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Numerical Simulation of Projectile Impact on a Target Plate using Ls-Dyna

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***Abstract*:**
Usually, the metal matrix composites have been developed greatly due to the wide range of applications in aerospace and automotive industries. The paper describes the numerical simulation method of the ballistic impact of bullet as a projectile on the Al-SiC metal matrix composite plates using the LS-DYNA software.In this study the metal matrix composite materials selected as Aluminium 75% and silicon carbide 25% to improve the ballistic resistance. The material of the bullet model was selected as 4340-Steel; hence the bullet and target plate models are designed in the CATIA-V5. Subsequently, the models were imported into the LS-DYNA for simulation. This analysis of the impact of the bullets is carried out using the Lagrangian method. Analysis is performed for target plate thickness varying from 2mm to 5mm. The simulation for the 2mm-5mm metal matrix plates were runs at different velocities till the penetration takes place. In this analysis we observed for 2mm thick plate the penetration occurs at 178m/sec, similarly for 3mm, 4mm and 5mm thick plate the penetration occurs at 235m/sec, 253m/sec and 282m/sec. A numerical study was done and the results were represented graphically as pressure vs time, stress vs strain, resultant displacement vs time, kinetic energy vs time, total energy vs time and resultant displacement vs resultant velocity graphs. This simulation study could be further performed in order to investigate the stress-strain distribution and deformation on the metal matrix target plates during the projectile impact and penetration.
Keywords: Al-Sic Plate, Steel Projectile, Ballistic Impact, Numerical Simulation, LS-DYNA

INTRODUCTION:

Metal matrix, polymer matrix and ceramic matrix composites are the composite materials which constituent'scombinations of two or more materials, hence one material for metal matrix be metal and polymer matrix be polymer. When three materials are present, it is called hybrid composites.Development of hybrid metal, polymer and ceramics matrix composites has become a crucial area of research interest in materials science. In recent years, because of high strength, high stiffness, toughness, density, good wear resistance and specific modulus the metal matrix, polymer matrix and ceramic matrix composites have shown great interest towards potential applications in aerospace, defence, security and automotive industries. Automotive,

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defence and aerospace applications like drive shafts, car brake disks, high temperature engine components, brake drums and rotors, bumpers and fenders, bracing beams, military tank Armor's, combat helmets, aircraft mid fuselage, jet engine fan blades, space and satellite structures, helicopter transmission structures, structural components of landing gear and personal protectionswhich require an exhaustive analysis of composite behaviour under dynamic loading so as to satisfy the security requirements[1].Recently, the automotive industries like Honda and Toyota using metal matrix composites in cylinder liners of engines.

Matrix composite materials, due totheir inherently advanced mechanical residences like excessive-precise strength and stiffness, are extensively applied in aerospace, civil, and armour protection applications, to reinforce the ballistic overall performance of composite laminate, it's essential to in addition to observe its ballistic response and higher recognize its impact/penetration behaviours[2].Over the decades, considerable research work has been done by many research scholars from alternative ways of aspects. The efforts to review the ballistic behaviours of composites mainly and specially focus on the ballistic limit, residual velocity and speed, impact energy absorption and failure modes, three methods like experiment test and check, theoretical evolution and numerical simulation. Theoretical models can explicitly explain the connection between the ballistic performance of composites and influential parameters like impact velocity, nose shape of projectiles, material characteristics and boundary conditions. Analytical study may be a best study to completely understand the damage and energy dissipation mechanisms of matrix composites. Analytical investigations for composite materials under low to high impact velocities are administered and a number of other theoretical models are also proposed by many researches.

Investigations on the projectile impact behaviour, like impact damage initiation and propagation also as ballistic limit, are the inspiration of personnel and structural analysis[3]. There are several theoretical models that describe the ballistic impact on composites, presented an analytical method to identify different damage and energy absorbing mechanisms during ballistic impact supported wave theory. Currently, finite element method (FEM) has been accustomed simulate high velocity impact behaviour of composites by some researchers. Some researchers simulated the ballistic impact response of laminated Kevlar composite panels and mild steel platesimplemented in LS-DYNA with velocities ranging from 820-870 m/sec and observed that the results are significantly influenced by the shape of projectile nose[4].

