EXPERIMENTATION AND NUMERICAL SIMULATION OF MECHANICAL SHOCK ABSORBING TECHNIQUE AT HIGH STRAIN RATES USING AUTODYN

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Abstract - *Shock is generated by an instantaneous decrement in velocity of high speed projectile. Electronic circuitry used in missiles and deep penetrating bombs undergoes very high magnitude of deceleration when the projectile penetrates through rigid concrete structures. In this study, cylindrical configuration for shock mitigation, made of Aluminium, has been simulated in the AUTODYN module workbench(ANSYS). Cylindrical configuration was chosen from literature survey [1]. Different equations of state and strength models like Johnson cook, Von – Mises etc. were used in these simulations. Graphs were plotted to show the mitigation behavior of Aluminium cylinder at different input parameters and the analytical findings were compared with the experimental results.*

***Key Words*: autodyn; deceleration; shock-absorbers; simulation.**

1.1 ENERGY ABSORPTION

Energy absorption is a technology in which either fully or partially, the kinetic energy of the fast-moving component can be transformed into another form of energy, either reversible or irreversible. Elastic and spring energy are reversible whereas energy encountered during Plastic deformation is irreversible in nature.

O. Lfayefunmi [1] concentrated on the cone shaped shells under hub pressure and outer weight. Yanshan Lou et al. [2] directed parametric reviews on the quasistatic hub pound of the frusta with little semi-apical points utilizing limited component technique. M. R. Allazadeh et al. [3] worked on the material attributes of steel, Aluminum, wood and woven graphite epoxy composite because of high strain stack and portrayed the anxiety wave wonder in an exceptionally precise manner. M. M. Tones [4] led limited component display of pounding conduct of thin tubes with different cross-areas and conveyed the post preparing examination indisputably. M.D Nouri and H. Hatami [5] embraced tests and numerical investigation of the impact of longitudinal fortification on round and hollow and funnel shaped safeguard under effect stacking and attempted to characterize the hypothetical parts of effect mechanics.

1.2 DONNELL-SORT SHELL HYPOTHESIS

As said in Ref [1] Seidi inferred an expression in view of the Donnell-sort shell hypothesis for the basic clasping load for an axisymmetric mode in a tapered shell subjected to pivotal pressure. Seide's recipe might be composed as

$$F_{crit} = \frac{2\pi E t^2 Cos^2\beta}{\sqrt{3(1-v^2)}} = F_{cyli} Cos^2\beta$$

E young's modulus of material utilized, β is cone-pinnacle edge and v is the speed at which the shot hit the objective. Accordingly, the basic clasping of the cone is same as that of barrel duplicated by the square of the cosine of the cone semi-vertex edge, which demonstrates that heap required to clasp the chamber was more than cone design of same material means it can assimilate more vitality than cone for a similar material.

1.3 Shock mitigation

Christopher Liam [6] modelled shock mitigation seats for high speed crafts, His study was limited to a shock of 10G for 30 to 75millisecond. Davies, S Steinberg [7] studied the design and development of shock absorber for electronic but he was limited to low velocities and high frequency shocks Sean D. Keams [8] studied the shock mitigation of mechanical shocks on high speed boats. Shkolnikov [9] studied the strain rates and its effect on crashworthiness of the structural members of the vehicle. A. Othman [10] simulated the crushing of double thin walled cylinders filled with foam and brought out the trend of dynamic load and energy absorbed w.r.t displacement for various geometries and material

A.A.A Alghamdi [11] studied the various types of energy absorbers with their characteristics and empirical relations including conical structure.

This research paper used the mechanical methodology to mitigate the high-level shock just by converting the kinetic energy of the projectile into the plastic deformation energy of Aluminium cylinder. This technique is very much useful where pneumatic and hydraulic shock absorbers are not working.

MATERIAL AND METHOD

Material, Equation of state, failure model and strength model used were mentioned in the table 1. Aluminium was used as a shock absorbing material because of its high damping properties. It is a ductile material and due to its high toughness (29MPa-m$^{1/2}$) it can absorb more energy as compare to other metals before fracture. It has an ultimate bearing stress of 607 MPa.

Table-1: Properties of materials

Material	EoS	Failure model	Strength model	Density (g/cm^3)
Steel 4340	Shock	Johnson Cook	Johnson Cook	7.83
Steel 1006	Shock	JC	JC	7.896
Aluminium	Puff	Hydro(P_{min})	Von Mises	2.785

JOHNSON COOK CONSTITUTIONAL EQUATIONS

Blake Marshal shrub [12] additionally assessed the four dynamic examination codes, five constitutive models alongside two langaragian investigation programs and inferred that Holmquist Johnson cook (HJC) to be best examination.

Johnson cook model were taken in light of the fact that it characterized the mechanical conduct of metals. Von mises model was an adaptable plastic quality model. It will be characterized the utilizing materials of shear modulus and yield quality. The von-mises yield stress is given as,

$$\sigma = (A + B\varepsilon_n)\ (1+ C\ ln\varepsilon_p)\ (1-T_m)$$

where ε is identical plastic strain εp is plastic strain-rate for ε_0= 1.0/s, T is the homologous temperature (T − T_{room}) / (T_{melt} − T_{room}), and T is outright temperature for 0≤T≤1.0. The five constants are A, B, n, C, and m. The statement of the arrangement of first sections exhibit the anxiety will be an element of strain $\varepsilon_p \leq$ 1.0 and T=0. The definition in the second and third arrangement of sections express the finish of strain rate and temperature, individually.

