Notch Effect on the Stress Triaxiality Behavior of Al Alloy Specimens

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1. Introduction

In metal structures, various stress and strain distributions are formed according to the notch shape, depth, and radius. Driemeier et al. [1] investigated the stress triaxiality of aluminum alloys with different notch radii and observed that the fracture type varied with varying notch radius. Digital image correlation (DIC) can be used to measure the deformation of a structure and the finite element method (FEM) is widely used in engineering studies as a method for analyzing strain or stress. In some studies, the experimental results were interpreted combining the DIC and FEM. In the Aidi and Case [2], the notch effect on center-notched carbon fiber reinforced polymer composites was evaluated under tensile loading.

In this study, un-notched specimens, small-notched (S-notched) specimens with a radius of 2.5 mm, and large-notched (L-notched) specimens with a radius of 228.1 mm are fabricated using an aluminum alloy (Al6061-T6). Tensile test is used to find the difference of mechanical engineering properties between un-notched, L-notched and S-notched specimens. The strain distributions of the un-notched, S-notched, and L-notched specimens are observed through DIC. FEM is used to compare the strain concentration behavior and determine the effect of notch radius. The distribution of stress triaxiality and the position of stress triaxiality in the two types of specimen are calculated by FEM.

2. Material and Test

Specimens were made by an Al6160-T6 plate with the thickness of 4mm. The specimens were made by sectioning perpendicular to the rolling direction. The geometry of the specimens was shown in Fig. 1.

The tensile test apparatus was a mechanical tensile tester (R & B Unitech-M) with 5-ton capacity. The rate of cross head was 0.5 mm/min. To obtain the relationship between nominal strain and nominal stress, an extensometer with gauge length of 25 mm was mounted on the gauge portion of the specimen and its strain was measured until fracture.

DIC was used to measure the strain distributions of the un-notched, L-notched, and S-notched specimens. Tensile tests were carried out at the same rate of 0.5 mm/min. At the same time, speckle patterned images were recorded by a CCD camera at one sheet per second.

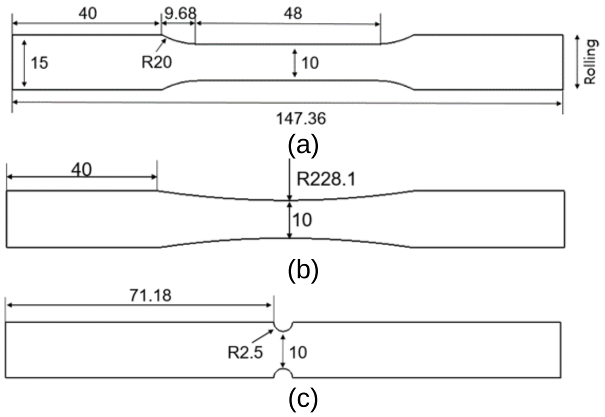


Fig.1 Geometry of specimens: (a) un-notched, (b) L-notched and (c) S-notched

Finite element method (Abaqus 2019) was used to verify the DIC results and find the distribution of stress triaxiality generated in the specimen. Considering the effect of stress concentration, the mesh around the notch tip was made with an element size approximately 2 times smaller than that in other parts of the specimen.

3. Results and Discussion

3.1 Tensile behavior

The result of tensile test was shown in Table1. The nominal yield stress, nominal maximum stress and nominal fracture stress of S-notched and L-notched specimens became larger than those of un-notched specimens. Compared with L-notched specimens, the elastic modulus, nominal yield stress, nominal maximum stress and nominal fracture stress of S-notched specimens were higher.

3.2 Digital image correlation (DIC) measurement

The results of DIC were shown in Fig.2 and Fig. 3. For the L-notched specimen, the maximum strain showed a uniform distribution over the portion with minimal width during the load increase until the ma ximum stress point. After the maximum stress point the strain was concentrated around the middle part of the specimen width. For the S-notched specimen

Table1 Mechanical engineering properties measured for un-notched, L-notched, and S-notched specimens

	Average breaking stress (MPa)	Average maximum stress (MPa)	Average yield strength (MPa)
Un-notched	289.8	316.5	262.5
L-notched	292.9	318.5	267.3
S-notched	330.4	340.5	301

the strain was concentrated at the tip of the notch after the yield point.

