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Dynamic Response of Metallic Foams Bumper with Morphology Design Variation in ABAQUS Software Simulation

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Abstract:
Variation design of open-cell foams located in the bumper car were investigated in this paper. A brief experimental result on the dynamic response of crash was focused on energy absorption and deformation behavior. The bumper design was based on typical design of bumper compared with gradual density of hexagonal foam type.The method used was imitate crashing real behavior dynamic explicit using ABAQUS simulation software with some extra constraint, such as: crashing object and crash direction. Results showed the design strongly affect the value of energy absorption and deformation. Energy absorption was higher using hexagon foams compare to the normal bumper structure with 4.8740 E6 Joule and 4.8572 E6 respectively. Furthermore, highest energy absorption was by simulated redesign hexagon foam into varying thickness (gradual density) – similar to cortical bone structure – with 4.950 E6 Joule. Meanwhile the deformation shows highest value on typical design of bumper with 4 cm translation after crashed. Expected design has to be safe for passengers with have high ability to absorb energy and minimize the deformation movement.

Keyword: Crashing, Finite Element Method, Dynamic Explicit, Aluminum Foams

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Introduction

Metallic foams categorized as newform shape that could be ferro or non-ferro material, such as aluminum foams or alloy steel foams. The morphology of metallic foams is depended on manufacturing processes and metal type **(Pahlawan et al., 2022)**. The typical form of metallic foam divided into two type category, open cells foam type and closed cells foam type. To make an open cells foams type, the crucial part is on the mold template with specific cell size and relative density. Mold template usually used is ceramic powder embedded in casting sand. Then high temperature liquid of metal poured into the mold and cooled. In other hand, there are several ways to make a closed cells foams type such as bubbling the liquid metal in slurry condition, compacted TiH_2 (foam agent) and metal particles heated, etc. Aluminum foam have unique structure characteristic aspect than other compact metal in terms of lightweight, energy absorbing, thermal management, noise absorbing.**(Ashby, et al., 2000)**.

For example, on mechanical damping aspect, when a speed object strikes a piece Aluminum foam, the work required to crush the walls of the millions of air cells in the foam will slows the object down **(Ningtyas, Hidayat, & Rofiyanto, 2021)**.

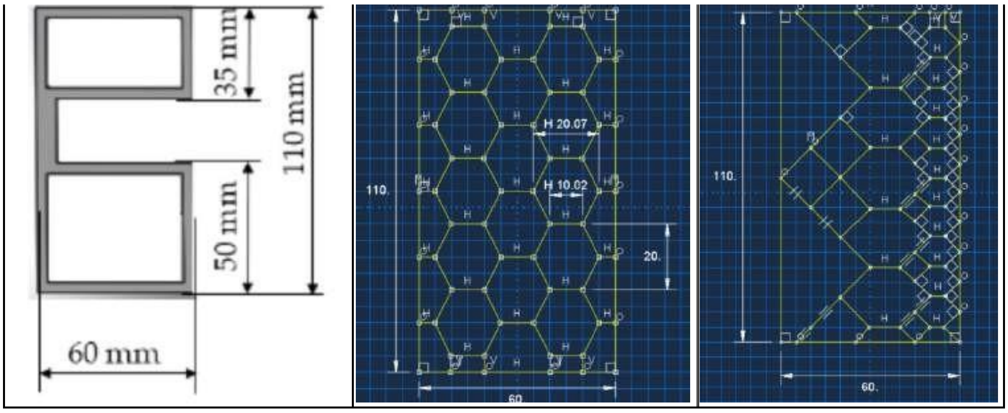
In previous studies, there were high correlation between 2D images of metallic cross area sections foams with its mechanical properties. In other word 3D image of metallic foams could be represented by just examined 2D image sections. Due to acquired 3D models of its real metallic foams were difficult to achieve.**(Campana, 2021)**.

