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Adhesive Fracture Characteristic of DCB Specimen due to Single and Heterogeneous Materials under Tearing Load

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찢김 하중에서 단일 재료 및 이종 접합 재료에 따른 이중외팔보 시험편의 접착제 파손 특성

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ABSTRACT

In this study, the adhesive fracturing characteristics of a DCB specimen due to single and heterogeneous bonding materials under tearing load was investigated. The experiments were conducted to examine the fracturing properties of the adhesive DCB specimen. As an experimental condition, a forced displacement of 3mm/min was applied to one side while the other side was fixed. As a result of the experiment, it was found that the AL6061-T6 material was superior to the CFRP material in terms of maximum stress, specific strength, and energy release rate when compared to the adhesive fracturing property of a single material. We tested CFRP-AL, a heterogeneous bonding material, and compared its experimental results to the results from the single materials. Based on these results, CFRP-AL with a heterogeneous bonding material was observed to have the superior structural safety compared to single materials for the mode III fracture type.

Keywords : Adhesive Fracture(접착제 파괴), Single Material(단일 재료), Heterogeneous Material(이종 재료), Double Cantilever Beam Specimen(이중 외팔보 시험편), Tearing Load(찢김 하중)

1. Introduction

In this study, various studies were conducted to examine the fracture characteristics of adhesives for mode III by using double cantilever beam specimens made of heterogeneous bonding materials. At first, in order to secure the physical properties of the lightweight materials used in the study, a tensile test was conducted with CFRP and AL6061-T6 to find out the Young's modulus, yielding point, and maximum tensile strength. Other properties were found based on the Mil Sheet provided by the manufacturer. The second previous study investigated

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the adhesive fracture characteristics for mode III when the single materials, CFRP and AL6061-T6 were used. The reason for conducting the previous research by using a single material was due to the investigation on some differences in terms of non-strength compared with the heterogeneous bonding material. Finally, a study on the fracture characteristics of the adhesive was conducted by using CFRP-AL, a heterogeneous bonding material[1-6].

2. Experimental Setup and Tensile Tests

In order to examine the fracture characteristics of the adhesive depending on the material, the tensile tests were conducted to investigate the physical properties of the material. Fig. 1 shows the dimensions of AL6061-T6 specimen, and the dimensions are designed based on the specimen of KS B 0801 No. 5.

Fig. 2 is a photo of the specimen by the design dimensions. Fig. 3 shows the dimensions of the CFRP tensile specimen due to ASTM D3093. Fig. 4 is the actual shape of the CFRP tensile specimen.