In the present research paper, we have carried numerical simulation of projectile impact on target plate by using LS-DYNA software. Hence the material of plate taken is metal matrix composite material as Aluminium-silicon carbide. Hence the material selection is considered based on the percentage i.e. Aluminium 75% + Sic 25%[5].The contact and penetration process also as damage evolution mechanisms are investigated. In this paper, the analysis of the impact of bullets is carried out using the Lagrangian method. Analysis is performed for target plate thickness varying from2mm to 5mm at different velocities till the penetration of the target plate takes place. The ballistic impact results are represented graphically as a pressure vs time, stress vs strain, resultant displacement vs time, kinetic energy vs time, total energy vs time and resultant displacement vs resultant velocity graphs.

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EXPERIMENTAL:

FINITE ELEMENT MODELLING OF TARGET PLATE AND PROJECTILE:

Finite element model of metal matrix target plate geometry with Lagrangian mesh was shown in figure-1(a). The target plate is kept fixed rigidly to reduce the number of elements for the analysis. The thickness of the plate varies from 2mm – 5mm.The material of plate is taken is Metal Matrix material as Aluminium-silicon carbide. Hence the material selection is considered based on the percentage i.e. Aluminium 75%+ Sic 25%.

The table-1 shows the value of plate materials properties of metal matrix composite.

Here the mechanical properties of Al-SiC metal matrix composites are investigated[6].Hence it is found that increase in the silicon carbide percentage it leads to the increase in hardness and decrease in elongation. And also increase in density leads to very high increase in strength. The aluminium gives the best tensile strength as per the weight percentage ratio.

Table-1 Plate Material Properties of Metal Matrix Composite

S.NO	PROPERTY	VALUE (Al 75% + Sic 25%)
1	Density (kg/mm^3)	2.88e-6
2	Tensile strength (Mpa)	186.21
3	Young's Modulus (GPa)	115
4	Yield Stress	0.1862100
5	Tangent Modulus	1.4800
6	Hardening parameter(beta)	0.0
7	Poisson's ratio	0.27
8	Failure Strain	0.1860000
9	Flexural strength (Mpa)	41
10	Co-efficient of thermal expansion	15
11	Thermal Conductivity (W/Mk)	145

The bullet is aligned so that the plate takes maximum impact. The projectile considered is bullet for the ballistic impact. The bullet is made of Alloy Steel 4340[7].Alloy steels are designated by AISI four-digit numbers. AISI 4340 steel may be a heat treatable and low steel containing chromium, nickel and molybdenum. It has high toughness and strength within the heat-treated condition. The finite element model of 4340 steel projectile geometry with Lagrangian mesh was shown in figure-1(b). Bullet is defining as a semi-hemisphere cylindrical projectile. Total length of the bullet is 25mm, radius of the semi-hemisphere and cylinder is 5mm. Table-3 indicates the Keyword Input Data.

Table-2bullet Material Properties of 4340-steel

S No	PROPERTY	VALUE
1	Density (kg/mm^3)	7.83E-6
2	Youngs Modulus	206.39999
3	Tensile strength (MPa)	745
4	Yield strength (MPa)	470
5	Bulk modulus (kPa)	1.59E+8
6	Shear modulus (kPa)	8E+7
7	Poisson's ratio	0.29
8	Thermal conductivity (W/Mk)	44.5
9	Bending Damping Factor	0.0
10	Axial Damping Factor	0.0

11	Yield stress (kPa)	7.92E+5
12	Strain rate constant	0.014
13	Melting temperature (K)	1793

Table-3 Keyword Input Data

CONTACT	PLATE	PROJECTILE
*MAT	PLASTIC KINEMATIC	ELASTIC
*SEC	SOLID	SOLID
*CONTACT	ERODING SURFACE TO SURFACE	
*NODE SET	12194 nodes	
*ELEMENT	14608 elements	
*VELOCITY	50-300 m/sec	

