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Effects of U-Shaped Side Groove on the Fracture Properties of Aluminium Alloy 6061 using Finite Element Method Analysis

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Abstract: Automotive industry engineering responsible to produce the automotive vehicles with a safe used for the people. They usually used the aluminium alloy to produce the good product regarding to the properties that suitable for the automotive making. The material of aluminium alloy 6061 used in this study to investigate the fracture properties of the alloy. One parameter has been applied in this study which is the effect of the side groove depth on the aluminium alloy specimen. In this research, single edge notch bending test with different side groove depth ratios was conducted through a simulation by using the Abaqus software in order to identify the absorb energy, displacement and also the maximum principal stress and strain on the specimen. Various side groove depths on the specimen which is 2 mm, 3 mm and 4 mm were conducted through the SENB simulation. It shows that the absorb energy value is decreasing when the side groove depth is deeper. The value of the displacement of fracture show that the displacement is increasing when the side groove depth is deeper. In conclusion, the aluminium alloy 6061 tend to become less on ductility behaviour when the side groove depth is deeper due to the result obtained.

Keywords: SENB, Abaqus, Side Groove Depth, Al6061, Finite Element Method

1. Introduction

In the recent years, aluminium alloys have been widely used in automobile, ship, aerospace, transportation, furniture, medical devices, constructional engineering, food packaging, military industry, chemical industry, electronic industry, petrochemical industry as well as other manufacturing fields due to their advantages of low density, high specific strength, high specific stiffness, good plasticity, excellent conductivity and thermal conductivity and so forth [1]. All materials that undergo the process of fracture have its own fracture behaviour. Fracture behaviour usually related to the fracture of micromechanics and the process of the fracture in aspect of stabilization. This fracture behaviour of material widely characterized as being ductile or brittle. Fracture behaviour of pure aluminium usually undergo a ductile fracture because of its properties. It this study, the side groove is applied on the

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specimen and it need to be investigate regarding to the fracture behaviour when the side groove is applied.

Side groove is the one of the type notch that can be defined as deep line cut at a surface of specimen. According to research made by J.P Hess et al. defined the presence of side groove can stimulate plane strain fracture in thin section of specimen that usually have ductile behaviour [2]. Thus the used of side groove are important especially to the small specimen and it can increases the percentage of the notch or crack front when the experiment was conducted [3].

Single edge notch bending test also can be done by using simulation through any related software such as Abaqus software. The model for the simulation on the Abaqus can be divided as 3 parts which is the major specimen, the boundary and also the load applied on the specimen. Besides, there are some point that need to be consider while making the simulation which is the rigid bodies or the deformable bodies were used on the specimen model and also the load applied specimen. The type of mesh can be divided into two types which is fine mesh at the notch region and coarse mesh at the remaining part of the specimen [4]. By using Abaqus software, the fracture properties of the aluminium alloy 6061 can be determined such as the maximum Von Misses stress, the maximum displacement and the absorbed energy through the bending simulation test conducted on the Abaqus.

Lastly, the effects of the side groove with different depth on the aluminium alloy 6061 can be determine on the fracture behaviour after conducting the simulation for the different depth of the side groove to obtain the absorb energy and displacement on the aluminium alloy 6061 specimens.

2. Materials and Methods

2.1 Materials

For this research, the material used for the analysis for the specimen model is aluminium alloy 6061 while for the striker model is the stainless steel. The parameters shown on the Table 1 below.

Table 1: The material properties of the specimen and striker model

No	Parameter	Specimen model	Striker model	Unit
1	Young's modulus	70	193	GPa
2	Poisson's ratio	0.33	0.31	-
3	Density	2600	7750	kg/m^3

A single edge notch bending test was conducted using Abaqus Software as a simulation as the load force for this simulation is set to -10N due to the force facing downward on the load specimen. Figure 1 shows how the simulation is being setup in Abaqus software following the single edge notch bending test. The geometry of the specimen is shown on the Table 2 of the specimen been created by parts which is for the specimen and also the load boundary specimen. The load boundary is made in circle shape with the radius is specified for 3 mm radius. The interaction between both specimen model and load boundary is touching each other for each surface. Side groove was created in the middle of the specimen with different depth while the shape of the side groove is the U-shaped. The depth of the side grooves is set as 2 mm, 3 mm and 4 mm to investigate the influences of the depth on the fracture behaviour of aluminium alloy.

