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TORSION PROPERTY OF THE STRUCTURE BONDED ALUMINUM FOAM DUE TO IMPACT

An aluminum foam added with foaming agent, is classified into an open-cell type for heat transfer and a closed-cell type for shock absorption. This study investigates the characteristic on the torsion of aluminum foam for a closed-cell type under impact. The fracture characteristics are investigated through the composite of five types of aluminum foam (the thicknesses of 25, 35, 45, 55 and 65 mm), when applying the torsional moment of impact energy on the junction of a porous structure attached by an adhesive. When applying the impact energy of 100, 200 and 300J, the aluminum foams with thicknesses of 25 mm and 35 mm broke off under all conditions. For the energy over 200J, aluminums thicker than 55 mm continued to be attached. Furthermore, the aluminum specimens with thicknesses of 55 mm and 65 mm that were attached with more than 30% of bonding interface remained, proving that they could maintain bonding interface against impact energy. By comparing the data based on the analysis and test result, an increase in the thickness of specimen leads to the plastic deformation as the stress at the top and bottom of bonding interface moves to the middle by spreading the stress horizontally. Based on this fracture characteristic, this study can provide the data on the destruction and separation of bonding interface and may contribute to the safety design.

Keywords: Aluminum foam, Bonding stress, Fracture energy, Adhesively bonded structure

1. Introduction

With industrial development, metal products have been used at the wide range and require additional functions to adjust various environments. Furthermore, as light weight has been one of the most important factors to maximize mechanical efficiency, the development on materials with light weight and high strength has been in the spotlight. Among various subjects, mixing different materials has shown the performance better than a single material, and composite materials have been developed to overcome the limitations of single materials. Reducing weight is the very important topic for the transportation industry, such as automobiles and airplanes, to save energy and minimize emissions. With the less amount of material, one can reduce weight but also decrease the strength. So, the composite material allows the lighter weight with similar performance. FRP is also available, but the aluminum as composite metal is more popular as it becomes light-weighted, resistant to corrosion, non-toxic, adhesive, reflexive with sound absorber. Based on such many advantages, it is not only used in industries but also has various uses in our lives [1-5]. Among the aluminum production processes, this study focuses on the aluminum foam added with foaming agent when melted. The specimen in this study is attached by the adhesive designed to prevent the destruction of the porous structure, which occurs when applying the existing mechanical method, such as a bolt and nut, a rivet or a welding to the aluminum foams for closed-cell type with shock absorption property [6-11]. 3D models as the structural mechanics are designed and the mechanical behaviors are analyzed for the inspection of the destruction at bonding interface by applying the torsional moment of impact energy to two aluminum foams. In addition, the mechanical characteristics can be systematically analyzed by investigating the fracture of bonding interface through the comparison with experiment data.

2. Specimen

2.1. Configuration and dimension of specimen

The specimen for a closed-cell type is used in this study. Fig. 1 shows the bonding condition of adhesive at the aluminum foam specimen bonded for impact experiment. At the temperature of 75°C, the adhesive for bonding sprayed with the thickness of 3 mm is hardened for 3 hours. The mechanical properties of aluminum foam applied to the analysis as well as the specimen are shown in Table 1.

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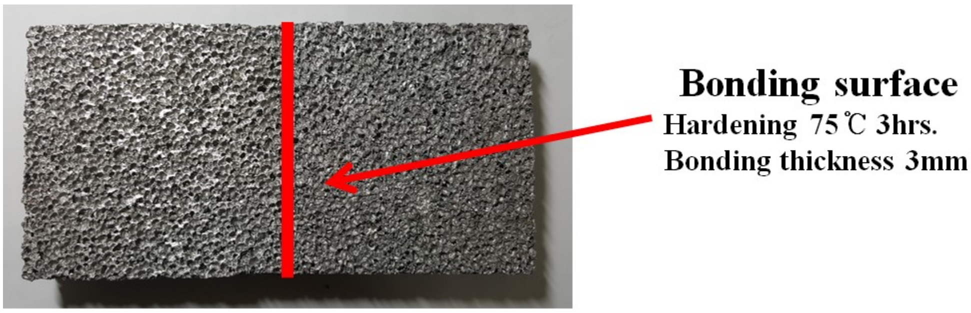


Fig. 1. Aluminum foam specimen bonded for impact test

TABLE 1

Mechanical properties of aluminum foam

Property	Value
Young's modulus (GPa)	2.374
Poisson's ratio	0.29
Density (kg/m^3)	400
Yield strength (MPa)	1.8
Shear strength (GPa)	0.92

2.2. Conditions for testing and analysis

Fig. 2 shows the testing equipment as an impact tester of Dynatup 9250 HV. The diameter of a striker in the device to apply the impact to a specimen is 12.5 mm, and its impact energies and speeds are shown in Table 2. Impact energies are converted from impact velocity of the striker in the testing model.

