VIBRATION WELDING OF LONG AND CONTINUOUS CARBON FIBER REINFORCED POLYPROPYLENE

A.Sasaki[1]*, T.Hayashi[1], K.Akiyama[1]
[1] Composite Materials Development Center, Mitsubishi Rayon Co., Ltd., Toyohashi, Japan
* Corresponding author(**sasaki_ak@mrc.co.jp**)

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1 Introduction

Carbon fiber reinforced plastics have high relative stiffness and strength and are used in various industrial applications. As for automotive industry, the composites have been used for sports cars and luxurious cars. Common automobiles need to reduce the weight to increase fuel efficiency. In order for the composite to be used for mass-production cars, its high productivity is required. Thermoset composites where epoxy resin is used as a matrix do not meet the demand. Recently, carbon fiber reinforced thermoplastic composite (CFRTP) is gaining attentions because of its short molding cycle. So far, super-engineering plastics such as PEEK and PPS are mainly used as a matrix, but too expensive to be used for mass-production cars.

We developed polypropylene (PP) matrix CFRTP and its molding technologies. We applied special surface treatment to carbon fiber and modified PP to enhance the adhesiveness between the two materials. By doing so, we developed PP-matrix composite of superior mechanical properties.

In the case of CFRTP, two parts can be jointed not by adhesive but fusion welding. Fusion welding such as vibration welding, hot-plate welding and ultrasonic welding has been extensively studied in the field of injection molding [1]. However, research on fusion welding of long or continuous fiber reinforced composites is limited. Jandali investigated shear strength of welded continuous carbon fiber reinforced PP of fiber volume fraction 33.6% and its typical shear strength was 4.7MPa-9.1MPa[2]. Gehde studied vibration welding of PP-matrix glass mat and shear strength at welding penetration 0.5mm was 14MPa[3].

In this paper, vibration welding of modified-PP matrix CFRTP was experimentally investigated. The length of carbon fiber was 35mm or continuous. The volume fraction of carbon fiber was larger than those of previous studies. Thermoplastic neat film was inserted at the welding part and its effects were investigated.

2 Experiment

2.1 Materials

Carbon fiber (TR50S) was provided by Mitsubishi Rayon. Special surface-treatment was applied to this carbon fiber to enhance the adhesiveness to maleic acid modified PP.

Uni-directional tape was made by impregnating carbon fiber tow with melted modified PP. Tape width was 12.5mm and thickness 0.2mm. Volume fraction of carbon fiber was 45%.

UD tape was cut by 35mm and randomly dispersed and consolidated. The consolidated sheet was pre-heated to 210 degree C and pressed at 18MPa and 130 degree C to make a 2mm-thick random chop panel.

A UD prepreg-sheet was made by putting the tapes side by side and consolidating at 170 degree C. 10 prepreg-sheets were laid-up uni-directionally and consolidated at 210 degree C and subsequently cooled down and pressed at 3MPa to make a 2mm-thick UD panel.

2.2 Vibration welding

Test specimens of 25mm width and 120mm length were cut from random chop panel and UD panel. In the case of UD panel, fiber direction was parallel to the longer dimension of the specimens. Single-lap samples of lap length 20mm were made by vibration welding machine (Branson, 2800J-DC, M-624HRi). Welding conditions were as follows; frequency 240Hz, amplitude 0.5 to 1.8mm, welding pressure 2-6MPa and welding time 3-20sec. Holding conditions such as pressure and time after vibration welding were also varied.

2.3 Evaluation

Before and after welding, thickness of panel and welded sample was measured by micro gauge and penetration depth was calculated for each experiment. Tensile tests were conducted for welded samples by tensile testing machine (Shimadzu) at drawing speed 2mm/min.

3 Results and discussion

3.1 Vibration welding of random chop panel

Fig.1 shows the effects of vibration amplitude on penetration depth of modified PP random chop panel. The vibration occurred parallel to the longer dimension of the specimens. Welding pressure was 6MPa and when the vibration stopped, the samples were held at the same pressure for 5sec. By larger amplitude, penetration occurred more quickly. Fig.2 shows lap shear strength of these samples. The effects of vibration amplitude were negligible and penetration depth had strong effects. Shear strength were almost constant between penetration depth 0.5mm and 1.5mm.

