test analysis has become both time and cost efficient. FEM is used increasingly in simulating and calculating the dynamic response and failure mechanisms of sandwich panels subjected to low velocity impact. Once validation of a sandwich panel model has been achieved, it is possible to conduct a wide range of impact response investigations by varying face sheet and core parameters.

While past studies have explored the performance of sandwich structures consisting of foam, balsa wood, and honeycomb cores, bagasse's potential as an energy absorption material has never been numerically tested before. One study which could be considered comparatively close, demonstrated the results of an experimental and numerical low velocity impact test of a sandwich structure consisting of E-glass/epoxy composite laminate facesheets and balsa wood core. Abdalslam [13] conducted the impact test using a drop-weight tower and analyzed the damage between E-glass/epoxy laminates and core at both faces. There was considerable damage in the form of delamination, fibre fractures and matrix cracking. The same test was then simulated using LS-DYNA and solved in terms of load-time and deflection-time response of the impact. In order to validate the numerical simulation results, the impactor and sandwich panel contact force history data was compared to the previous experimental data. While there was a significant similarity between the results of the physical and virtual peak loads, there was a wide discrepancy in the unloading phase (See Fig. 1). In much the same manner, the FE simulation results of this projected will be validated against the experimental tests conducted in PLTOFF Thomson's undergraduate research project [14].

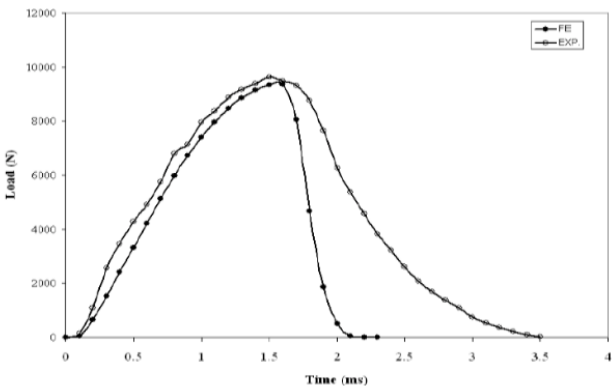

Figure 1. Comparison of experimental and numerical load-time histories [13].

IV. Methodology

A. Quasi-static Compression Test

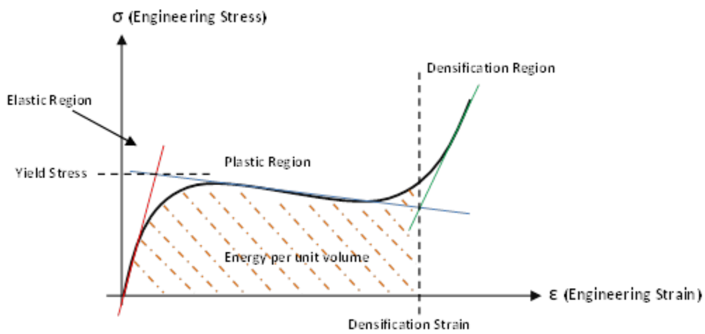

Figure 2. Non-linear stress-strain curve [14]

A typical non-linear stress strain curve consists of three stages. The first stage is linear where the material deforms elastically and returns to its original length when the compression load is removed. When the loading continues, the material reaches its yield point where it begins to deform permanently into the plastic region until it eventually breaks or distorts until flat (See Fig. 2). The strain at which the material has completely failed is the densification strain. ANSYS Mechanical has been used to model the non-linear material behaviour of bagasse under quasi-static compression loading from stress-strain relationships of differing fibre volume fractions obtained from previous experiments.

Unfortunately, the engineering stress-strain curve obtained from the 2013 experiments are an inaccurate representation of the effect of compression loading in reality. The difference between engineering and true stress contributed to an inaccurate estimation of the experimental compressive strength. PLTOFF Thomson's difficulties are summarised below [14]:

a) When the cylindrical sample was loaded in compression, the material shortened but also spread in the lateral direction with an increase in its cross-sectional area.
b) As the sample was fully constrained, the frictional force opposing the lateral force increased the energy consumed as more work was done in the process. This affected the values of stress obtained from experiment.
c) The uneven distribution of frictional force on the entire cross section of the sample resulted in a barrelling effect with the cylindrical sample shearing at 45 degrees.