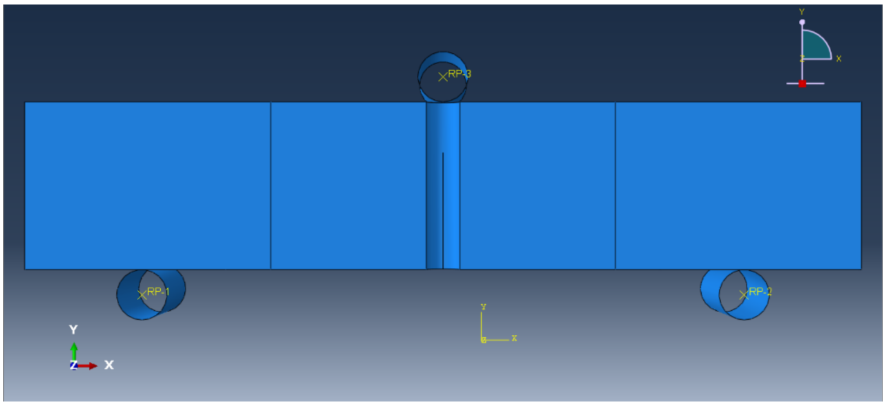

Figure 1: The assembly of the whole simulation with specimen of single edge notch bending test.

Table 2: The dimension of the aluminium alloy 6061 specimens

Parameter	Dimension
Beam length , L (mm)	100
Beam width , W (mm)	15
Beam height , B (mm)	10
Crack length , a (mm)	3

2.2 Finite element modelling

In order to construct the simulation, there are some basic steps that need to be follow in Abaqus. This method can ease the simulation to conduct the simulation well. Basically, in Abaqus the process flow can be seen in the Figure 2.

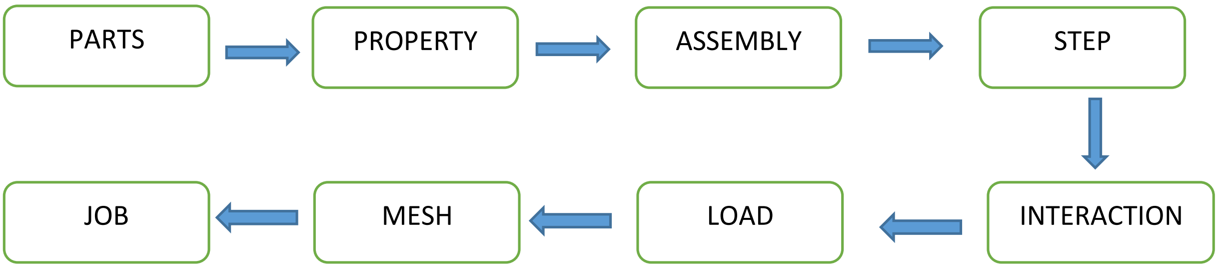

Figure 2: The steps to create the simulation using Abaqus

Next for the interaction between the specimen and the boundary conditions shown as Figure 3. It was using the general contact for this simulation. From the general contact, the important one that need to know is the reference point where the load is applied. In this simulation, the references point is at the point where the contact between the specimen and load boundary are contact each other. Besides, the direction of the interaction between the specimen need to be consider to get a better result. Lastly, the meshing part is shown on the Figure 4 for the single edge notch bending test simulation. Meshing was important as it was representing an element while the time required to solve depend on this meshing criteria. In this simulation, the mesh on the crack specimen or the notch is finer in order to gain the more accurate result.