Fig.3 shows the effects of welding pressure on penetration depth. The vibration amplitude was 1.5mm and when the vibration stopped, the samples were held at the same pressure for 5sec. At higher welding pressure, penetration occurred more quickly. Fig.4 shows lap shear strength of these samples. At lower welding pressure, higher lap shear strength was obtained. Again optimum penetration depth was 0.5-1.5mm.

Fig.5 shows the effects of holding pressure and time on penetration depth. At first, the samples were welded at amplitude 1.5mm and welding pressure 6MPa for 5 sec, and then held at 6, 12 or 24MPa for 5 or 10 sec. At higher holding pressure and longer holding time, penetration progressed further. Fig.6 shows lap shear strength of these samples. As for holding pressure 6 and 12MPa, shear strength was almost same, but at holding pressure 24MPa, shear strength became lower.

3.2 Vibration welding of UD panel

UD panels of modified PP matrix were welded at welding pressure 6MPa and amplitude 1.5mm. Two vibration directions were employed. One was parallel to fiber direction (referred as 0 degree) and the other was transverse direction (referred as 90 degree). In each case, samples were held at 6MPa for 5sec. Fig.7 shows the effects of vibration direction on penetration depth. At 0 degree vibration, quicker penetration was observed than 90 degree vibration. Fig.8 shows lap shear strength of these samples. As for 0 degree vibration, penetration depth was 0.01mm for 3sec vibration, and under this condition, the highest lap shear strength 20.2MPa was achieved. In the meantime, the highest strength was 18.0MPa for 90 degree vibration at penetration depth 0.11mm.

3.3 Effects of inserted neat film

As a comparison, a piece of 0.1mm thick neat modified PP film was inserted on the lap area of either specimen by ultrasonic welder (Branson, 2000LP) before vibration welding. As for random panel, welding pressure, amplitude and time were 6MPa, 1.5mm, and 5sec and holding pressure and time were 6MPa and 5sec. As for UD panel, welding direction, pressure, amplitude and time were 0 degree, 6MPa, 1.5mm and 5sec and holding pressure and time were 6MPa and 5sec. In those conditions, the penetration depth was 0.5mm and 0.3mm for random panel and UD panel, respectively.

Table 1 shows that inserted film had no effects for random panel and decreased shear strength for UD panel.

4 Conclusion

Lap shear strength of random chop panel of carbon fiber reinforced modified PP was 15-20MPa between penetration depth 0.5-1.5mm. In the case of UD panel, high lap shear strength was achieved at relatively small penetration depth.

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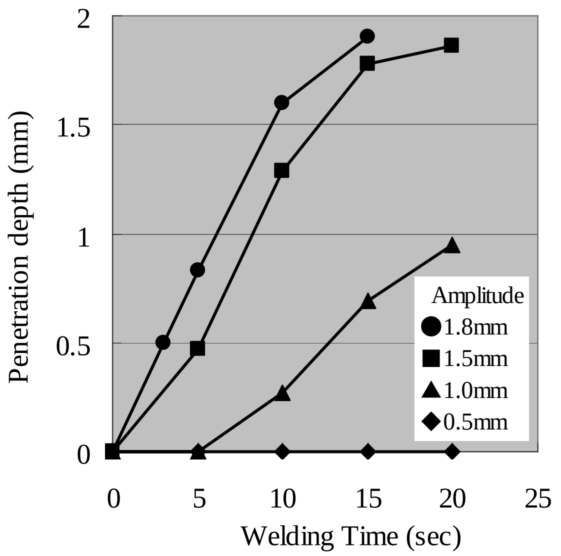

Fig 1. Effects of vibration amplitude and time on penetration depth of modified PP random chop panel.