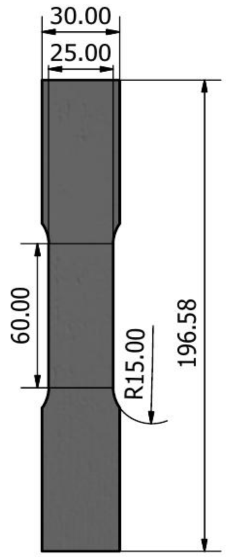


Fig. 1 Dimensions of AL6061-T6 specimen

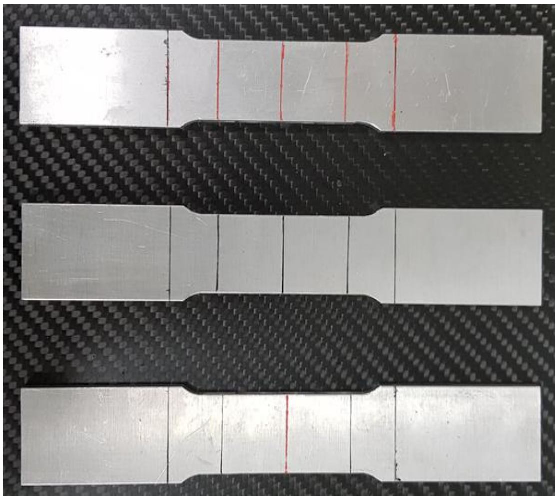


Fig. 2 Shape of AL6061-T6 specimen

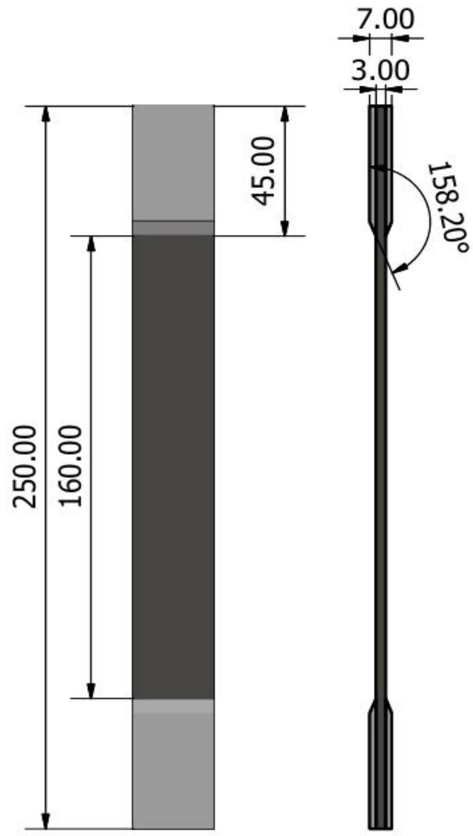


Fig. 3 Specification of CFRP specimen

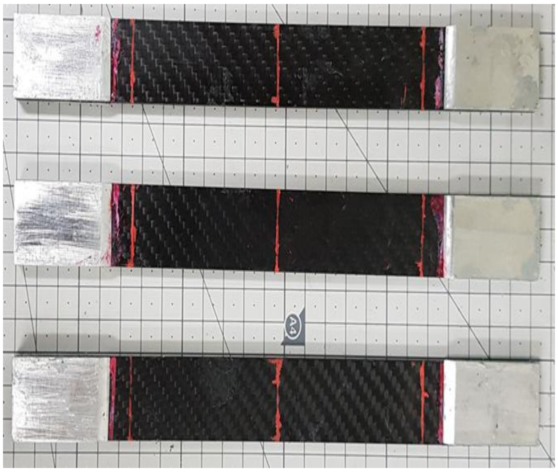


Fig. 4 Shape of CFRP specimen

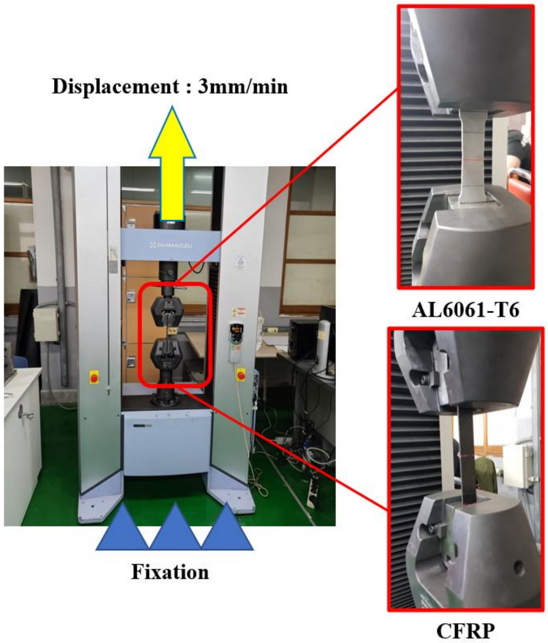


Fig. 5 Experimental set-up and condition

Fig. 5 shows the experimental set-up and condition. To proceed with the tensile test, the specimen was mounted on the AG-X Plus equipment of Shimadzu, a universal testing machine, and the lower part was fixed and the upper part was applied by a forced displacement of 3mm per minute.

