

INVESTIGATION ABOUT JOINT STRENGTH OF WELDING AND SHEAR PROPERTY OF CF RTP

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1 Introduction

In recent years, several measures for the better global environment have been taken in a variety of different fields. In a transportation sector, it has been necessary to install extremely light material into vehicle body structure for massive energy consumption saving [1]. At the same time, taking into consideration collision protection and vehicle maneuverability, it is very important to sustain or improve vehicle body strength and stiffness with demand of user's requirements.

From this viewpoint, carbon fiber reinforced plastics (CFRP) have been investigated as materials for high performance applications because they have higher specific strength and stiffness than conventional generally available metal such as steel or aluminum alloy.

With respect to carbon fiber reinforced thermosetting (CFRTS), which has been mainly used for primary structure of an airplane, adhesive bonding is useful as a utility joining method because it has some advantages over mechanically fastened joints [2]. However, generally understood, the joint strength with using adhesive bonding depends directly on adhesive cement itself. So, however, strong the base materials are, the joint strength is not higher than adhesive cement.

And then, the authors focused on welding joint using carbon fiber reinforced thermoplastics (CFRTP), which are composed of carbon fiber and thermoplastic resin such as polypropylene or polyamide. CFRTP can be easily deformed and jointed by heat, then press molding and welding joint like metals can be used for their manufacturing.

In addition, the availability of the welding joint in CFRTP leads to a solution to prevent the joining area from stress concentration, so that the body structure achieves high strength and stiffness.

In this paper, to apply the welding technology for the CFRTP vehicle body structure, the authors examined fundamental mechanical properties of CFRTP and strength of the welding joint by basic tensile test. Then it investigated about the relation of welding strength expectable to the physical properties of material.

2 Objective

CFRP had been widely used as high performance structural materials for aerospace and leisure applications because of its high specific strength and stiffness. However, it still remains problems, high cost and low productivity, and its scope has remained small in the entire industry.

CFRTP is expected as a material which is compatible in not only a weight saving but high-cycle and low-cost manufacturing and high recyclability. At this time, in order to realize the weight saving of a vehicle body substantially, there is the necessity of using CFRTP as the main structure of a vehicle body.

Generally, the main structure of a vehicle body has a large-sized and complicated form. In a current manufacturing process of automobile, the joining has been one of the key technologies because of easy to fabricate the vehicle body for improving speed of production. When it comes to applying CFRTP to

vehicle body material, welding joint of CFRTP is considered one of the promising joining methods. As shown in Fig.1, its new joining method is different from some conventional adhesive joints, and it is capable of joining two parts made from CFRTP just by heating up them and putting pressure upon each other without bonding or fastening like conventional welding metals[3]. For designing and manufacturing the main structure of a vehicle body, it is essential to evaluate not only the mechanical properties but joint strength. And it is necessary to find some designing methods to strengthen the welding joint part with regard to CFRTP. To apply the welding technology for the CFRTP vehicle body structure, fundamental mechanical properties of CFRTP and strength of the welding joint by basic tensile test were examined. Then it investigated about the relation of welding strength expectable to the physical properties of material.

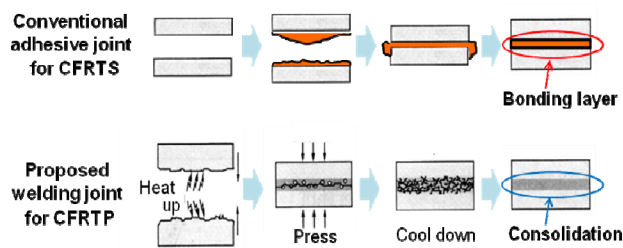


Fig.1 Comparison between joining methods

3 Test specimens and base materials

3.1 New Composite materials

CF and polypropylene (PP) examined in this study are reformed by chemical method respectively to improve adhesive strength between them. They have been developed as part of Japanese National Project, Development of Sustainable Hyper Composite Materials Technology [1]. In the latest studies [4][5], the interfacial shear strength between CF and developed PP has come closer to that between CF and epoxy, which is thermosetting resin, and this is more greatly larger than the value of between CF and normal PP. We evaluated the two types of CFRTP, by G2-PP with 2.0 wt% of the maleic anhydride and by Homo-PP without the maleic acid degeneration. (Teb1.1)