In order to accurately model the impact test simulation, the engineering stress strain values were converted to true stress strain using Eq. 1 and Eq. 2 before inputting the defined curve in LS-DYNA.

$$\sigma_{true} = \sigma_{eng}(1 + \varepsilon_{eng}) \quad (1)$$

$$\varepsilon_{true} = ln(1 + \varepsilon_{eng}) \quad (2)$$

B. Impact Test Simulation

The development of the FEM model involved a number of steps and refinement procedures to accurately represent the experimental tests and improve the simulation results.

1. Geometry and mesh

A cylindrical model with a diameter of 40 mm and length of 60 mm was used in conjunction with an impactor of mass 8.6 kg in order to replicate the experimental setup (See Fig. 3). The configuration was defined with solid elements and meshed with 60 edge elements after a mesh refinement process that assisted in choosing the optimum mesh for result accuracy.

The sandwich panel was created with a 200 mm x 200 mm rectangular cross section with two facesheets separated by a thick core. The element selection was based on the material thickness, hence the facesheets were defined as shell elements due to their thin structure. The core structure representing bagasse was defined as a solid. The 20mm thick core and the two 1mm facesheets produced an overall 22mm thick sandwich structure. The impactor was created as a cylinder with a hemispherical head to exert a distributed force at its impact location.

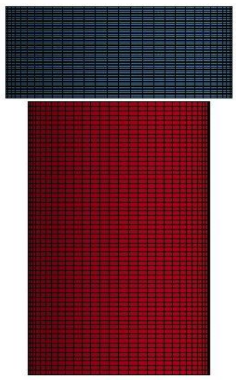

Figure 3. Impact test model

2. Boundary conditions

It is important to set the appropriate boundary conditions on the FEM to reflect the physical test setup. The cylindrical bagasse sample was initially fixed completely at the bottom with the nodes constrained in all directions to restrict movement, however this produced a barrelling effect on the sample which mimicked the experiment. This occurred because the model’s cross section was restricted from expanding evenly upon impact. The issue was resolved by fixing the centre node in the *x* and *y* radial coordinates and constraining the surrounding nodes at the base as fixed in the *z* direction. This allowed the cross section of the model to expand evenly whilst also calculating the true stress at each node in accordance with the material behaviour described by true stress-strain curve input.

The purpose of the sandwich panel impact simulation was to test the impact response of bagasse composite as a core material. Since no results of this particular experiment exists to validate the data against, there was no requirement to replicate a clamping system that is usually used in experiments to hold test specimens. Instead, the bottom facesheet was fully constrained in all directions. These boundary conditions take into account the needs of future study of impact barrier simulation as the tests configuration consists of the bagasse sandwich panel modelled upright with a concrete wall adhered to its back facesheet.

3. Material properties

There has been limited research conducted into the compressive strength and energy absorption characteristics of bagasse. Therefore, the material properties of bagasse were defined from the data obtained by the manufactured samples used by PLTOFF Thomson in 2013 for experimental tests [14]. The Young's modulus, yield stress and densification strain were determined from the stress-strain curve defining the material behaviour of samples of varying fibre volume fractions. LS-DYNA PrePost has an extensive range of material models inbuilt to define various metals and composites. The model used to define the bagasse sample was MAT_PIECEWISE_LINEAR_PLASTICITY (24), which was also used in the quasi-static compression test. This model is used to define a Multilinear Isotropic Hardening material type and enables the specification of the failure strain and experimental input curve to accurately define material behaviour. The material of the impactor was defined with properties of steel and modelled as a rigid body using MAT_RIGID (020) to prevent any deformation of the impactor upon surface-to-surface contact.

