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Numerical Simulation of Bird Strike Effect on a Composite Wing Leading Edge

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Abstract:
Birdstrike on aircraft is a major threat to human life and there is a need to develop structures which have high resistance towards birdstrike. This paper describes the numerical simulation of bird strike on the Aluminium Silicon Carbide (Al-SiC) metal matrix composite wing leading edge using LS-Dyna software. The metal matrix composite chosen has the composition of Aluminium 85% and Silicon Carbide 15%. At this composition the impact force of the material is high which means the material is more resistant to impacts which is suitable for the wing leading edge as it is subjected to events like birdstrike. For this simulation we have chosen the wing structure of Boeing 737 aircraft. The wing leading-edge section was designed using CATIA V5 with skin thickness of 2mm. Also, the ribs and the spar were designed for better results. A hemisphere cylindrical bird model is used for bird strike and is designed in LS Pre-Post V4.7.7 with length 196mm and diameter 98mm. The wing leading edge model was imported to the LS Pre-Post and was aligned properly for birdstrike analysis. The analysis of the birdstrike is carried out using the Lagrangian method. The required keyword input data such as Boundary Definition, Control, Contact Definition, Material properties for the bird and the wing leading edge section and Velocity for the bird are defined as per the requirements of the analysis. The simulation was run at different velocities ranging from 50-150m/s. The results were obtained graphically as Pressure vs. Time, Effective Stress vs. Time, Effective Plastic Strain vs. Time, Rigid Body Displacement vs. Time, Internal Energy vs. Time and Kinetic Energy vs. Time graphs. Using these graphs, the graphs for the Effective Stress vs. Effective Plastic Strain & Rigid Body Displacement vs. Velocity were plotted. In this analysis, it was observed that the Effective Stress of the wing leading edge with Al-SiC material has been increased by approximately 100 MPa with respect to the traditional Al 7075 T6 material. Also, the pressure distribution over the wing leading edge surface is smoother during impact for wing section with Al-SiC material. The energy absorption of the wing section has been increased. The overall strength of the wing leading edge section with Al-SiC as the material has been increased when compared to the wing leading edge section with Al 7075 T6 material.

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1. INTRODUCTION

An aircraft doesn't fly alone in its airspace, it shares the airspace with the birds too which are not controlled by pilots or any kind of user and might collide with the aircraft during its flight. It is impossible to prevent the collision of bird with aircraft. Therefore, an aircraft itself must be able to withstand such situations with lesser damage to its structure. Bird strike can be defined as the collision between bird and anaircraft, particularly during aircraft take-off and landing. The bird attack is common and serious threat to aircraft and passenger'ssafety. In the aviation sector, bird impact is considered an important problem that causes material damage and threatens flight as well as passenger's safety. In order to safeguard the aircraft and passengers it is must that the aircraft structural parts are designed such that they provide high resistance towards events like bird-strike.It is

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imperative that today's designed and manufactured aviation structures comply with safe flight and take-off & landing requirements. In order to satisfy these requirements, the behaviour of structural parts against bird impact is investigated by using the Finite Element Method of analysis and / or tests. Through the obtained results, it is aimed to improve the design process and to produce more durable and safe structures.Bird strikes occur mainly during the initial climb, take-off and landing. Since most birds fly mainly during the day, most of the bird strikes occur during the day. The International Civil Aviation Organization (ICAO) reported bird strike 65.139 for the period 2011-2014, and the Federal Aviation Authority reports sent 177.269 wildlife strikes in civil aircraft between 1990 and 2015, with an increase of 38% in 7 years from 2009 to 2015.The nature of aircraft damage from bird strikes creates a high risk to continue the safe flight. The most common effects due to bird strike are structural damage, damage of control surface, empennage.Especially large group of birds at lower altitude are dangerous because it leads to multiple strikes and damages and it becomes difficult for to recover in time at low speed and altitude.Federal Aviation Administration (FAA) and other similar administrations has defined minimum requirement for the aircraft structure with reference to the damage tolerance and fatigue evaluation of structures which includes that an aircraft must be capable of completing the flight successfully with likely structural damages which might occur as a result of events like bird-strike at normal flying condition.

In present we are using the Lagrangian method to predict the impact behaviour of birds.

Bird attacks usually occur in short periods of time that last a few milliseconds therefore, it is necessary to simulate the detailed bird model with properties similar with real life bird in order to get proper and useful data from the analysis.According to the reference papers it was found that the bird during impact on a rigid body behaves like a fluid. AFinite Element Analysis (FEA) simulation is carried out at different velocities to study the behaviour of bird impact forces and pressures on aircraft structural components.For bird,gelatine was found to be good equivalent material model with an initial density of 912kg/m^3 and porosity of 10%. The bird impacts on a rigid target is distinctly divided into four phases. The first phase is the initial impact in which very high shocks or pressure from Hugoniot are generated. The second phase involves the reduction of very high shock pressures at constant fluid flow pressures. In the third phase, the bird material constantly flows towards the target and an equivalent jet stream is created. The last phase concerns the impact of the bird that deforms the slab with different pressure values obtained. It was found that birds behave like liquids during impact.

