RESEARCH ON THE JOINTING METHOD OF CFRTP FOR STRUCTURAL APPLICATIONS

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1 Introduction

Among all types of CFRP (carbon fiber reinforced plastics), the most common matrix resin is thermosetting resin such as epoxy. CFRTS (CFRP with thermosetting resin matrix) shows several superior performances like heatproof and high specific strength, leading to a considerable potential of weight-lightening. As a result, CFRTS has been applied to special industrial fields such as aircraft, F1 and space usage [1]. However, long time and expensive equipments are necessary for CFRTS's molding, which causes high processing cost, then CFRTS's application field has been limited.

On the other hand, CFRTP (carbon fiber reinforced thermoplastics) is expected to realize low-cost and high-cycle molding, along with improvement of process ability, repair ability and recyclability. Hence, though there remains some technical difficulties in such as weaker interfacial adhesiveness between CF and thermoplastics, and impregnation of thermoplastics into CF-bundle, CFRTP has a possibility to lighten the weight of mass production automobile drastically.

Especially, the largest difference between CFRTP and CFRTS is the molding method. Because CFRTS is a brittleness material, CFRTS is molded as possible to avoid making holes and joint parts. Therefore, manufacturing facilities of CFRTS are large-scale and expensive such as autoclave, which is major reason of the limited application field of CFRTS [2]. However, CFRTP can be easily deformed and jointed by heat, then press molding and welding joint like metals can be used for their manufacturing.

Then, to apply CFRTP to various industrial fields as structural material, it is necessary to establish affordable jointing methods. Mechanical fastening, such as bolt connection, rivet connection, adhesive bonding and welding are well known as jointing methods for structural members [3]. In this research, we focused on welding joint by using the thermal plasticity of CFRTP itself to apply to automotive structural members [4]. Carbon fiber reinforced polypropylene is used to clarify its' basic characteristics of joint efficiency by using both single lap joint specimen and cross joint specimen.

2 Joint strength by surface welding

2.1 Single lap joint

We made test pieces of 15×100×2 mm for UD (unidirectional) material and 25×100×2 mm for random material, then jointed by ultrasonic welding under the condition of 25 mm of lap length and 1.0 sec of weld time. We also welded small pieces of random material to the edge of test pieces to avoid moment generation during tensile test. We calculated average shear strength by the equation below:

$$\bar{\tau} = \frac{F}{LB} \tag{1}$$

Where $\bar{\tau}$ is average shear strength, F is maximum load, L is lap length and B is breadth of test piece.

Figs. 1 and 2 show the results of tensile test. Average strength of UD material is 21 MPa and that of random material is 17 MPa. We think that the difference comes from joint surfaces shown in Figs. 3 and 4.

2.2 Cross joint

We orthogonally jointed the test pieces of the same size of single lap joint specimen by ultrasonic welding under the condition of 1.0 sec of weld time. We could not join the entire joint surface, so we just show the relationship between displacement and load in Figs. 5 and 6.

2.3 Discussion

We think that ultrasonic welding is an effective jointing method for single lap joint because almost the entire joint surfaces are welded. However, for cross joint, we still need to use our ingenuity because we could not join the entire surface.

3 Joint strength by spot welding

3.1 Single lap joint

We jointed the test pieces of the same size of surface joint specimen by ultrasonic spot welding. We decided weld time as below: for random material, 1.5 sec and 2.5 sec for φ2 mm, and 2.5 sec and 3.0 sec for φ3 mm; for UD material, 2.5 sec.
Figs. 7 and 8 show the results of tensile test and Figs. 9 and 10 show the joint surfaces. Effective welded area was calculated by excluding the hole area of the ultrasonic hone.

3.2 Cross joint

We orthogonally jointed the test pieces of same size of surface joint specimen by ultrasonic welding. Weld time is 1.5 sec for φ2 mm and 2.5 sec for φ3 mm for random material, and 2.5 sec for UD material.
Figs. 11 and 12 show the results of tensile test. The definition of effective welded area is the same as single lap joint specimen.

3.3 Discussion

When we made diameter of hone larger, welded area and maximum load became larger accordingly. Then the maximum load of jointed specimen is more influenced by the diameter of hone than welding time.
Joint strength of spot welding specimen is almost the same as surface welding specimen. However, the hone's hole makes effective welded area smaller and stress concentration might occur for larger load. Therefore, we need to consider the size and the shape of the ultrasonic hone.

4 Conclusions

In this research, we focused on ultrasonic welding and considered influencing factor on shear strength and peel strength. As a result, we found that this method is effective because joint efficiency is as good as hot press jointing.

