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Analysis of Static and Dynamic Strength of Al Based MMCS Used As A Skin of High Speed Aerospace Vehicle

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Abstract:-The materials behaviour is very typical in nature under the dynamic loading, since it depends on size and geometry of a component, surrounding environment of the component, non-homogeneity of the material. Experimental set-up for the analysis of materials which used as a skin of aerospace vehicle is very expensive and time consuming. Therefore another alternative method is simulation codes like LS-DYNA. LS-DYNA is a finite element code that gives an approximation towards the solution. Simulation of impact phenomenon requires a numerical approach that allows one body (fragment) to pass through another body (target). The aim of the present work is to study the damage behavior of different plate materials with different thicknesses subjected to impact loads, by using explicit finite element code LS-DYNA. In this project, target plates of 3mm and 6mm thickness of materials Titanium and Aluminium alloys are made to impact by Tungsten fragment with different velocities 300, 500, 700 and 1000 mm/milli-sec. Different kinetic energy and residual velocity of fragments against time, graphs are plotted to analyze the damage on different target plates. It is observed that the element size significantly affects the numerical results; therefore a sufficiently refined mesh was used.

Keywords:- Structural analysis of wings with fuselage, Dynamic analysis by LS-DYNA

I. INTRODUCTION

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The response of any structural element, when subjected to dynamic (impact) loading such as projectile hitting a target is significantly different compared to its response to a static force. Dynamic strength characteristics of projectile/target undergo considerable changes due to impact. When the impact is made with high velocities, projectile and target experience plastic deformation, material failure, and decrease in strength, cracks formation and propagation etc. All these effects need to be accounted in numerical simulation tools in order to get accurate representation of the actual behaviour.

LS-DYNA is a general-purpose finite element code for analyzing the large deformation, dynamic response of structures including structures coupled to fluids. The methodology of this work is based on explicit time integration.

Special discretization is achieved by the use of four node tetrahedron and eight node solid elements, two node beam elements, three and four node shell elements, eight node solid shell elements, truss elements, membrane elements, discrete elements and rigid bodies. A variety of element formulations are available for each element type. LS-DYNA currently contains approximately one hundred constitutive models and ten equation of state to cover a wide range of material behavior. For the present work two constitutive models are chosen which exhibits strain rate effects.

Target damages when target is subjected to impact load by high velocities of fragment. The damage to the target depends on various factors such as:

- the geometric shape of the fragment and Target
- the geometric size of the fragment and Target
- the material of the fragment and Target
- the number of fragments hitting the target
- the velocity of the fragment
- the angle of hit with the normal direction of the target
- the thickness of target

The objective of this work is to study the damage behavior for different materials and different thickness of target. The amount of damage caused by impact of fragment with plate is determined primarily by the factor kinetic energy released.

II. METHODOLOGY AND ANALYSIS

Creating geometric model

In this work ANSYS software was used as the pre-processor and postprocessor. The pre-processing task includes building the geometric model and defining the relevant material properties, applying the boundary conditions and loading conditions. The figure 1 shows the geometric model of the plane which was used to analyse the static and dynamic strength of the al based MMCs materials.

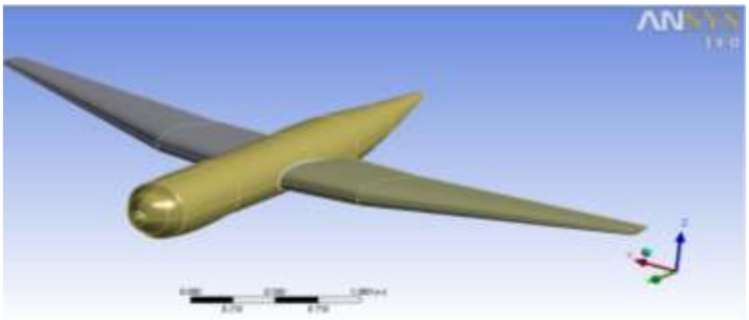

Fig. 1: Geometric Model of the plane

Meshing

Mesh size plays a very important role in the accuracy of the results. Choosing appropriate element type and the mesh size is utmost important. With increase in mesh quality and size, results tend to converge and stabilize. Lot of effort has gone in choosing the appropriate element type and mesh size for this impact study. The mesh was refined in the impact zone. The mesh density was reduced as the distance from the impact area increased. Care was also taken to maintain correct aspect ratio in the grid especially in and around the impact zone where the aspect ratio of the elements was maintained close to unity. The aspect ratio was allowed to increase towards the periphery of the plate. The geometry with discretisation is shown in figures 4.1 to 4.3 displaying different views.