Fig. 2. Impact test device Dynatup 9250 HV

TABLE 2

Impact velocity due to impact energy

Impact energy (J)	Impact velocity (m/s)
200	4.02
300	4.92
400	5.83

Fig. 3 shows the configuration of model and the analysis condition. Five specimens from the 3D model before being bonded by adhesive with a width of 100 mm, a length of 100 mm, and five different thickness of 25 mm, 35 mm, 45 mm, 55 mm and 65 mm. The distribution contour of stress on the bonding interface is investigated by applying torsional moment on the fixed fore-end and on the opposite side in a short time. The thickness ranges from 25 mm to 65 mm. To describe the separation of bonding interface in reality, the bonding adhesive interface is supposed to be attained at the stress of 9 MPa. However, the result can differ from that of the actual experiment, which is affected by bonding force from the residual adhesive.

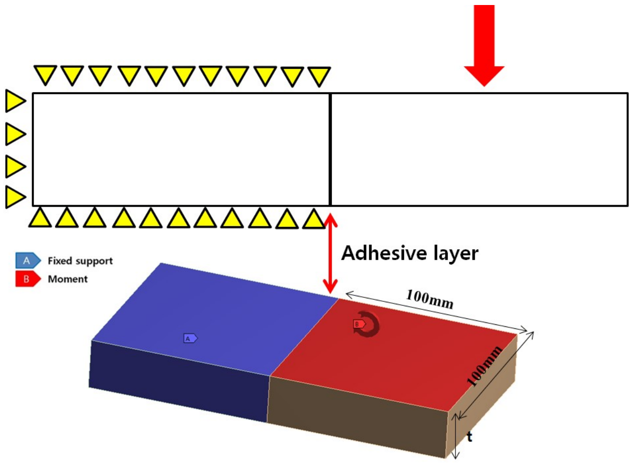


Fig. 3. Analysis condition of model

3. Study result

Fig. 4 shows the contour of equivalent stress happening at the bonded interface by impact energy according to the thickness of each specimen. From the case 1 of specimen with 25 mm thick to the case 5 of specimen with 65 mm thick, the stress is shown to decrease greatly as the thickness becomes thick. In case 1, the equivalent stresses of 38.4 MPa, 58 MPa and 76 MPa happen at the impact energies of 200 J, 300 J and 400 J respectively. In case 5, the equivalent stresses of 7.9 MPa, 4.2 MPa and 5 MPa happen at the impact energies of 200 J, 300 J and 400 J respectively. On the basis of this study result, it is shown that the maximum efficiency of impact absorption is carried out at 300 J of impact energy. Fig. 5 shows contours of equivalent stresses at the bonded interfaces at cases 1 and 2 with the impact energy of 200 J. This result is caused by the

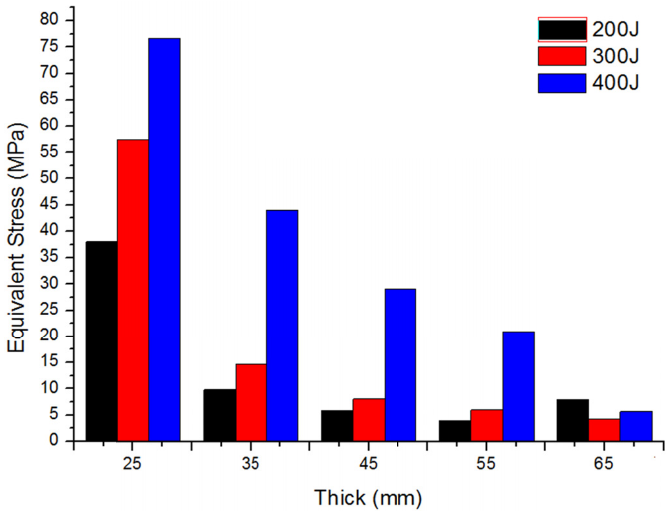
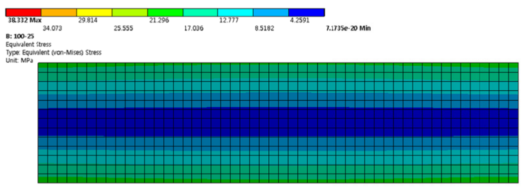
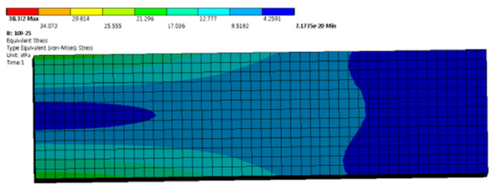