Acknowledgement

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References

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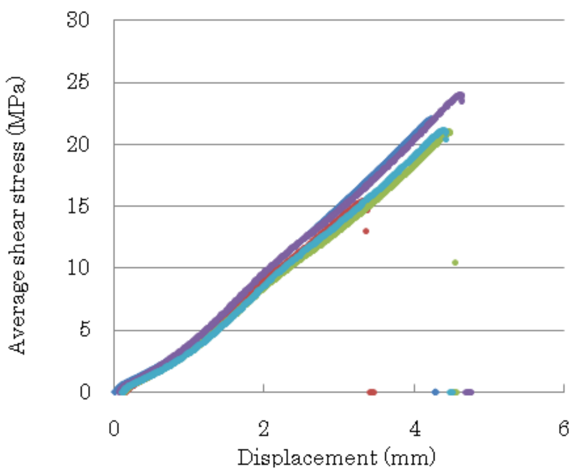

Fig. 1 Relationship between displacement and average shear stress of single lap joint (UD).

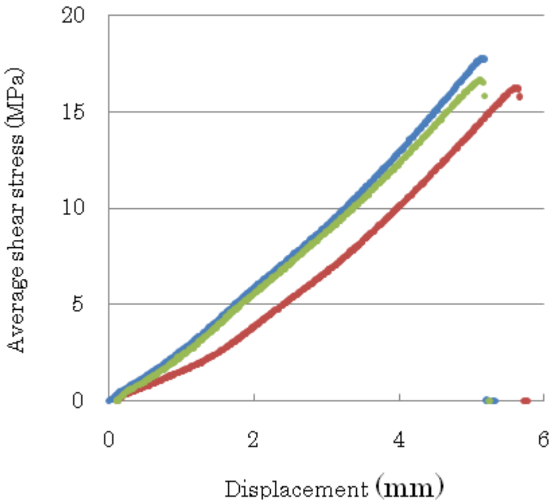

Fig. 2 Relationship between displacement and average shear stress of single lap joint (Random).

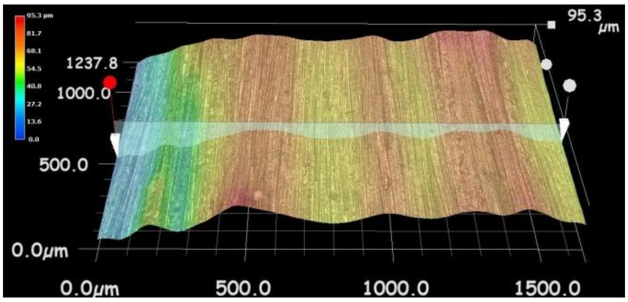

Fig. 3 Joint surface (UD).

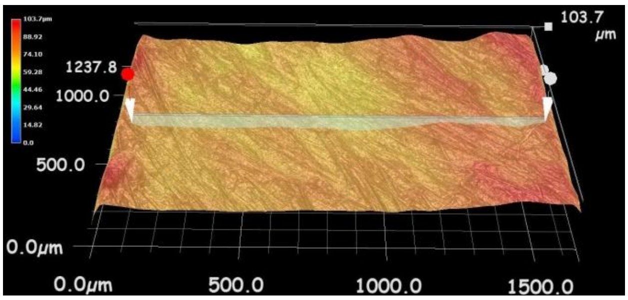

Fig. 4 Joint surface (Random).

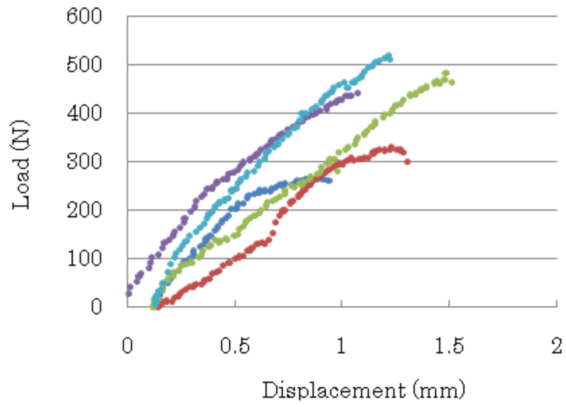

Fig. 5 Relationship between displacement and load of cross joint (UD).