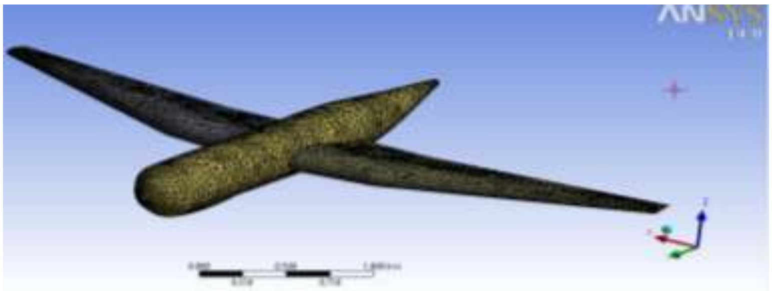

Fig. 2: meshing of the geometrical model of the plane

Following are the quality checks maintained for elements.

Warpage - 5
Skew - 60
Aspect - 5
Length - 1.5
Jacobian - 0.7
Mesh type - quads
Max angle - 135
Min angle - 45

When any node is not coplanar to other nodes of a 2D element, warpage is occurred. It is eliminated by dividing into two trias (triangles). Skew is calculated by finding the minimum angle between two lines joining opposite mid-sides of the element.

Material properties

Different materials such as Titanium alloy and Aluminium alloy were considered for the target. Definition of material stress-strain curve plays an important role in the accuracy of the results obtained from the programme – LS-DYNA. Experimentally determined stress strain curves were shown in the figure nos 3 and 4 for the used target materials. The table no 1 shows the mechanical properties of the target materials.

Table No I. The mechanical properties of the target materials.

Properties		**Density Kg/mm^3**	**Young's Modulus KN/mm^2**	**Poisson's Ratio**	**Yield Stress KN/mm^2**	**Failure Strain**	**Cowper Symonds strain rate parameters**	
							C	**P**
Types of material	Al Alloy	2.8E-06	73.08	0.33	0.339896	0.113	6500	4
	Ti Alloy	4.47E-06	110.32	0.3	0.82737	0.015	120	9

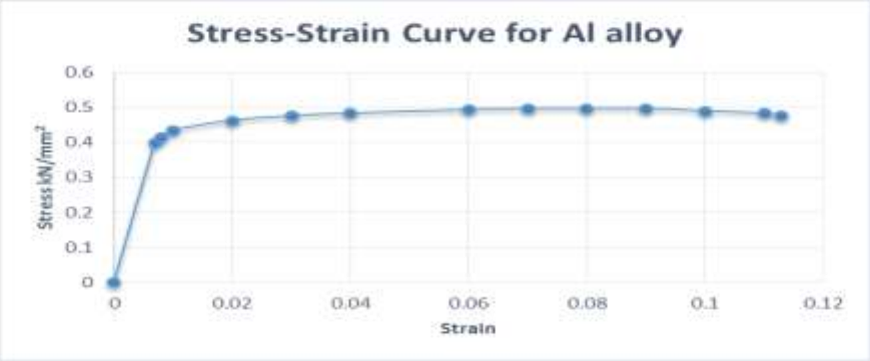

Fig. 3: Stress- Strain curve for Al Alloy

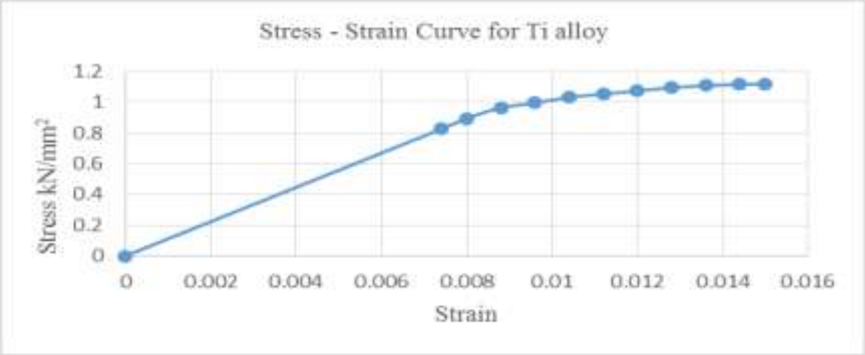

Fig. 4: Stress-Strain curve for Ti Alloy

Appling boundary and loading conditions

The figure 5 shows the finite element model after applying the boundary conditions.