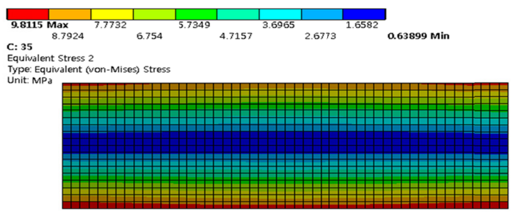
Fig. 4. Maximum equivalent stresses at the bonded interface by thickness due to impact energies



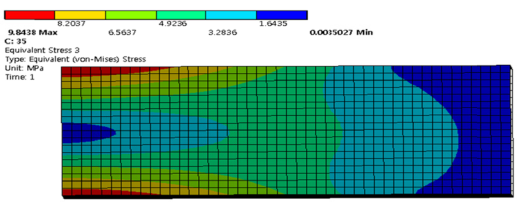
(A -1) Bonding surface (200J, Case 1).



(A-2) Stress contour of side plane(200J, Case 1).



(B-1) Bonding surface (200J, Case 2).



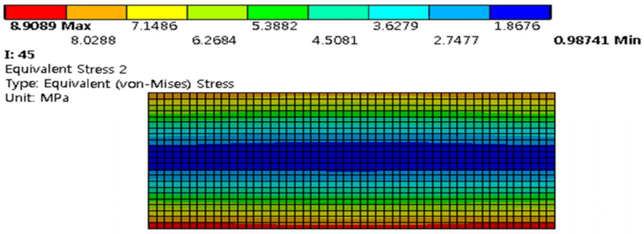
(B-2) Stress contour of side plane (200J, Case 2).

Fig. 5. Contour of equivalent stress at the bonded interface due to impact energy of 200J

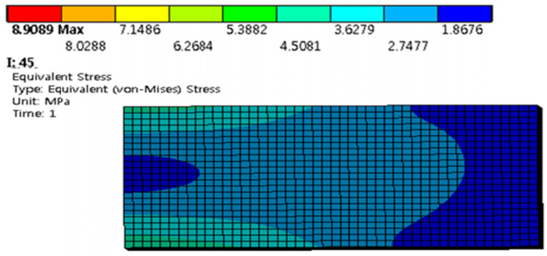
decrease in the area of bonded interface and the concentrated force due to the damage of internal lattice structure. As shown by Fig. 5(A), it is shown that the maximum stresses happen at the corners of extreme upper and lower parts and the moving directions of stresses due to these corresponding damages are directed toward the adhesive interfaces. Fig. 5(B) shows the stress contour at the side of specimen. It is considered that the stress happening at the bonded interface affects the analysis model. Figs. 6(A,B,C) show the contours of internal equivalent stresses in cases 3, 4 and 5 respectively at the impact energy of 300 J. As the maximum equivalent stress of 7.8 MPa becomes less than the bonded strength of 9 MPa, it is shown that the bonded interface is not broken as the significant part at the bonded structure. By this result, the separation of bonded interface at aluminum foam due to the torsion of external force and the mechanical property at the condition applied with impact energy can be investigated properly. Figs. 7(A,B) show the contours of equivalent stresses in cases 4 and 5 respectively at the impact energy of 400 J. By comparing with the stress contours at the impact energy of 300 J, the stress more than the bonded strength happens and the bonded interface is fallen off in case 3 at the impact energy of 400 J. In case 5 of specimen with 65 mm thick, the higher stress of 0.8 MPa happens by comparing with the stress contours at the impact energy of 300 J. Through this result, the equivalent stress happening at the adhesive interface lower than the stress of bonding limit can be calculated and the thickness of the minimum limit about the part at which the impact can be determined. Also, the equivalent stress happening at the adhesive interface can be investigated as the thickness increases and the fracture scale due to the bonding limit can be seen. Fig. 8 compares the strain energies in Cases of 1,2,3,4 and 5 at the impact energies of 200 J, 300 J and 400 J. As the thickness of specimen increases, the strain energy decreases and the damage due to the separation of bonded interface decreases. The possibility of deformation by impact energy can be analogized by using the result of strain energy happening at each specimen thickness. Fig. 9 compares the analysis value of strain energy with the experimental value at each specimen at the impact energy of 300 J. As the analysis values approach the experimental values, all the analysis results can be confirmed at evaluating the durability of these specimens with aluminum foam under impact. So, the analysis results in this study can be trustworthy at applying to real field [12].