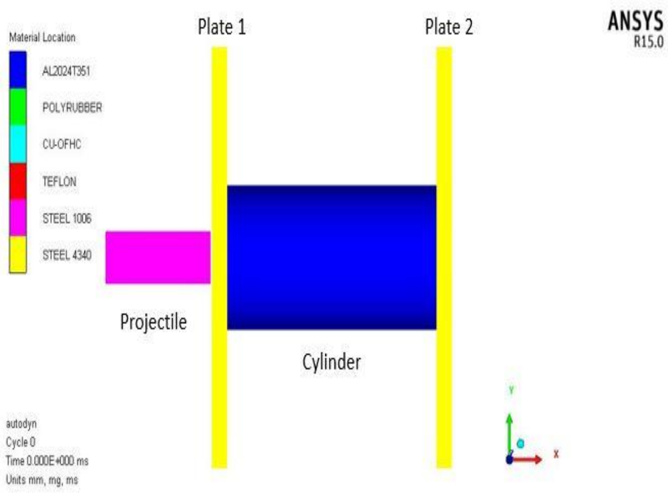


Fig.1. layout of the model

SIMULATIONS USING AUTODYN

Numerical simulation described below was carried out using AUTODYN model of Ansys as known as hydrocode. Autodyn software is basically used for non-linear dynamic problems. Explicit modelling feature of Autodyn includes different solvers such as Lagrange, Smooth Particle Hydrodynamics (SPH), Euler and Arbitrary Lagrange Euler (ALE). Different solvers could be specifically used in different problems like CFD used in fluid dynamics.

Simulation 1

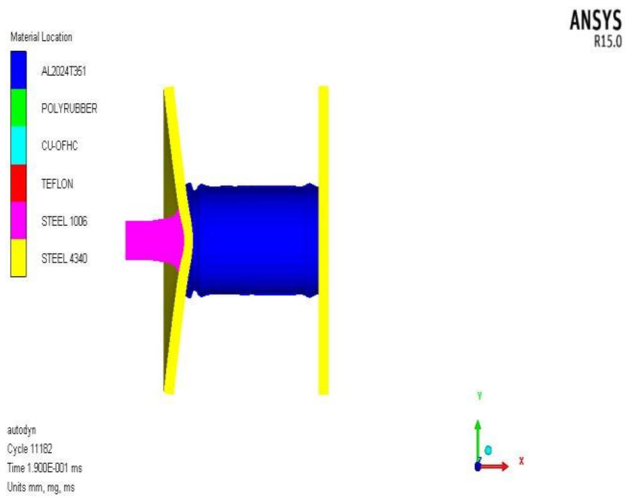


Fig.2. Steel projectile hitting the target with velocity of 100m/s

Simulation 2

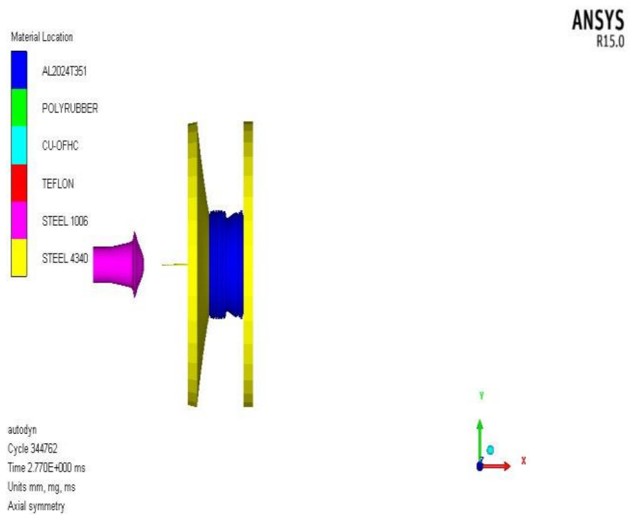


Fig.3. Steel projectile hitting the target with velocity of 390m/s

EXPERIMENTATION

Trail 1

25mm diameter steel projectile weight 90g was fired from 40mm diameter gun with a velocity of 100m/s placed at 2m from the target. Target was an Aluminium cylinder having dimension length 140mm, diameter 70mm, thickness 1mm fixed centrally between the two similar steel plates (200*200*10) mm^3.

