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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 techniques 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. 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. II. METHODOLOGY OF EXPERIMENTATION A. Methode Crashworthiness Characteristic is determined by calculating: Specific Energy Absorption (SEA) and Crush Force Efectivity (CFE). SEA and CFE are determined based on the amount of data deformation and energy absorbed. This data is obtained from testing specimen 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. Direction 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 and thickness of the Al SHS beam was 100 mm / 250 mm Figure 2. Aluminium Hybrid-Composite Reinforced Natural Fiber (*Musa acuminata balbisiana*) Al-CRNF Crash Box TABLE I. MATERIAL PROPERTIES OF THE (AL6063) AND CRNF WITH DIFFERENT LAY-UP SEQUENCE Properties Material Young's Modulus (GPa) Tensile Strength (MPa) Density (Kg/m<sup>3</sup>) Al6063 57.1 221.4 2700 CRNF [00]2n 142.9 2063.8 1450 CRNF [900]2n 7.6 58.5 CRNF [450]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 [00]2n, [900]2n, and [450]2n where n is 1 or 2 as a function of the number of stacking layers, 2 or 4, respectively. The detailed dimensions of each specimen are summarized in Table 2. TABLE II. DIMENSION OF SPECIMENTS Specimen Type Width (mm) Thick (mm) Dimension Length (mm) Weight (gr) Al (Without CRNF laminate) 60 1.96 250 302.5 Al- CRNF [00]2n 65 2.5 250 345.8 Al- CRNF [900]2n 65 2.5 250 346.5 Al- CRNF [450]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  $\pm 7.67$  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. mean crushing load depending on the lay-up sequence and laminate thickness was the same as that of the crushed length ( L). 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-Compicite Reinforced Natural Fiber (Musa acuminata balbisiana) Al-CRNF Crash Box 160 Al 140 Al- CRNF [0]2n 120 Al- CRNF [90]2n Load ( KN) 100 80 Al- CRNF [45]2n 60 40 20 0 0 20 40 60 80 Displacement (mm) Figure 3.

Displacement-Load Curve Aluminium Hybrid-Compicite 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 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 [00]2n, [450]2n, and [900]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 beam Parameter of SEA and CFE were defined as follows: SEA = (1) CFE = (2)  $\mu$ : mass/unit length of the specimen, L: 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 its 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	$\mu$ (gr/mm)	Dimension (mm)	SEA (J/gr)	CFE
Al (Without CRNF laminate)	1.22	56.9	21.3	0.254
Al- CRNF [00]2n	1.38	37.3	28.8	0.283
Al- CRNF [900]2n	1.39	45.3	24.7	0.318
Al- CRNF [450]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 [00]2, [900]2 and they were slightly improved by increasing the thickness of the CRNF laminate.

ACKNOWLEDGMENT This work was supported by the Minister of Technology Research and Higher Education grant funded by the Indobesia government . REFERENCES [1] K. S. Kumar, I. Siva, N. Rajini, J. T. W. Jappes, and S. C. Amico, "Layering pattern effects on vibrational behavior of coconut sheath / banana fi ber hybrid composites," Mater. Des., vol. 90, pp. 795–803, 2016. [2] A. K. Bledzki, P. Franciszczak, Z. Osman, and M. Elbadawi, "Polypropylene biocomposites reinforced with softwood , abaca , jute , and kenaf fibers," Ind. Crop. Prod., vol. 70, pp. 91–99, 2015. [3] M. R. Sanjay, G. R. Arpitha, and B. Yogesha, "Study on Mechanical Properties of Natural - Glass Fibre Reinforced Polymer Hybrid Composites : A Review," in Materials Today: Proceedings, 2015, vol. 2, no. 4–5, pp. 2959–2967. [4] F. Iucolano, D. Caputo, F. Leboffe, and B. Liguori, "Mechanical behavior of plaster reinforced with abaca fibers," Constr. Build. Mater., vol. 99, pp. 184–191, 2015. [5] A. K. Toksoy, "Thin-Walled Structures Partial Al foam filling of commercial 1050H14 Al crash boxes : The effect of box column thickness and foam relative density on energy absorption," Thin-Walled Struct., vol. 48, pp. 482–494, 2010. [6] J. Obradovic, S. Boria, and G. Belingardi, "Lightweight design and crash analysis of composite frontal impact energy absorbing structures," Compos. Struct., vol. 94, no. 2, pp. 423–430, 2012. [7] N. Tanlak and F. O. Sonmez, "Optimal shape design of thin-walled tubes under high-velocity axial impact loads," Thin-Walled Struct., vol. 84, pp. 302–312, 2014. [8] [9] X. An, Y. Gao, J. Fang, G. Sun, and Q. Li, "Crashworthiness design for foam-filled thin-walled structures with functionally lateral graded

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Sujita Darmo was born in Magetan, February, 16th 1972. I start my education at elementary school, SDN 1 Genilangit in 1984, junior high school, SMPN Poncol in 1987, senior high school, SMAN 1 Magetan in 1990, get Bachelor of Engineering from Mechanical Eng. Dept. Brawijaya University in 1995, get Master of Engineering from ITS, Surabaya, in 2000. Student Postgraduated of Mechanical Eng. Dept. Brawijaya University in 2015-now. Working as a lecturer at the Department of Mechanical Engineering Universitas Mataram since 1997. As the author of the some article with the topic are pack carburizing, surface treatment, tube thin wallet structure, Engineering Journal, IJAER, IJMET, Advanced Material and Technolog and getting patent about the design of polesh pearl tool in 2015. Member of team assesor of Mechanical Engineering in Regional Development Service Development Institute (LPJKD) of West Nusa Tenggara Province. Expert Staff Mechanical Engineering of Association of Indonesian Construction Experts (ATAKI) branch of West Nusa Tenggara province 86 International Journal of Science and Engineering Investigations, Volume 7, Issue 73, February 2018 [www.IJSEI.com](http://www.IJSEI.com) [ISSN: 2251-8843](https://doi.org/10.24127/ijsei.v7i73.77318) 87 [Paper ID: 77318-13](https://doi.org/10.24127/ijsei.v7i73.77318) International Journal of Science and Engineering Investigations, Volume 7, Issue 73, February 2018 [www.IJSEI.com](http://www.IJSEI.com) [ISSN: 2251-8843](https://doi.org/10.24127/ijsei.v7i73.77318) 88 [Paper ID: 77318-13](https://doi.org/10.24127/ijsei.v7i73.77318) International Journal of Science and Engineering Investigations, Volume 7, Issue 73, February 2018 [www.IJSEI.com](http://www.IJSEI.com) [ISSN: 2251-8843](https://doi.org/10.24127/ijsei.v7i73.77318) 89 [Paper ID: 77318-13](https://doi.org/10.24127/ijsei.v7i73.77318)