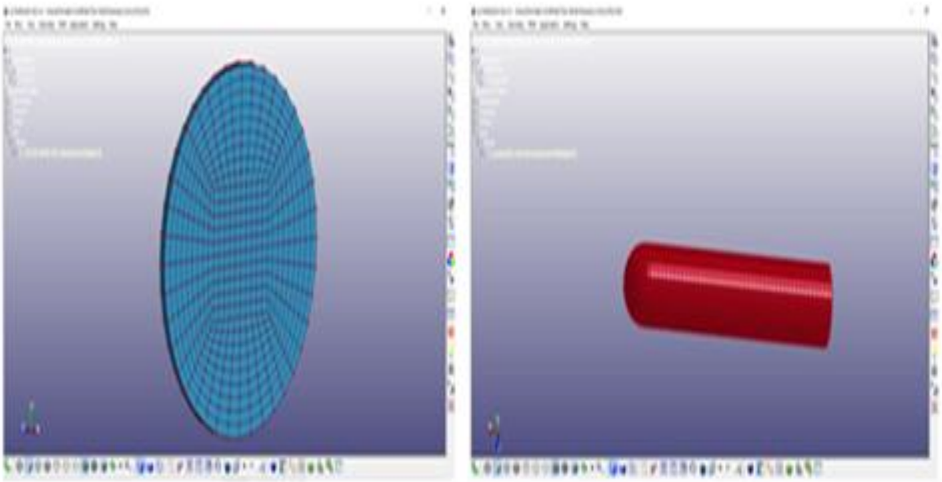

Fig.1 (a&b) Meshed Target Plate and Meshed Bullet(Projectile)

ANALYSIS OF RIGID TARGET PLATE WITH BULLET MODEL:

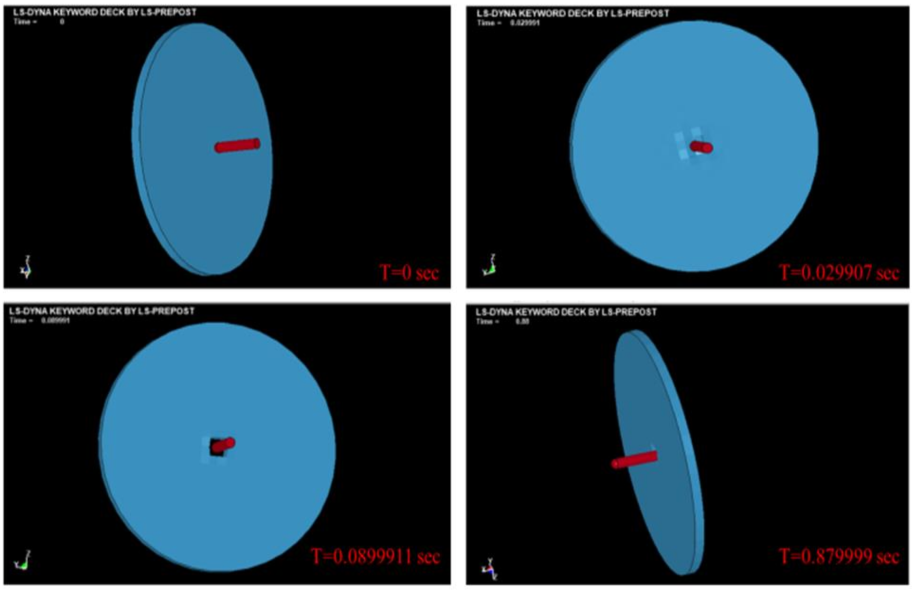

Fig.2a Stages of bullet impact on target plate

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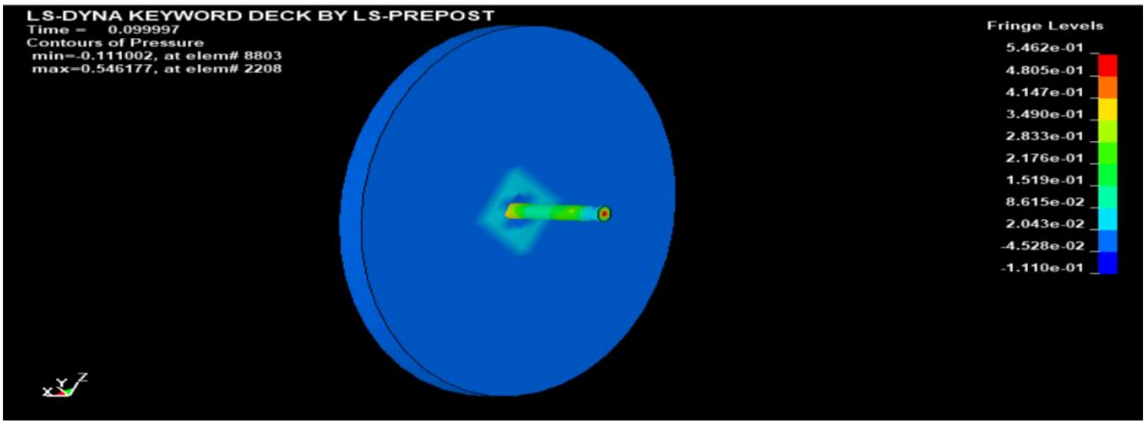

