Plastics Research Online
10.2417/spepro.006848

Forming process for carbon-fiber-reinforced thermoplastic sheets

Daichi Tatsuno, Takeshi Yoneyama, Kiichirou Kawamoto, and Masayuki Okamoto

A production process using a mechanical servo press shows promise for forming, trimming, and joining carbon-fiber-reinforced thermoplastic sheets for the fabrication of automobile parts.

Carbon-fiber-reinforced thermoplastic (CFRTP) is expected to prove useful for many applications in the future, particularly with regard to mass-produced automobile parts. CFRTP is attractive for short-time production for a number of reasons: it is deformable when in melt form; can be easily solidified by cooling; and is simply joined. Additionally, CFRTP that is reinforced with textile carbon-fiber fabric has high mechanical strength. Unlike conventional metal materials, however, processing technologies that use CFRTP have not been well developed. Making parts using this material therefore represents a challenge that currently hinders the widespread of use of CFRTP, particularly in relation to rapid production.

Many approaches have been developed with the aim of making parts using CFRTP.[1–3] Impregnating thermoplastic resin into the reinforcing textile is one such approach, but it requires excessive pressure, heat, and time (because molten thermoplastic has a high viscosity). In reactive processing, on the other hand, a monomer with low viscosity is impregnated into the reinforcing textile. Curing the resin takes time, however, thereby precluding the use of this technique for rapid production. In contrast to these approaches, press forming[4] represents a method that enables part formation over much shorter timescales.

We have been working on the development of a press-forming technique to obtain good quality parts using CFRTP for rapid production. We have also developed a method for trimming and joining CFRTP using a press machine.

Figure 1 illustrates the press-forming process that we have developed.[5] In this approach, the CFRTP sheets are heated, press-formed, and cooled under pressure in the die. We employed shear cutting, which is widely used in the trimming of sheet metal, as the trimming method. We also investigated the use of welding, in which heat and pressure are applied locally to a part, to make a closed section beam. To form, trim, and join the part, we used the mechanical servo press, which is now widely used in the field of metal forming. The use of a mechanical servo press for processing CFRTP therefore represents a significant step for the development of production technologies for CFRTP.

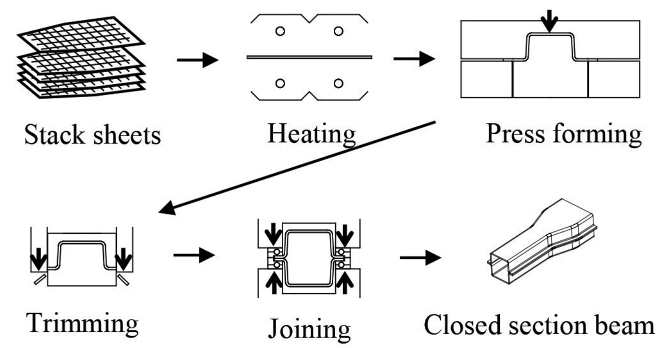

Figure 1. *The press-forming process that we have developed and demonstrated for the formation of a variant cross-section beam.*

Figure 2(a) shows a variant cross-section beam after press forming. To fabricate this part, we heated the CFRTP sheets to 280°C, press-formed them, and then cooled them under 10MPa for 30 seconds using a room-temperature die. We used an 0.2mm-thick CFRTP sheet that consisted of plain-woven carbon fiber fabric (with a tow size of 3K) impregnated with nylon 6 (PA6). We stacked 15 of these sheets before heating and consolidated them as part of the press-forming process, allowing us to effectively skip a step in the preparation of a consolidated CFRTP sheet. Furthermore, because each layer is separated when a quasi-isotropic laminate is formed, there is less interaction between the adjacent layers and wrinkles are thus reduced. Our microscopic observation of the inner structure, and the three-point bending test on the

