ANALYSIS OF LOW-VELOCITY IMPACT RESPONSE IN AA5083 PLATE

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ABSTRACT

This paper investigates the low velocity impact performance of AA5083 using ABAQUS software. The impact resistance was measured in terms of depth of indentation created over AA5083. Low-velocity impact results indicates, that the angle of inclination of the impact resisting body have a great influence on the impact resistance properties. The analysis study was carried out for different orientations of the alloy plate with respect to the horizontal datum namely 30°, 60°, 90° respectively. A Finite Element Method (FEM) model has been developed using ABAQUS software tool to analyse and study the low-velocity impact test on the AA5083 plate. Results from the FEM model reveals that the depth of indentation over AA5083 is minimum when the angle is inclined at 90°.

Keywords: Low-velocity impact, AA5083, Angle of inclination, ABAQUS.

1. INTRODUCTION

Alloys are the combination of one or more metal with different atomic radius and electronegativity elements. Alloys have occupied various industrial applications such as aerospace, automobiles, aircrafts, defense, sports equipment and manufacturing of machinery component. Due to its less weight, high strength, and good material properties like isotropic, crystalline structure and ease to machine [1]. In Boeing 787, most of the components are made up of alloy materials like aluminium and titanium which leads to reduction in fuel consumption by 20% [2]. AA5083 aluminium alloy have magnesium as a second major element and traces of manganese and chromium. Aluminium alloys are used in different applications and one of the most important applications are aircraft structure. The properties of AA5083 alloy are high strength, high stiffness, easy to machine with high dimensional stability [1-3].

The main risks of aircraft structure are structural failure and damage. The reasons for the failure of aircraft structure are formation of voids in the microstructure of the materials error in manufacturing process [4]. The impact loading can be categorized into low-velocity impact, intermediate velocity impact, high-velocity impact and hyper-velocity impact. The range of low-velocity impact is below 10 m/s. The intermediate velocity is occurred between the 10 m/s and 50 m/s, high velocity impact range is between 50 m/s and 1000 m/s and hyper velocity impact range is between 2 km/s to 5 km/s. In this paper low-velocity impact analysis were discussed. The low-velocity impact causes unseen impairment with a large area of dynamic structural response, like impact by a bird during takeoff and landing, tool drop [6-8]. By finite element analysis method deformation produced by low-velocity impact test can be predicted. This method reduces time consumption and reduce cost to conduct experimental study [9]. In this paper ABAQUS software is used to analyse the low-velocity impact test to predict the deformation produced.

2. ANALYSIS PROCEDURE

The 3D finite element modelling is a better way for simulating impact damage on an alloy, especially with regards to the delamination of layers because it is the main failure mechanism and which causes more impact energy absorption [9-10].

For high strain rate deformation in many finite element programs, the Johnson-Cook plasticity model were incorporated. Being an empirical or purely phenomenological model, it is heavily dependent on experimental
data [12-13]. Despite this, its parameters are more easily obtainable than those in physical-based constitutive models. The material law was defined using Johnson-Cook formulation. This is given in equation 1.

\[
\sigma = (a + b\varepsilon_p)(1+c\ln \dot{\varepsilon}/\dot{\varepsilon}_0)(1-T^{*m})
\]  

(1)

\(\sigma\) = true stress level, \(a\) = yield stress, \(\varepsilon_p\) = true plastic strain, \(b\) = Hardening modulus, \(n\) = Hardening Exponent, \(c\) = Strain rate coefficient, \(\dot{\varepsilon}\) = Strain rate, \(\dot{\varepsilon}_0\) = Reference strain rate.

In the finite element design, the low-velocity impact on Aluminium alloy was analysed using ABAQUS software. The bullet was used as a three dimensional(3D) rigid body while the plate was used as a 3D deformable part. The solid model of an impactor(bullet) and plate is created by ABAQUS software. The diameter and length of the bullet was defined as 5mm and 20mm. The diameter of the plate was given as 100×100×10mm. The velocity at which the impactor strikes the plate is 3 m/s.

The material property for both the impactor(bullet) and plate was assigned using PROPERTY module in the menu. The material properties were assigned as per the table 1.