4. Conclusion

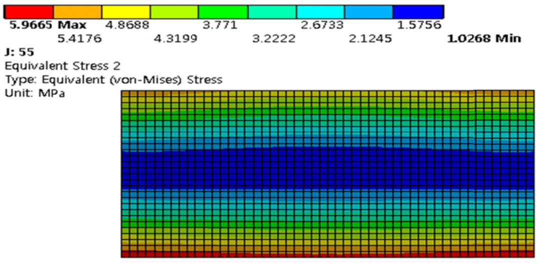
This paper has drawn the conclusion of torsional characteristics of two attached aluminum foams under impacts from simulation analysis and their test results. In each Case with different impact energy, aluminum foams are completely separated until Case 2, but the adhesion is maintained over 300J after Case 3. Furthermore, as impact energy increases, the bonding interface of Case 4 rapidly decreases. Therefore, the minimum thickness to maintain adhesion under the impact energy was investigated in Case 4. As the falling off of the bonded interface due to each impact energy does not happen at the impact energy of 300 J, the specimen keeps the durability. Based on analysis result of this paper and the data related to interfacial failure and destruction



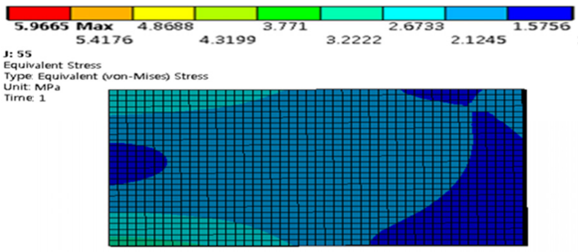
(A-1) Bonding surface (300J, Case 3).



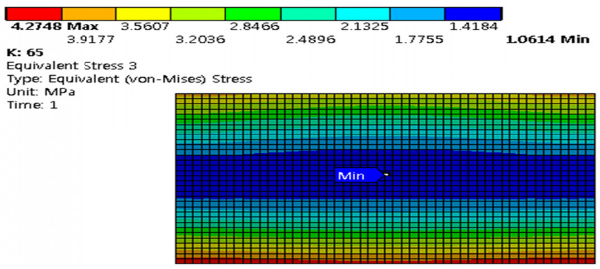
(A-2) Stress contour of side plane (300J, Case 3).



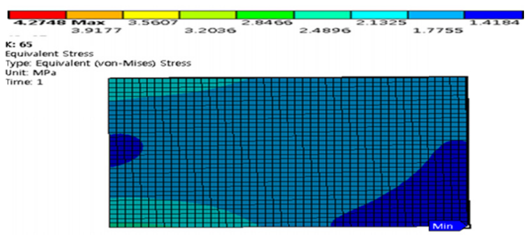
(B-1) Bonding surface (300J, Case 4)



(B-2) Stress contour of side plane (300J, (Case 4)

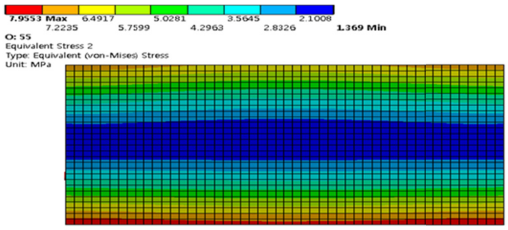


(C-1) Bonding surface (300J, Case 5)