2. METHODOLOGY

Using LS-DYNA software by taking hemi-spherical cylinder bird model using Lagrangian method numerical analysis is carried out.For the three-dimensional modelling finite element bird and wing leading edge models was developed. Once the geometry of bird and the leading edge was done, it was imported into the finite element meshing in LS-DYNA for finite element grid. Now required inputs and the properties are given to the elements for the impact analysis. The properties are taken from our own material properties, some unknown and confidential data can be assumed for the impact analysis of bird and wing leading edge.

There are different formulations for the analysis of finite elements that differ in the reference coordinates to describe the movement and the control equation. In this we use material coordinates as a reference generally indicated by X. The nodes are associated with particles in the material under examination.

In Lagrangian methods the computational grid (free community of computers linked to perform grid computing. In a computational grid, an outsized computational project is break up into amongst individual machines, which run calculations in parallel then go results to the first computer) is embedded and deformed with material. Since there is no transfer of heat or matter by the flow of a fluid, especially horizontally in the atmosphere or the sea between the grid and material, no advection term appears in governing equation. The masses of each material element keep constant during the deformation.

The major advantage of Lagrangian method is that, this method is conceptually simpler and is more efficient that the other two computational methods. Also, it is easier to impose boundary conditions on the finite element model and to track the material interfaces.

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In this paper an approximate model of bird and wing leading edge is developed using LS-DYNA software. These models are created using Lagrangian model respectively.

3. MATERIAL PROPERTIES AND CONFIGURATION

3.1 WING LEADING EDGE MODEL

The wing leading edge consists of the major parts wing skin, internal ribs and the front spar. The material for these parts is Metal Matrix Composite material i.e. Aluminium Silicon Carbide. The material selection is considered based on the percentage content of the Aluminium and Silicon Carbide. For the selected material the composition is 85% of Aluminium Alloy and 15% of Silicon Carbide. This composition is selected for its higher impact resistant property which is the foremost requirement for reducing the damage caused in event of birdstrike.

Mechanical properties of Al-SiC metal matrix composites were investigated and it was found that the elongation tends to decreases according to the increase in weight percentage of Silicon Carbide and hence it leads to increase in hardness. Density of the Al-SiC with different composition of SiC metal matrix composites was investigated. Density increases with increase in SiC composition, but very high increase in strength. It appears that the hardness increases results to decrease in elongation % of Al-SiC metal matrix composites. Tensile strength of the Aluminium Silicon Carbide metal matrix composites increases gradually at the increased composition of the silicon carbide in it but at 15% of SiC in Al gives the best tensile strength as per the weight percentage ratio. It was found that the weight to strength ratio for Al-SiC MMC is about three times that of mild steel during tensile test. Al-SiCMMC material is two times less in weight than the Aluminium of the same dimensions. Also, the study and mechanical testing of Al-SiC MMC shows that the material is able to withstand higher amount of impact forces than that of the traditional Aluminium alloy. This indicates that the Aluminium silicon carbide composite material is having less weight and more strength hence it is very much useful in practical aerospace applications.Fig 3.1 shows the Wing Leading Edge Model.

The table 1 includes the material properties values of the metal matrix composite which has been used for the analysis. The table 2 shows the Wing Leading Edge Configuration.

Table 1 Properties of Aluminium 85% and Silicon Carbide 15% MMC

PROPERTY	VALUE
Density, kg/mm^3	2.79e-6
Tensile strength, MPa	221.23
Poisson's ratio	0.29
Young's Modulus, .10^{3}MPa	185
Bending Strength, MPa	350
Tangent Modulus, MPa	148
Cowper Symond's Constant, C	6500
Cowper Symond's Constant, P	4

Table 2 Wing Leading Edge Configuration

PARTS	DIMENSIONS
Wing Skin Thickness	2 mm
Wing Skin Length	1186mm
Internal Ribs Thickness	20mm
Distance Between Ribs	372mm
Front Spar Thickness	5mm

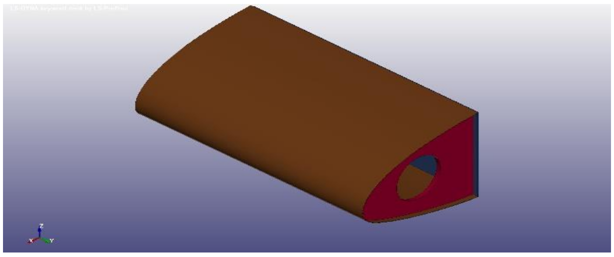

Fig 3.1 Wing Leading Edge Model

3.2 BIRD MODEL

Bird is defined as a semi hemisphere cylindrical projectile. The bird has the properties like that of gelatine and acts as elastic fluid. Thus, for the analysis the properties of the bird were used similar to that of gelatine. The following table 3 contains the properties of the bird material used for analysis. Table 4 shows the Bird model configuration.Fig 3.2shows the Bird Model.

