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Crassworthiness Characteristic of Aluminum Hybrid Composite Reinforced Natural Fibre Crash Box

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Abstract-Crash box is a thin-walled structure. It installed between the bumper and the frame on the front of the vehicle is a very important part as the impact energy absorber in this frontal collision front crash. To improve crashworthiness characteristics .has done some research. They are material selection, design parameter, joining technicques for enhanced specific energy absorbed and crush force efficiency. Few study for composite material and natural fiber used as crash box. In this study, natural fiber of Musa acuminata balbisiana used as reinforcing composite material for hybrid aluminum square crash box

Keywords- *Crash Box, Crashworthiness, Natural Fiber*

I. INTRODUCTION

The cash box is a passive safety, automotive system. It located between bumper and side rails protects passengers and expensive vehicle components by absorbing initial kinetic energy in a frontal vehicle crash event by ensuring a low plastic flow stress level on the auto-body frame .In the previous study, the crash box material had been developed from Stainless Steel, Aluminum, Hybrid Al-Composite, Foam filled and crash box shape was circular, rectangular, hexagonal etc.). In this study, natural fiber used to as reinforce composite material for hybrid aluminum square crash box. In fact, composites have a greater capacity to absorb energy compared to metals, mainly due to the different modes of failure that govern energy absorption [1-4]

The crushing behavior of partially Al closed-cell foam filled commercial 1050H14 Al crash boxes was determined at quasi-static and dynamic deformation velocities. The quasi-static and dynamic crushing of the boxes were simulated using the LS-DYNA [5-9]. The results showed that partial foam filling tended to change the deformation mode of empty boxes from a non-sequential to a sequential folding mode. In general, the experimental and simulation results showed similar mean load values and deformation modes. The SEA values of empty, partial and fully foam filled boxes were predicted as a function of box wall thickness between 1 and 3mm and foam filler relative density between 0 and 0.2, using the analytical equations developed for the mean crushing loads. The analysis indicated that both fully and partially foam filled boxes were energetically more efficient than empty boxes above a critical foam filler relative density. Partial foam filling, however, decreases the critical foam filler density at increasing box wall thicknesses.

During the last decades the attention given to vehicle crash energy management has been centered on composite structures. The use of fiber-reinforced plastic composite materials in automotive structures, in fact, may result in many potential economic and functional benefits due to their improved properties respect to metal ones, ranging from weight reduction to increased strength and durability features [10-12]. Although significant experimental work on the collapse of fiber-reinforced composite has been carried out, studies on the theoretical modeling of the crushing process are quite limited since the complex and brittle fracture mechanisms of composite materials. Moreover most of the studies have been directed towards the axial crush analysis, because it represents more or less the most efficient design.

The effects of delamination failure of hybrid composite box structures on their crashworthy behavior will be studied and also their performance will be compared with non-hybrid ones. The combination of twill-weave and unidirectional CFRP composite materials are used to laminate the composite boxes. Delamination study in Mode-I and Mode-II with the same lay-ups was carried out to investigate the effect of delamination crack growth on energy absorption of hybrid composite box structures [13-15]. The end-loaded split (ELS) and double-cantilever beam (DCB) standard test methods were chosen for delamination studies. In all hybrid composite boxes the lamina bending crushing mode was observed. Regarding the delamination study of hybrid DCB and ELS the variation of the specific energy absorption (SEA) versus summation of GIC and GIIC were plotted to combine the effect of Mode-I and Mode-II interlaminar fracture toughness on the SEA. From this relationship, it was found the hybrid laminate designs which showed higher fracture toughness in Mode-I and Mode-II delamination tests, will absorb more energy as a hybrid composite box in crushing process. The crushing process of hybrid composite boxes was also simulated by finite element software LS-DYNA and the results were verified with the relevant experimental result. These failure modes which are known as the lamina bending, brittle fracture, transverse shearing and local buckling contribute to specific energy absorption (SEA) of composite box.