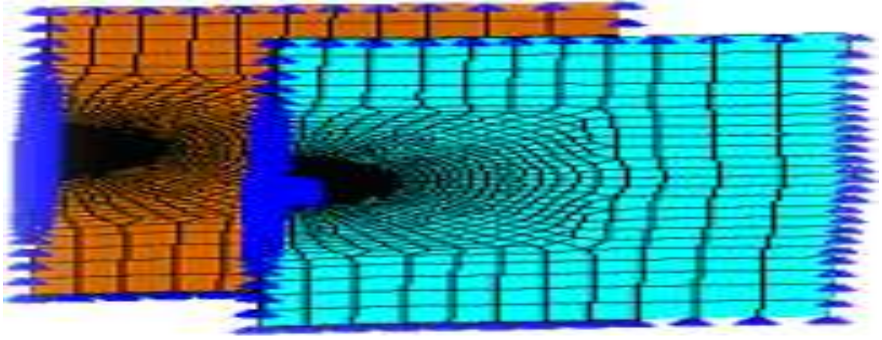

Fig. 5: Finite element model with boundary conditions

Structural analysis

The different composition of Al based MMCs material were used to analysis dynamic strength adoptability for the High Speed Aerospace vehicle. The sample no.1 and 2 metal composition are Al6061+TiB2+Ni+Fly ash and Al6062+Ni+ TiB2 respectively. The figures no 6 to 10 shows the snap shots of the ansys results with metal comosition is Al6061+TiB$_2$+Ni+Fly ash and figures no 11 to 13 shows the snap shots of the ansys results with metal composition is Al6062+Ni+ TiB$_2$.