The same material properties were allocated to the core of the sandwich panel, however defining the properties of Glass Fibre Reinforced Plastic (GFRP) facesheets proved to be difficult. The data was again sourced from a past UNSW research project, which validated the simulation results of GFRP facesheet sandwich panels against past dynamic modelling experimental tests [15]. The GFRP facesheets were defined by the material model MAT_ENHANCED_COMPOSITE_DAMAGE (054/055), which is mainly used for orthotropic materials of thin shell elements [16]. The material codes, 054 and 055, represent two different failure criteria but 054, defined by the Chang-Chang matrix failure criterion, was chosen to analyse the damage of the composite facesheets upon impact. The failure criterion works by deleting the damaged elements in the composite layers of the model enabling the impactor to penetrate the material as expected in a physical test [17].

Another core material used in the sandwich panel for the purpose of comparing results was balsa wood. It is a lightweight material that is commonly used in laminates and other structural applications [18]. The balsa wood material was defined using the MAT_WOOD (143) model on LS-DYNA. Despite the fact that balsa wood is an orthotropic material, it is modelled in LS-DYNA as a transversely isotropic material because the orthotropic properties of balsa wood vary in the longitudinal, radial and tangential directions, which is difficult to define in FEM. The chosen material type accounted for properties in the perpendicular and parallel directions with multiple material property inputs [19]. As it was a soft material of relatively low density, the model was refined by reducing the time step scale factor and modifying the hourglass formulation type to suit the low density material. Hourglass formulation defines the mode of deformation for under-integrated elements [20]. It also mitigates instabilities involved in severe deformation problems in soft materials.

4. Contact definitions

Both the bagasse sample and sandwich panel impact tests involved the use of the AUTOMATIC_SURFACE_TO_SURFACE contact type to establish the contact interface between model and impactor but it does not account for surface delamination. This contact definition is capable of monitoring both the impactor and panel surfaces upon impact simulation to check for penetration. The initial velocity conditions on the impactor were set by rearranging the kinetic energy equation to find velocity using the mass of the impactor.

$$v = \sqrt{\frac{(2*KE)}{m}} \tag{3}$$

In order to model possible delamination or debonding of the facesheets from the core, the contact definition AUTOMATIC_SURFACE_TO_SURFACE_TIEBREAK is defined between the materials. The tiebreak contact also prevents the penetration of the facesheet into the core due to impact by enabling CONTROL_CONTACT definition, allowing the compression of sandwich panels [21]. Contact equation 2 was used in this project, which applied the tiebreak definition to nodes that are initially in contact resulting in the modelling of possible delamination between the facesheets and core.

V. Results

A. Verification of stress-strain relationship

In order to ensure the FEM software accurately models the nonlinear material behaviour for impact test simulations in the next component, the ANSYS compression test results are compared to the experimental stress strain curves at different fibre volume fractions in the graph below. The experimental curves do not follow a smooth polynomial behaviour due to minor experimental or calibration errors. However, the curves were smoothened out by manually selecting points that formed the piecewise Multilinear curve for the purpose of defining the Multilinear Isotropic material models in ANSYS.