Table 3 Bird material properties

PROPERTY	VALUE
Density ρ, Kg/mm^3	9.5e-9
Young's Modulus, MPa	2.39
Bulk Modulus, MPa	1.995
Poison's ratio, μ	0.3

Table 4 Bird model configuration

Parameters	Dimensions
Length of Cylinder, mm	149
Diameter of Cylinder, mm	98
Diameter of Hemisphere, mm	98

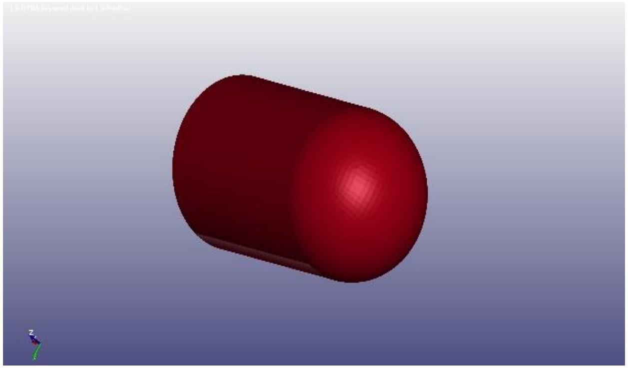

Fig 3.2Bird Model

4. FINITE ELEMENT METHOD

4.1 FINITE ELEMENT WING LEADING EDGE MODEL

The finite element wing leading edge model was created by using CATIA. Fig. 4.1 shows the finite element model of metal matrix composite wing leading edge geometry with Lagrangian mesh. The model contains of three major parts namely Wing Skin, Ribs and Front Spar. The mesh is solid mesh and the mesh size for all the parts are kept constant i.e. 10 mm for analysis. The entire finite element model of wing leading edge contains total number of 34,190 elements and 64,181 nodes.

Fig 4.1 Meshed Wing Leading Edge Model

4.2 FINITE ELEMENT BIRD MODEL

The finite element bird model is defined as a semi hemisphere cylindrical projectile. The total length of the bird projectile is 196 mm and the diameter of semi-hemisphere and cylinder is 98 mm. The bird model is designed using the L/2D ratio rule in LS-PrePost software. The bird is meshed as a solid part with element size of 3.5 mm. The bird model consists of 56364 elements and 59426 nodes.Fig. 4.2 shows the finite element model of bird geometry with Lagrangian mesh.

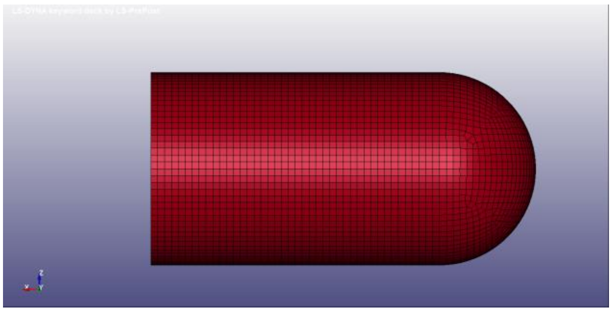

Fig 4.2 Meshed Bird Model

4.3 FINAL MODEL

The fig 4.3 shows the finite element model of the wing leading edge and the bird are aligned properly for the simulation. The bird is placed at the centre of wing leading edge model with a gap of 6 mm from the front surface of the wing leading edge.

Fig 4.3 Final Meshed Model

5. FINITE ELEMENT ANALYSISOF BIRDSTRIKE

The numerical analysis of birdstrike on a composite wing is carried out using the LS-Dyna software which is based on the Finite Element Analysis technique. As discussed earlier, the respective meshed wing leading edge model and the bird model were meshed as required and were aligned properly for the analysis. In LS- Dyna, the analysis is based on the Keyword data inputs. Therefore, the required data for the analysis of the birdstrike were entered with the help of the reference papers and each data are discussed in this chapter for clarification of the Finite Element Analysis of the birdstrike problem.

5.1 KEYWORD DATA INPUT

BOUNDARY
In order to fix the degree of freedom of the spar, the keyword Boundary is used.

CONTACT
Two different contact algorithms are used in this simulation.

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First is the ERODING_NODES_TO_SURFACE.It defines the contact between the bird and the wing leading edge where the bird is considered as the slave and the wing skin as the master. This contact algorithm is used in order to simulate the splashing effect of bird when it strikes over the wing leading edge surface.

