AFI-2019
November 6-8, 2019, Sendai, Miyagi, Japan

CRF-44

Internal defect of plastic-fabricated Carbon Fiber Reinforced Thermo Plastics

Yuya Kodaira[1], Toshiyuki Takagi[2], Hiroyuki Miki[3], Hiroyuki Kosukegawa[2], Noboru Nakayama[4]
[1]Interdisciplinary Graduate School of Science and Technology, Shinshu University
4-17-1, Wakasato, Nagano-shi, Nagano, 380-8553, Japan
[2]Institute of Fluid Science, Tohoku University
2-1-1 Katahira, Aoba-ku, Sendai, 980-8577, Japan
[3]Frontier Research Institute for Interdisciplinary Science, Tohoku University
6-3, Aoba, Aramaki, 980-8577, Sendai, Japan
[4] Faculty of Engineering, Shinshu University
4-17-1, Wakasato, Nagano-shi, Nagano, 380-8553, Japan

ABSTRACT
In this study, the purpose was to clarify the mechanism of internal defects when joining a molten CFRTP plate and an aluminum piece. A piece of aluminum provided with a groove for inserting CFRTP is heated to an arbitrary temperature, and CFRTP is inserted and expanded. As a result, a force was generated to push the Al piece from the inside of the groove and a method was developed to obtain the joing strength. Nondestructive inspection was used to evaluate internal defects generated when CFRTP was thermally expanded.

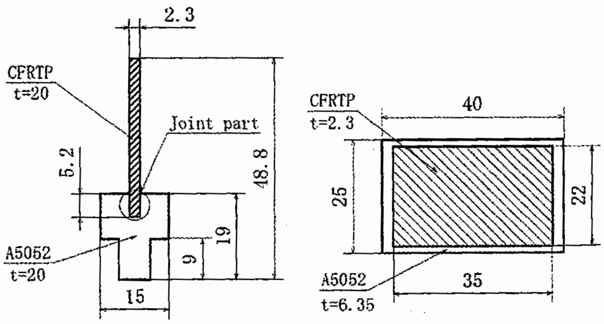
1. Introduction
Recently, weight reduction of transportation equipment is required to reduce CO_2 emissions [1]. Therefore, carbon fiber reinforced plastic (CFRP) having excellent specific strength and elastic modulus is now being adopted. Among them, thermoplastic CFRP (hereinafter referred to as CFRTP) having a short forming time has attracted attention, and dissimilar joining technology is required [2]. This techniques include mechanical joining [3] and adhesive joining [4], but in the case of mechanical joining, weight increase and stress concentration of the processed part, quality variation and hardening time are required for adhesive joining, etc., each having a problem there. Therefore, we developed a method to obtain the joining strength by heating the aluminum piece provided with the groove to an arbitrary temperature, inserting the CFRTP and expanding it to generate a force to push the Al piece from the inside of the groove [5].

In this study, the purpose was to clarify the mechanism of internal defects when joining a molten CFRTP plate and an aluminum piece. The nondestructive inspection was used to evaluate the internal defects generated when CFRTP was thermally expanded in the test pieces manufactured by the developed joining method.

2. Method
2.1 Test piece
As the CFRTP plate to be joined, a 2.3 mm thick 10-layer stampable sheet (Ichimura Sangyo Co., Ltd.) was used, in which 3K plain weave carbon fiber was impregnated with PA6 as a matrix resin. This was inserted into aluminum (A5052) heated for 5 minutes at 723 K and joined to produce a test piece shown in Fig. 1(a). As a comparison, a test piece manufactured by placing and joining a CFRTP plate of t = 2.3 to an A5052 plate of t = 6.35 heated at 723 K for 5 minutes is shown as Fig. 1 (b). These were observed using an ultrasound imaging system and an x-ray examination system. The direction of observation is the direction shown in Fig.2.

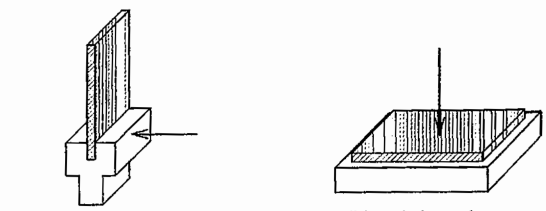
Corresponding author: Yuya Kodaira
E-mail address: y.kodaira@taiyo-ind.co.jp

2.2 Observation by ultrasonic imaging device
The possibility of ultrasound image observation of the interface between CFRTP and A5052 was investigated using an ultrasound imaging system. The ultrasound imaging system used is Hitachi Engineering & Services (FS200 II). Ultrasonic testing of joined plates was performed from the CFRTP side and the A5052 side respectively. The test was conducted with a 50 MHz probe.