3.2 Molding process of base material

We evaluated two types of reinforced plastics, uni-directional(UD) and random chopped plate (Random). UD is the base material to evaluate a characteristic of composite, and Random is developed for more practical use. Fig.2 shows two types of fiber reinforced form. The UD materials were obtained by laminated molding of UD prepreg tapes with Vf=40% as shown in Fig.3. The laminates was fabricated through a process of stacking prepreg cut tapes on the mold, heating them up by hot plate and pressing tapes in the molds concurrently with cooling them down. The Random plate was made from G2 prepreg tape(35mm length) by the expert Toyobo, because the advanced technique needed in the molding process.

Table1 Interfacial shear strength between CF and PP

	Homo (CF-UD/HOMO-PP)	G2 (CF-UD/G2-PP)
CF	TR50S(Mitsubishi Rayon)	
Polypropylene	Homo(normal)	G2(with Maleic acid)
Interfacial shear strength (Microdroplet)	10.3 (Mpa)	38.7 (MPa)
Interfacial shear strength (fragmentation)	4.8 (MPa)	17.7 (MPa)

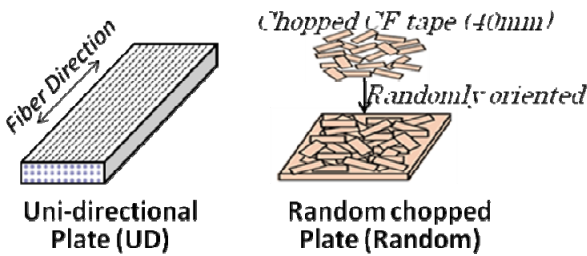


Fig.2 Two types of fiber reinforced form

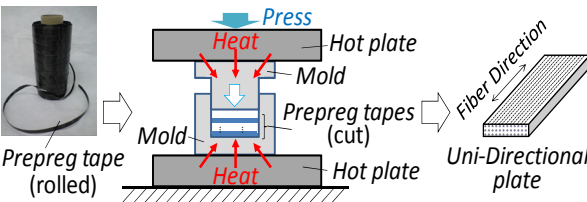


Fig.3 Process of laminate molding for UD test pieces

3.3 Result of the tensile test and double notch shear test

To obtain the characterization of the base material, tensile test and double notch shear test were examined. The size of a specimen for tensile test was 20mm in width and 2mm in thickness, and 13mm in width and 4mm in thickness for shear test. The shear strength was examined in accordance with the double notch shear test (ASTMD3846). Fig.4. shows geometry of specimen and photo of test configuration for double notch shear test. The notches on the specimen were processed with machining after fabrication of a base material. The measurement was done 5 times for each material respectively.

Fig.5 shows the results of tensile test. In the comparison of the UD-Homo and the UD-G2, the difference is not seen in the mean value of strength and modulus and the UD-Homo of the coefficient of variation is large. As for Random material, both strength and modulus considerably fell below the UD material, and the coefficient of variation was large. The reason of these low properties of Random material is the direction of the chopped tape. It seems that the material characterization of the Random is greatly influenced by the array of the chopped tape where we cut out from the random sheet.

Fig.6 shows the results of strength in compression load and strength in tensile load of double notch shear test. In the comparison between the compression load and the tension load, as for material type, a significant difference was not seen. However, shear strength in compression load tended to be a little higher than the strength in tensile load. The value of the Random material was smaller than that of the UD material, and this was the same tendency as the result of the tensile test.