Fig.2b Fringe Pattern for the Impact

The bullet model is created using cylindrical shape with hemispherical end hitting the plate model to its centre point with a different velocity till the penetration of target place takes place. Here we use software LS-DYNA where we select the material as *MAT_PLASTIC_KINEMATIC for plate and *MAT_ELASTIC for the bullet model. The different velocities are assigned using the *INITIAL_VELOCITY card. The bullet model is moved in x-direction for impact simulation. The impact time given is the contact between the plate and the nodes of the bullet. The velocity used here is varied for different thickness of the target plate. The simulation will be done from different varying velocities. The model used here was a rigid plate to get the exact pressure values. The output of the simulation can be seen in the figure-2 a&b.

RESULTS AND DISSCUSSION:

The variation in pressure during the penetration of the target plate is shown in pressure vs time graph in figure-3a. Simulation of the Al-SiC plate was carried out by 4 different thickness of the plates such as 2mm, 3mm, 4mm and 5mm. Hence the depending on the thickness of the plate, during the simulation the penetration of plate takes at different velocities. The velocities at which the penetration of different thickness of plate is recorded as for 2mm the penetration occurs at 178m/sec, for 3mm, 4mm and 5mm the penetration occurs at 235m/sec, 253m/sec and 282m/sec. The pressure vs time graph is gradually varying and it is clearly seen that by increasing the thickness of the plate, the resistance will be good and the impact pressure will increase.The variation in Effective stress and Effective plastic strain during the penetration of the target plate is shown in pressure vs time graph in figure-3b.

