

# Estimation of shear strength of FRP joints using adhesives with ceramics particles

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**Abstract.** We proposed adhesives with thermosetting resin and ceramics particles for single lap joints of GFRP and tried to decompose by microwave irradiation. It was obvious that the optimum amount and radius of particles to satisfy high strength before irradiation and low strength after irradiation.

## 1. Introduction

Multi materials composed of metal and FRP with the high strength and the light weight are expected to reduce CO<sub>2</sub> and keep the energy saving for vehicles. The dissimilar material joining is one of the remarkable technologies for multi materials, however, it is difficult to decompose the joining structure for recycling. Therefore, the adhesive joining technology for metal and FRP with the high joining strength and easy decomposable function is needed.

There are several researches about decomposable adhesive using thermoplastic resin with filler [1][2], however, the adhesive based on thermosetting resin is more effective to apply the bonding structures such as FRP and metals to keep high bonding strength and easy decomposable function.

The purpose of this study is to develop adhesive materials based on thermosetting resin and ceramics filler for joining different kinds of materials such as FRP and metals, and to decompose the bonding structures conveniently. As the first step, we propose the adhesives with thermosetting resin and ceramics particles for a GFRP joint and try to decompose by microwave irradiation.

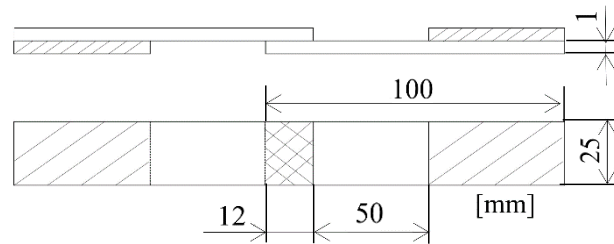
## 2. Single lap joints with thermosetting resin and ceramics particles

Test specimens were GFRP (E-glass: non-crimp fabric [0/90]<sub>s</sub> / Resin: vinyl ester), and the specimens were prepared as single lap joints in Figs.1, 2 based on JIS K 6850.

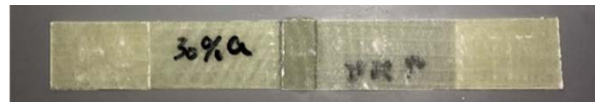
Test specimens are bonded with the adhesives based on thermosetting epoxy (Araldite®, Huntsman Japan Co.). The adhesive is included with SiC particles. The volume of the particles are 0, 10, 20, and 30%, and the diameter are 0.02, 0.3, 1.2, 80 μm. The thickness of adhesive layer is 0.1mm.

A tensile shear test is carried out with tensile testing machine (Shimadzu Co. Ltd.), and the tensile speed is 1.0mm/min. The microwave irradiation is controlled with the microwave apparatus (MOASTORE Co. Ltd.) and the frequency and power are 2.45GHz, 500W.





**Figure 1.** Shape of test specimen

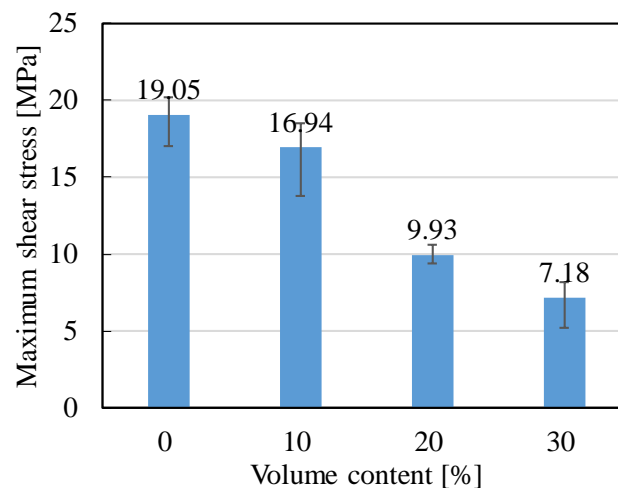


**Figure 2.** A sample of test specimen

### 3. Effects of volume fraction of particles on shear strength

A tensile shear test of GFRP joints with the proposed adhesive was carried out with/without microwave irradiation, and effects of the volume fraction of ceramics particles on the adhesive strength were investigated.