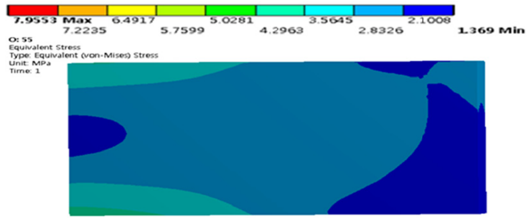


(C-2) Stress contour of side plane (300J, Case 5)

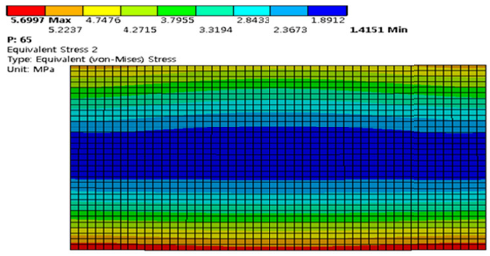
Fig. 6. Contour of equivalent stress at the bonded interface due to impact energy of 300J



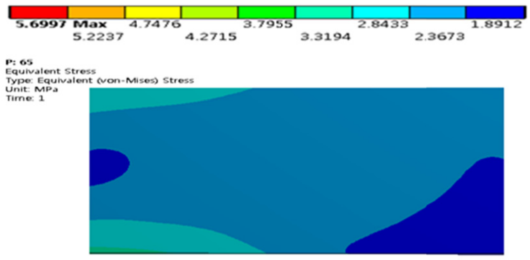
(A-1) Bonding surface



(A-2) Stress contour of side plane (400J, Case 4)



(B-1) Bonding surface (400J, Case 5)



(B-2) Stress contour of side plane (400J, Case 5)

Fig. 7. Contour of equivalent stress at the bonded interface due to impact energy of 400J

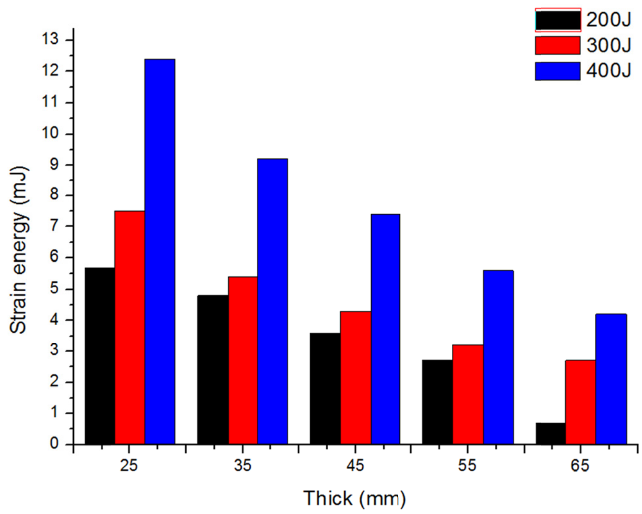


Fig. 8. Strain energies at bonded interfaces due to impact energies of 200J, 300J and 400J

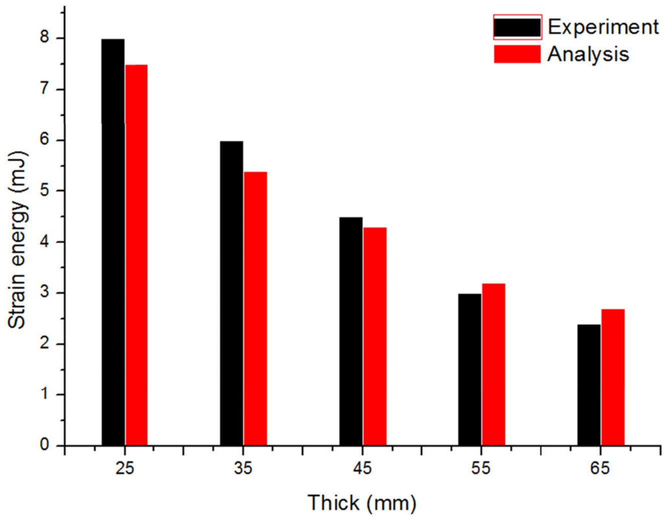


Fig. 9. Comparison of experiment and analysis on strain energy due to specimen thickness at impact energy of 300J

of the bonding interface to compare between the analysis result and test data, this paper is considered to contribute to the safety design of the structure using aluminum foam.

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