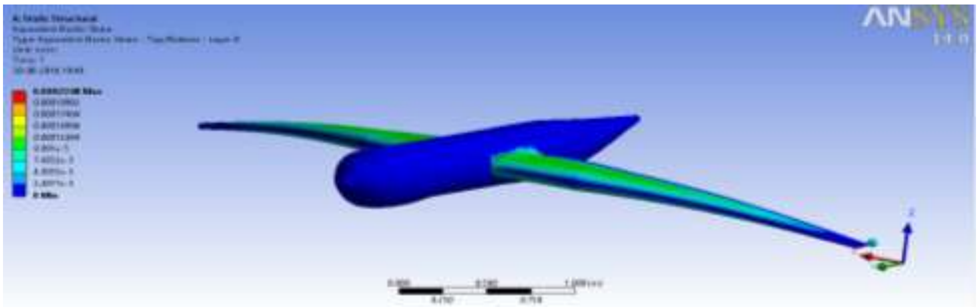

Fig. 6: Equivalent elastic strain

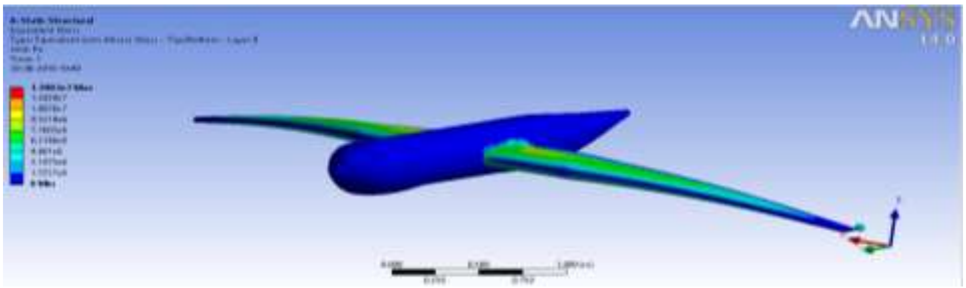

Fig. 7: Equivalent stress

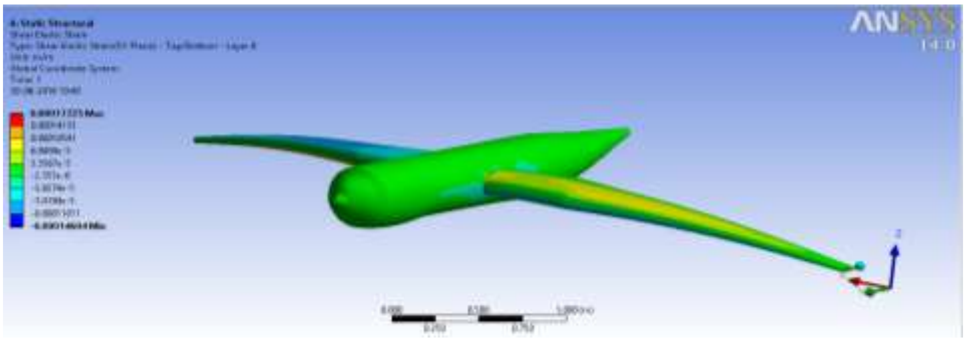

Fig. 8: Shear Elastic Strain

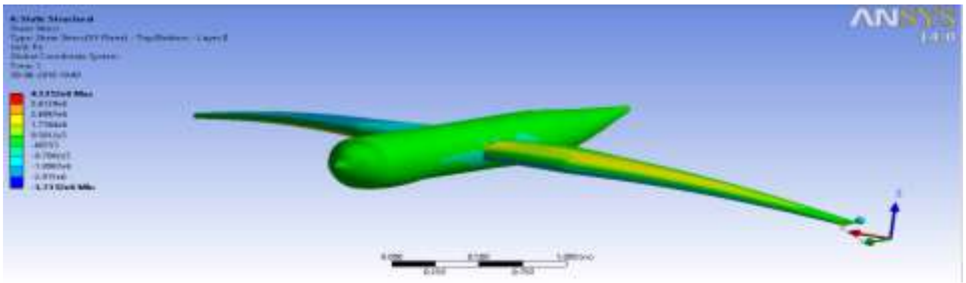

Fig. 9: Shear Stress

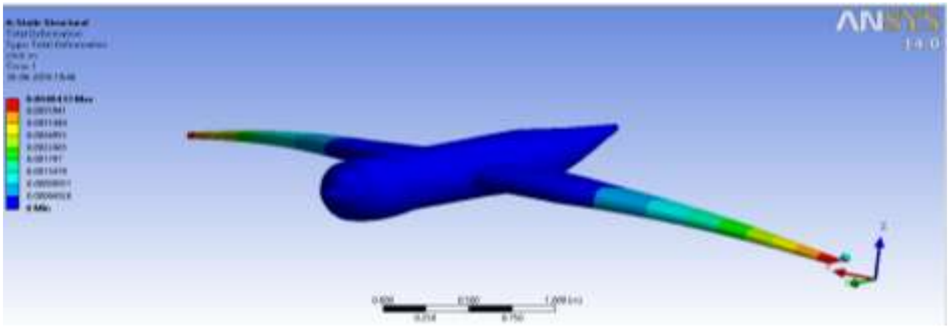

Fig. 10: Total Deformation

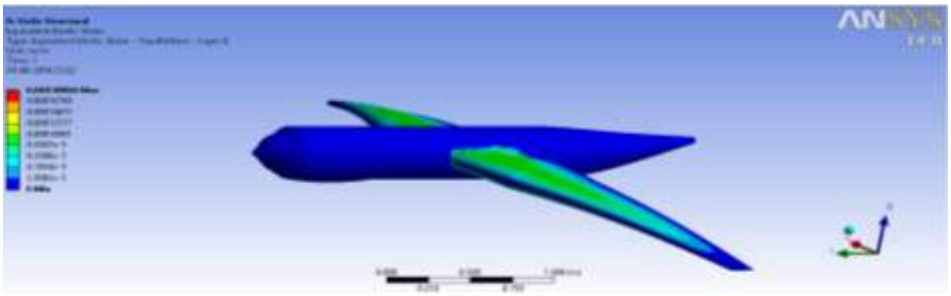

Fig. 11: Equivalent elastic strain

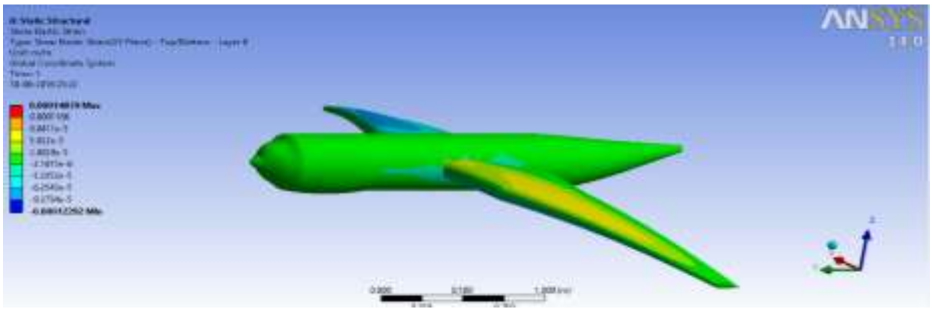

Fig. 12: Shear Elastic Strain

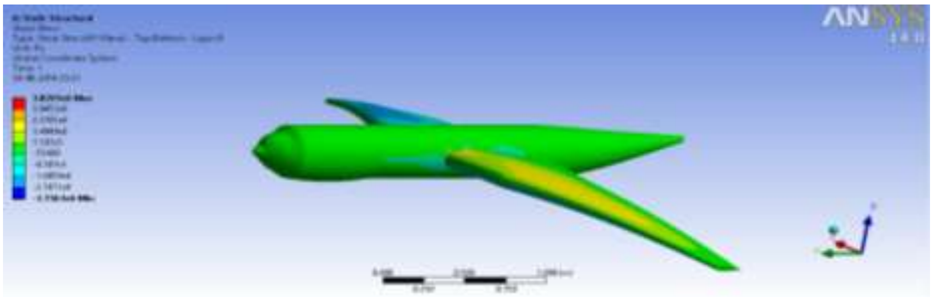

Fig. 13: Shear Stress

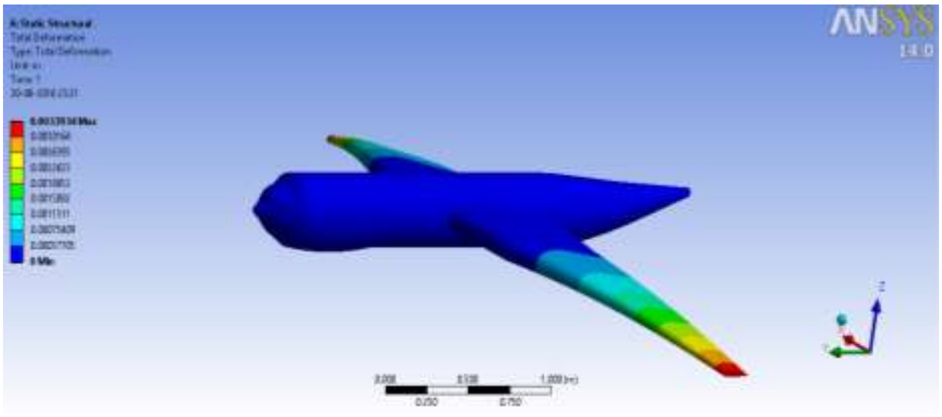

Fig. 14: Total Deformation