3.3 Finite element analysis (FEA)

Comparing the calculation results of the FEM with the results of the DIC measurement, the trends of the strain distribution along the coordinate (y_1-y_2) almost coincide, but there was a slight difference in the measured values.

The position of maximum stress triaxiality just before fracture obtained by FEM was at the notch tip of the S-notched specimen and at the center of the L-notched specimen.

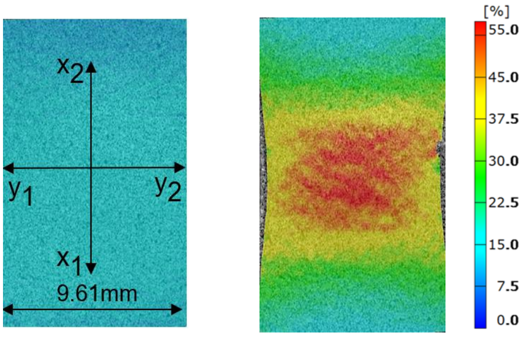
The position h of maximum stress triaxiality, which measured the distance from the notch tip to the maximum stress triaxiality point, was calculated as a function of the notch radius, as shown in Fig. 4.

4. Conclusion

Notch strengthening effects were produced in both S-notched and L-notched specimens: the S-notched specimen had greater strengthening.

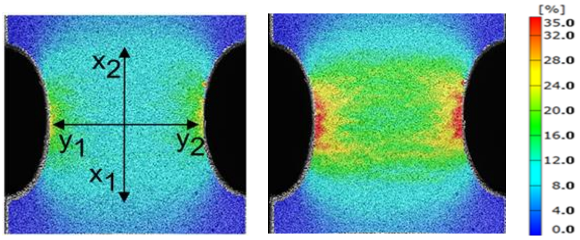
The position of the maximum strain varied depending on the notch radius. The maximum strain occurred at the center for the L-notched specimen and at the notch tip for the S-notched specimen.

The maximum strain for the S-notched specimen was smaller than that for the L-notched specimen. It was smaller by 13% with load-wise strain (ε_x) and smaller by 5% with width-wise strain (ε_y). However,



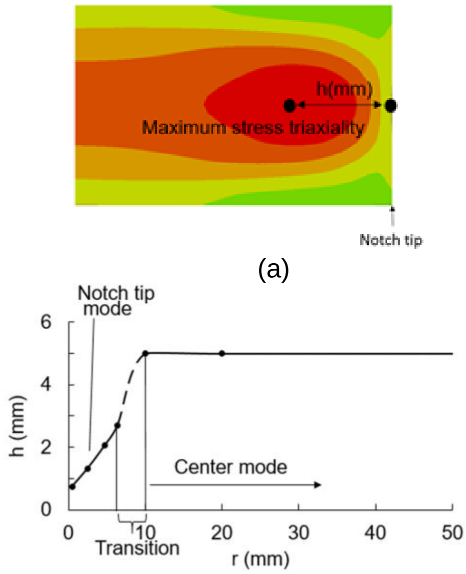
(a) (b)

Fig. 2 Longitudinal strain (ε_x) distributions of an L-notched specimen at the (a) maximum stress point and (b) breaking point



(a) (b)

Fig. 3 Longitudinal strain (ε_x) distributions of an S-notched specimen at the (a) maximum stress point, and (b) breaking point



(b)

Fig. 4 (a) Distribution of the maximum stress triaxiality around the notch tip and (b) distance (h) as a function of different notch radii

the S-notched specimen fractured much earlier than the L-notched specimen.

For the notch tip mode, it was confirmed that the notch strengthening effect changed significantly even with a slight change in the notch radius.

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References

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