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Influence of Cell Size on Die Bending of Aluminum Alloy Honeycomb Structure

Y.Takayama[1,a], Y.Kitanosono[2],E.Watanabe[2] H.Watanabe[1,b]and H.Kato[1,c]
[1]Department of Mechanical Systems Engineering, Utsunomiya University,
Utsunomiya, Tochigi 321-8585, Japan
[2]Graduate student, Utsunomiya University Japan

The material of the test specimen is made of 5052 aluminum alloy. The size of the cell used two kinds (1/4in and 1/8in). The density in the honeycomb core is equal. The test specimen is cut out from a metallic version. The size is 220mm×20mm×7mm, 12mm, and 18mm. The type is bent by installing the examination jig in Instron type [TENSILON] (UCT-5T) and each test piece is examined. Afterwards, coordinates of the cell are put out by taking the image of the test specimen with the scanner, and using the coordinates reading software. And, the average warp is put out by using the expression and the additional theorem of the product in the vector from the coordinates, and the afterwards, coordinates of the test specimen is investigated.

Keywords: honeycomb structure, aluminum magnesium alloy, cell size, strain distribution.

1. Introduction

In late years the exhaust gas of the transportations including automobile has been considered to be one of the causes of global warming. Saving weight of the transportation body is a feasible way of reducing the exhaust gas. Honeycomb structure having light weight, high specific stiffness and high specific strength is gotten attracted attention for weight saving. Although the honeycomb sandwich structure, which consists of honeycomb core and skin sheets, has high specific strength, it is not appropriate for mass production because of low flexibility in fabrication including adhesion technology. Then, the honeycomb structure is made as a final shape of product to use without secondary forming. If the honeycomb structure has a good workability, its possibility of application in the transformation systems must be extended.In the present study, we focus workability of the honeycomb sandwich structure. For the 5052Al alloy honeycomb structure, the influence of cell size on deformation behavior of die bending was examined through observation of deformed structure and measurement of strain distribution.

2. Experimental Procedure

2.1 A sample and a specimen making condition

Two sorts of honeycomb cores of the 5052Al alloy had been used to make sandwich structure, which have a core size of 3.175 mm (1/8 inch)/ a foil thickness of 3.81×10^{-2} mm (1.5×10^{-3} inch) and core size of 6.350 mm (1/4 inch)/ a foil thickness of 7.62×10^{-2} mm (3.0×10^{-3} inch), respectively. Three kinds of honeycomb sandwich panels with thickness of 7mm, 12mm and 18mm were made of cores with thickness of 5mm, 10mm and 15.9 mm (5/8 inch) and skin sheets of 5052Al with thickness of 1.0 mm. The core and the skin sheets were bonded with epoxy film adhesive by heating at 120°C for 60min. From the panel, bending specimens of 220mm long and 20mm wide were machined as longitudinal direction parallel to the extended (X_1) and width (X_2) directions of the core.

2.2 Guide bend test (* Die bending)

Die bending test was performed at a constant pushing speed of XX×10^{-2} m/s with a specially designed concave die having a radius of YY mm. The die was designed as ZZmm long and Uumm wide as shown in Fig. 5.

2.3 Springback measurement

The springback (elasticity recovery) in the die bending was measured as follows. The initial upper side of the test specimen was assumed to be a working reference plane. Indenter was pushed down by a given distance from this state (position). The distance of pushing was set as δ_{ind} as shown in Fig. 1. While the load was released by returning, the distance where the intender parts from the test specimen was set as δ_n with a permanent strain from the working reference plane. The amount of springback η is given as

$$\eta = \delta_{ind} - \delta_n . \tag{1}$$

In this study the amount of the springback was evaluated from the displacement of the center partmentioned above because of ease in measurement though the bend angle was often employed for the evaluation.