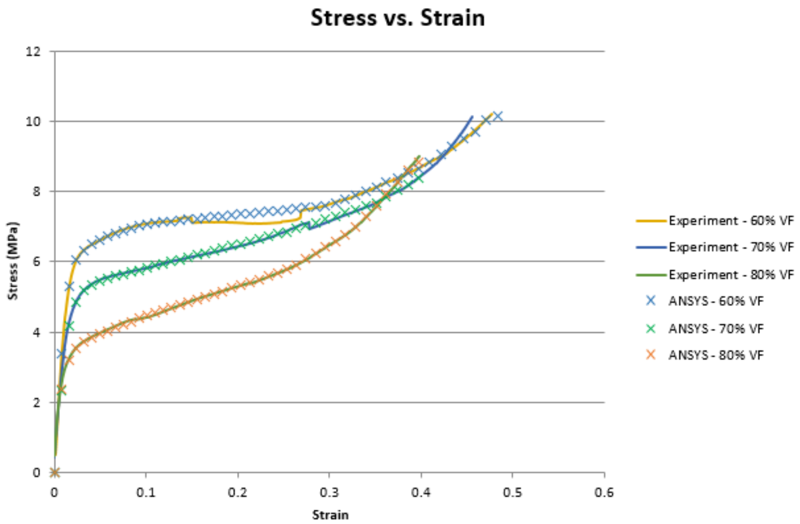

Figure 4. Experimental & simulation comparison Stress-strain relationship

The stress strain curves inputted into ANSYS FEM software were returned almost exactly, indicating the appropriateness of the geometry and loads modelled as shown in Fig. 4. In the experiment, the bagasse cylindrical samples experienced a barrelling effect due to the bottom surface being constrained in all direction. This made it difficult to measure the true stress of the material accurately due to the non-homogeneous nature of bagasse. Constraining just the centre node of the cylinder whilst keeping the surrounding nodes free in the radial direction enabled the cross-sectional area of the model to expand uniformly while keeping its original shape as mentioned previously. Thus, the engineering stress strain inputted into ANSYS enabled validation of the composite model once the boundary conditions were modified to avoid the barrelling effect.

Initially, the yield stress was calculated with the 0.2% strain method using an excel spreadsheet but the interval between each recorded strain data point was much greater than 0.2% and the yield stress was calculated to be the last data point on the elastic curve region. Since the resultant stress strain curve from ANSYS corresponded to the experimental curves, the desired parameters were calculated in the experiment using MATLAB. The mechanical properties are listed in table below:

Table 1. Material properties of composite with varying bagasse fibre VF

Fibre volume fraction	E	σ_{ys}	Densification strain
60%	420.3 MPa	7253.5 KPa	0.3412
70%	296.4 MPa	5291.60 KPa	0.3761
80%	299.6 MPa	3593.3 KPa	0.3114

It can be observed from that as the volume fraction increases, the yield stress decreases. This tendency is also observed in Fig. 4 where the highest curve representing the stress strain data of 60% volume fraction has the highest yield stress in comparison to the lowest curve representing the 80% volume fraction data. The material begins to deform in to the plastic region after surpassing the yield point. It can be concluded that the lower fibre volume fraction samples can endure the highest load without causing permanent deformation. This is likely because the lowest fibre volume fraction composite has the highest amount of Durabond resin or matrix that transfers loads to and from the lightweight bagasse fibres.

B. Validation of impact test results

The results from the low velocity drop tower impact tests simulated at a range of potential energies were used to produce Force vs. Displacement plots to find the maximum values obtained upon impact. The energy absorbed by the varying fibre volume fraction samples was calculated by estimating the area under the force-displacement curve using the finite difference method coded in MATLAB. Figure 5 illustrates the experimental results obtained by PLTOFF Will Thomson to compare against simulation results in Fig. 6. Both the experimental and LS-DYNA results for each respective impact energy have been presented in *Table 2.*

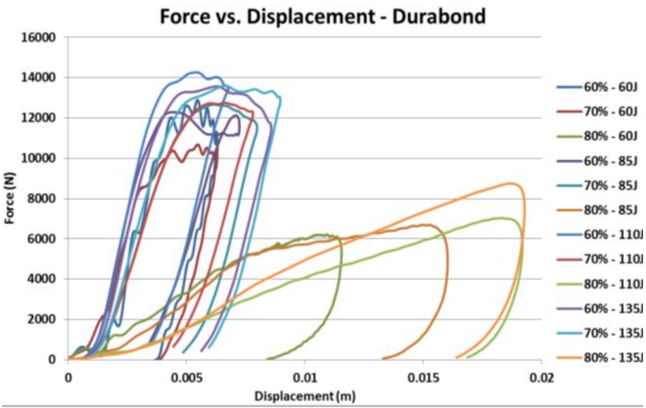

Figure 5. Experimental results [14]