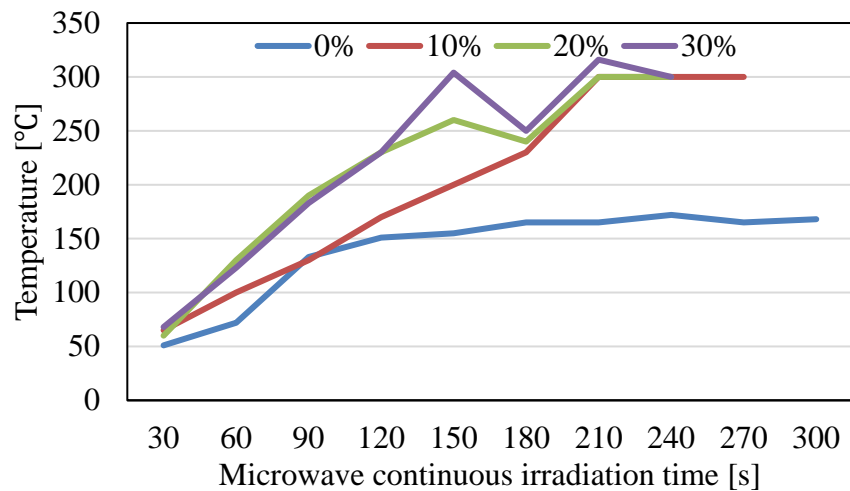
Figure 3 shows experimental results of shear strength of GFRP single lap joint before microwave irradiation in case of volume contents of particles 0, 10, 20 and 30% with  $0.3\mu\text{m}$  diameter. The number of test specimen is 3. The average value is shown in the figure, and max. and min. values are shown in the scatter bar. The shear strength reduces with the increase of particles volume. In case of 30% volume, the strength shows 62.3% reduction compared with the strength of 0% volume.



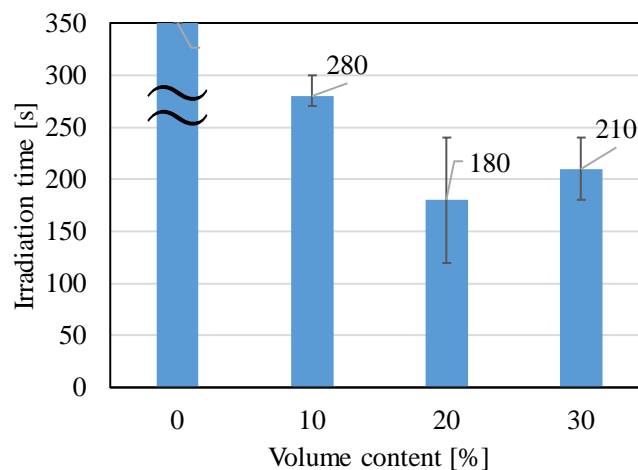
**Figure 3.** Results of shear strength of GFRP single lap joint before microwave irradiation (Volume contents of particle: 0, 10, 20, and 30%)

The temperature on the surface of test specimen is measured with thermometer (FT-H20, Keyence Co. Ltd.). Figure 4 shows the temperature change due to microwave irradiation. In case of 0% volume, the temperature tends to saturate  $160^{\circ}\text{C}$  and the value is under the thermal decomposition temperature of thermosetting resin. On the other hand, the temperature increases  $300^{\circ}\text{C}$  in case of over 10% volume due to the self-heating of ceramics particles.

Figure 5 shows the irradiation time of microwave until disappearance of adhesion, and the disappearance time of adhesion reduces with the increase of ceramics volume.