Different types of adhesives (acrylic and epoxy) and laser-welding are considered [15-16]. The obtained results demonstrate that continuously joined structures are at least equivalent to and generally better than spot-welded structures, and have further advantages typical of these joining solutions (higher stiffness and fatigue strength, improved vibration response, especially in the case of adhesive joints). The use of structural adhesives in car body construction has a lot of advantages: the joint is not localized in small areas (thus stress concentrations are nearly eliminated), the adhesive layer produces in addition, valuable insulating, protecting and damping effects, and, finally, it is possible to join different materials of almost any kind. The strength of introducing the main clause so that Hybrid Aluminum-Composite Reinforced Natural Fiber (Musa acuminata balbisiana) is the challenge to apply to Crash box material.

II. METHODOLOGY OF EXPERIMENTATION

A. Methode

Crashworthiness Characteristic is determined by calculating: Specific Energy Absorption (SEA) and Crush Force Efectifity (CFE). SEA and CFE are determined based on the amount of data deformation and energy absorbed. This data is obtained from testing speciment with dropped weight impact test apparatus, Figure 1. SEA is energy absorbed by crash boxes per unit mass. CFE is ratio between of peak load and average load.

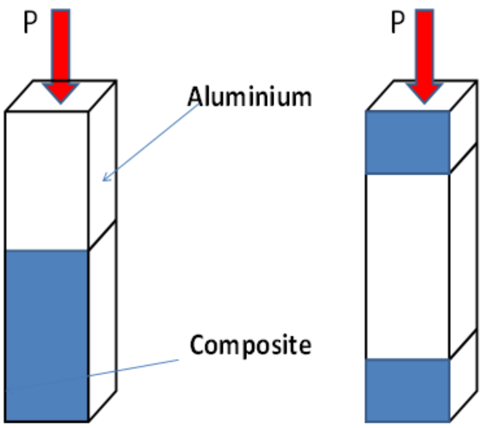

Figure 1. Directiom load for dropped weight impact test

B. Material

An extruded Al SHS beam whose material was Al 6063 was used for the crash box, Figure 2. Al 6063 material has been widely used in light weight vehicle body structures. The outer section dimensions of the Al SHS beam are 60 mm x 60 mm x 250 mm (width, height, length), and the thickness is 1.96 mm. Ratio between width anthickness of the Al SHS beam was 30.6, and this value is similar to that of the crash box. The surface of the Al specimen was then coated by polyester composite. BR127, produced by CYTEC Corporation reinforce natural fiber and 1 layer of film adhesive, FM300, produced by CYTEC were wrapped to improve the joint strength between aluminum and composite in the specimen. A unidirectional CRNF (Composite Reinforced Natural Fiber) prepreg, USN150B, produced by SK Chemical Corporation, was used for the reinforcement composites. The mechanical properties of Al6063T5 and CRNF designed with different lay-up sequences were measured by a tension test according to ASTM B557 and ASTM D3039, respectively. The mechanical properties are shown in Table 1.

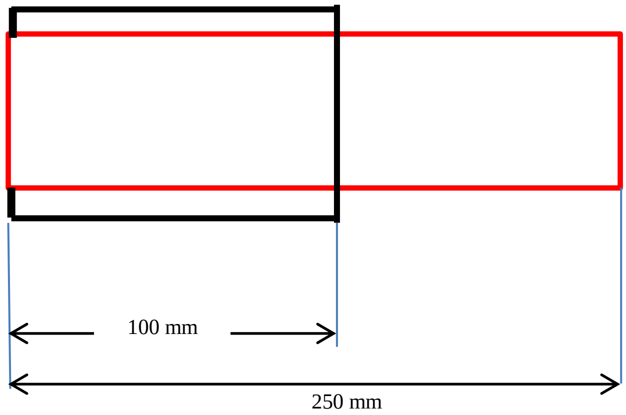

Figure 2. Aluminium Hybrid-Compocite Reinforced Natural Fiber (Musa acuminata balbisiana) Al-CRNF Crash Box