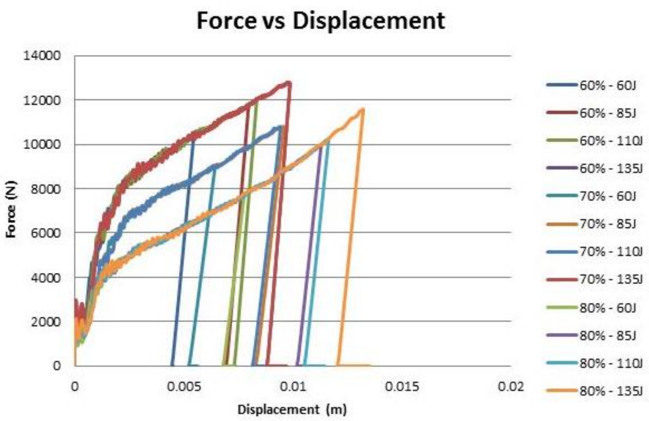

Figure 6. LS-DYNA impact test results

Table 2. Comparison of impact test results

Impact energy 60J

Volume fraction	Results	δ (mm)	F_{max} (N)	E_{abs} (J)
60%	Exp	6.3	12890.1	29.6
	LS-Dyna	5.5	10407.4	36.3
70%	Exp	6.2	10680.7	32.3
	LS-Dyna	6.4	8974.9	36.1
80%	Exp	11.5	6219.8	38.6
	LS-Dyna	7.8	7712.5	38.2

Impact energy 85J

Volume fraction	Results	δ (mm)	F_{max} (N)	E_{abs} (J)
60%	Exp	7.2	12937.8	49.4
	LS-Dyna	7.9	11791.5	63.3
70%	Exp	7.9	12889.3	61.6
	LS-Dyna	9.6	10809.4	65.8
80%	Exp	16	6851	70.55
	LS-Dyna	11.3	9996	67.5

Impact energy 135J

Volume fraction	Results	δ(mm)	F_{max} (N)	E_{abs} (J)
60%	Exp	8.5	13965.9	82
	LS-Dyna	9.9	12809	85.9
70%	Exp	8.9	13922.8	82.1
	LS-Dyna	11.5	12178.7	86.2
80%	Exp	19.2	8791.4	89.6
	LS-Dyna	13.23	11586.7	87

Impact energy 110J

Volume fraction	Results	δ (mm)	F_{max} (N)	E_{abs} (J)
60%	Exp	6.7	14709.3	57.6
	LS-Dyna	8.4	12001.9	67.6
70%	Exp	7.8	13030.7	57
	LS-Dyna	9.4	10794.2	64.3
80%	Exp	19.1	7140.3	73.7
	LS-Dyna	11.7	10266.6	70.8

The difference between the results presented in the tables above is highlighted in the following bar charts representing the maximum force, maximum displacement and energy absorbed. The data is grouped in terms of impact energy and fibre volume fraction.

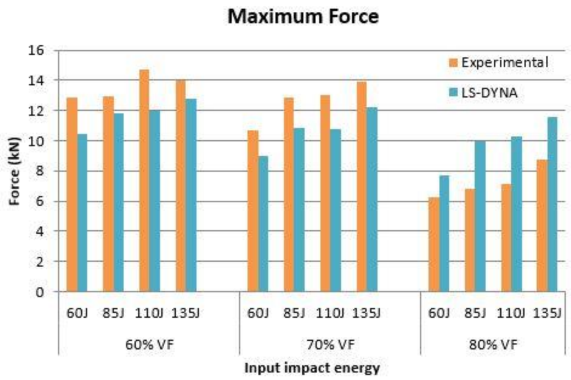

Figure 7a. Maximum force comparison

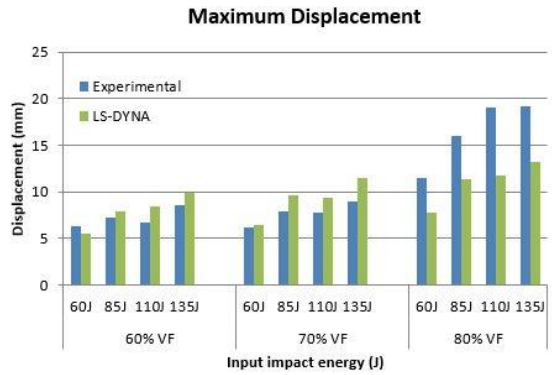

Figure 7b. Maximum displacement comparison

The first bar chart representing the maximum force of bagasse samples at differing volume fractions and impact energies shows a slight trend between the values in Fig. 7a. The highest peak force is achieved by the lowest volume fraction samples when the 60% and 80% samples are compared. The converse is achieved for the maximum displacement where the highest volume fraction samples have experienced the greatest deformation as observed in Fig. 7b. However, there is a considerable difference between the nature of the resultant and experimental force vs. displacements plots. For 60% and 70% volume fraction, the maximum force is lowest in the simulation in comparison to the experimental results and vice versa for the maximum displacement values. This is due to the behaviour of the stress-strain curve defined in the quasi-static compression test that is used in LS-DYNA. LS-DYNA results portray that the impact resistance is higher for lower volume fractions because less force is required to cause the same amount of deformation in the sample. There is a difference between the experimental and simulation force and displacement values but both models absorb nearly the same amount of impact energy.

