Study of Honeycomb Structure Aero-Engine Casing

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Abstract— The accidents are considered as one of the most threatening dangers in daily life. It is an unexpected event that can change people's life radically. In an attempt to protect the vital resources, equipment and people from those accidents, protective constructions as energy absorbers are involved. The plastic responses and the energy-absorbing performance of structures, particularly under dynamic loadings, are of current interest sin the research community. The present approached work deals with energy absorption of aircraft structures, such as wing or casing during blade off events. The tubular structures are used as energy absorbers and these are employed replace the presently using part. The tubular structures with different cross sections are studied using commercial explicit finite element solver LS-DYNATM, The best suitable tubular structures as energy absorption point of view are considered for further study. Numerical models have been validated through the experimental results of the previous studies, A good agreement between the experimental sand numerical results is obtained.

Key words: Honeycomb, Aero-Engine Casing

I. INTRODUCTION

A major hazard in modern jet-powered commercial and military aviation is the failure of a blade of an aero engine fan, compressor or turbine at very high rotating speeds due to high-cycle fatigue, bird strikes, hail stone impact blade detachment, overheating, material defects, Debris may be propelled at high velocities from the runway during aircraft takeoffs and landings etc., which cannot be avoided even in modern advanced gas turbine engines. This affects the flying performance in a number of direct and indirect ways and even leading to loss of the airplane and hundreds of passengers.

It is a major challenge for a designer to implement the casing structure which is less in weight and having the capacity to contain the blade or to absorb the maximum amount of energy from the released blade.

Hence there is a requirement of special type of material which is having high specific energy absorption capacity (capacity to absorb the maximum of energy with less amount of weight) compared to metallic structures. One of such special type of materials is honeycomb structures.

II. HONEYCOMB STRUCTURES

Honeycomb structures are natural or manmade structures that have the geometry of honeycomb. It takes the name by its visual resemblance. In engineering terms it is a sandwich structure which consists of two thin facing layers separated by a thick core as shown in Figg. 1. The honeycomb structures are generally preferred in such a locations where maximum amount of energy within a minimum amount of space, which is a major challenge to designers for impact protection conditions.

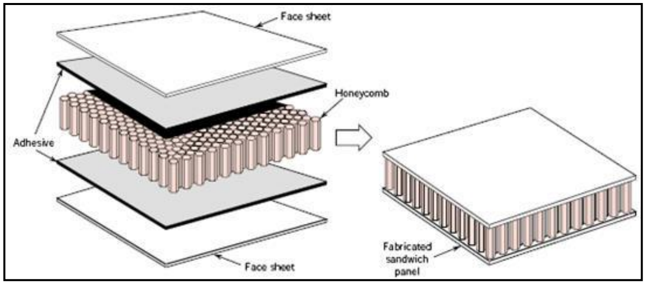


Fig. 1: Honeycomb structure

These sandwich structures are having wide range of applications which includes

- Automotive industries
- Electrical equipment industries
- Sports industries
- Aerospace industries Etc.

In a sandwich structure, face sheets can be made of many different materials which can be isotropic material or a composite material. The most commonly used facing materials are aluminium alloys and composite materials.

The other constituent component of the honeycomb sandwich structures is the core material. To maintain the effectiveness of the sandwich structure the core must be strong enough to withstand the compressive or crushing loads placed on the sandwich panel.

III. METHODOLOGY

In order to understand the blade containment on honeycomb structure for energy absorbing characteristics during impact event, the following methodology is adopted. For this case the modeling of the core structure is done by using the available modeling and meshing tool HYPERMESH v12.0. Then the analysis is carried out by importing the model to available solver tool LS DYNA 971 R 8.0 solver. Number of impact analysis are also carried out on the sandwich panel structures by considering the optimum sandwich structure with damage parameters taking into consideration and this is implemented to casing like structure for blade containment analysis during blade off event. The results which are obtained from the solver tool will be correlated with the available literature to understand the model accuracy and numerical values.

IV. BLADE CONTAINMENT ANALYSIS

Blade containment study is carried out on the honeycomb structures made up of hexagonal and circular geometries. The blade like geometry hits a casing like target with an initial velocity, the modeling of the blade and target are considered from reference, the comparison between flat metallic target and target made up of honeycomb structures is done.

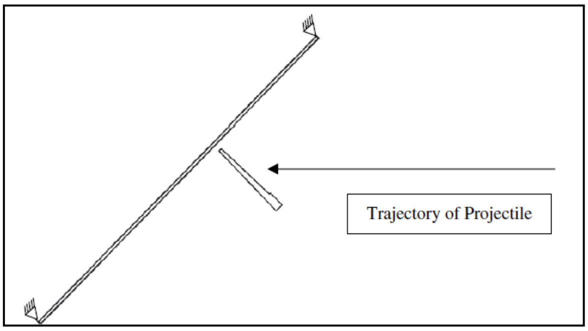


Fig. 2. Geometric model of blade and target

The geometric model used in the study is as shown in Fig and the boundary conditions usedfor the analysis is as shown inFig. 2 and **Error! Reference source not found.**. The target dimension is 0.6096 m by 0.6096 m and made up of 304L stainless steel plates The blade is made up of Ti-6Al-4V material and its specifications are as shown in Fig.