| Table 1. Summary of material parameter for AA5083 |
|-----------------------------------------------|
| **Category** | **Parameter name** | **Value** | **Source** |
|----------------|--------------------|----------|------------|
| Physical properties | Density | 2660 kg/m³ | United states of America Department of Defense 1998 |
| Thermal properties | Thermal Coefficient of thermal expansion | 2.34x10⁻⁷ /K | United states of America Department of Defense 1998 |
| | Inelastic heat | 0.9 | |
| | Specific heat | 900 J/(kg. K) | |
| Isotropic Elastic Model | Young’s modulus | 71.7 GPa | |
| | Poisson’s ratio | 0.33 | |
| Johnson Cook plasticity model | A | 137.89 MPa | Calculated from experimentation at the University of Manitoba |
| | B | 216.73 MPa | |
| | N | 0.4845 | |
| | C | 0.002 | |
| | M | 1.225 | |
| | Tm | 933 K | United states of America Department of Defense 1998 |
| | Tref | 293 K | |
| Johnson Cook Dynamic Failure Model | D1 | 0.178 | Failure parameters for AAS5083-H116(GRYTTEN , et al.2007) |
| | D2 | 0.389 | |
| | D3 | -2.246 | |
| | D4 | 0 | |
| | D5 | 0 | |
The solid models for the simulation were assembled in the required orientation using
ASSEMBLY option in the module dropdown box. In first case, the plate was inclined to the
axis at 30° and the orientation of the bullet was 90° to the axis of the plate. It is shown in figure
1. In second case, the plate inclination was changed to 60° to its axis and the impactor angle
remains same, as shown in figure 2. In third case, the inclination of the plate was further
changed to 90° to its axis and the impactor remains same, as shown in figure 3.

The STEP section of the module was used to create each frame in which the dynamic explicit
models are created. In the interaction section of the module the type of the contact between
the two models were assigned. In load section at module the boundary condition of plate was
assigned to arrest all degree of freedom.

In the MESH section define the type of mesh, element type and the dynamic model to achieve
accurate results. The plate was designed using 46, 080 C3D8R elements with 8-node 3D linear
brick. The interference between the impactor and an alloy was analysed using COH3D8
cohesive elements.
The job section was used to create analysis. After assigning all the required parameters for analysis, the analysis part was done. Based on the number of elements the size and the time requirement are increased for analysis.

3. RESULT AND DISCUSSION

As per the result obtained from the simulation, the deformation produced in the plate at 30° inclination is high as is shown in Figure 6. The shear stress produced in 30° is 2.826*10e8 and it is high compared to the other degrees of inclination such as 60° and 90°. From the graph shown in Figure 7, it is observed that the depth of indentation is 2.694*10e-1. It is much higher depth of indentation than the other two degrees of inclination.

As per the result obtained from the simulation, the deformation produced in the plate at 60° inclination is high as is shown in Figure 8. The shear stress produced in 60° is 2.694*10e8 and it is high compared to the other degrees of inclination such as 30° and 90°. From the graph shown in Figure 9, it is observed that the depth of indentation is 2.694*10e-1. It is much higher depth of indentation than the other two degrees of inclination.
From the simulation results, it was found that the deformation produced in the plate at 60° inclination is higher than 90° inclination. It is shown in Figure 8. The shear stress produced in 60° is 2.728*10e8. It is more when compared to the 90° inclination and less than 30°. From the graph, shown in Figure 9, it is observed that the depth of inclination is 2.277*10e-1. It is higher depth of indentation than 90° inclination but lower than the 60° inclination.

![Figure 10. Deformation of the plate at 90°](image1)

![Figure 11. Depth of indentation at 90°](image2)

As per the result obtained from the simulation, the deformation produced in the plate at 90° inclination is low. It is shown in Figure 10. The shear stress produced in 90° is 2.442*10e8. It is less when compared to the other degrees of inclination say 60° and 90°. From the graph, shown in Figure 11, it is observed that the depth of inclination is 2.088*10e-1. It is considerably less depth of indentation than the other two degrees of inclination.

| S.NO | Angle (degree) | Depth of indentation (mm) | Stress value (N/mm²) |
|------|----------------|--------------------------|---------------------|
| 1.   | 30             | 2.694*10e-1              | 2.826*10e8          |
| 2.   | 60             | 2.277*10e-1              | 2.728*10e8          |
| 3.   | 90             | 2.088*10e-1              | 2.442*10e8          |

From the table 2, it is clear that the depth of indentation is minimum when the impactor strikes the plate which is inclined at an angle of 90° as well as the stress value is also low, when compared to other two inclination plates say 60° and 90°.

### 4. CONCLUSION

Complete design was done by ABAQUS software. After the designing, the analysis of plate with three different inclination (30°, 60°, 90°) was done to find the depth of indentation as well as the amount of stress produced. The depth of indentation is 2.694*10e-1 at 30°, 2.277*10e-1 at 60°, 2.088*10e-1 at 90° respectively. The stress value is 2.826*10e8 at 30°, 2.728*10e8 at 60°, 2.442*10e8 at 90° respectively. It was found that the depth of indentation produced in 90° inclination plate is minimum when compared to other two degrees of inclination.
At the peak, when the plate is 90° perpendicular to the impactor, the depth of indentation and stress is minimum. Further in future, the composite materials are used instead of alloy material for the analysis purpose, it will give more progress in the material properties and its application.

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