The loading force is the highest and the displacement is lowest for the 80% volume fraction simulated results in comparison to the experimental data. A possible reason for this discrepancy could be that the physical sample constructed with 80% bagasse fibres and polyurethane resin contained voids that may not have been filled completely by the resin. The presence of voids negatively affects the mechanical resistance of the bagasse sample and cannot be modelled in LS-DYNA where the cylinder is defined as a completely solid material. Figure 8 displays a comparison of the experimental and simulation energy absorbed results.

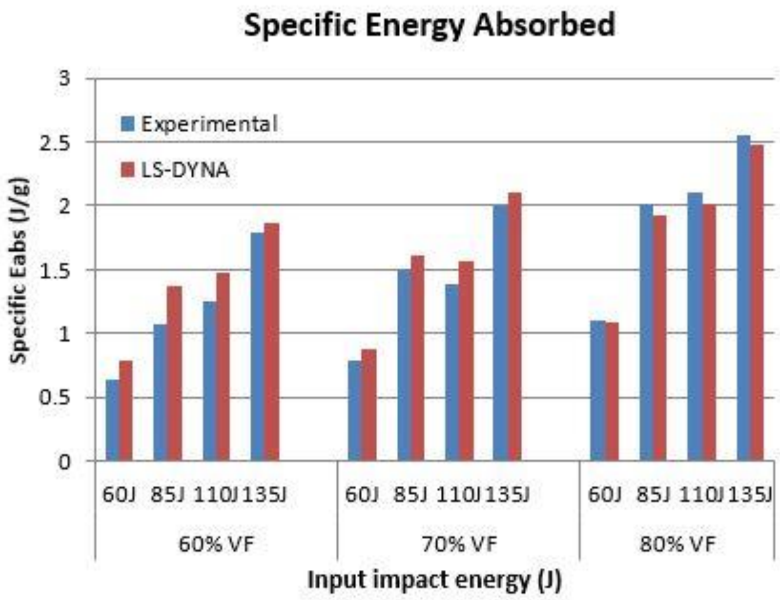

Figure 8. Specific energy absorbed comparison

There is also a close correlation between the compared energy absorption values. Figure 8 reinforces the relationship established between the input energy and resultant absorbed energy. The energy absorbed by the model not only increases with input energy but also with fibre volume fraction. The theory that the higher the volume fraction, the greater the energy absorption is proved as the 80% has the lowest density and Young's modulus in comparison to 60% volume fraction. Therefore, the core of the sandwich panel structure would consist of 80% bagasse fibre volume fraction in order to obtain maximum energy absorption. Care must be taken to ensure the structure is modelled correctly as the greatest deformation capability of the highest fibre volume fraction must have some level of resistance in order to prevent the vehicle from traversing through the bagasse sandwich structure and rapidly impacting with the concrete wall behind.

C. Sandwich panel results

The final numerical experiment tested the significance of bagasse as a sandwich structure. The results of a low velocity impact test conducted at an initial kinetic energy of 30J or velocity of 2.7 ms^{-1} on a sandwich panel are compared to a bagasse composite without the top facesheet. The results of the bagasse sandwich panel are also compared with a structure with Balsa wood core and presented in force and displacement plots.