Furthermore, the effective density (ρ_d) of foams affected its energy absorption and weight properties. It is important if the products or components design made by metallic foams have to optimize its shape function and weight effectiveness.**(Bici, 2021)**

This study focused on analyzing the behavior of two different morphology of foams that applicated on car bumper with respect to its impact energy absorption in ABAQUS software impact simulation.

Methods

Morphology designs are based on typical bumper car design on market as shown in Figure 1(a) and conceptual design of foam imbued inside of bumper car design with two different types, uniform density type and gradual density type are in Figure 1(b) and Figure 1(c) respectively.



(a) (b) (c)

Figure 1: Cross section morphology design of bumper car design of the (a)typical bumper on market, (b) hexagonal foam bumper and (c) gradual density level hexagonal foam bumper.

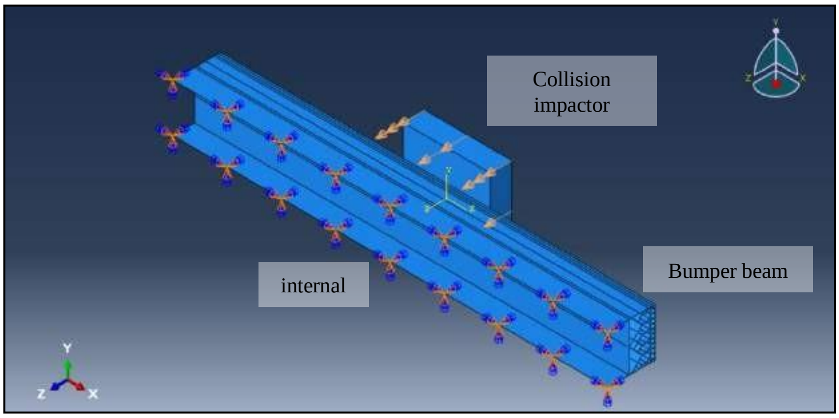


Figure 2. Finite element model

Table 1. Physical Properties Al-7075

Material	Density (g/cm^3)	Displacement (U/mm)	Energy Absorption Rate	Weight (kg)
Al 7075	2.70	11.20	56.76	4.717

Each element line was designed in 2 mm thickness. The following simulations are mimic the real crash accident, where speed set equal to 25 m/s and the rigid box obstacle as collision impactor with surface area 300 x 300 mm^2, where illustration finite element is shown in Figure 2.

Impact process simulation carried in ABAQUS software limited to 0.020 (s) timestep, with initial range is 20 cm between impactor and bumper.

Results and Discussions

For overall results of simulations are show high resistance from bumper during initial contact of impact process. The impactor failed to break thoroughly the bumpers and ensure all the crash process was stopped while impactor bounced back.

Typical design bumper visualized in Figure 3 has deformation in entire part after impact simulation. Maximum deformation located right in impactor first trace and made 4,2 cm penetration depth. External surface bend exceptionally as shown in Figure 1(a). The first layer (external part) buckled and pushed toward internal layer then made some another force to second layer (internal part). Moreover, the collision impactor tilted 25° as shown in Figure 3(b), right after connected to second layer. Different speed would affect the buckling behavior and tilted the bumper more diverse. The average value of energy exerts is constantly high with 4.8765 E6 Joule.

As shown in Figure 4(a), Hexagonal foam bumper has small dimple on both internal support plates. Hexagonal structure rupture begins from robust structure with initial high energy impact and decline right after due to destruction continue begin within its foam,