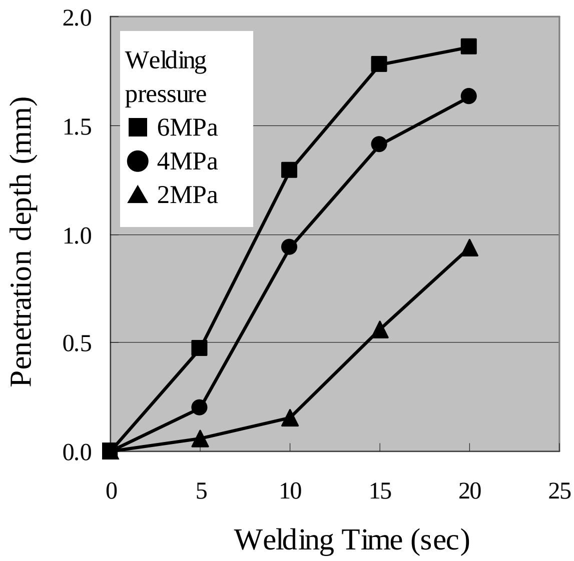

Fig.3. Effects of welding pressure and time on penetration depth of modified PP random chop panel.

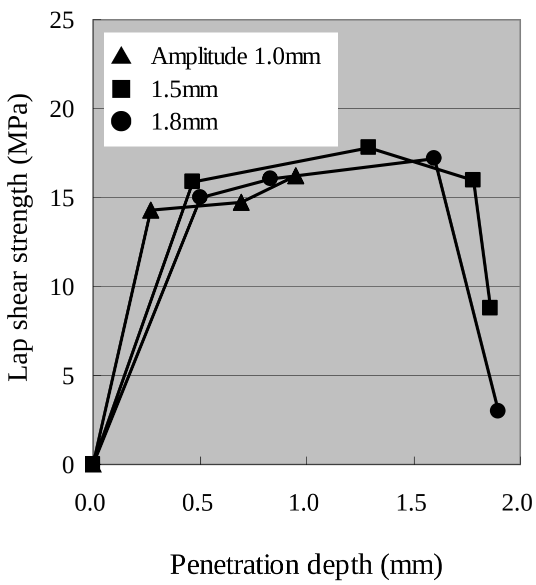

Fig.2. Effects of vibration amplitude and penetration depth on shear strength of modified PP random chop panel.

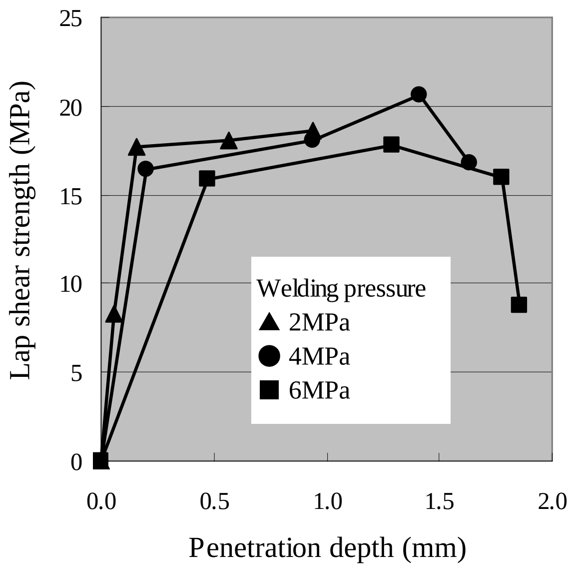

Fig.4. Effects of welding pressure and penetration depth on lap shear strength of modified PP random chop panel.

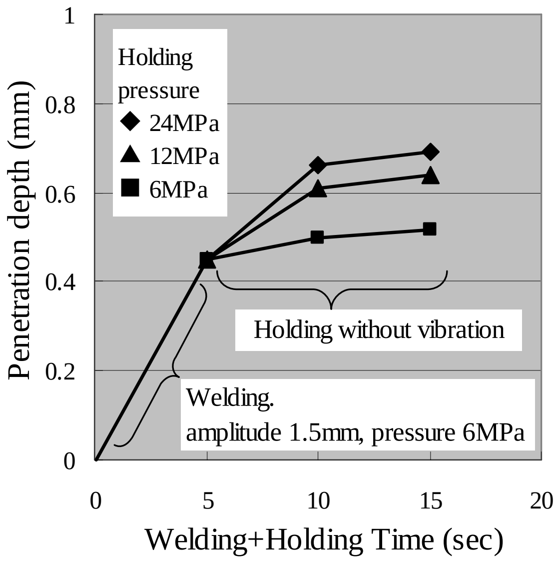

Fig.5. Effects of holding pressure and time on penetration depth of modified PP random chop panel.