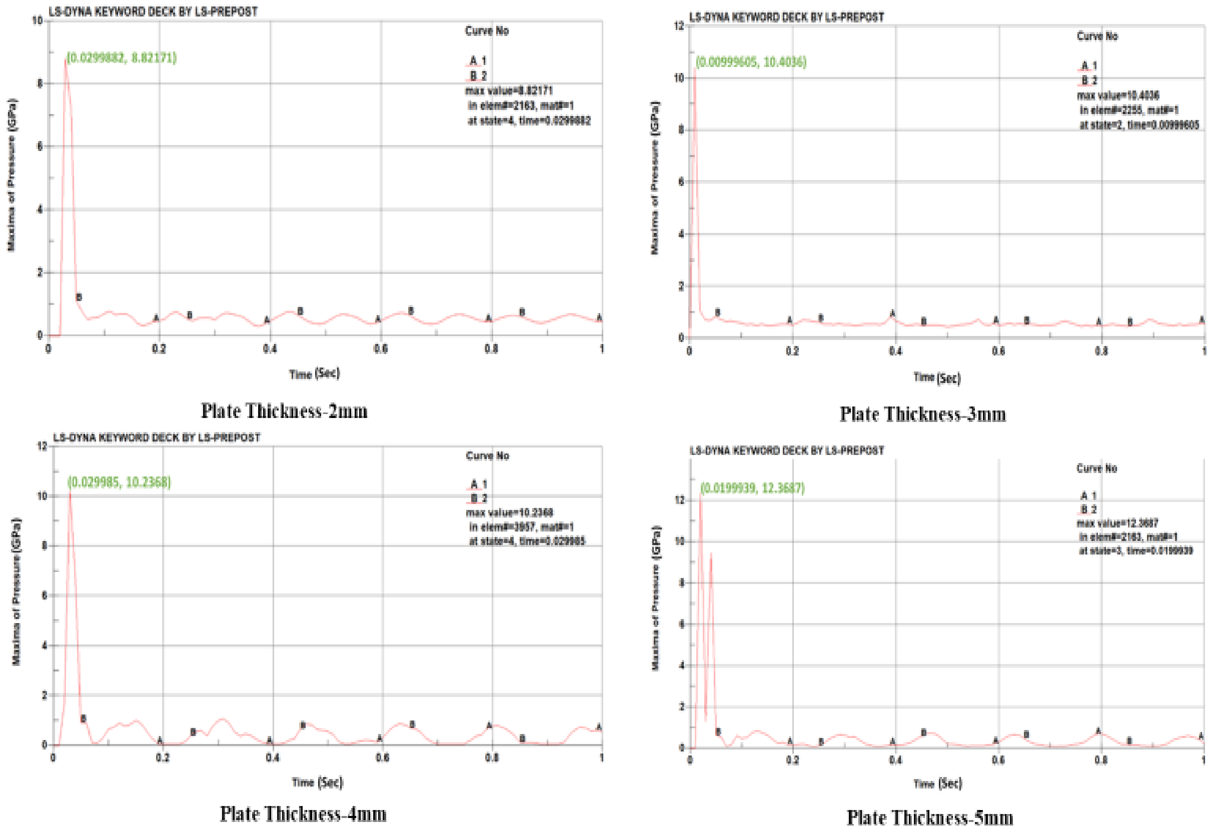

Fig. 3a Pressure vs Time graph for 2mm, 3mm, 4mm and 5mm thick plate

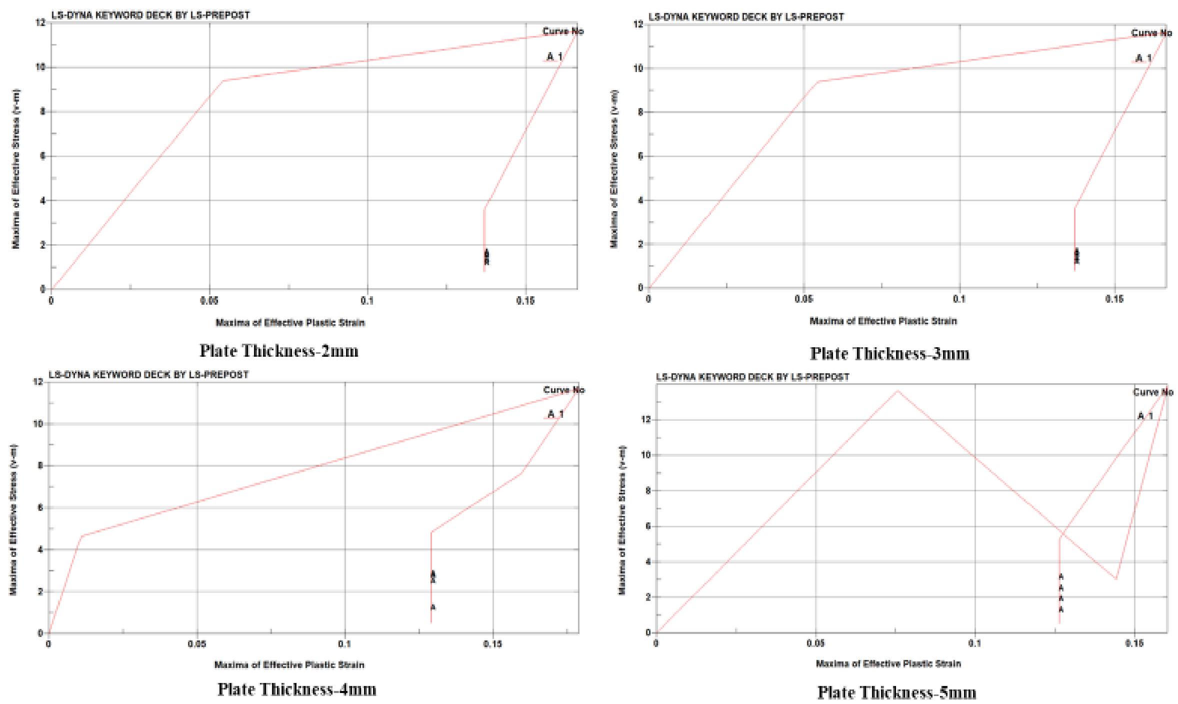

Fig. 3b Stress vs Strain graph for 2mm, 3mm, 4mm and 5mm thick plate

Basically, the displacement-time graph represents velocity variation. Here, the y-axis represents distance and the x-axis represents time. The projectile model

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travels in the x-direction for the impact simulation. Hence the purpose of using the displacement-time graph is shown in figure-3c represents that the simulation analysis is done for plate impact is to compare the values with respect to the different thicknesses of 2mm, 3mm, 4mm and 5mm. Figure.3d shows the variation of kinetic energy versus time for different failure criteria. From the graphs it is verified that the more kinetic energy loss is observed when the maximum strain failure criteria is used [8]. Generally, the reduction in kinetic energy of bullet is leads to the damage of target plate.