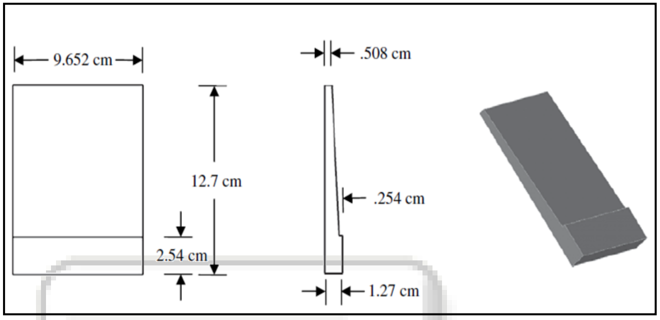


Fig. 3: Specifications of blade geometry

A. *Johnson cook material model*

MAT_JOHNSON_COOK is especially used as material model in case of high strain rate conditions and the same is considered as the material modeling for honeycomb target. The parameters used in the study are as shown in **Error! Reference source not found.** 1.

The Johnson–Cook (J–C) constitutive relation and fracture criterion was selected as the material model for target. The Johnson–Cook(J–C) constitutive relation can describe the behavior of material subjected to large strains, high strain rates and high temperatures, and can be expressed as

$$\sigma_e = (A + B\varepsilon_e^n) \left(1 + C\frac{\dot{\varepsilon}_e}{\dot{\varepsilon}_0} \right) (1 + \ T^{*m}) \qquad 3.1$$

Where A, B, C, n and m are material constants, σ_e is the equivalent von Mises stress, εe is the equivalent plastic strain; $\dot{\varepsilon}_e$is a dimensionless strain rate, $\dot{\varepsilon}_0$is a user-defined reference strain rate. $T^{*m} = \frac{(T-T_r)}{(T-T_m)}$is the homologous temperature, where T is the absolute temperature, Tr is the room temperature and Tm is the melting temperature of the material. The Johnson–Cook fracture criterion is based on damage evolution, where the damage D of a material element is expressed as

$$D = \frac{\varepsilon_{pe}}{\varepsilon_f} \qquad 3.2$$

Where ε_{pe} is the increment of equivalent plastic strain that occurs during an integration cycle and $\varepsilon_f$is the fracture strain. Failure is assumed to occur by element erosion when D equals unity. The fracture strain depends on stress triaxiality, strain rate and temperature, and is given by

$$\varepsilon_f = \left(D_1 + D_2 exp(-D_3\sigma^*)\right)(1 + D_4 ln\dot{\varepsilon})(1{+}D_5 T^*) \qquad 3.3$$

Where $D1$ to $D5$ are material constants, $\sigma^*$is the stress triaxiality ratio

A	B	C	m	T_m	T_r
1380	948	0.005	1	1800	293

Table 1: Parametrers of target

The models of the honeycomb structures are as shown in Fig, the hexagonal and circular core is 3.7625mm in height and the above and below face plates are 1mm each. The thickness of the core is 1mm.The adhesive bonding between the face sheet and the core is modelled as *CONTACT_TIED_NODES_TO_SURFACEor*CONTACT_TIEBREAK_NODES_TO_SURFACE and failure is defined in terms of shear and tensile stresses.

$$\left(\frac{\sigma_n}{\sigma_{nf}}\right)^2 + \left(\frac{\sigma_s}{\sigma_{sf}}\right)^2 \geq 1 \qquad 3.4$$

Where σ_{nf} and σ_{sf} are tensile and shear failure stress respectively.The impact test is carried out on these honeycomb structures and the simulation results are as shown in Fig. 4.

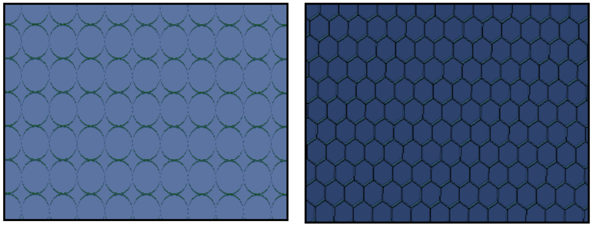
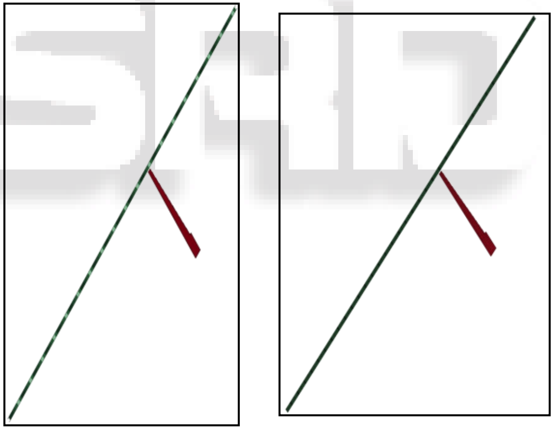