Trail 2

25mm diameter steel projectile weight 290g was fired from 40mm diameter gun with a velocity of 390m/s placed at 2m from the target. Target was Aluminium cylinder having dimension length 140mm, diameter 70mm, thickness 1mm fixed centrally between the two similar steel plates (200*200*10) mm^3

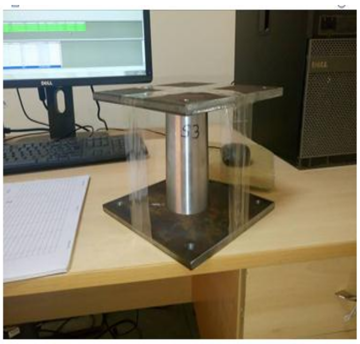
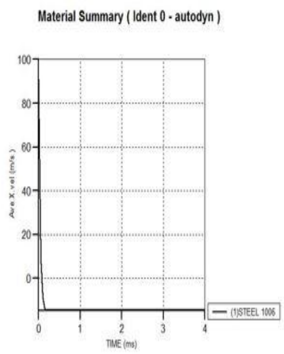


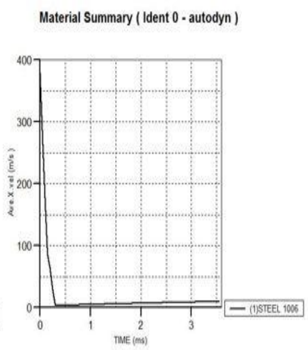
Fig. 4. AL Cone **Fig.5.**Al cone embedded in Steel plates

Fig.6.fixtures **Fig.7.**Gun target arrangement

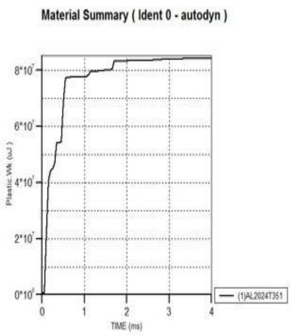
Two trails were conducted, first at lower velocity and with less weight projectile and second trail was conducted with high velocity and with heavy weight projectile.

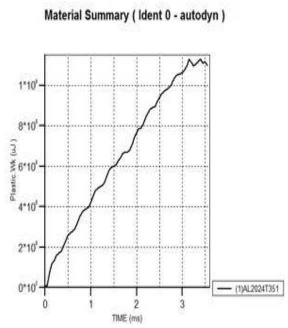
RESULT AND DISCUSSION





Graph.1. Average velocity vs Time graph sim 1
Graph.2. Average velocity vs Time graph sim 2





Graph.3. Plastic work vs Time graph sim 1.
Graph.4. Plastic work vs Time graph sim 2.

In trail 1 velocity of steel projectile instantly decrease from 100m/s to 0m/s in 0.15ms with a deceleration of 1828m/s^2. Energy stored in Aluminium in the form of plastic deformation was 8.4*10^7 μJ as shown in the graph 3.

In trail 2 velocities of steel projectile instantly decrease from 390m/s to 0m/s in.3ms with a deceleration of 2314m/s^2. Energy stored in Aluminium in the form of plastic deformation was 8.4*10^7 μJ as shown in the graph4. Also, this experiment conformed the deformation pattern as seen below in Fig.8(a) and Fig.8(b)

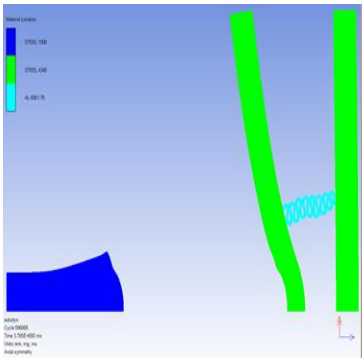
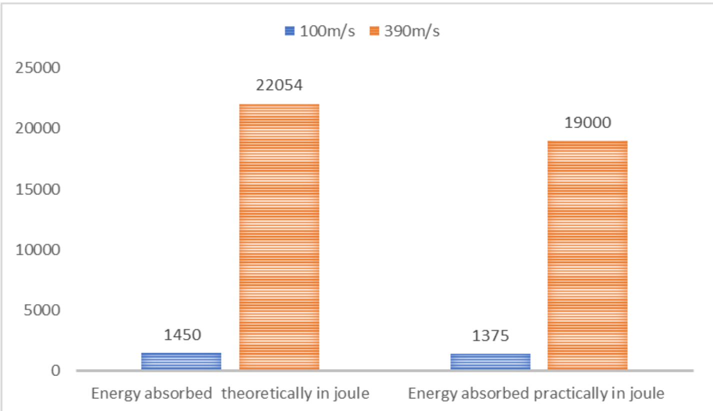


Fig.8(a) Compression in simulation
Fig.8(b) Practical compression in trail 2



Graph.5. Energy absorbed vs velocity graph

Error

$$e = \text{energy absorbed} \left(\frac{\text{theoretically} - \text{practically}}{\text{theoretically}} \right) *100$$

Error in first trail was 5.17% and error in second trail was 13.84%. Error upto this level was acceptable. This error occurred due to various reasons written below;

a)Presence of friction between plates and table.

b)Gravity comes into picture.

CONCLUSION

Mechanically methodology is very much useful in high level shock mitigation. It has very less effect of temperature, pressure and humidity variations, only the frictional losses are present. It could be very much useful in defence equipments. Non-metals like Polyurethane rubber, Teflon and Glass-epoxy mitigate the shock upto certain level. After that role of metallic and spring shock absorbers comes into picture. Material with high toughness and high compressive strength can absorb large amount of energy by undergoing plastic deformation.

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