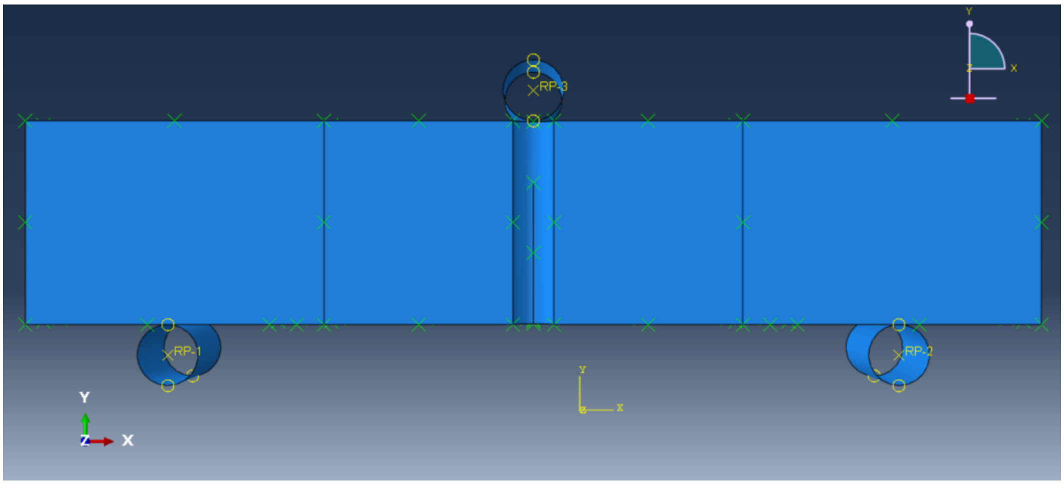

Figure 3: The interaction between specimen and boundary conditions

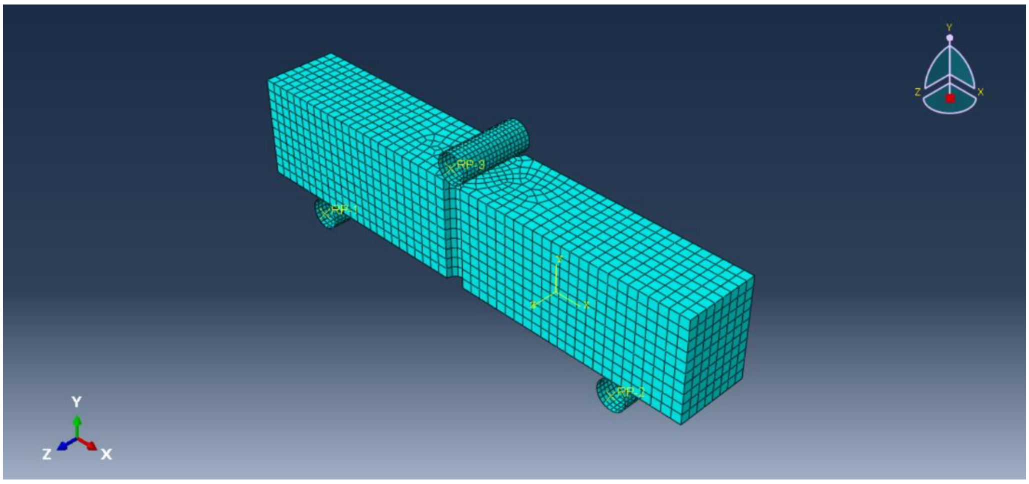

Figure 4: The meshing for overall part

3. Results and Discussion

Based on the simulation, the result obtained is the energy absorb, displacement of the fracture and also force that required to break the specimen into two pieces was been discussed on this simulation. This result can indicate the fracture behaviour of the aluminium alloy specimen model. Table 3 below show the result obtain from the simulation which is absorb energy, maximum displacement force, max principal stress and strain for the various side groove depth that already been conducted in this study.

Maximum energy absorb data result is obtained from the Abaqus features through the ODB history output. The energy absorb also can be determine when the displacement and the force value are known and some calculation need to done to gain the result of the energy absorb. For this study, energy absorb and the displacement of the fracture is the important data result to conclude the properties fracture off the aluminium alloy specimen with various side groove depth. The data been collected after a completed time increment which is shown below. From Figure 5, the result can be interpret as the maximum absorb energy had been decreased when the side groove depths ratio increases [5]. The trend of result was same as the theory from other research where it indicates when the absorb energy tends to decreases, the specimen will undergo brittle behavior [6]. In Figure 6, the graph shows the total absorb energy vary with the time increment for each side groove depth ratio. By made some comparison to some research that been conducted by experiment, the result indicates as the deeper side groove will undergo the brittle behaviour [7]. Hence, increasing the side groove depths gave a result of low absorb energy when conducting the single edge notch bending test. Thus, it also can be concluded where lower absorb energy during fracture tends to undergo rapid crack propagation or as brittle fracture [3].

Table 3: The fracture properties of Al6061 at different side groove depths

No	Side Groove Depth Ratio	Maximum Absorb Energy (J)	Maximum Displacement (mm)	Maximum Principal Stress (MPa)	Maximum Principal Strain (%)
1	0.25	1437.59	1.241994	317.7	28.85
2	0.4	1050.05	1.528161	298.0	31.54
3	0.5	739.88	1.966241	281.2	36.86

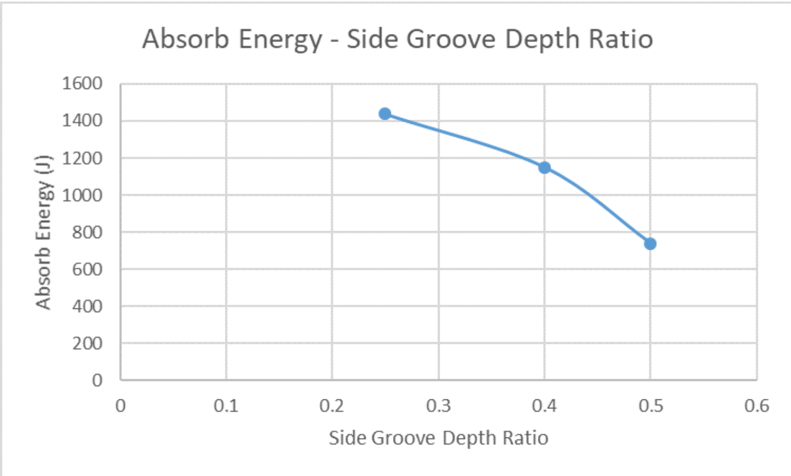

Figure 5: The absorb energy versus the side groove depth ratios of the specimen.