1. Bagasse without facesheet

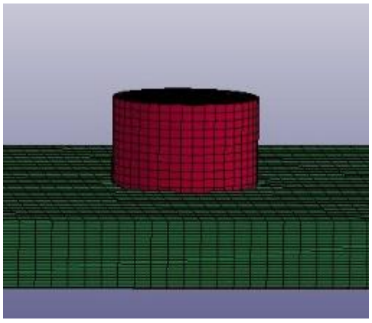

Figure 9. Without top facesheet

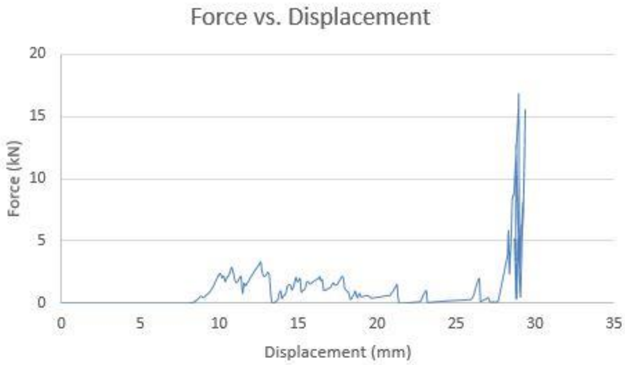

Figure 10. Force vs Displacement

It can be observed Fig. 9 that the impactor has penetrated into the material upon collision. This behaviour was expected for bagasse without facesheet as the fibrous nature of the composite enabled it to deform or crush easily. The force on the panel fluctuated between 0N and 3kN upon initial contact and reached a peak of 16.7kN before rebounding off the bottom facesheet as shown in Fig. 10. The increased loading force was caused due to crushing of the material. This model is not recommended for higher velocity impacts as it is clear that the impactor would penetrate through the core, resulting in failure.

2. GFRP facesheets with bagasse core

The test was repeated at an initial velocity of 30J on two sandwich structures constructed of GFRP facesheets separated by a bagasse core and Balsa wood core. The force and displacement curves of both simulations were plotted to compare the energy absorption capabilities.

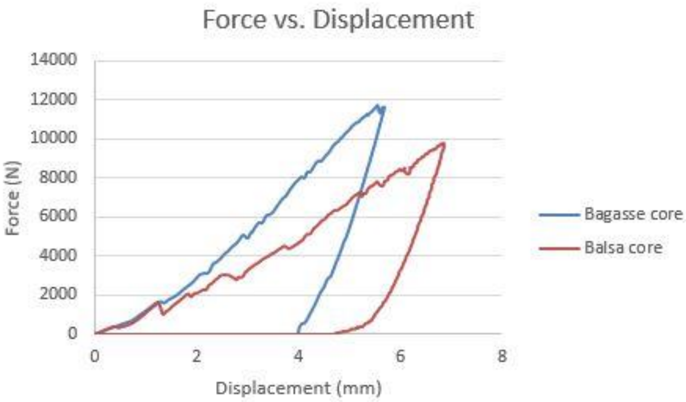

Figure 11. Comparison of Bagasse and Balsa core sandwich panels

The addition of a top facesheet proved beneficial in the impact simulation as the GFRP facesheet absorbed some of the energy before the impactor contacted the core. The stiffness and the fracture toughness of the sandwich panel increased the energy absorption and also prevented the impactor from penetrating into the core. It can be observed in Fig. 11 that the bagasse sandwich panel reached a peak force of about 11.7 kN and a deformation of 5.7 mm before unloading. The total energy absorbed by the model from the impact was 21.4J in the form of core crushing and matrix cracking. The remaining energy was dissipated as heat or transferred to the impactor. The balsa core model absorbed 23.4J so there was only an 8.5% difference between the sandwich panel results. Although balsa wood is already utilised in a variety of structural applications, bagasse is suited to be a more economical implementation as core of a sandwich panel for impact barrier applications.