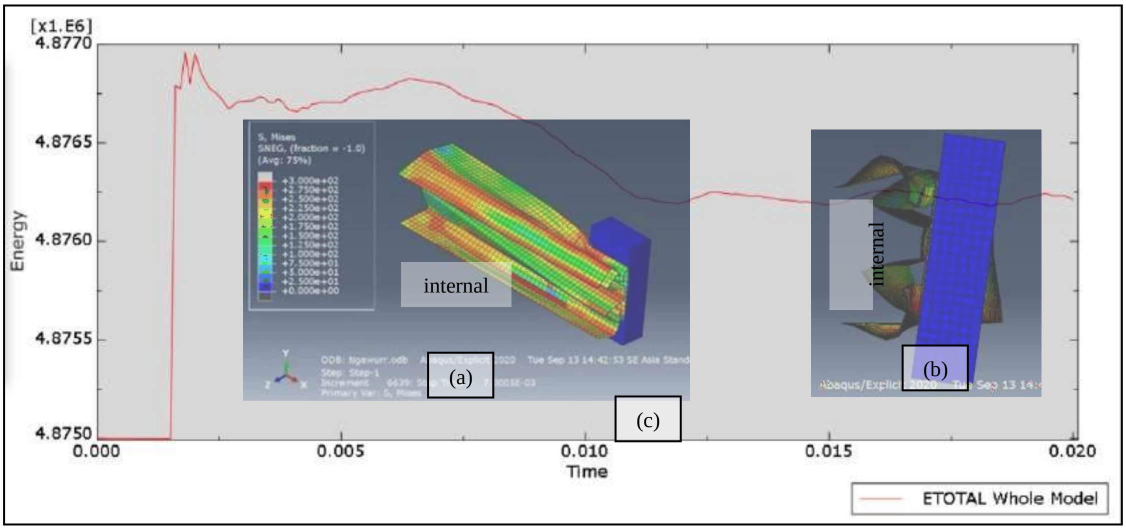


Figure 3. Response of typical bumper in half cut point of view during maximum force energy phase of (a) perspective point of view (b) side point of view and (c) energy absorption graphic.

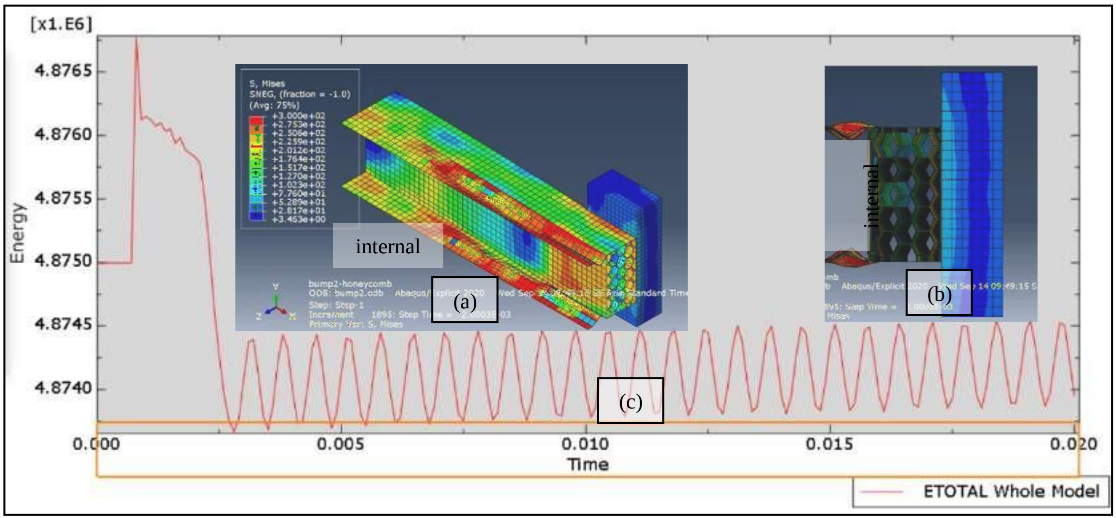


Figure 4. Response of hexagonal foam bumper in half cut point of view during maximum force energy phase of (a) perspective point of view (b) side point of view and (c) energy absorption graphic.