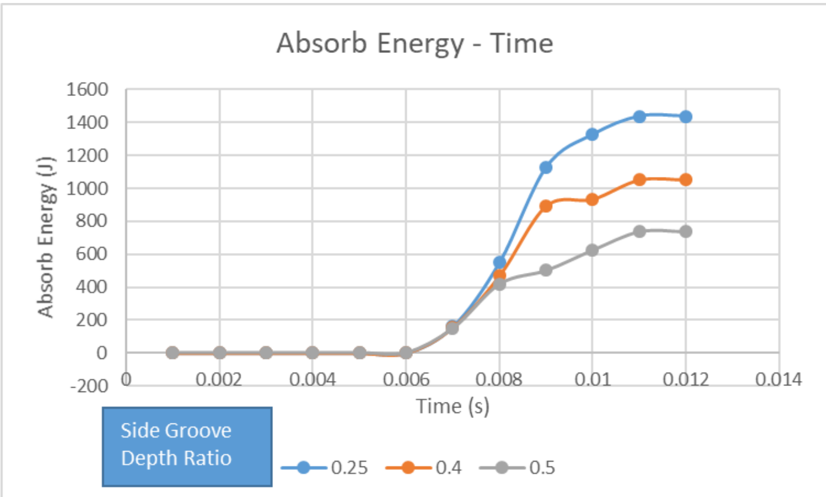

Figure 6: The absorb energy versus the time for different side groove depth ratios of the specimen

Next, the graph in the Figure 7 shows the relationship between maximum displacement fracture and the side groove depth ratios. It is the type of the result that focus on the how much the crack or fracture been done to the specimen when the load is applied on the specimen [8]. The result shows the increasing of the maximum displacement when the side groove depth ratio is increase. The result from the previous paper mentioned that when the specimen has the higher value of the maximum displacement show that the specimen or material is in brittle behavior [9]. Figure 8 shows the maximum displacement of fracture in time increment. The higher side groove ratio depth value show the displacement occur much faster than the other side groove depth ratio. It shows the side groove influence the displacement of fracture when the side groove depth is increasing [10].