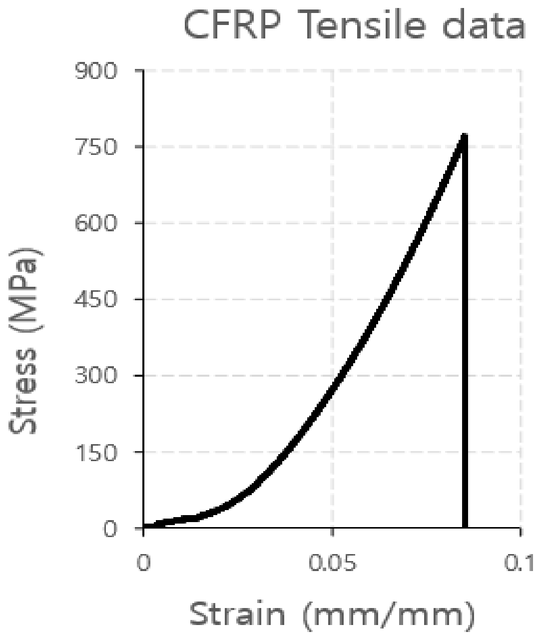


Fig. 6 Graph of strain vs. stress on CFRP specimen

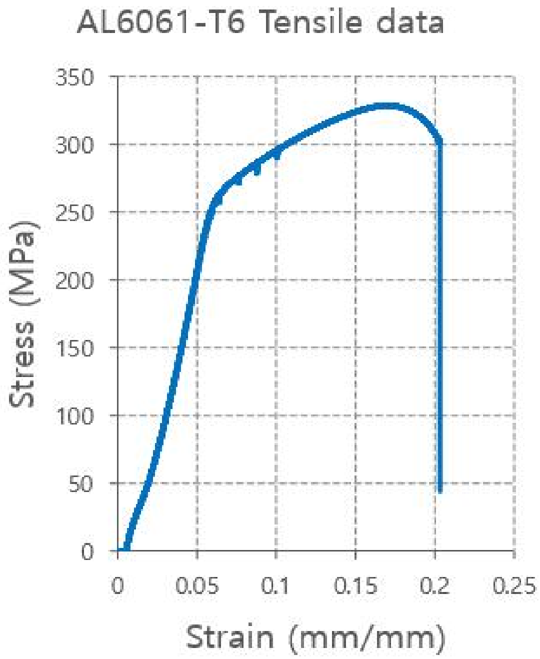


Fig. 7 Graph of strain vs. stress on AL6061-T6 specimen

Fig. 6 is a graph of strain vs. stress on CFRP specimen. The material properties measured through the tensile test are Young's modulus and ultimate tensile strength. For the remaining density and Poisson's ratio, the physical properties were identified by referring to the Mil sheet issued by the manufacturer. Fig. 7 is a graph of strain vs. stress on AL6061-T6 specimen. The material properties of CFRP are listed in Table 1. And Table 2 shows the physical properties of AL6061-T6.

Table 1 Material properties of CFRP

Property	Value
Density(kg/m3)	1,760
Poisson’s ratio	0.1
Young’s Modulus(MPa)	7,688.9
Ultimate Tensile Strength(MPa)	771.3

Table 2 Material properties of AL6061-T6

Property	Value
Density(kg/m3)	2,700
Poisson’s ratio	0.33
Young’s Modulus(MPa)	4,005
Yield Strength(MPa)	264
Ultimate Tensile Strength(MPa)	328

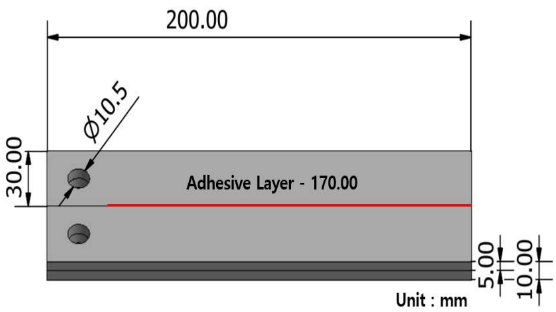
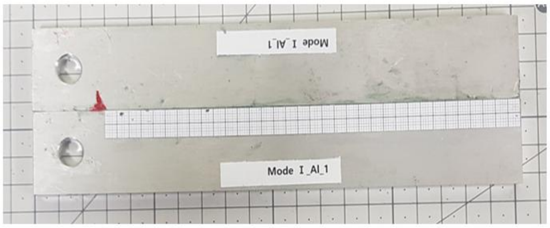
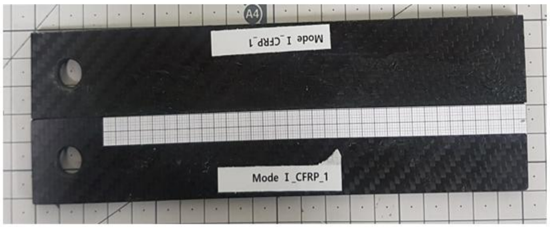