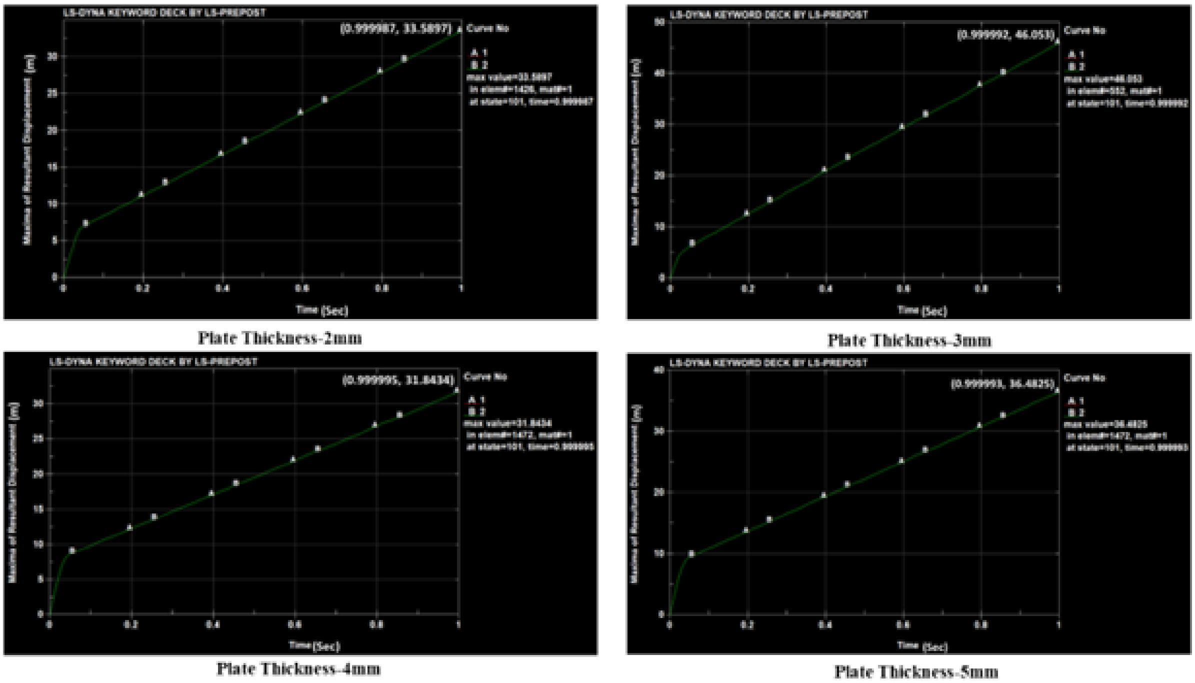

Fig. 3c Displacement vs Time graph for 2mm, 3mm, 4mm and 5mm thick plate

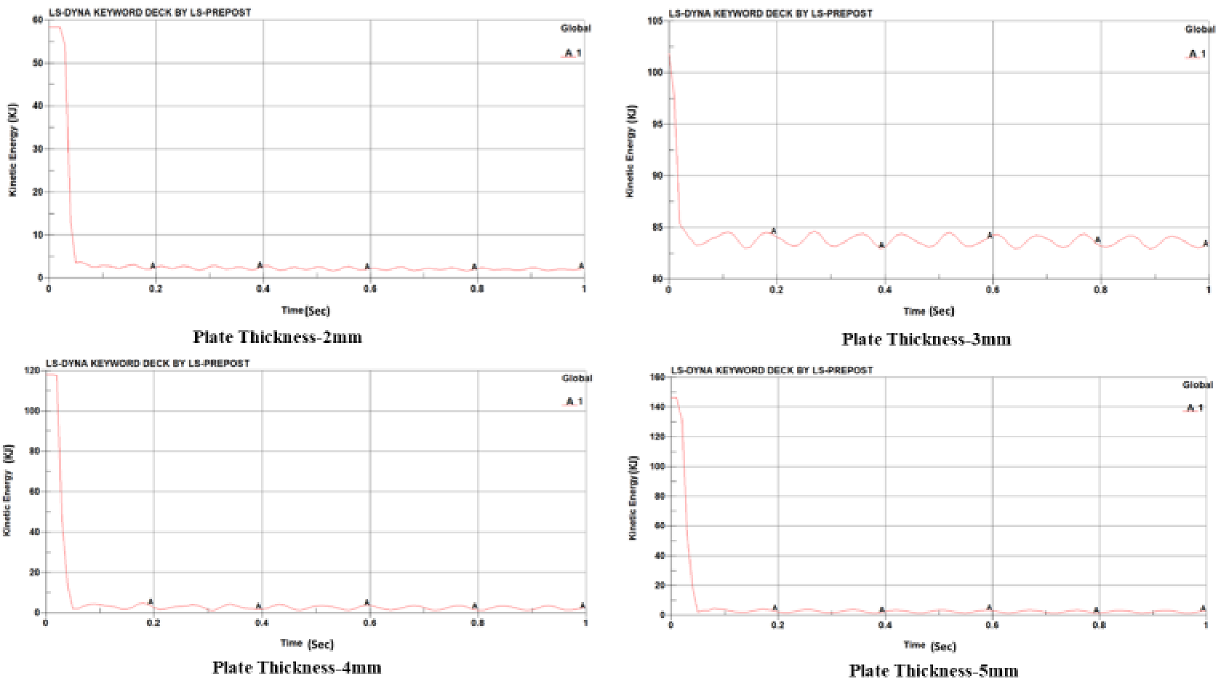

Fig. 3d Kinetic energy vs Time graph for 2mm, 3mm, 4mm and 5mm thick plate

Figure-3e shows the total energy absorbed by 2mm, 3mm, 4mm and 5mm thickness 75%Al-25%SiC plates, which is impacted at 178m/sec, 235m/sec, 253m/sec and 282m/sec. The total energy versus time shows the energy absorbing capacity of the target plate. The gradually decrease in the energy, because the during penetration of the target plate the energy is released. It means that the most energy of the projectile has been absorbedby the target plate[9].The projectile velocity during the impact simulation was recorded and is represented by Displacement vs velocity graphs as shown in Figure-3f. From graphs it is absorbed the positive residual velocity which means that the projectile has fully penetrated the target plate.