Continued on next page

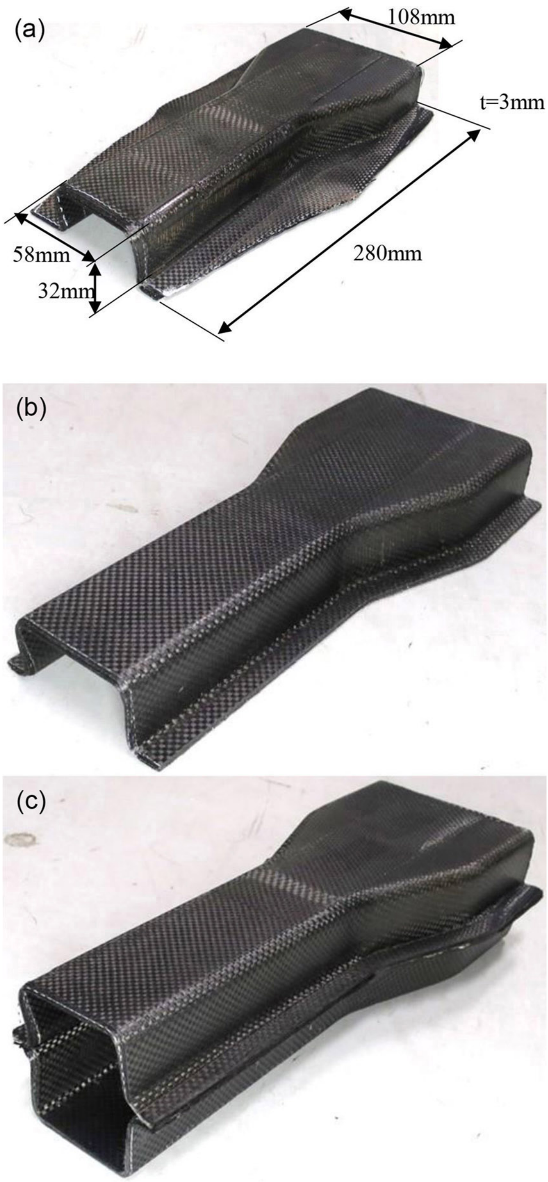

Figure 2. *(a) A variant cross-section beam after (a) press forming and (b) trimming (by shear cutting). (c) A closed cross-section beam joined by welding. t: Thickness.*

specimen cut from the beam, revealed that the variant cross-section beam is without voids and has a bending strength of more than 600MPa.

We successfully employed shear cutting to trim the CFRTP part: see Figure 2(b). Furthermore, we completed the trimming in only a few seconds, with a cutting speed of 26mm/s and a clearance between the cutting blades of 0.1mm. This result confirms that our approach shows promise for rapid production. Figure 2(c) shows the closed-section beam after two variant cross-section beams have been joined. To achieve this, we heated, pressed, and cooled the flange part under 5MPa by using heating plates. Our microscopic observations of the inner structure at the joined region of the part showed the joined interface to be well welded.

In summary, we have demonstrated our simple and quick process for forming, trimming, and joining CFRTP sheets using a mechanical servo press. This process shows promise for the production of parts using CFRTP sheets. In our future work, we will investigate the effect of the die temperature on the mechanical strength of the parts after press forming.

The authors gratefully acknowledge support from A-STEP of the Japan Science and Technology Agency.

Author Information

Daichi Tatsuno and Takeshi Yoneyama
Kanazawa University
Kanazawa, Japan

Kiichirou Kawamoto and Masayuki Okamoto
Komatsu Industries Corp.
Kanazawa, Japan

References

1. K. Friedrich and A. A. Almajid, *Manufacturing aspects of advanced polymer composites for automotive applications*, **Appl. Compos. Mater. 20**, pp. 107–128, 2013.
2. K. van Rijswijk and H. E. N. Bersee, *Reactive processing of textile fiber-reinforced thermoplastic composites—an overview*, **Compos. Part A: Appl. Sci. Manufact. 38**, pp. 666–681, 2007.
3. C. Hopmann, M. Hildebrandt, R. Bouffier, and K. Fischer, *Inline-impregnation—individualized production of thermoplastic continuous fiber reinforced composite parts*, **Proc. SAMPE**, 2015.
4. J. Chen, J. A. Sherwood, P. Buso, S. Chow, and D. Lussier, *Stamping of continuous fiber thermoplastic composites*, **Polym. Compos. 21**, pp. 539–547, 2000.
5. D. Tatsuno, T. Yoneyama, K. Kawamoto, and M. Okamoto, *Production system to form, cut, and join by using a press machine for continuous carbon fiber-reinforced thermoplastic sheets*, **Polym. Compos.** in press, doi:10.1002/pc.24242