TABLE I. MATERIAL PROPERTIES OF THE (AL6063) AND CRNF WITH DIFFERENT LAY-UP SEQUENCE

Material	Properties		
	Young's Modulus (GPa)	*Tensile Strength (MPa)*	*Density (Kg/m^3)*
Al6063	57.1	221.4	2700
CRNF [0^0]2n	142.9	2063.8	1450
CRNF [90^0]2n	7.6	58.5	
CRNF [45^0]2n	16.1	229.7	

For the experimental parameters that affect the crashworthiness characteristics and axial collapse behavior, two different laminate thicknesses were applied for each of the three different lay-up sequences. The two laminate thicknesses were 0.304 mm and 0.608 mm, resulting from stacking 2 or 4 plies of prepreg. The corresponding thickness ratios of aluminum:CRNF were 1:0.16 or 1:0.31, respectively. The three lay-up sequences were [0^0]2n, [90^0]2n, and [45^0]2n where n is 1 or 2 as a function of the number of stacking layers, 2 or 4, respectively. The detaile dimensions of each specimen are summarized in Table 2.

TABLE II. DIMENSION OF SPECIMENTS

Speciment Type	Dimension			
	Width (mm)	*Thick (mm)*	*Length (mm)*	*Weight (gr)*
Al (Without CRNF laminate)	60	1.96	250	302.5
Al- CRNF $[0^0]2n$	65	2.5	250	345.8
Al- CRNF $[90^0]2n$	65	2.5	250	346.5
Al- CRNF $[45^0]2n$	65	2.5	250	373.5

III. EXPERIMENT RESULTS AND DISCUSSION

A. Dropped Weight Impact Test

The test procedure is the specimen placed at the base of the test machine with steel base. The impactor with total weight of 103 kg will be dropped from a height of 3 meters with a speed of ± 7.67 m/s.This test utilizes earth gravity to produce impact velocity on the impactor to crash the material. The kinetic energy of the impactor will be absorbed by the material through plastic deformation occurring on the surface of the wall. These will reduce its speed until the impactor stops.

B. Axial Collapse Behavior

Axial collapse behavior was analyzed by the load–displacement curve and macroscopic observation of damage propagation in the CRNF layer. Depending on the hybrid specimen with different lay-up sequence, the axial collapse behavior was vastly different. The load–displacement curve results for each specimen are presented in Fig. 3 and the progressive buckling behavior with damage propagation on the CRNF layer is presented in Fig. 4 depending on the lay-up sequence.

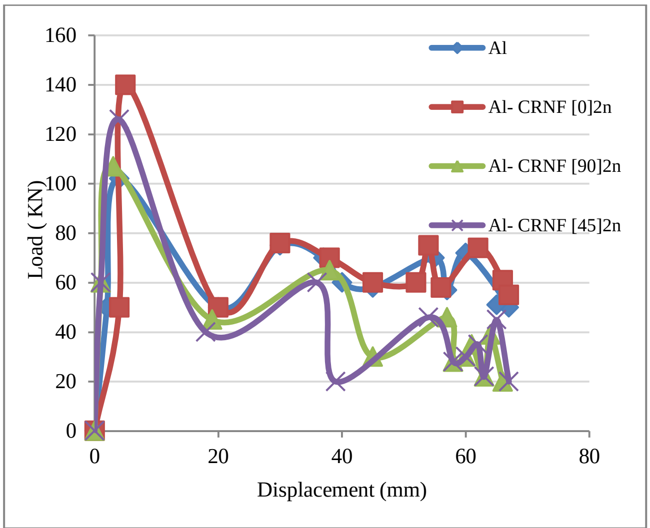

Figure 3. Displacement-Load Curve Aluminium Hybrid-Compocite Reinforced Natural Fiber (Musa acuminata balbisiana) Al-CRNF Crash Box

The mean crushing load (Pmean), which is an important design variable for a crash box, could be defined by the ratio of absorbed energy and crushed length. The variation trend of the mean crushing load depending on the lay-up sequence and laminate thickness was the same as that of the crushed length (ΔL). The hybrid specimen with high mean crushing load can absorb energy with less deformation of structural members.