**Figure 4.** Temperature change due to microwave irradiation (Volume contents of particle: 0, 10, 20, and 30%)

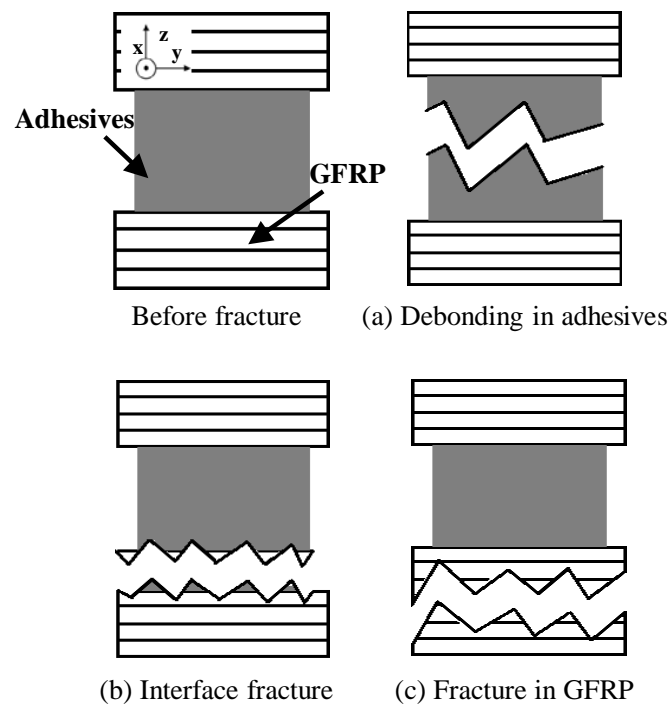
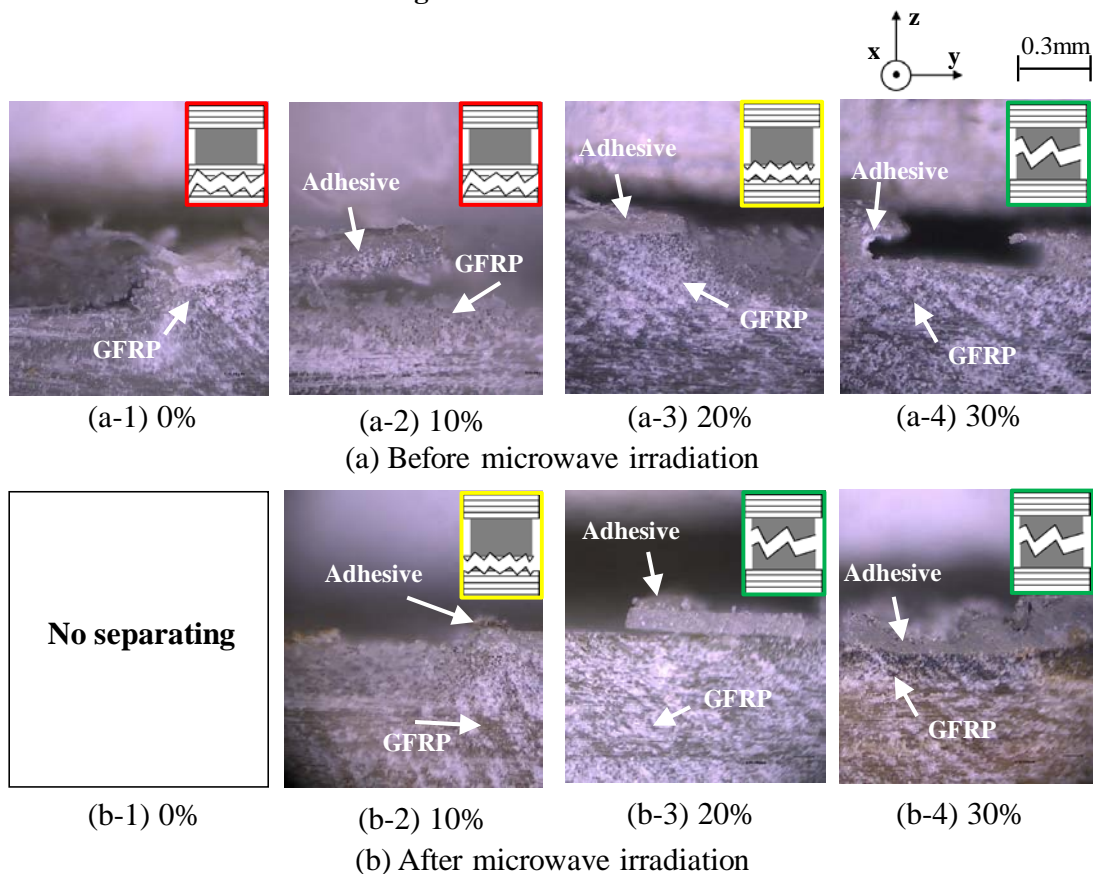


**Figure 5.** Irradiation time of microwave until disappearance of adhesion (Volume contents of particle: 0, 10, 20, and 30%)

#### 4. Observation of fracture surface

After the tensile shearing test, the fracture surfaces of test specimens were observed with CCD microscope. The pattern of fracture on the cross section of specimens is clarified to 3 types (debonding in adhesives, interface fracture between adhesives and FRP, and fracture in FRP) in Fig.6.

Figure 7 shows the observational results with/without microwave irradiation in case of several volume contents of ceramics particles. Figure 7(a) shows the fracture surface after tensile shear test without microwave irradiation, and Figure 7(b) shows the fracture surface with microwave irradiation before tensile shear test. In case of 0% volume of particles, the fracture in FRP appeared after tensile shear test without microwave irradiation (Fig.7(a-1)), however, the specimen was not separated with only microwave irradiation (Fig.7(b-1)) because the temperature of adhesive resin was not reached to the thermal decomposition temperature (Fig.4).