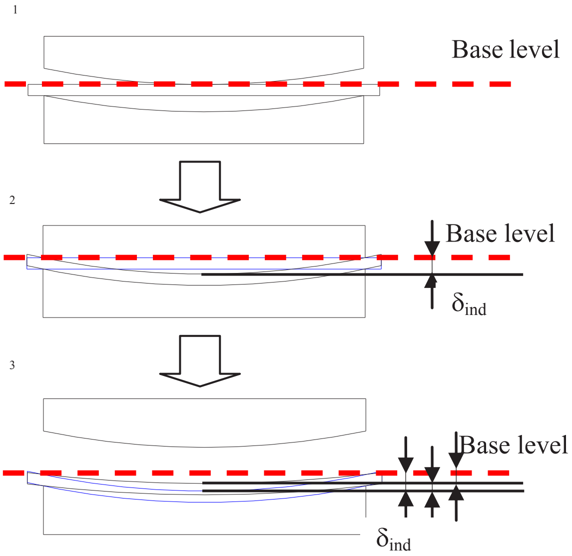


Fig. 1 springback

2.4 Mean shear strain measurement

Shear strain was calculated from change in cell shape of honeycomb core in cross section of the test specimen. Coordinates on the corners of each cell were measured in the section before and after the test by the coordinates reading software to determine angles θ_0 and θ_1 formed by length and thickness directions before and after the test. The section photograph and after it examines it, the section photograph and the cell outline chart are shown Fig. 2. First of all, it drank and measured coordinates were assumed to be a vector element to the section photograph way as Fig.2. Next, θ_0 and θ_1 were obtained by using the formula of the product in the vector. The value was used and the shear strain γ for each cell.

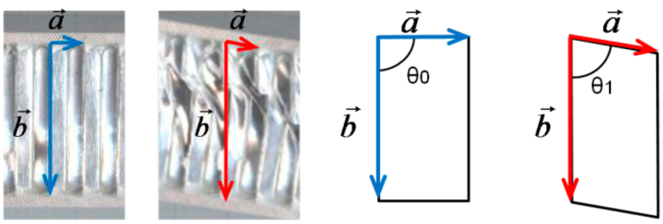
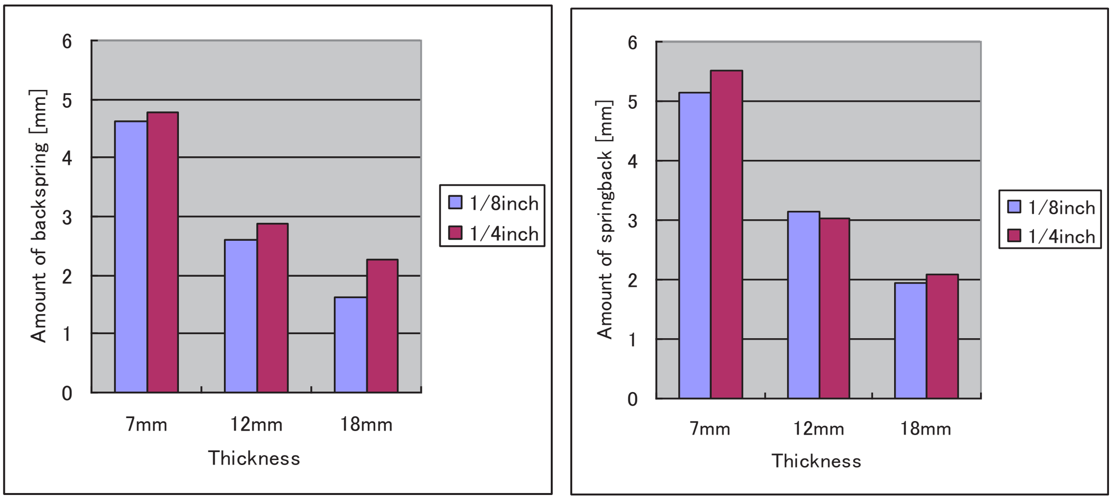


Fig. 2 section of cell and simplified schematic

3. Result of experimentation

3.1 Springback measurement



X_1 Direction X_2 Direction

Fig. 3 result of amount of springback

Fig. 3 shows result of amount of springback. It became a result that the amount of the springback of the specimen (1/4in) was larger than the specimen (1/8in). This reason is that range of caused shear strain was small. Moreover, the specimen (X_2 direction) have that the springback was large overall. The specimen (X_2 direction) is endured with two cell walls for the tensile stress and the crushing stress that hangs to the specimen in the die bending. Because power is applied in the direction where it tries to peel off the cell wall, it becomes easy to cause the shearing and the springback becomes small a specimen (X_1 direction) on the other hand. This is thought that the amount of the springback became small because of the destruction of the part in the core though either size of the cell has not changed into the specimen (thickness 18mm) either.