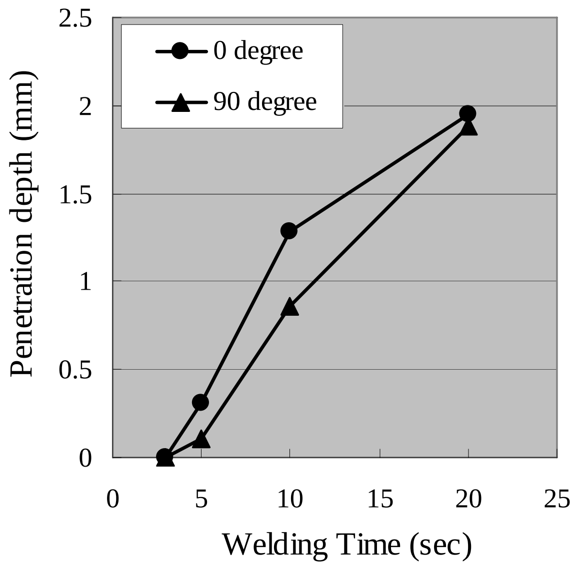

Fig.7. Effects of vibration direction and time on penetration depth of modified PP UD panel.

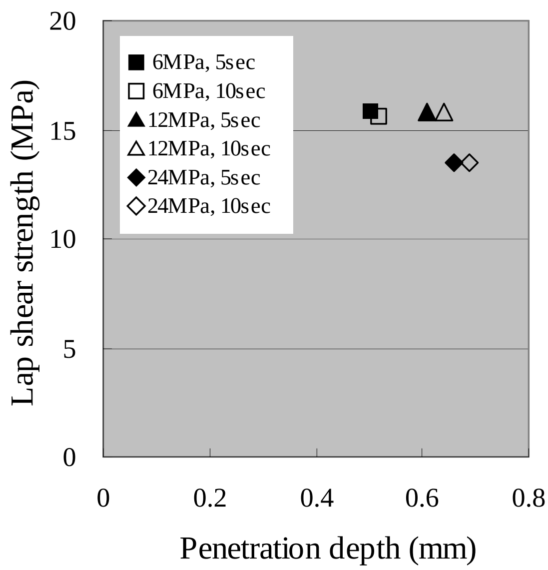

Fig.6. Effects of holding pressure and penetration depth on lap shear strength of modified PP random chop panel.

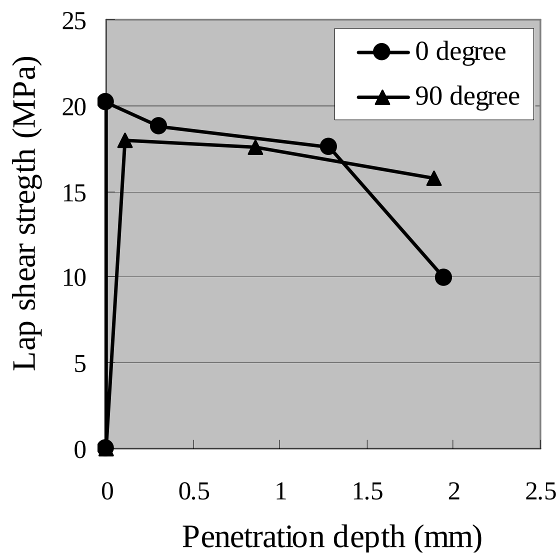

Fig.8. Effects of vibration direction and penetration depth on lap shear strength of modified PP UD panel.

Table 1. Effects of inserted modified-PP neat film on lap shear strength of random chop panel and UD panel.

	Penetration depth	No film	Film insert
Random	0.5mm	15.9MPa	15.3MPa
UD	0.3mm	18.8MPa	17.1MPa

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