**Figure 6.** Pattern of fracture surface**Figure 7.** Pattern of fracture surface

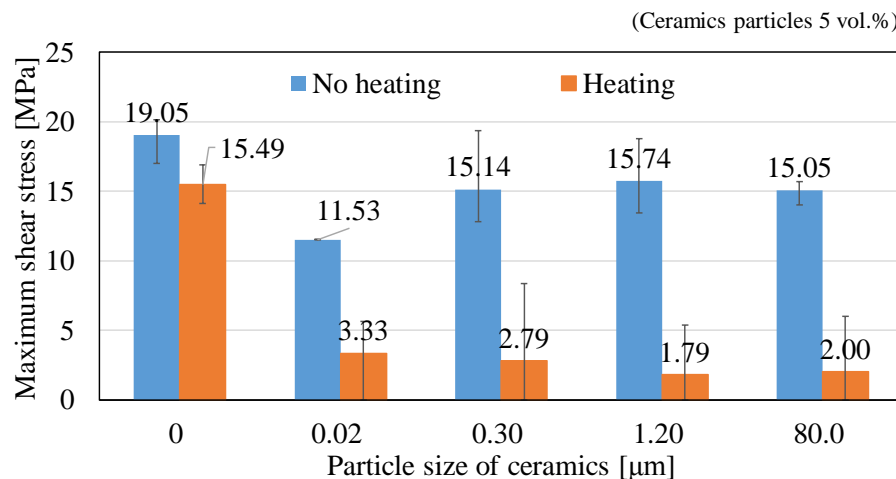
In case of 10% volume, the fracture in FRP also appeared without microwave irradiation (Fig.7(a-2)), and the interface fracture appeared with microwave irradiation (Fig.7(b-2)). The pattern is effective for material joining which keeps the high bonding strength without microwave irradiation and easy decomposable function with microwave irradiation.

In case of over 20% volume, the interface fracture and fracture of debonding in adhesives appeared without microwave irradiation in Fig.7(a-3, a-4), and the max. shear strength are low in Fig.3. As the results, it was obvious that the optimum amount of volume fraction of ceramics particles to satisfy the high strength before microwave irradiation and 1 easy decomposable function after irradiation.

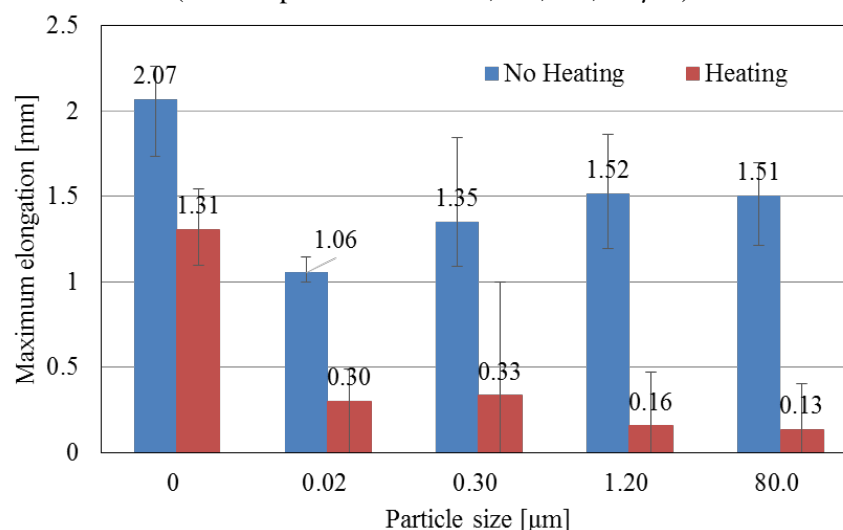
### 5. Effects of particles size on shear strength

The tensile shear test was carried out in case of various particle diameter with/without microwave irradiation and the irradiating time is 180 sec. Figures 8, 9 shows the experimental results of max. shear strength and elongation in case of various diameter of particles with 5.0% volume contents.

In case of  $0.02\mu\text{m}$  diameter of particles, the shear strength and elongation before irradiation show a remarkable reduction compared with over  $0.3\mu\text{m}$  diameter. Too small size of particles is not effective for reinforcement of adhesive resin.



**Figure 8.** Results of shear strength of GFRP single lap joint with/without microwave heating (Case of particle size: 0.02, 0.3, 1.2, 80  $\mu\text{m}$ )



**Figure 9.** Results of max. elongation of GFRP single lap joint with/without microwave heating (Case of particle size: 0.02, 0.3, 1.2, 80  $\mu\text{m}$ )

## 6. Conclusion

For bonding structures with different kinds of materials, we proposed the adhesives with thermosetting resin and ceramics particles for a GFRP joint and try to decompose by microwave irradiation. The single lap joints with GFRP were prepared, and a tensile shear test of GFRP joints with the proposed adhesive was carried out with/without microwave irradiation, and effects of the volume fraction and diameter of ceramics particles on the adhesive strength were investigated.

As the results, it was obvious that the optimum amount of volume fraction and radius of ceramics particles to satisfy the high strength before irradiation and low strength after irradiation. In case of the optimum volume contents, the observational results of fracture surface shows that the single lap joint keeps the high bonding strength without microwave irradiation and easy decomposable function with microwave irradiation.

## Acknowledgements

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## References

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