3.2 Result of mean shear strain measurement

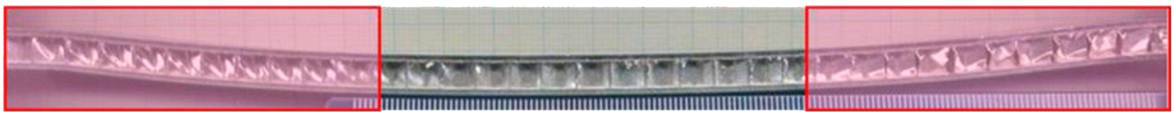
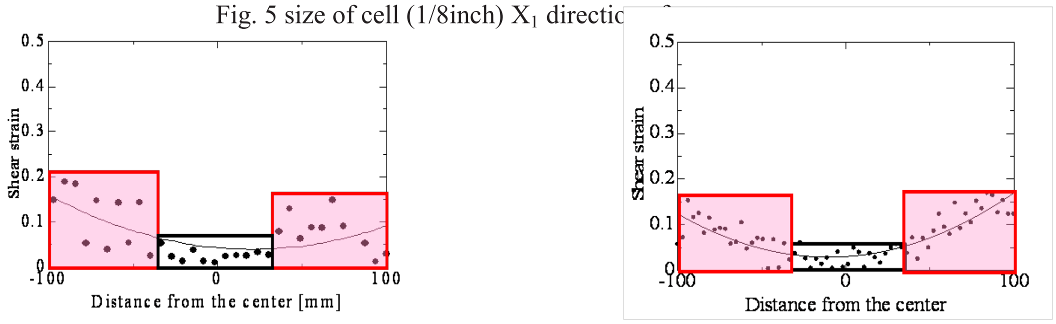


Fig. 4 size of cell(1/4inch) X_1 direction after test

Fig. 5 size of cell (1/8inch) X_1 directic



1/4inch 1/8inch

Fig. 6 dispersion diagramof shear strain

Fig. 4, Fig. 5 and Fig. 6 show the section photograph after it examines it of the specimen (X_1 direction thickness 7mm) and the dispersion map of the shear strain. The range of shear strain that the macro cannot do is shown. The value of the shear strain didn't especially have the difference. We compared the specimen (1/4in) with the specimen (1/8in) and have that the specimen (1/8in) has range of wide shear strain.

Fig. 7 size of cell(1/4inch) X_2 direction after test

Fig. 8 size of cell(1/8inch) X_2 direction after test

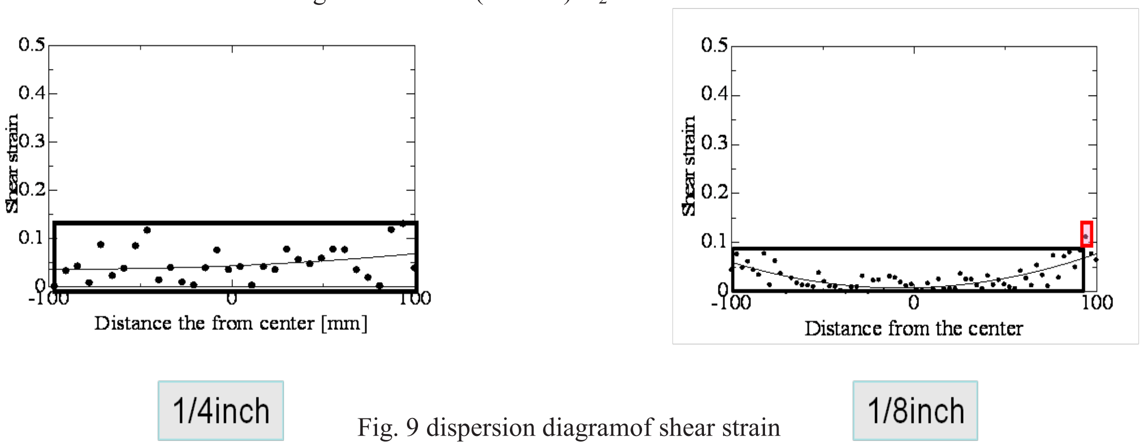


Fig. 9 dispersion diagramof shear strain

Fig. 7, Fig. 8 and Fig. 9 show the section photograph after it examines it of the test piece (X_2 direction thickness 12mm) and the dispersion map of the shear strain. And, the range of determination cannot do is shown. It was not seen at all and the shearing was able to do the die bending beautifully in the specimen (1/4in) though the specimen (1/8in) hardly caused the shear strain.