The second contact algorithm used is the TIED_SURFACE_TO_SURFACE, which is used to define the contact between the parts of the wing leading edge. Since the wing skin, ribs and the front soar are connected to each other either with the help of rivets or weld, this contact algorithm simulates similar effect on parts of the wing leading edge.

CONTROL
This keyword is used to define the TERMINATION time of the simulation and the TIMESTEP of the analysis. The termination time for the simulation is kept as 1.5ms and timestep is kept as 0.01ms with TSFAC value of 0.6 and ERODE function is set to 1.

DATABASE
Under database ASCII and BINARY_D3PLOT functions are defined. The ASCII function contains GLSTAT and MATSUM function which presents the required graphs after the simulation is completed. The D3PLOT function is used to define the timestep of the calculation of the values during the analysis which is kept equal to that of the TIMESTEP in CONTROL function i.e. 0.01ms.

INITIAL
This function is used to define the VELOCITY for the bird. The velocity of the bird is entered in the X-axis. The simulation is carried out with three different velocities 50m/s, 100m/s & 150m/s.

MAT
The function MAT is used to define the material type and material properties for different parts used in the analysis. Two different material types are used to define the material property of the bird and the wing leading edge parts separately.

MAT_001_FLUID_ELASTIC_FLUID is used to define the material properties for the bird. This material type is used in order to provide actual bird like material property. The values of the properties are entered as per the reference papers which are available in the fifth chapter of the report.

MAT_003_PLASTIC_KINEMATIC is used to define the material properties for the wing leading edge parts. This material type is used for composite materials to simulate the material deformation and failure under impact load. The material properties are obtained from the reference papers related to the mechanical testing of Al-SiC and other similar reference papers.

PART
This function is used to link the SECTION and MATERIAL to all the parts that are used for the simulation.

SECTION
This function is used to define the SECTION of the model whether the model is SOLID, SHELL or BEAM as per requirement. For our analysis, all the parts are defined as SOLID section.

SET
The function Create Entity is used to define node sets to enter the boundary conditions. Two sets of nodes are created. One set of nodes consists of Bird nodes, the node set is defined with the velocity. The other set of nodesconsists of the nodes of Spar element which are used to fix the degree of freedom in the boundary function.

5.2 ANALYSIS OF WING LEADING EDGE WITH SEMI-HEMISPHERE CYLINDRICAL BIRD MODEL

With all the required keyword input data the analysis was run with three different velocities. The output of the simulation can be seen in the below figures.

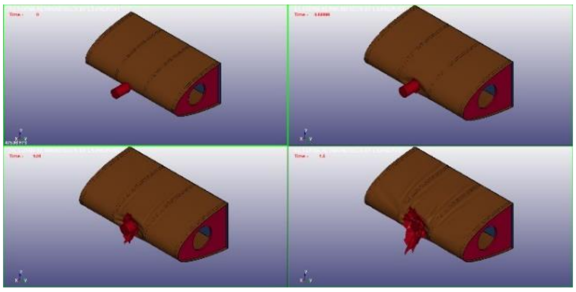

Fig 5.1 Stages of bird impact on wing leading edge

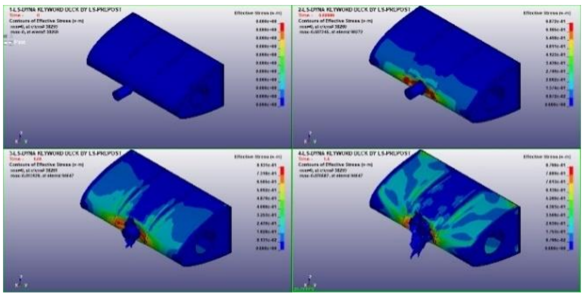

Fig 5.2 Stress on wing leading edge

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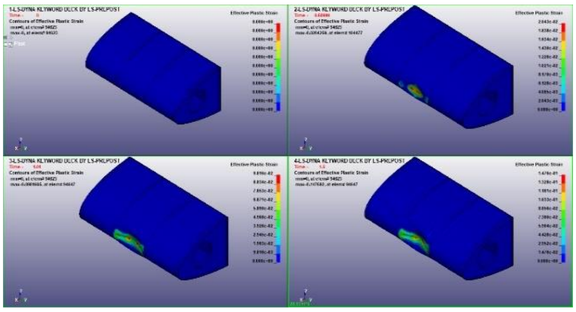

Fig 5.3 Strain on wing leading edge

6. RESULTS AND DISSCUSSION

6.1 TRANSIENT CURVES

The results obtained are represented graphically as Effective Stress vs. Effective Plastic Strain, Internal Energy vs. Time, Total Energy vs. Time, Kinetic/Internal Energy Ratio vs. Time, Pressure vs. Time, Rigid Body Displacement vs Time and Rigid Body Displacement vs. Velocity for two different material at three different velocities.