Fig. 8 Dimensions of double cantilever beam specimen



AL6061-T6



CFRP

Fig. 9 Shape of double cantilever beam specimen bonded with single materials

3. Experiment on Single Materials

3.1 Specimen and experiment setup

Fig. 8 shows the dimensions of the double cantilever beam specimen for mode III. The double cantilever beam specimen was manufactured by referring to the British industrial standard BS7991:2001, and the single material specimen was made of a material with the thickness of 5 mm as a single sheet. Since each material was bonded with the thickness of 5 mm, the specimen with the 그림 8 heterogeneous material was designed and manufactured by setting the total thickness of 10 mm. The adhesive interface was set to the length of 170 mm in order to investigate the fracture characteristics of the adhesive according to the crack propagation. Fig. 9 shows the actual shape of double cantilever beam specimen bonded with the single material. Fig, 10 shows the experimental set-up and condition for the tearing fracture of mode Ⅲ. As a method of mounting the double cantilever beam specimen, the experiment was conducted by mounting the adhesive interface perpendicular to the ground for the tearing fracture. As an experimental condition, a forced displacement of 3mm/min was applied to the upper part with a load cell measuring the reaction force. The lower part was fixed and the reaction force according to the forced displacement was stored as the experimental results[7-8].

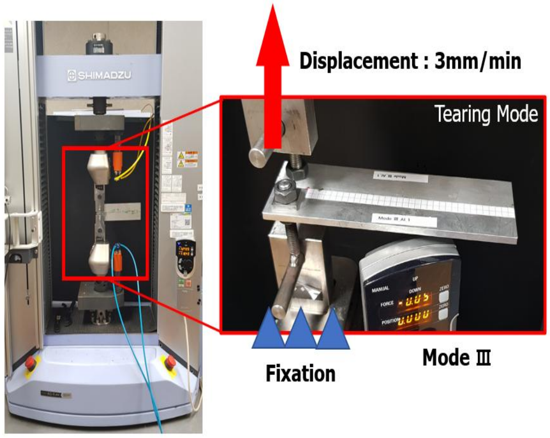


Fig. 10 Experimental set-up and condition

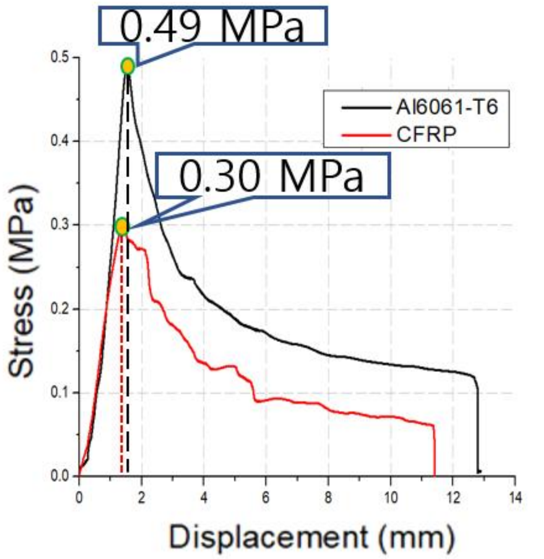


Fig. 11 Graph of displacement vs. stress on single materials

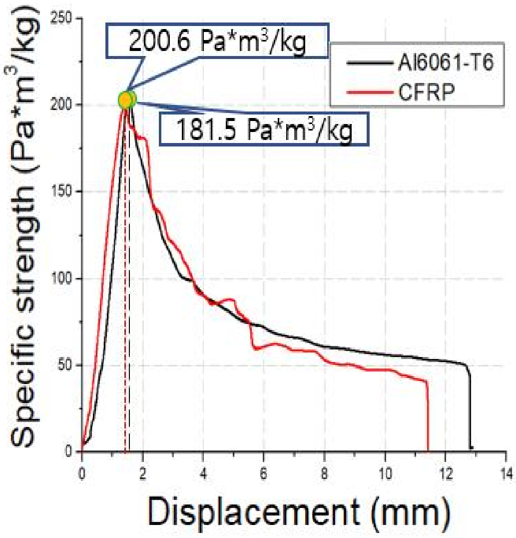


Fig. 12 Graph of displacement vs. specific strength on single materials

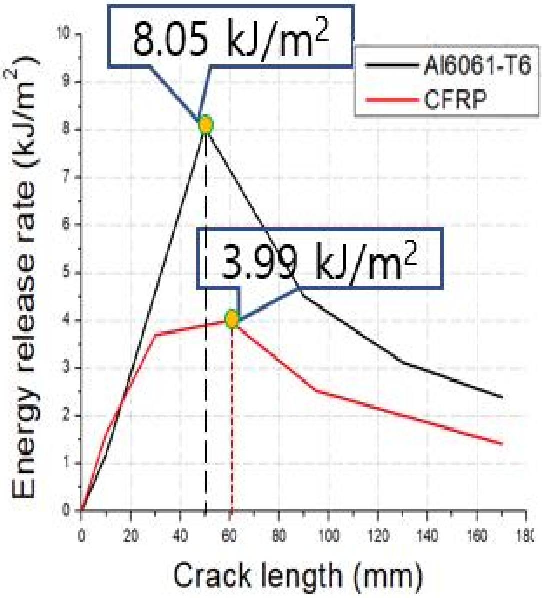


Fig. 13 Graph of crack length vs. energy release rate on single materials

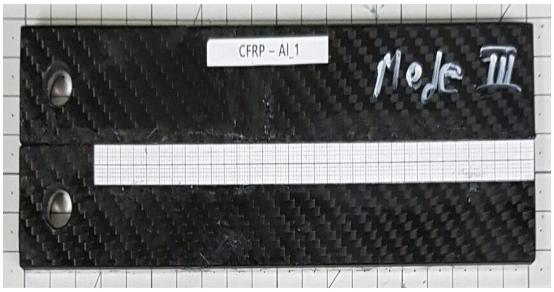
3.2 Experimental results