III. CASE STUDIES

The similar cases for which simulation has been carried out are tabulated in 4.4. Simulation has been carried out for all the cases and results have been documented. The last case 20 is simulated by considering target as a hollow cylindrical cone with a diameter of 290mm and 2.5mm thickness, impacted with a velocity of 700mm/ms by nine cube shaped fragments of 15mm at a time, shown in figure 15. The fragments are assigned with tungsten material properties and target is assigned with titanium material properties.

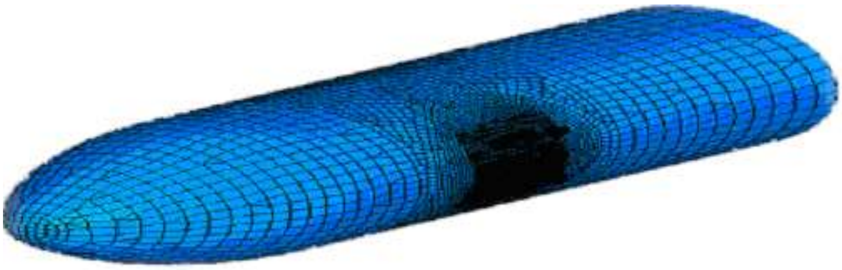

Fig. 15: Isometric view of target (hollow cylindrical cone)