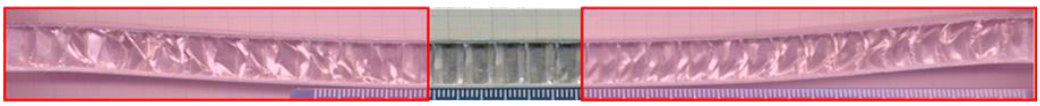
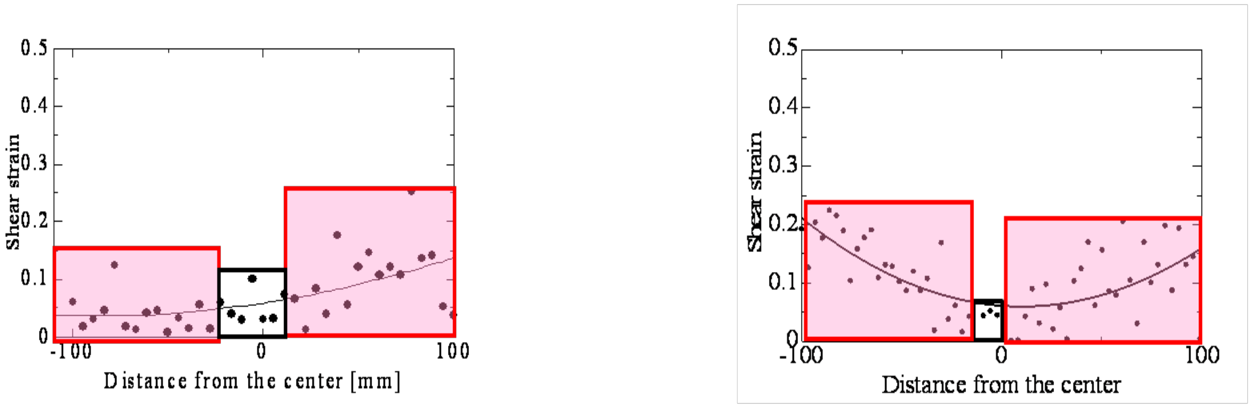


Fig. 10 size of cell(1/4inch) X_1 direction after test

Fig. 11 size of cell(1/8inch) X_1 direction after test



1/4inch

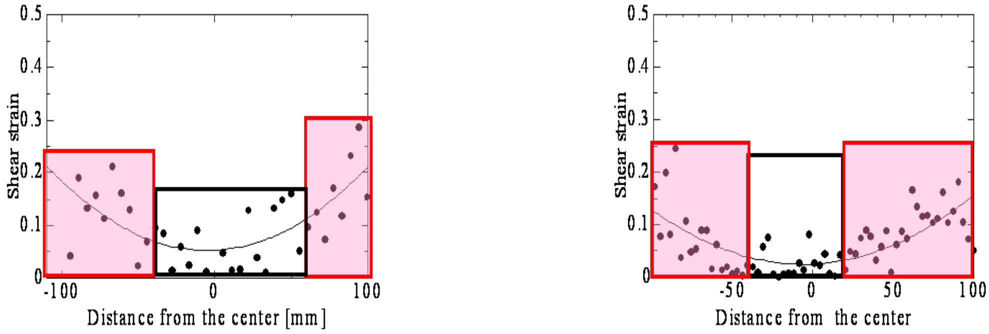
1/8inch

Fig. 12 dispersion diagramof shear strain

Fig. 10, Fig. 11 and Fig. 12 show the section photograph after it examines it of the test piece (X_1 direction thickness 12mm) and the dispersion map of the shear strain. Compared to the result of the specimen (thickness 7mm), the range of the shear strain was wide.

Fig. 13 size of cell(1/4inch) X_2 direction after test

Fig. 14 size of cell(1/8inch) X_2 direction after test



1/4inch

Fig. 15 dispersion diagramof shear strain

1/8inch

Fig. 13, Fig. 14 and Fig. 15 show the section photograph after it examines it of the test piece (X_2 direction thickness 12mm) and the dispersion map of the shear strain. The range of determination cannot do from the X_1direction is as narrow as the test piece of other thickness. Right and left bias are seen within the range where the shearing is caused a little in specimen (1/8in). The test specimen of size 1/4in of the cell understands and it has been understood that the way to cause the shearing is small compared with size 1/8in of the cell. The range where the shearing is caused tends to be wide, and to increase as the thickness of the test piece increases also the value of the warp. As for the test specimen in the X_2 direction, the tendency with a narrow range where the shearing is caused when processing it was seen compared with the test piece in the X_1 direction. This is thought to be changeable from the difference of the direction by the difference of how to apply power on the joining surface in the core how to cause the shearing. Moreover, the shearing was caused by the test piece though the value of the warp hardly changed. It is thought that the purpose of this is to take not the value of the warp of a local shearing but the value of an average warp cellular individual.

4. Conclusion

It is possible to process it to the curved surface without causing the shearing because central indenter of an appropriate curvature radius is used in honeycomb structure (thickness 7mm X_2 direction). The shearing can be made easy not to cause by enlarging the size of the cell. Even if the size of the cell is enlarged, strength and the plastic forming of the level that to keep the density can be given.