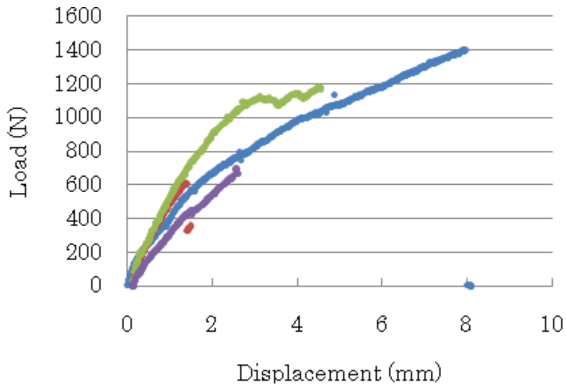

Fig. 6 Relationship between displacement and load of cross joint (Random).

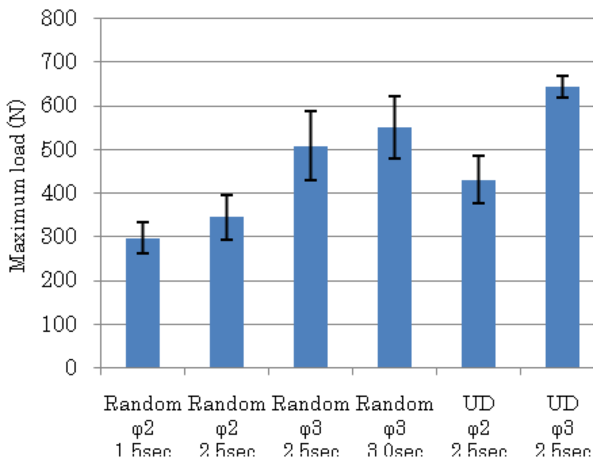

Fig. 7 Maximum load of specimens of single lap joint by spot welding.

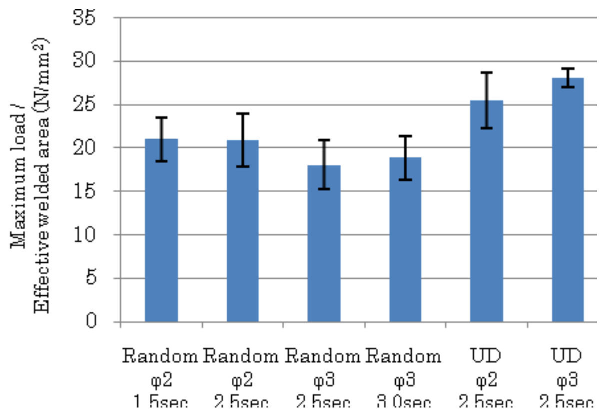

Fig. 8 Comparison of shear strength among the conditions of spot welding.

(a)

(b)

Fig. 9 Joint part of single lap specimens by spot welding (UD): (a) oscillation time of 2.5 sec with horn diameter of 2 mm; (b) oscillation time of 2.5 sec with horn diameter of 3 mm.

Fig. 10 Joint part of single lap specimens by spot welding (Random).

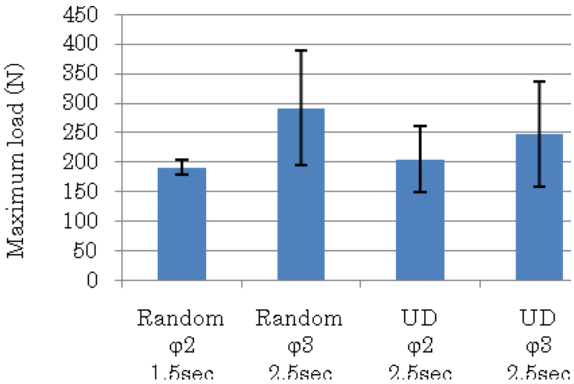

Fig. 11 Maximum load of specimens of cross joint by spot welding.

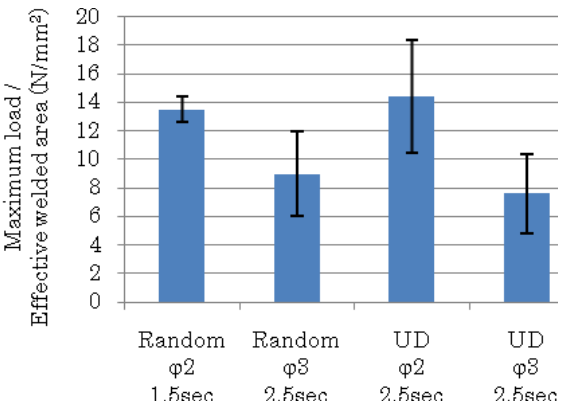

Fig. 12 Comparison of peel strength among the conditions of spot welding.