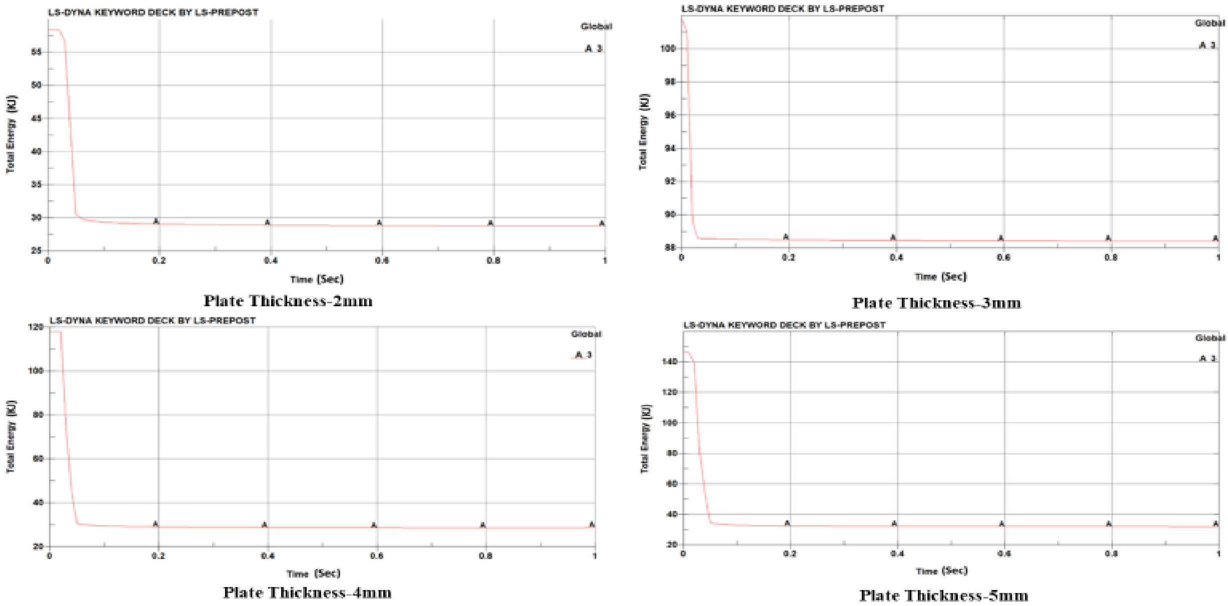

Fig. 3e Total energy vs Time graph for 2mm, 3mm, 4mm and 5mm thick plate

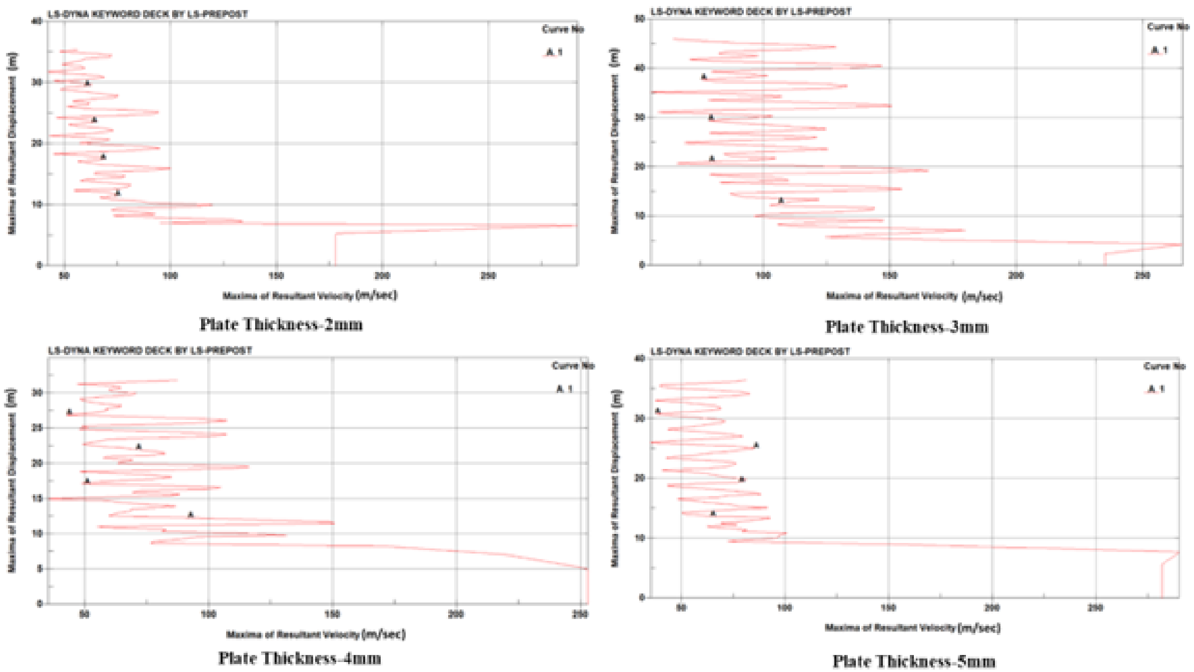

Fig. 3fDisplacement vs Velocity graph for 2mm, 3mm, 4mm and 5mm thick plate

CONCLUSION:

Inpresent paper details a numerical simulation, based on LS-DYNA code. The influence of 4340-steel projectile geometry on the ballistic performance of the Al-SiC composite material plate has been presented. In this study LS-DYNA software has been used for ballistic performance, followed by Lagrangian method. The pressure, stress-strain, Displacement, internal energy, total energy and resultant velocity graphs. The stress-strain has been solved in every incremental time steps. The data resulting from this numerical is used to develop the advanced models for isotropic materials. Hence purpose of numerical simulation is to carry out the protective behaviour and energy absorbing capacity of the Al-SiC composite plate with different velocity impacts. The results obtained indicates the dynamic response and the failure behaviour of Al-SiC plate upon the ballistic impact.

Fibre reinforced metal matrix and polymer matrix composites is considered for armour applications in aerospace. The metal matrix composites (MMC's) have advantages of wear resistance, hardness, strength and higher elastic modulus. Al, Ti and Ni can also be used as metal matrix composite materials, and these can be reinforced with Al_2O_3or SiC particles and whiskers. Hence, the penetration depth of the projectile into target plate is depends on frictional behaviour of created hole surface, the MMC plate and steel projectile.

In past few decades, the researchers have investigated on laminate armours to achieve light weight armours and good durability. Enhancing ballistic resistance of armours is became accepted practice in armour design [10].

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