6.1.1 ALUMINIUM SILICON CARBIDE

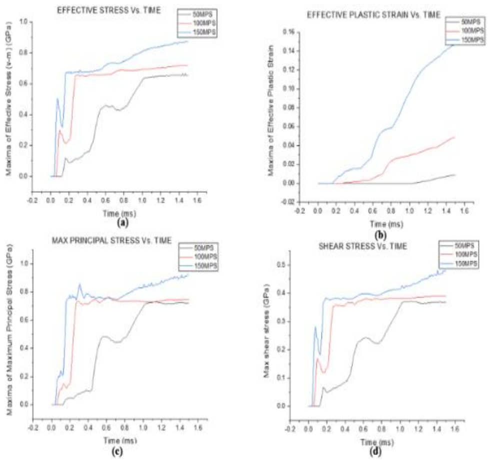

Fig 6.1: (a) Stress Vs. Time, (b) Strain Vs. Time, (c) Principal Stress Vs. Time, (d) Shear Stress Vs. Time.

The above Fig. 6.1 (a), (b), (c) and (d) shows the variation of Effective Von-Meiss Stress, Effective Plastic Strain, Maximum Principal Stress and Shear Stress with respect to Time over the wing leading edge surface and its corresponding parts respectively for three different velocities.

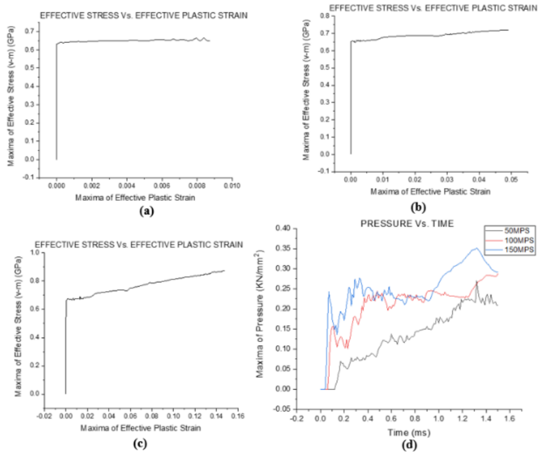

Fig 6.2: (a) Stress Vs. Strain @ v= 50m/s, (b) Stress Vs. Strain @ v= 100m/s, (c) Stress Vs. Strain @ v= 150m/s, (d) Pressure Vs. Time.

The above Fig. 6.2 (a), (b), (c) shows the variation of Strain with respect to the Stress applied at three different velocities i.e. 50m/s, 100m/s and 150m/s respectively. The final graph Fig 6.2 (d) shows the Pressure distribution over the wing surface with respect to time for three different velocities.

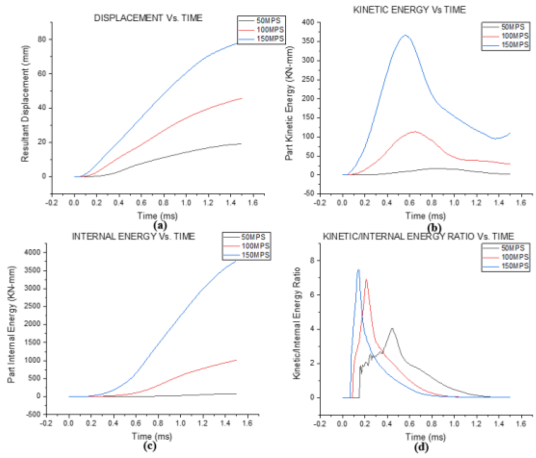

Fig 6.3 (a) Displacement Vs. Time, (b) Kinetic Energy Vs. Time, (c) Internal Energy Vs. Time, (d) Kinetic/Internal Energy Ratio Vs. Time

The above figure 6.3 (a) shows the wing skin displacement with respect to time for different velocities. The other figures fig 6.3 (b) and (c) shows the Kinetic Energy and Internal Energy of the wing model with respect to Time. The final graph fig 6.3 (d) shows the Kinetic/Internal Energy Ratio with respect to Time.

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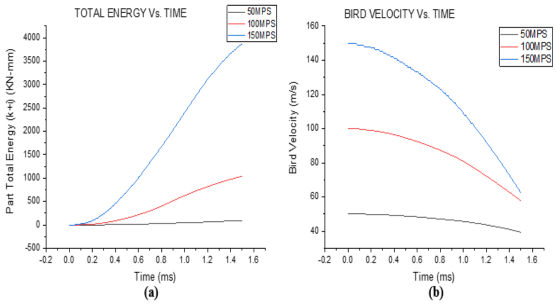

Fig 6.4 (a) Total Energy Vs. Time, (b) Bird Velocity Vs. Time

The above figure 6.4 (a) shows the Total Energy absorbed by the wing leading model with respect to Time and fig 6.4 (b) shows the Bird Velocity upon impact over the wing leading edge with respect to Time.