Different gap between plates

In this section, results of 18 case studies are shown where a 15 mm cube shaped tungsten fragment is made to impact with a velocity of 700mm/ms onto two Titanium target plates of size 300x300x3 mm by varying gap of 50, 150, 200, 250 and 300mm between two plates. The fragment is positioned at a distance of 0.5mm from the first target plate for all cases. It is observed that the fragment penetrated easily through two plates by reducing its velocity and kinetic energy. Figures from 5.55 to 5.64 show the corresponding plots for cases 15 to 19 analyzing velocity and kinetic energy of the fragment. The velocity and kinetic energy results obtained are listed in the tables II and III. Velocity and kinetic energy values for 100mm gap between plates are taken from case 7 of section 5.2 as it is similar one.

Table II Change in velocity

Gap (mm)	Initial velocity (mm/ms)	After 1st plate (mm/ms)	After 2nd plate (mm/ms)
50	700	691	681.00
100	700	691	680.20
150	700	691	682.00
200	700	691	680.25
250	700	691	680.50
300	700	691	681.50

Table III Change in KE

Gap (mm)	Initial KE (kg-mm/ms^2)	After 1st plate (kg-mm/ms^2)	After 2nd plate (kg-mm/ms^2)
50	7980	7780	7490
100	7980	7780	7450
150	7980	7780	7500
200	7980	7780	7450
250	7980	7780	7450
300	7980	7780	7510

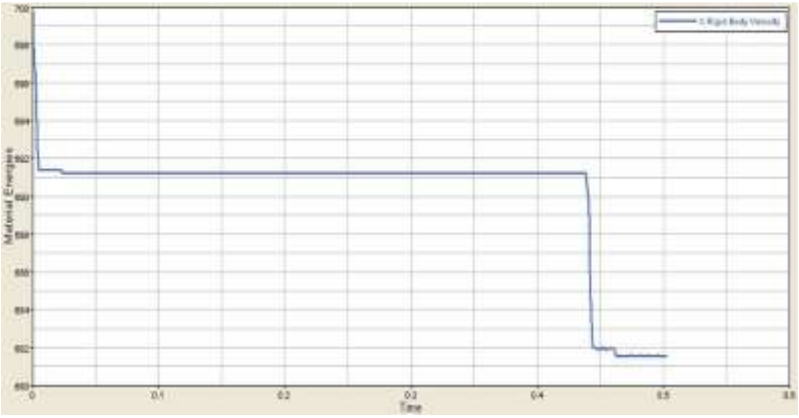

Fig. 16: Velocity plot of the fragment for 300mm gap

The velocity drop and kinetic energy drop are calculated from tables II and III and graphs are plotted with initial velocity as shown in the figures 18 and 19. It is found that maximum velocity drop and kinetic energy drop occurred when gap of 100mm is kept between plates. Hence gap of 100mm is found to be effective.