(a) Joining test piece (b) Joining plates

Fig. 1 Dimension of test piece



(a) Joining test piece (b) Joining plates

Fig.2 Observation direction of test piece

2.3 Observation by X-ray inspection device
The possibility of x-ray observation of the joined interface between CFRTP and Al piece was examined using a transmission x-ray inspection system. X-ray examination apparatus used is DAGE Japan Ltd. (XD7600NTDiamond). The X-ray irradiation of the CFRTP-A5052 plate assembly was performed from the CFRTP side. The tube voltage of x-ray was set to 60 to 130 kV, and the tube power was set to 1.5 W.

3. Results and Discussion

3.1 Observation by ultrasonic imaging device

Fig. 3 shows a waveform image of the joining surface observed from the side of the joined test piece. The white distribution in the central part is considered as the unjointed void part. Fig. 4 shows the waveform observation of the entire joining surface from the CFRTP side. Although it can be observed with a 15 MHz probe, the entire waveform gate can only obtain an image of only the CFRTP matrix. When the interface is gated, it is affected by defects in the base material, but it is observable to some extent. From the A5052 side, it was possible to observe to some extent with a 50 MHz probe. Although it is observable to some extent by gating the junction interface, it is a sample that is difficult to observe because the CFRTP material as well as the aluminum material have defects. It is difficult to reliably detect a defect of about 0.1 mm from the extent of the current base material.

Fig. 3 Waveform image of the joining test piece

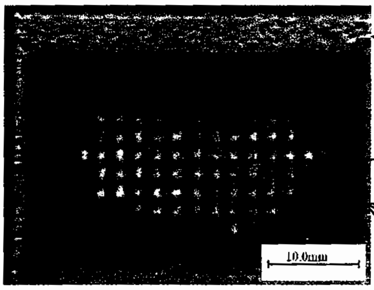


Fig. 4 Waveform image of the joining plates

3.2 Observation by X-ray inspection device

Fig. 5 shows the results of x-ray inspection of joined test piece. At the bottom of the groove of the Al piece, there is a part that looks light 2mm or so. Since the heat conduction is high, it is considered that the expansion is caused by the generation of voids and the movement of resin.

Fig. 6 shows the results of x-ray inspection of the joined plate. Since the measurement was made by transmitting x-rays, the tube voltage transmitting Al did not show differences in resin, carbon fiber, or voids, and appeared as a uniform distribution.

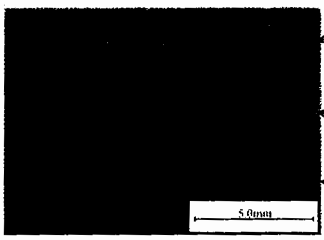


Fig. 5 X-ray examination image of the joining test piece

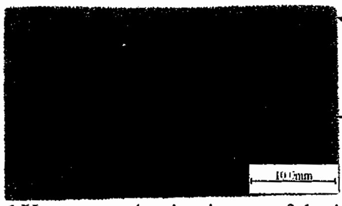


Fig. 6 X-ray examination image of the joining plates

Therefore, the joint plate was erected so that the interface between CFRTP and Al was at the center, and x-ray inspection was performed. The observed image is shown in Fig.7. White part appeared in CFRTP and Al interface. This is considered to be the void or part of the resin alone.

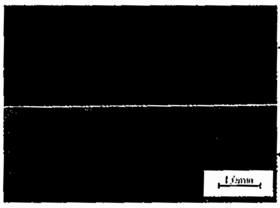


Fig.7 X-ray examination image of the joining plates (Horizontal direction with joining surface)

4. Concluding Remarks

In this study, the purpose was to clarify the mechanism of internal defects when joining a molten CFRTP plate and an Al piece. The nondestructive inspection was used to evaluate the internal defects generated when CFRTP was thermally expanded in the test pieces manufactured by the developed joining method. As a result, the following was found.

(1) In ultrasonic flaw detection, it can be confirmed by observation from the direction orthogonal to the joining surface, but it is difficult to confirm a slight gap of about 0.1 mm.

(2) In x-ray inspection, although it can be confirmed by observation from the joint surface and the horizontal direction, the difference between defects and resin rich hardly appears because resin transmittance is also high.

Although the observation of the joint piece was performed by two methods, it was found that the observation of the void of about 0.1 mm, which is a defect, was difficult by any method. In the future, how voids or defects can be clearly confirmed, to continue to explore.

Acknowledgments

This study has been supported by the collaborative Research Project of the Institute of Fluid Science, Tohoku University.

References

[1]T., Ishikawa, *J. Jpn. Soc. Precis. Eng.*, 81-6(2015), 489_493.
[2]K., Nakata, *J. Smart Process.*, 4-2(2015), 64_72.
[3]M., Ueda, et al., Comps. Struct., 94-11(2012), 3388_3393.
[4]Sato, C., *J. Jpn. Foundry Eng. Sci.*, 83-12(2011)738-742.
[5] Kodaira, Y., et al., *J. Jpn. Soc. Technol. Plas.*, 59-690(2018), 135-140.