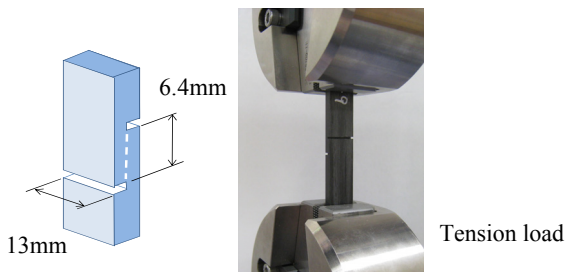


Fig.4 Geometry of specimen for double notch shear test and photo of test configuration

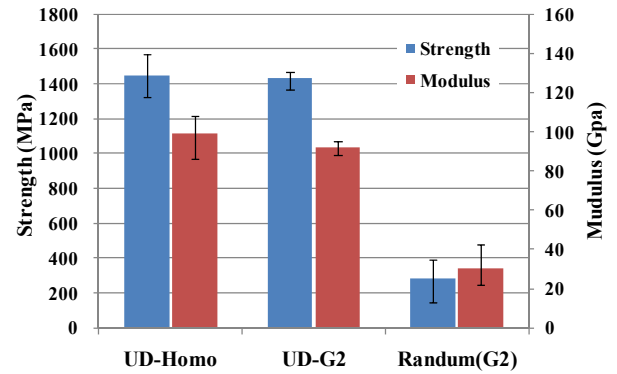


Fig.5 Comparison between strength and modulus of tensile test

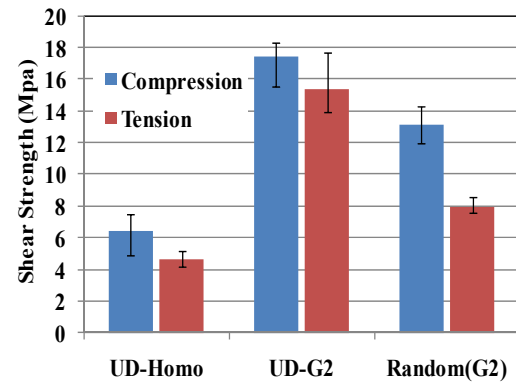


Fig.6 Comparison between strength in compression and strength in tension of double notch shear test

4 Tensile test of Welding joint

4.1 Joint Geometry and Process of Welding

For fundamental examination of joint geometry, we evaluate the single lap joint and the scarf joint. The single-lap joint and the scarf joint, 2 mm thickness of laminate and 25mm length of lap, were conducted by heat plate welding as shown in Fig.7.

The single lap joint is the simplest joining structure and basic in the evaluation of joint performance. In this joint, the fiber intertwining can be expected, but the load offset and the stress concentration will generate.

On the other hand, the scarf joint is the structure that improves the fault of the single lap joint, the load offset and the stress concentration[6].

4.2 Tensile test for welding joint

We evaluated the performance of the welding joint by the tensile test. From the result of the test, the assumed shear strength τ_j^* derived by the following equation (1) where P means a maximum load b means a width of specimens and L means lap length.

$$\tau_j = P / b L \quad (1)$$

The test result is shown in Fig.8. In the comparison between the single lap joint and the scarf joint, the assumed shear strength of the scarf joint of UD materials tended to be higher than that of the single lap joint. In contrast, as for the Random material, the value of scarf joint was less than that of the single lap joint. This is because the strength of lap part was decreased by shortening the fiber in the scarf part with machining. Fig.9 shows fracture surface after the tensile test. It was seen that the effective lap length had shortened because the scarf of Random(g2) was damaged.

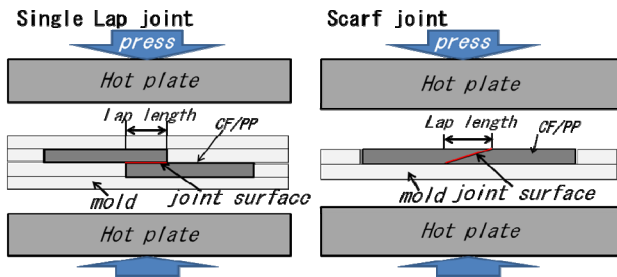


Fig.7 Joint geometries and measures;
(Left) Single lap joint (Right) Scarf joint

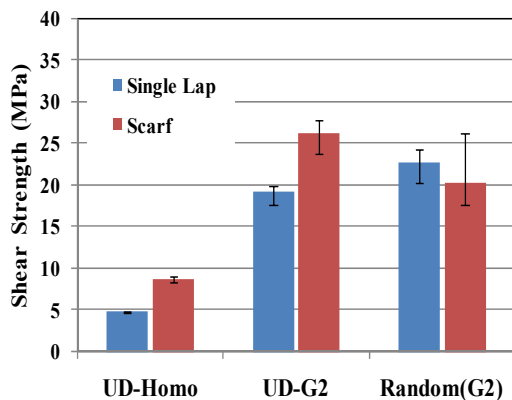


Fig.8 Comparison of the assumed shear strength between single lap joint and scarf joint in tensile test