3. Von-Mises stress distribution

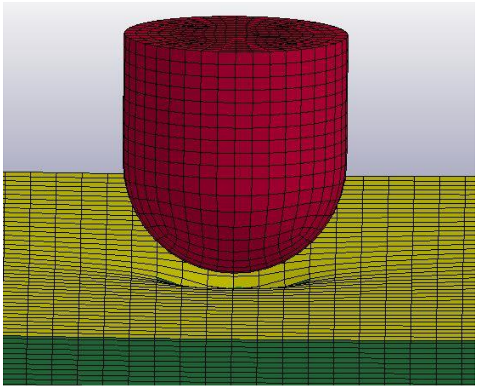

Figure 12. Damage caused by impact

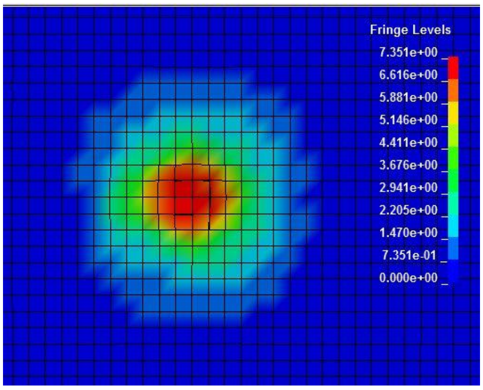

Figure 13. Von-Mises stress concentration area

The contact definition AUTOMATIC_SURFACE_TO_SURFACE enabled the deflection of the sandwich panel as the downwards compressive force from the impactor was transferred onto the surface. The impact simulation also resulted in permanent deformation of the material as the model failed to return to its pre-impact position once the impactor lost contact of the surface as evident in Fig. 12. The permanent deformation was caused by the material exceeding the elastic limit at the yield point and moving into the plastic region of the defined stress-strain relationship.

The sandwich panel experienced the highest stress concentration at the centre of the panel where the impactor came into contact with the facesheet. The stress was distributed around the localised area and continued to dissipate throughout the material from the high stress region. The material deflected the most at the point of impact as deflection is dependent on stress and time. It is indicated by the high Von-Mises stress concentration in Fig. 14. As explained above, the material failed when the stress surpassed the material's yield stress, causing the elements to be deleted from the model. This was also evident in the physical aspect of core crushing.

VI. Conclusion

With the advancement of finite element technology and the ability to build numerical models, experimentation has become both time and cost efficient. This project has simulated quasi-static compression tests and low velocity impact tests to investigate the compressive strength and energy absorption characteristics of bagasse as a composite and the core of a sandwich panel. The low velocity impact test results on bagasse composites were validated against the experimental results obtained from a previous UNSW research. It was found that the higher volume fraction bagasse samples absorbed the most energy upon impact. From the compression tests it became evident that bagasse is a low density material with sufficient energy absorption characteristics that further analysis was worthwhile. Thus, a sandwich panel model was created with an 80% bagasse fibre volume fraction core, which enhanced the overall strength and stiffness of the structure, such that it became comparable to the known balsa wood core. The suitability of bagasse as an effective impact barrier however, still requires discussion and a need exists for LS-DYNA greater scale higher velocity impact tests in order for the real applicability to be ascertained.

VII. Future work

The current crash barriers implemented around high speed car race tracks separating the spectators from vehicles are generally constructed of concrete or a similar rigid material. The aim of a bagasse sandwich panel is to absorb the energy that would otherwise be imparted to the concrete wall, preventing potential injury to the vehicle occupant. This project should be extended to model the impact test of a sandwich structure with bagasse core adhered to the concrete barrier. This would allow the car impacting the wall to also absorb some of the kinetic energy in the form of sandwich panel deformation and vehicle crumpling. The risk of injury or death is deemed to reduce significantly with the addition of the bagasse sandwich panel. The numerical simulations of impact on concrete with and without the bagasse sandwich structure are currently in progress. This content will be presented in the final Project Specific Deliverable. The impactor will be modelled as a hemispherical geometry to represent the general frontal form of the car, while a sandwich panel with bagasse core will be scaled to represent the impact barrier.

VIII. Recommendations

This project can be further extended in 2015 by simulating a vehicle impact. This could be achieved by replacing the hemispherical impactor with a scaled car model consisting of distinctive components of various material types. The impact simulation would require extensive research into the phenomenon of car crumpling upon impact to accurately simulate the effect of collision on each component of the car with consideration for occupant safety and maximum energy absorption. The same impact barrier with bagasse core can be utilised in the crash test but further investigation into the matrix used in the composite manufacture is recommended to improve the properties of bagasse for an economic and optimum impact barrier. It is also recommended to study the effect of different facesheets with a bagasse composite core.

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