Fig. 11 shows the graph of displacement vs. stress, indicating that the maximum stress of AL6061-T6 was 0.49 MPa and that of CFRP was 0.30 MPa. Fig. 12 is the graph of displacement vs. specific strength on single materials. AL6061-T6 has a maximum specific strength of 200.6Pa*m^3/kg and CFRP has a specific strength of 181.5Pa*m^3/kg. Finally, Fig. 13 shows the graph of crack length vs. energy release rate on single materials. The maximum energy release rates of Al6061-T6 and CFRP were shown to be 8.05kJ/m^2 and 3.99kJ/m^2, respectively. It is thought that AL6061-T6 has the structural safety excellent more than CFRP.

4. Experiment on Heterogeneous Material

4.1 Specimen

Fig. 14 is a double cantilever beam specimen bonded with the heterogeneous material manufactured on the basis of Fig. 8. The material of CFRP was used for the upper part of the specimen and AL6061-T6 was used for the lower part. The experiment was carried out with the same method as the double cantilever beam specimen using a single material[9-10].



CFRP-AL

Fig. 14 Shape of double cantilever beam specimen with heterogeneous materials(CFRP-AL)

4.2 Experimental results

Fig. 15 is the graph of displacement vs. stress on CFRP-AL specimen bonded with heterogeneous materials. Also, Fig. 16 is the graph of displacement vs. specific strength on CFRP-AL specimen bonded with heterogeneous materials. Fig. 17 is the graph of crack length vs. energy release rate on CFRP-AL specimen bonded with heterogeneous materials. The maximum stress of 1.67 MPa and maximum specific strength of 749.9 Pa*m^3/kg happened when the displacement was about 5 mm. The maximum energy release rate of 78.4kJ/m^2 occurred when the crack was propagated as much as the length of 10mm. Based on this result, it is investigated through the experiments that CFRP-AL specimen bonded with heterogeneous materials has the structural safety superior more than the specimen with single materials for mode III failure.