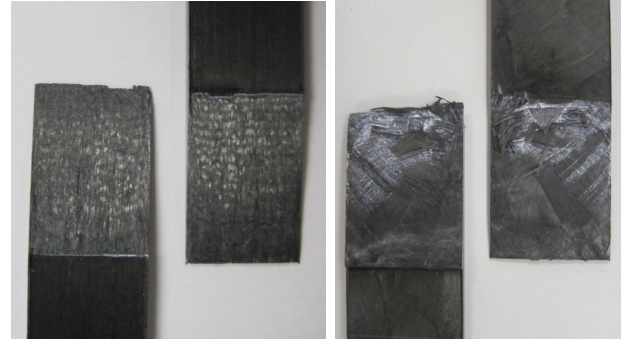


Fig.9 Fracture surface after tensile test,
(Left) UD-G2, (Right) Random(G2)

5 Discussion

As for UD materials, from Table 1 and Fig.6, it was found that the shear strength of double notch shear test was nearly the same as the value of interfacial shear strength by fragmentation. However, the shear strength in compression load tended to be a little higher than the strength in tensile load. It can be explained by assuming that the offset load entails peel stress at both ends of the shear plane of the specimen.

Moreover, Fig.10 shows the assumed shear strength of the welding joint plotted against the double notch shear strength in compression load. It is understood that the assumed shear strength of the single lap joint depends on the strength of double notch shear test, and the assumed shear strength of the scarf joint is higher than the strength of double notch shear test[7].

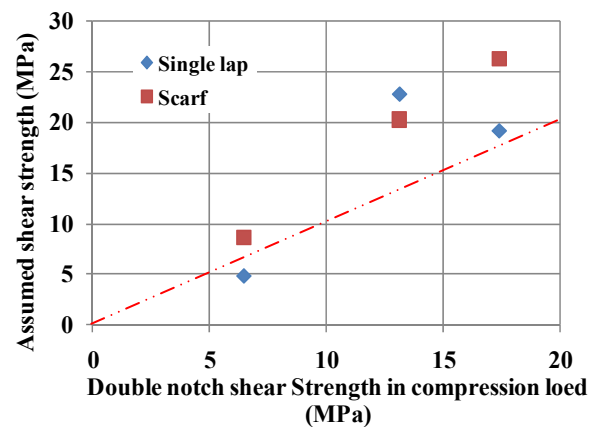


Fig.10 Dependence of the assumed shear strength of lap joint on the double notch shear strength in compression load

The reason for increase of the strength is not apparent but may be related to the influence of heating and pressing with welding process.

Moreover, the both values of the single lap and the double notch of these might be estimated more unjustified and smaller than an original, correct property.

Anyway, it had been understood to obtain joint strength with the welding joint as much as the shear strength of the material itself.

5 Conclusion

The authors examined fundamental mechanical properties of CFRTP and strength of the welding joint by basic tensile test. The results showed the following,

1. In UD material by normal PP and by reformed PP, there was no significant difference in the strength and modulus of UD material in tensile test.
2. The shear strength was nearly the same as the value of interfacial shear strength by fragmentation.
3. The assumed shear strength of the welding joint depends on the strength of double notch shear test.
4. The assumed shear strength of the scarf joint is higher than the strength of double notch shear test.
5. A guideline of designing for the welding method was proposed.

More detailed work is necessary to resolve this issue. For the future, the authors intend to construct the design method about the welding joint using CFRTP by verifying the joint strength with various different specifications such as joining geometry, adhesive force, fiber alignment, resin characteristics, molding condition, and so on.

Acknowledgement

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