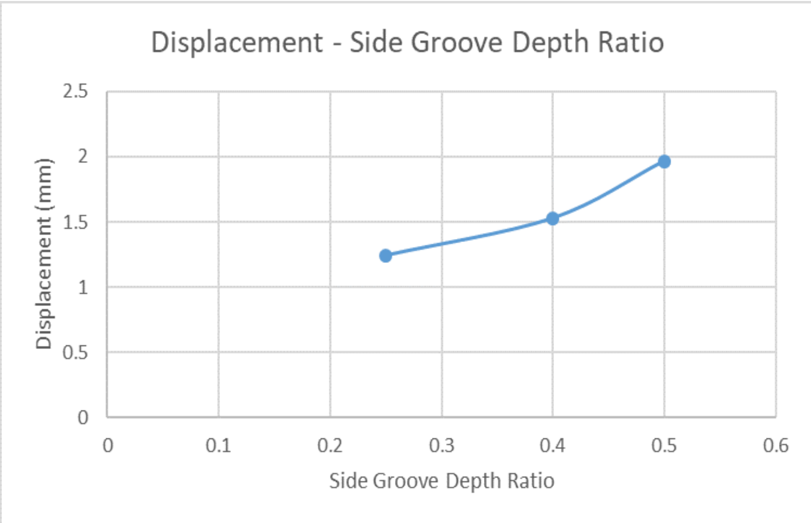

Figure 7: The displacement versus the side groove depth ratios of the specimen

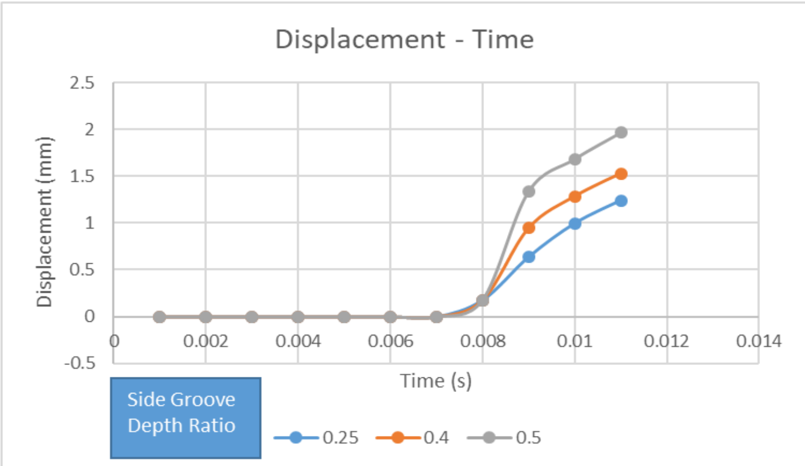

Figure 8: The displacement against the time for each side groove depth ratios

Next, the result that has been analyzed is the maximum principal stress and strain. From the Figure 9, it shows that the maximum principal stress is decreasing when the side groove depth ratio is increasing. When the side groove depth ratio is increasing, less stress will produce due the specimen is easy to have the displacement fracture. From the previous research, the result show that when the side groove depth is increasing, it influence the stress to become less on the specimen simulation [11]. Last but not least, the maximum principal strain shows the different relationship from the stress as the maximum principal strain tend to occur more on the higher side groove depth ratio. This result is shown on the Figure 10 to identify the relationship between the strain and the side groove depth ratio. In comparison to the previous research, the strain on the specimen tend to occur more at the higher side groove depth ratio as the specimen is more ductile from the specimen which is less in the side groove depth [5].

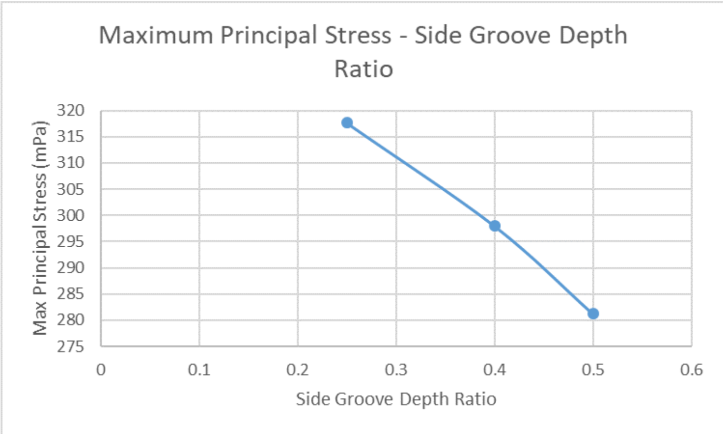

Figure 9: The maximum principal stress against side groove depth ratios

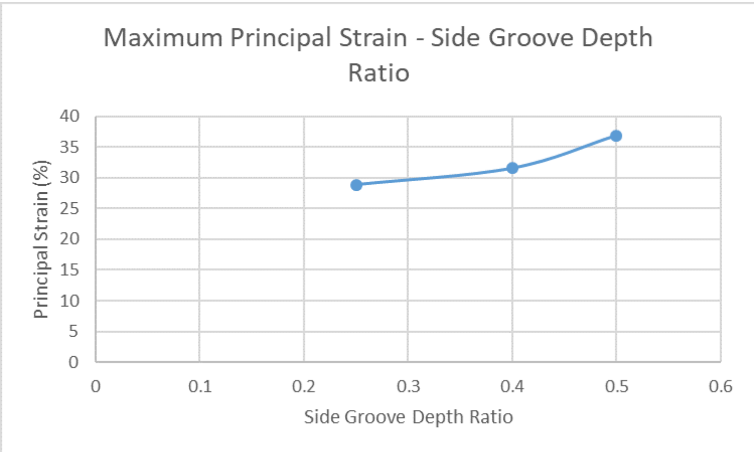

Figure 10: The maximum principal strain against side groove depth ratios

4. Conclusion

In this simulation of single edge notch bending test, a reasonable agreement of data obtained from dependency of the side groove depths ratio on the fracture properties of the aluminium alloy 6061. For this study, it concludes that when side groove depth ratio of specimen model increases, the maximum absorb energy became smaller. This shows that, the less absorb energy needed when the deeper side groove applied on the specimen model where less absorb energy have contributed to brittle fracture. Furthermore, by increasing the side groove depths, the outcome result for force required to fracture the specimen was decreased. This clearly shows that, less force needed as to break the specimen model until fracture when higher side groove depth ratio applies on it.

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