Fig. 4: Model of the honeycomb structures

Circular Hexagonal



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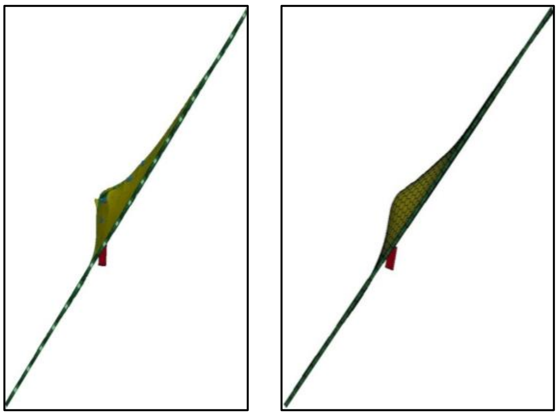

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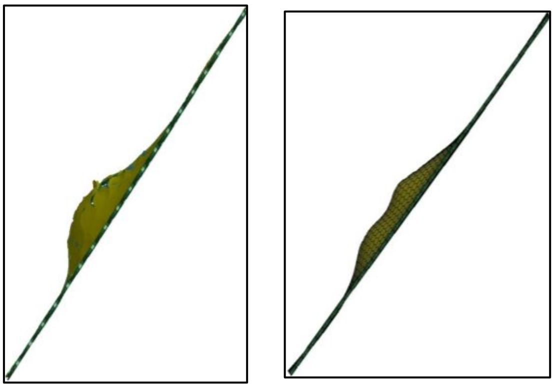

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Fig. 5: Containment results of honeycomb structures

The total energy absorbed by the composite is the summation of energy absorbed by all the three parts.

Based on the above results the energy absorption of the these honeycomb structure and metallic flat casing are tabulated and these are as shown in Fig. 6.

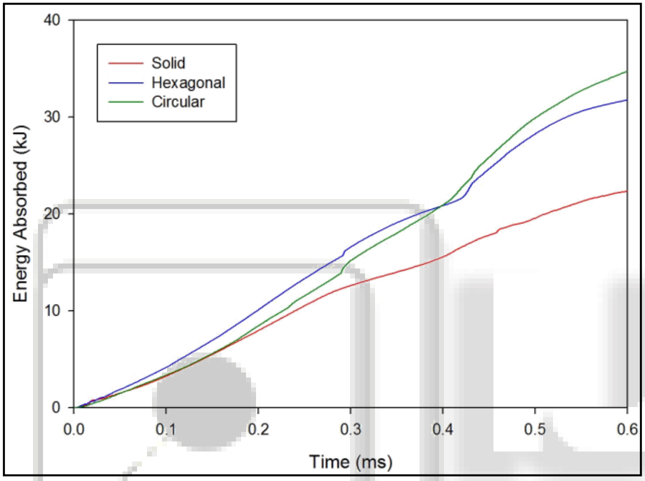

Fig. 6: Energy absorption of honeycomb structures

By combining all the results including flat, hexagonal and circular honeycomb structures, the specific energy absorption of the each one is calculated and the values are as shown in the Table 2.

Target	Energy absorbed (KJ)	Weight (Kg)	Specific energy absorbed (KJ/Kg)
Flat metallic	20.5	13.72	1.492
Hexagonal	31.82	12.62	2.5213
Circular	34.73	12.23	2.8397

Table 2: Specific energy absorption comparison

B. Summary

The containment analysis is studied by using an alternate geometry. The alternate geometry is considered to be flat solid casing and honeycomb casing. The numerical results are validated using the experimental results for the flat solid metallic casing which are found to be good in agreement. Further the honeycomb structure with the hexagonal and circular shapes with nearly same amount of weight are employed. Due to the high velocity impact condition the blade gets fragmented and the hexagonal honeycomb structure contained the blade with less amount of damage to the casing whereas the circular honeycomb structure resulted into more damage to the casing for containment. But these two structures showed the best results for containing the blade and its fragments compared to the metallic casing structure. From the results it is also observed that the specific energy absorption (SEA) of metallic casing, hexagonal honeycomb, and circular honeycombs are 1.639, 2.5213 and 2.8397 respectively. Hence the honeycomb structures showed good containment capability and the higher specific energy absorption behaviour compared to metallic casing.

V. CONCLUSION & FUTURE SCOPE

A. Conclusion

The present study mainly concentrates on the study of blade containment analysis during blade off.

Demonstrates the blade containment analysis on three types of alternate form of casing structures namely flat, hexagonal honeycomb and circular honeycomb structures. The specific energy absorption and the blade containment of each structure are studied and simulated using commercially available explicit finite element code LS-DYNA and the results of which showed that the honeycomb structures showed good containment capability compared to flat metallic casing.

B. Scope of Future Work

The progress in the field of blade containment is achieved by using alternate structure instead of normal metallic flat casing structure, which helped in the weight saving for the engine casing structures. In the same way the future work can be carried out on the casing structure made up of composite materials or metallic foam for blade containment analysis, which is also a weight saving structure like honeycomb.

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