The peak crushing load (Pmax) is related to the possibility of damage to connected members and the injury of passengers, and it was defined as the initial maximum crushing load in the load displacement curves of Fig.3.

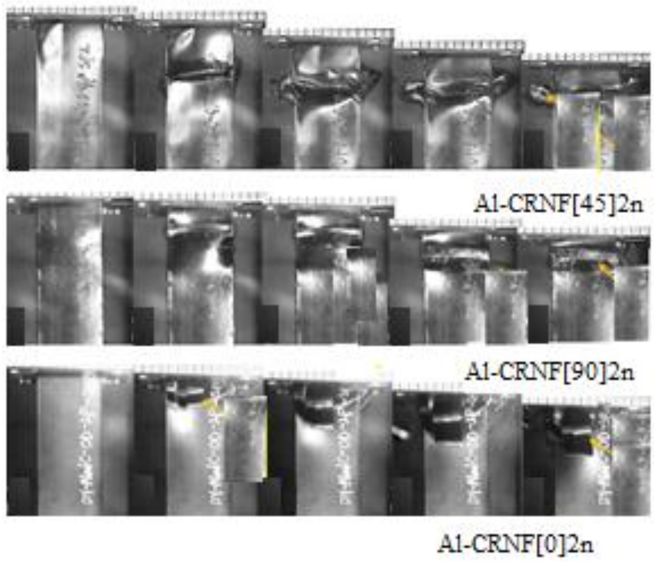

Figure 4. Progressive Bukling Behavior Aluminium Hybrid-Compocite Reinforced Natural Fiber (Musa acuminata balbisiana) Al-CRNF Crash Box

The peak crushing load was related to the mechanical properties of CRNF in the axial direction, and a high peak crushing load was recorded in the order of $[0^0]2n$, $[45^0]2n$, and $[90^0]2n$. Furthermore, the peak crushing load was higher in the specimen with thick CFRP (4 plies of prepreg) than the specimen with thin CRNF (2 plies of prepreg). To evaluate the crashworthiness performance of pure Al SHS beam and Al/CFRP hybrid SHS beamParameter of SEA and CFE were defined as follows:

$$SEA = \frac{E}{\mu \Delta L} = \frac{P_{mean}}{\mu} \quad (1)$$

$$CFE = \frac{P_{mean}}{P_{max}} \quad (2)$$

µ: mass/unit length of the specimen, ΔL: crushed length, Pmean: mean crushing load, and Pmax: peak crushing load. To consider the material or geometry variation in the specimen, the normalized total absorbed energy by mass needs to be considered to compare the energy absorption capability, and itis determined from the SEA. A high SEA value means that the crash box can become lighter. The CFE is related to the energy absorption efficiency, and a high value of CFE indicates that the behavior of the specimen is close to the ideal energy absorber. The crashworthiness performances (SEA and CFE) are presented in Table 3.

TABLE III. CRASHWORTHINESS CHARACTERISTICS OF SPECIMENTS

Speciment Type	Dimension			
	μ (gr/mm)	ΔL*(mm)*	*SEA (J/gr)*	*CFE*
Al (Without CRNF laminate)	1.22	56.9	21.3	0.254
Al- CRNF [0^0]2n	1.38	37.3	28.8	0.283
Al- CRNF [90^0]2n	1.39	45.3	24.7	0.318
Al- CRNF [45^0]2n	1.49	50.1	20.8	0.245

IV. CONCLUSIONS

The lay-up sequence of Musa acuminata balbisiana fiber are affecting SEA and CFE square crash box The specific energy absorbed (SEA) and crush force efficiency (CFE) were increased simultaneously up to 35% and 25%, respectively in the Al-CRNF hybrid crash box with a lay-up sequence [0^0]2, [90^0]2 and they were slightly improved by increasing the thickness of the CRNF laminate.

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