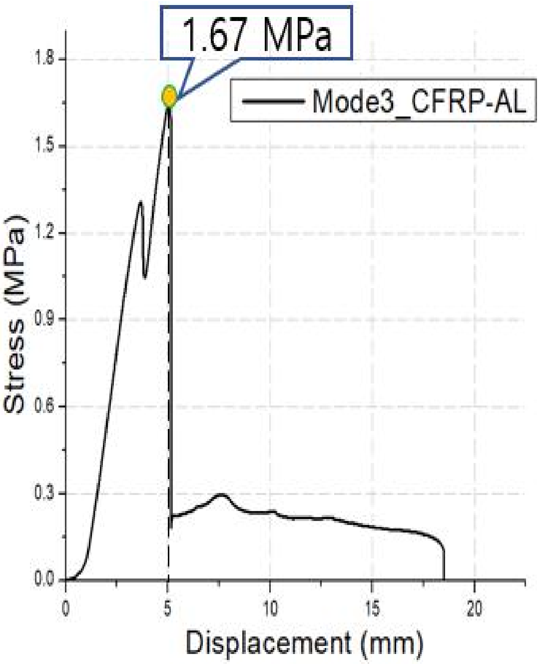


Fig. 15 Graph of displacement vs. stress on heterogeneous materials

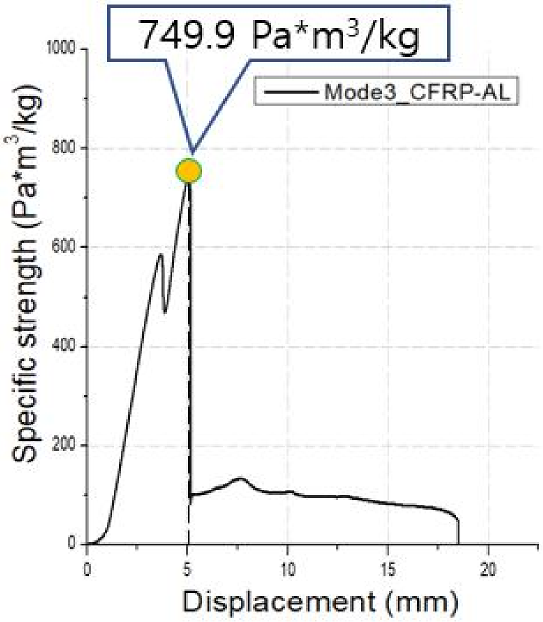


Fig. 16 Graph of displacement vs. specific Strength on heterogeneous materials

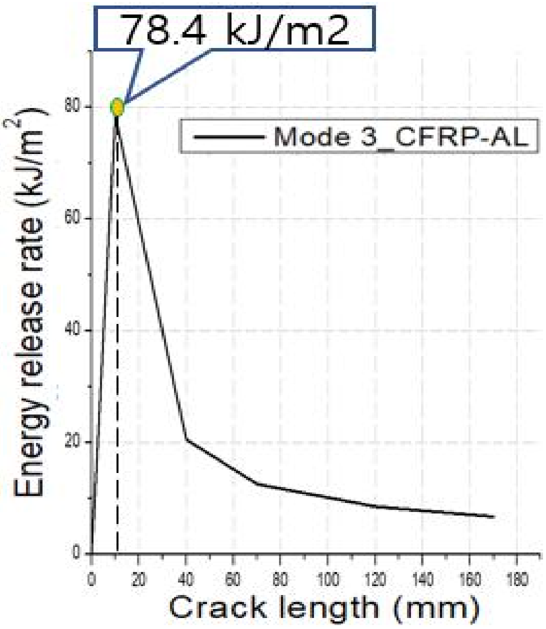


Fig. 17 Graph of crack length vs. energy release rate on heterogeneous materials

5. Conclusion

In this study, the adhesive fracture characteristics on the specimens bonded as double cantilever beam were investigated according to the single materials or the heterogeneous materials under the tearing load. The conclusions are as follows;

1. The stress, specific strength, and energy release rate were examined in order to investigate the fracture characteristics of double cantilever beam specimens using a single material. AL6061-T6 specimen had the maximum stress and specific strength when the displacement of about 1.7mm was applied, and at this moment, the maximum stress was 0.49MPa and the maximum specific strength was 200.6Pa*m^3/kg. In case of CFRP specimen, when a displacement of about 1.6mm was applied, the maximum stress and specific strength were measured. At this moment, the maximum stress and the maximum specific strength were 0.30 MPa and 181.5Pa*m^3/kg, respectively.
2. When comparing the energy release rate of double cantilever beam specimens with a single materials, AL6061-T6 specimen showed a value of 8.05kJ/m^2 when the crack propagation of about 50mm occurred, and in case of CFRP specimen, the crack propagation of about 60mm occurred. The maximum energy release rate of 3.99kJ/m^2 was shown through the experiments.
3. When CFRP-AL specimen bonded with the heterogeneous materials was utilized, the maximum stress and maximum specific strength appeared when the displacement was about 5 mm. Also, the maximum stress and the maximum specific strength were 1.67 MPa and 749.9 Pa*m^3/kg, respectively. The maximum energy release rate was seen to be 78.4kJ/m^2 when the crack was propagated as much as the length of 10mm. Based on this result, it is investigated through experiments that CFRP-AL specimen

bonded with heterogeneous materials has the structural safety superior more than the specimen with single materials for mode III failure.

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