6.1.2 ALUMINIUM 7075

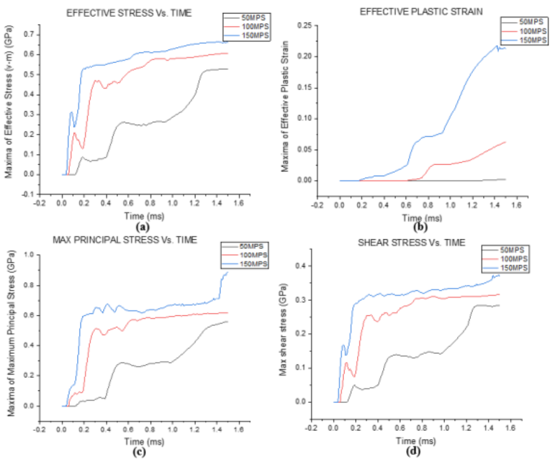

Fig 6.5: (a) Stress Vs. Time, (b) Strain Vs. Time, (c) Principal Stress Vs. Time, (d) Shear Stress Vs. Time.

The above Fig. 6.5 (a), (b), (c) and (d) shows the variation of Effective Von-Meiss Stress, Effective Plastic Strain, Maximum Principal Stress and Shear Stress with respect to Time over the wing leading edge surface and its corresponding parts respectively for three different velocities.

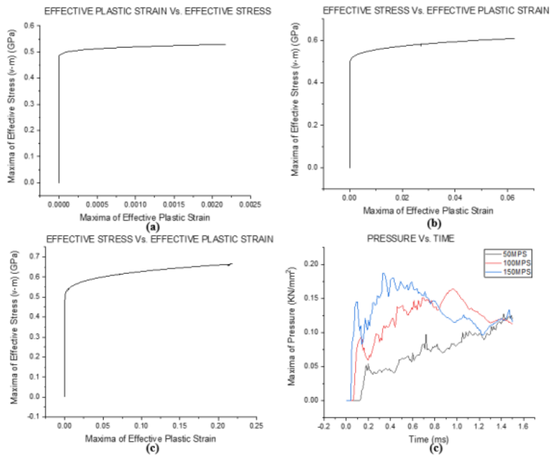

Fig 6.6: (a) Stress Vs. Strain @ v= 50m/s, (b) Stress Vs. Strain @ v= 100m/s, (c) Stress Vs. Strain @ v= 150m/s, (d) Pressure Vs. Time.

The above Fig. 6.6 (a), (b), (c) shows the variation of Strain with respect to the Stress applied at three different velocities i.e. 50m/s, 100m/s and 150m/s respectively. The final graph Fig 6.6 (d) shows the Pressure distribution over the wing surface with respect to time for three different velocities.

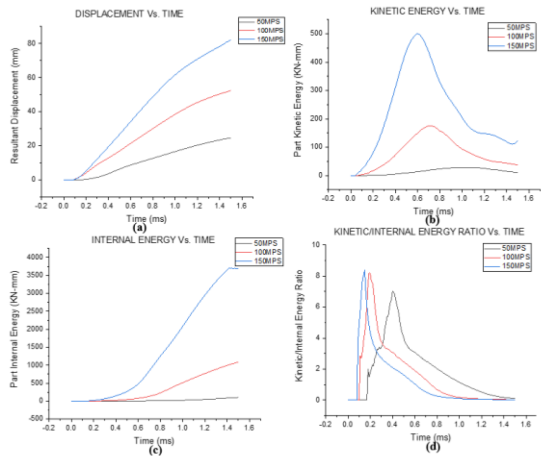

Fig 6.7 (a) Displacement Vs. Time, (b) Kinetic Energy Vs. Time, (c) Internal Energy Vs. Time, (d) Kinetic/Internal Energy Ratio Vs. Time

The above figure 6.7 (a) shows the wing skin displacement with respect to time for different velocities. The other figures fig 6.7 (b) and (c) shows the Kinetic Energy and Internal Energy of the wing model with respect to Time. The final graph fig 6.7 (d) shows the Kinetic/Internal Energy Ratio with respect to Time.

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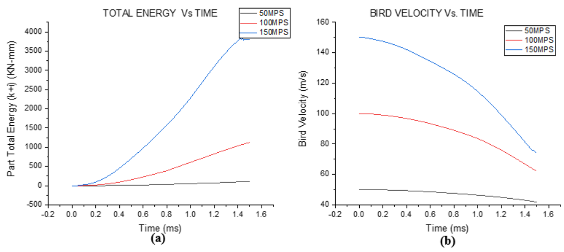

Fig 6.8 (a) Total Energy Vs. Time, (b) Bird Velocity Vs. Time

The above figure 6.8 (a) shows the Total Energy absorbed by the wing leading model with respect to Time and fig 6.8 (b) shows the Bird Velocity upon impact over the wing leading edge with respect to Time.