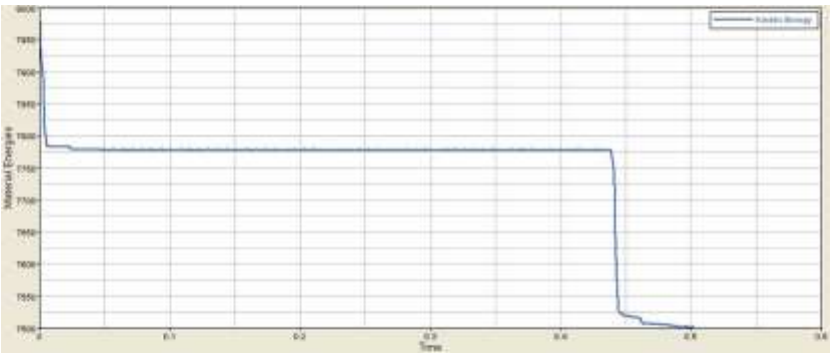

Fig. 17: KE plot of the fragment for 300mm gap

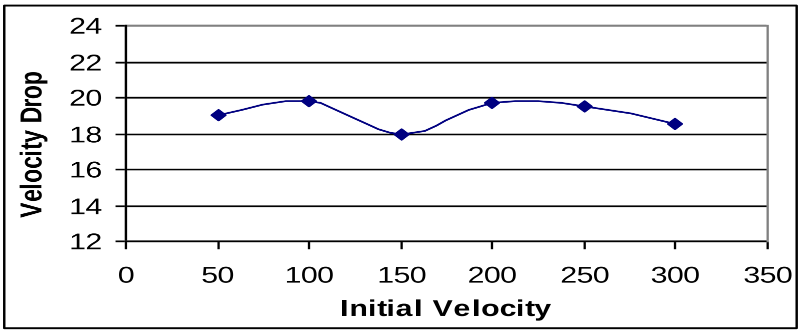

Fig. 18: Velocity drop plot for varying gap

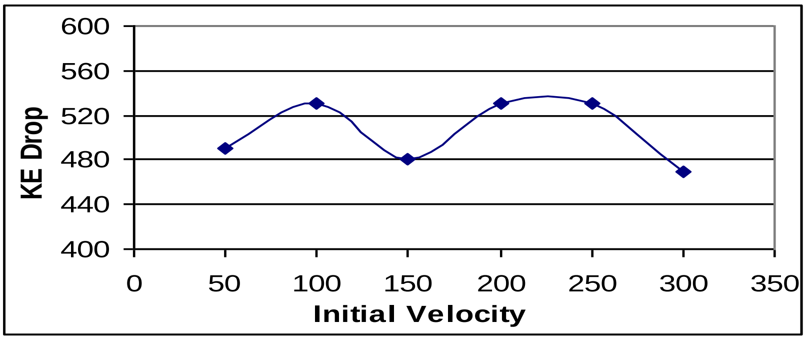

Fig. 19: KE drop plot for varying gap

Multi fragment impact

This is a last case 20 where, nine, 15mm cube shaped fragments are made to impact with a velocity of 700mm/ms onto hollow cylindrical cone of 290mm diameter with 2.5mm thickness. The fragments are positioned at a distance of 2.5mm from the target. At the impact zone fine mesh is considered as shown in the close view in the figure 20. Figures 21 and 22 show the velocity and kinetic energy plot of each fragment. The Vonmises stress plots are shown in the figures 23 describing after impact.