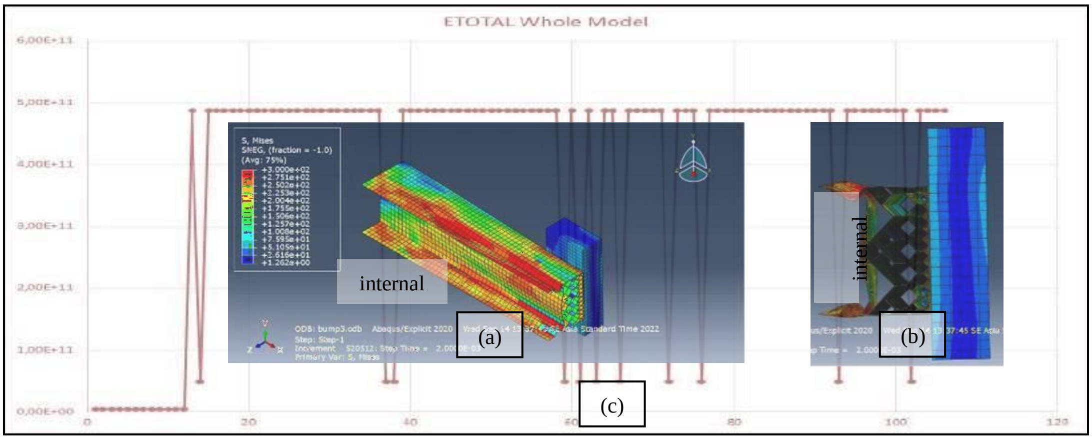


Figure 5. Response of gradual density level hexagonal foam bumper in half cut point of view during maximum force energy phase of (a) perspective point of view (b) side point of view and (c) energy absorption graphic.

Table 1. Simulation results

Bumper	ρeff (g/cm^3)	Max Deformation (cm)	Total Weight (kg)	Absorption Energy Rate (J/s)
Type-1	0,56	4,2	10	5E+4
Type-2	0,82	2	20	12,5E+4
Type-3	0,90	2,4	25	187E+4

layer by layer visualized in Figure 4(b), therefore the energy show plateau condition around 4.8742 E6 Joule shown in Figure 4(c). Shape deformation of this bumper is considered low with 20 mm in depth, due to each layer support the break event continuously and distributed to other layer within time step. Another explanation of this behavior is the hexagonal foams have denser compared to the previous one. Yet, take into account denser does not fit for energy absorber which is the main purpose of a bumper design.

For proposed conceptual design such as bumper with gradual density level of hexagonal foams show slightly different result of impact deformation behavior. The same thing from previous foams design, that dimples were happened in both internal support plates. But the depth of collision impactor reaches deeper than the uniform hexagonal foams design with 24 mm in depth shown in Figure 5(b). This bumper show has more uniform distribution of buckling it can be seen from red area were presented from center through edge bumper as shown in Figure 5(a). The value of energy presented in Figure 5(c)was relatively constant, due to foams structure rupture immediately begin -right after the impact- from internal part which less dense than followed by level of layer in front of it up to external layer which has denser. The value of energies exerts by the time have constant value since the initial contact of collision impactor until the end of simulation. The value of energies exerts surprisingly higher than other bumper morphologies with 4.950 E6 Joule.

For all simulation, the bumper made by foams shows a better performance of absorbing energy and absorbing energy rate by data in Table 1, rather than the typical bumper. Moreover, to control the absorbing rate energy the gradual foams density bumper has the most control ability the rate by constant plateau graph of energy absorbed.

Conclusions

This paper proposes the new conceptual design morphology foam by gradual density mimic cortical bone in terms of its gradual density. The bumper should consider some specific requirements such as total energy absorb, the energy absorbing rate and its deformation. This paper shows the better deformation is the uniform foams bumper type and higher energy absorption, yet it still has drawback in initial control of impact, this could be some troublesome for passengers feel unstable deceleration. The balance type of bumper performed by gradual density foams bumper type that has stable energies absorption since the beginning of collision.

In addition, the proposed gradual density foams bumper design has more potential by changing the foams shape and its circularity.

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