6.2 COMPARATIVE GRAPHS

For comparative study the resultant graphs from the analysis of the models with two different material on them were studied. The comparative graphs for both the simulation are taken at the velocity of 150 m/s since the wing leading edge model with traditional Al 7075 material fails at this velocity allowing the bird to penetrate the wing skin whereas the wing model with Al-SiC metal matrix composite material doesn't fail at the same velocity as shown in Fig 6.9 (a) and 6.9 (b).

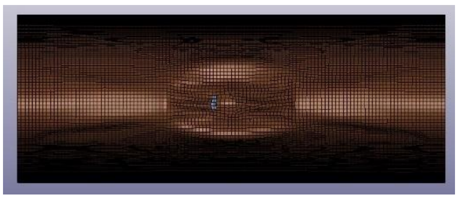

Fig 6.9 (a) Al 7075 Deformation

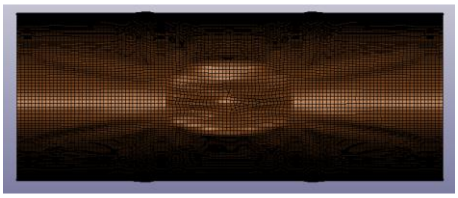

Fig 6.9 (b) Al-SiC Deformation

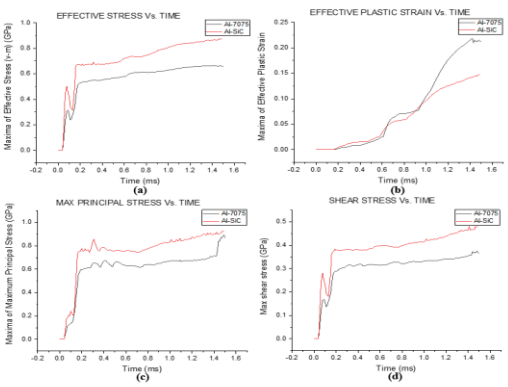

Fig 6.10: (a) Stress Vs. Time, (b) Strain Vs. Time, (c) Principal Stress Vs. Time, (d) Shear Stress Vs. Time.

The above Fig. 6.10 (a), (b), (c) and (d) shows the variation of Effective Von-Meiss Stress, Effective Plastic Strain, Maximum Principal Stress and Shear Stress with respect to Time over the wing leading edge surface and its corresponding parts respectively for two different material. The red line indicated the graph of Al-SiC material and the black line indicates for Al-7075 material.

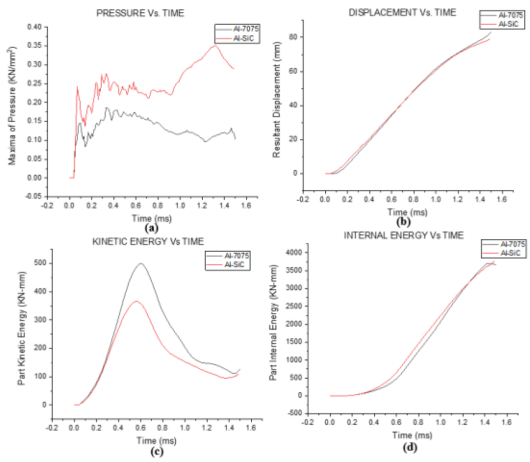

Fig 6.11 (a) Pressure Vs. Time, (b) Displacement Vs. Time, (c) Kinetic Energy Vs. Time, (d) Internal Energy Vs. Time

The above figure 6.11 (a) shows the Pressure distribution over the wing surface with respect to time for two different materials. Fig 6.11 (b) shows the Displacement of wing skin of the wing model with respect to Time. The final two graphs fig 6.11(c) and (d) shows the Kinetic and Internal Energy of the wing model with respect to Time for two different wing models with different materials. Red for Al-SiC and black for Al-7075.

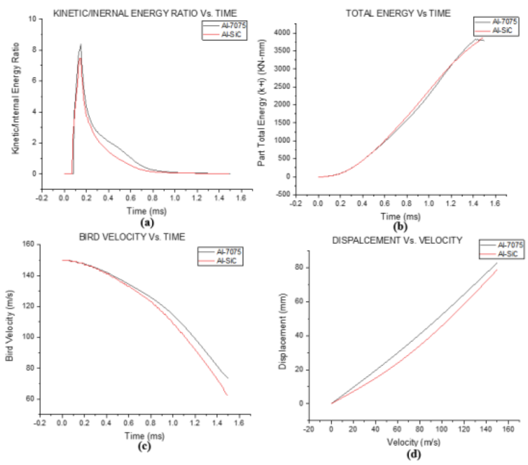

Fig 6.12 (a) Kinetic/Internal Energy Ratio Vs. Time, (b) Total Energy Vs. Time, (c) Bird Velocity Vs. Time, (d) Displacement Vs. Velocity

The above figure fig 6.12 (a) shows the Kinetic/Internal Energy Ratio with respect to Time, fig 6.12 (b) shows the Total Energy absorbed by the wing leading model with respect to Time, fig 6.12 (c) shows the Bird Velocity upon impact over the wing leading edge with respect to Time, and the final graph fig. 6.12 (d) shows the Displacement of wing skin of the wing models with respect to their velocities for two different materials. Red for Al-SiC and black for Al-7075.

