Experimental and Numerical Analysis of Single and Double Layered Aluminum Sheet 3105 with Mechanical Joints under Drop Hammer Impact

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1. Introduction

This study was conducted for three levels of impact energy. The sheets are of AL3105, with dimensions of 220*230 mm^2, 1 and 2 millimeters thickness. They are connected by bolt. The sheets are completely free on the fixture. The screws are made of bolt Standard din933. In the experimental method, the peak acceleration has been measured by the accelerometer sensor. The permanent deformation of the sheet is measured at the end of the impact. The parameters were evaluated with the impact acceleration on the sheet, the degree of permanent deformation, and the energy absorption for the sheets. Finite element software (Abaqus) has been used for numerical modeling. Comparing the results of experimental and numerical methods shows that these two research methods have similar results. The results also show that the absorption of energy in one-layer sheets is greater than double-layered as well as acceleration in double-layered sheets more than one-layer sheets.

2. Testing specimens

For hit test, flat st12 sheet with standard ASTMB209 has been used with a thickness of 1 mm. The overall dimensions of the sheets are 22*23 cm^2. The useful dimensions of these sheets are 21*22 cm^2. The sheets are joined by bolts. The bolts have been selected in accordance with full-time standard din933. There are three heights for dropping so six series of test specimens will consist of double-layered and three-layer specimens, each of which has three specimens for error analysis. Totally there are 18 testing specimens. In this paper, sheets are named AL, which stands for Aluminum (Figure 1).

3. Mechanical properties of sheets and bolts

To determine the mechanical properties of the steel plate, three experimental specimens were cut and tested according to ASTM E8 standard (Figure 2).

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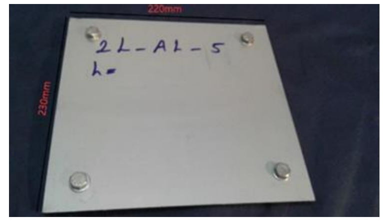

Fig. 1. Specimen 2L-Al

Fig. 2. Tensile test

4. Fixture

The fixture is used to hold the specimens and create an appropriate support. The fixture has free constraints for specimens (Figure 3).

Fig. 3. Fixture

5. Impact Test Machine and Accelerometer

The device used for impact test in this study is a drop hammer test machine (DH-TM-7500J) (Figure 4).

Fig. 4. Drop hammer test machine 7500 J

6. Experimental results

The results of this analysis are provided in the form of accelerometer-time diagrams. Also, the permanent deformation of each sheet as another important parameter in the investigation of performance of the sheets was measured after the end of the impact process. The deformation is 10% of the thickness of specimen when the dropping height is 5 cm. The deformation is 20% of the thickness of specimen when the dropping height is 7 cm.

The deformation is 68% of the thickness of specimen when the dropping height is 9 cm.

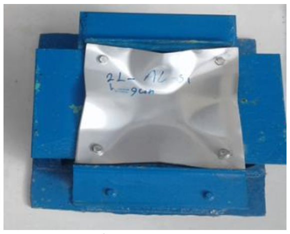

Fig. 5. Deformation specimen

7. Geometric Model and Materials Meshing

The geometric dimensions of the sheets in the numerical model are 22*23 cm^2 with a thickness of 1 mm. To model these elements, three-dimensional (Deformable) solid model was used. 900 sheets of 8-node 3D reduced-integration elements called C3D8R were used for sheet mapping. Also by partitioning (splitting the parts into simpler components to achieve a high quality and proper pattern) the optimum mesh of two-layer sheets is used to attach the sheets to each other. The screw is tied to the sheets. (Figure 6).

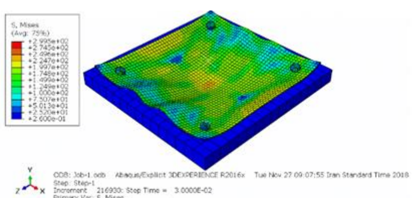

Fig. 6. Modeling the specimens with Abaqus

8. Modeling the behavior of steel

Stress-strain diagram of st12 sheet obtained in uniaxial tensile test is considered as the main characteristic of the behavior of this material.

9. Loading and boundary conditions

The steel sheets are 1 cm wide on the fixture seat. Only three degrees of transitional freedom are locked at the four edges for simplicity and holding the fixture in place. An equivalent velocity at the moment of impact onset is used to simulate the impact, which is obtained by placing the potential energy at the desired altitude with the kinetic energy at the moment of impact (Eq. 1).

$$v = \sqrt{2gh} = \begin{Bmatrix} h = 50mm & \rightarrow & v = 990\ mm/s \\ h = 70mm & \rightarrow & v = 117\ mm/s \\ h = 90mm & \rightarrow & v = 133\ mm/s \end{Bmatrix} \quad (1)$$

10. Results and discussion

After determining the appropriate mesh for the steel plate, the various laboratory specimens in this study were simulated by the mentioned modeling method. The results of the acceleration are shown in Figure 7. Figure 8 shows the force-displacement results and Figure 9 shows the displacement-time diagrams of the sheets.

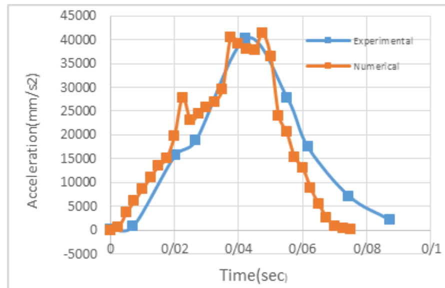

Fig. 7. Comparison of experimental acceleration results and finite element model

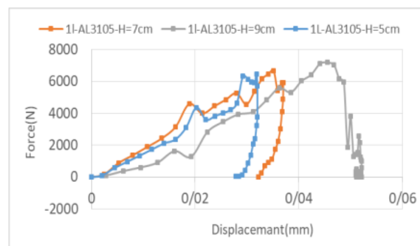

Fig. 8. Comparison of force-displacement results of finite element model

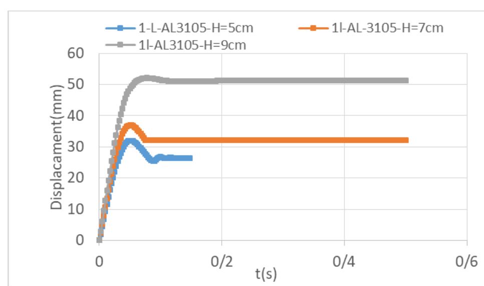

Fig. 9. Displacement-time diagram