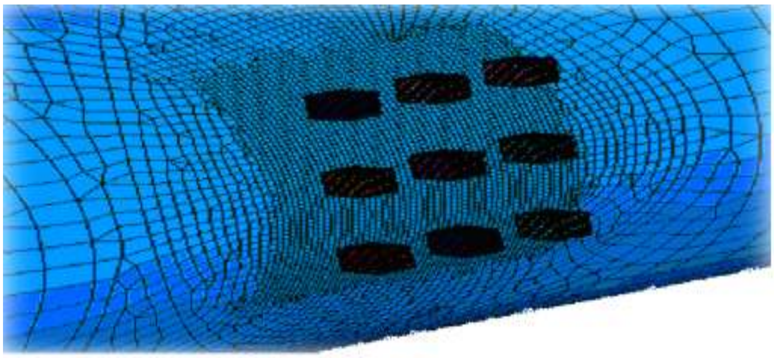

Fig. 20: snap shot of target area

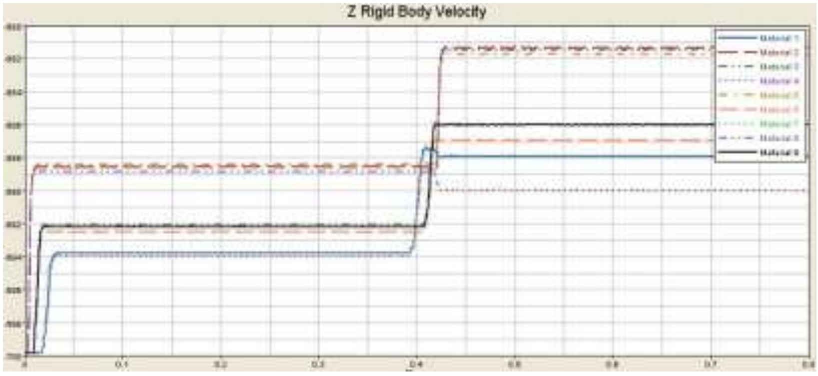

Fig. 21: Velocity plot of fragments

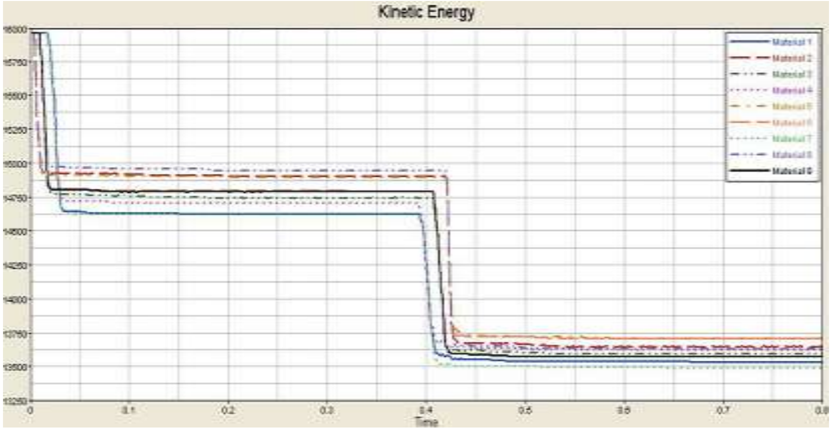

Fig. 22 Kinetic energy plot of fragments

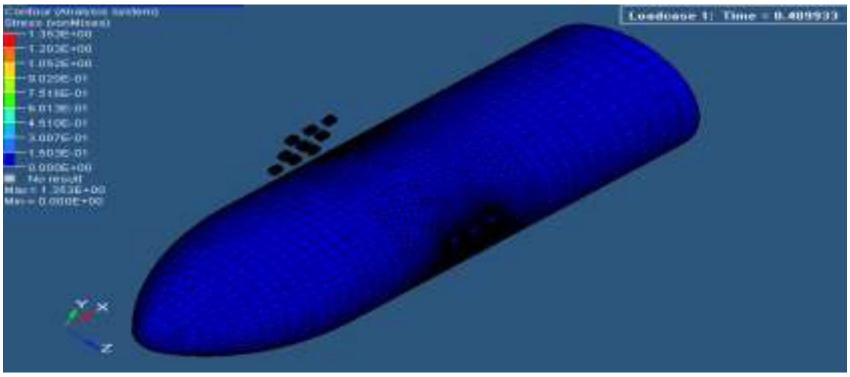

Fig. 23: Snap shot of hollow cylindrical cone after impact

IV. DISCUSSIONS

Torsional stress in a fuselage is created in several ways. For example, torsional stress is encountered in engine torque on turboprop aircraft. Engine torque tends to rotate the aircraft in the direction opposite to the direction the propeller is turning. This force creates a torsional stress in the fuselage. Also, torsional stress on the fuselage is created by the action of the ailerons when the aircraft is maneuvered. When an aircraft is on the ground, there is a bending force on the fuselage. This force occurs because of the weight of the aircraft. Bending increases when the aircraft makes a carrier landing.

The stringers are smaller and lighter than longerons and serve as fill-ins. They have some rigidity but are chiefly used for giving shape and for attachment of skin. The strong, heavy longerons hold the bulkheads and formers. The bulkheads and formers hold the stringers. All of these join together to form a rigid fuselage framework. Stringers and longerons prevent tension and compression stresses from bending the fuselage. The skin is attached to the longerons, bulkheads, and other structural members and carries part of the load. The fuselage skin thickness varies with the load carried and the stresses sustained at particular location. By doing the analysis the maximum deformation on wings formed when the velocity is high and constant. The maximum load applied on wing structure to stabilise aircraft at maximum load conditions. The dynamic analysis observed by impact velocities between the plate with different KE. It has been observed that alloy materials shows good results when compare with before researches did.

Although these concept avoids some of the questions surrounding aircraft design for low sonic boom by flying sub sonically overland, many interesting configurations have been developed recently to reduce sonic boom overpressure. Designs by most of the major business jet manufacturers include configurations with retractable nose booms, very long aircraft concepts, and joined wings.

The mechanism discovered is the turbulent wake coupling to the parachute's bow-shock causing it to change shape and standoff distance, resulting in depressurization of the canopy and resultant partial collapse. Following disruption of the bow shock the canopy re-pressurizes and the process repeats itself in a cyclical manner.

V. CONCLUSIONS

The deformations caused due to various impact velocities for different materials were analyzed. It has been found that velocity drop is increased as the impact velocity is increased.

The kinetic energy drop is increased by the increment of velocity i.e. energy absorption is more for higher velocities.

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