6.3RESULT AND DISCUSSIONS

Running the simulation for Al-SiC and Aluminium 7075 material for same time and comparing the graphs for the two different wing material the following observations were made:

- Maximum stress value obtained for the Aluminium Silicon Carbide is 877 MPa whereas for Aluminium 7075 the maximum stress value obtained is 665 MPa. For both the simulation the bird velocity is 150 m/s. This shows that the wing model applied with Al-SiC metal matrix composite material withstands more stress than that of traditional Aluminium alloy. The difference obtained is 212 MPa approximately.
- Maximum plastic strain value obtained for wing model with AL-SiC is 0.148 whereas for traditional Al 7075 alloy the plastic strain value obtained is 0.219. The change in dimension for Al alloy is more than Al-SiC wing model. For the same impact velocity and same simulation time wing model with Al 7075 alloy deforms more than the wing model with Al-SiC material.
- The wing model with Al-SiC material retains maximum pressure of 352 MPa whereas Al 7075 alloy retains maximum of 187 MPa pressure.
- Maximum displacement of wing skin with Aluminium Silicon Carbide is 78.9 mm whereas for Aluminium 7075 the max. displacement of skin is 83 mm. Therefore, the wing model with traditional Al alloy deforms more than that of wing model with Al-SiC material.
- The Al-SiC material has more strength to weight ratio and thus has higher impact resistant property than traditional Al alloy which is suitable for application in aeroplane parts which are subjected to events like birdstrike.

CONCLUSION

This analysis of the birdstrike on the metal matrix composite wing leading edge is carried out in the LS-Dyna software using Lagrangian method for the wing leading edge with two different material in which the bird velocity was varied from 50 m/s to 150 m/s. Penetration of the bird was observed in the wing leading edge model with Aluminium 7075 material at 150m/s but for the same speed and same duration of simulation no penetration was observed in the wing leading edge model with Aluminium Silicon Carbide material. It shows that the AL-SiC metal matrix composite has higher strength to weight ratio. The material can withstand higher impact force and thus prevents the parts from failure. These results are based upon the graphs obtained from the simulation which when compared with reference journals showed very less error percentage concluding that the simulation carried out were almost accurate. Thus, we can conclude that the metal matrix composite (Al-SiC) that we have used for the simulation has more tendency to withstand high impact force than that of the traditional aluminium alloy and hence can be used for the application in the aero industry to reduce the risk of damages caused during the event of bird strike.

REFERENCES

[1] Zeliang Yu, Pu Xue, Peilun Yao, M. S. Zahran, “Design of aircraft structures against threat of bird strikes”, Latin American Journal of Solids and Structures, 2019.

[2] Yadav Bharosh Kumar, “Design and analysis of a new type of aircraft wing leading edge against bird-impact”, International Science Community Association, 2017

[3] Vijay K. Goyal, Carlos A. Huertas, Thomas J. Vasko, “Arbitrary Lagrangian Eulerian Approach for Bird-Strike Analysis using LS-DYNA”, American Transactions on Engineering and Applied Sciences, March 01, 2013.

[4] Ugrcic, M. & Maksimovic, S.M. & Stamenkovic, Dragi & Maksimovic, K.S. (2015). Finite element modelling of wing bird strike. FME Transactions. 43. 76-81. 10.5937/fmet1501076U.

[5] Vijay K. Goyal, Carlos A. Huertas, ThomasJ. Vasko, “Smooth Particle Hydrodynamics for Bird-Strike Analysis Using LS-DYNA”, American Transactions on Engineering & Applied Sciences, March 04, 2013.

[6] Jun LIU, Yulong LI, Xiancheng YU, Xiaosheng Gao, Zongxing LIU, “Design of aircraft structures against threat of bird strikes”, Chinese Journal of Aeronautics, 2018.

[7] Earnest Vinay Prakash, Prabhat Sinha, “Analysis and Testing of Aluminium Silicon Carbide Metal Matrix Composites Engineering”, August 2015.

[8] Muhammed Muddassir, S.B Mallur, “Tensile Property and Hardness of Al-7075 Matrix Reinforced withSilicon Carbide Particles”, International Research Journal of Engineering and Technology, 07 July 2019.