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Dieless Forming Using 3D Printer Of Carbon Fibre Reinforced Plastic Parts

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Abstract

Dieless forming process using a 3D printer of carbon fibre reinforced plastic parts has developed to produce three-dimensional mechanical parts. Specimens for static and fatigue tests were manufactured by sandwiching the carbon fibres between upper and lower plastic plates made by 3D printing and by heating the sandwiched plates. The fatigue and static strengths were increased by thermal bonding of the plastic plates and carbon fibres. In addition, the strengths were heightened by including the carbon fibres in molten plastic.

Keywords: 3D printer; CFRP; Dieless forming

1. Introduction

The price of 3D printers drastically decreases due to the development of the fused deposition modelling process using plastics, and the application of 3D printers is expanding remarkably. With 3D printers, mechanical parts are manufactured by laying down successive layers of molten plastic without dies (Kumar, 2010). However, the strength of the mechanical plastic parts is not equivalent to conventionally manufactured ones. It is desirable to increase the strength of parts manufactured by the 3D printers. The use of carbon fibre reinforced plastics increases in aircraft and automobiles industries. Yanagimoto et al. (2012) developed a forming process of carbon fibre reinforced plastics.

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Most of carbon fibre reinforced plastics have comparatively simple shapes such as plates and curved shells, and it is not easy to manufacture three- dimensional mechanical parts. A 3D printing process of carbon fibre reinforced plastics enables a flexible manufacturing system, and the strength of mechanical parts is increased by inclusion of carbon fibres. In the present study, a dieless forming process of carbon fibre reinforced plastic parts using a 3D printer was developed to manufacture three-dimensional mechanical parts. The static and fatigue strengths of tensile and bending specimens made of carbon fibre reinforced plastic manufactured by 3D printing were measured.

2. Dieless Forming Process Using 3D Printer Of Carbon Fibre Reinforced Plastic

Tensile specimens made of carbon fibre reinforced plastic were manufactured by 3D printing, and the static and fatigue strengths of the specimens were measured. Carbon fibres are sandwiched by lower and upper plastic plates made by 3D printing using the fused deposition modelling process as shown in Fig. 1. First the lower plate is manufactured by 3D printing, then the carbon fibres are put on the lower plate, and finally the upper plate are made on the lower plate. The manufactured specimen is kept in a drying oven for 15 min. to bond the carbon fibres with the upper and lower plates.

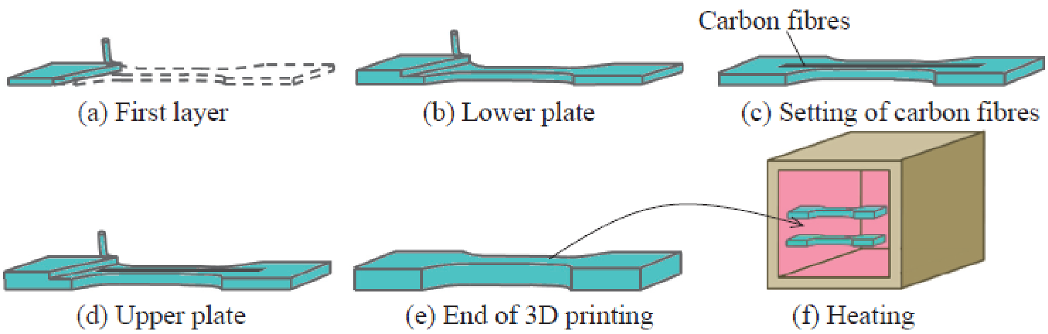

Fig. 1. 3D printing process of tensile specimens made of carbon fibre reinforced plastic.

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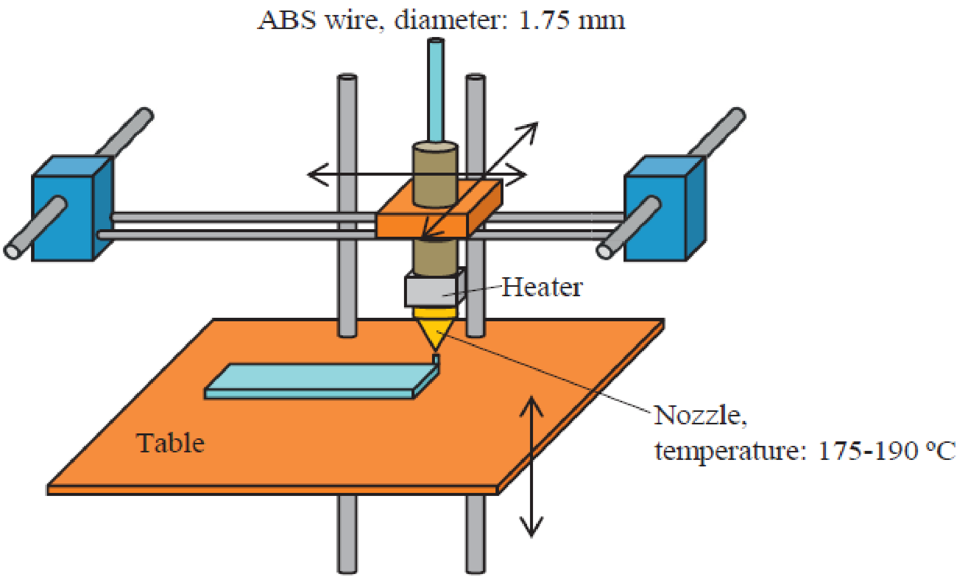

Fig. 2. 3D printer for manufacturing tensile specimens made of carbon fibre reinforced plastic.

The 3D printer for manufacturing carbon fibre reinforced plastic specimens is illustrated in Fig. 2. Molten plastic was extruded from the nozzle having 0.9 mm in tip diameter, and successive plastic layers were laid down. An ABS wire having 1.75 mm in diameter was melted for the extrusion. The temperature of the nozzle was between 175 and 190 oC. The nozzle speeds of the periphery and inside of the plate were 30 and 50 mm/s, respectively, and the speeds for the first layer were slowed down to 80% to stabilise the deposition. The height of one deposited layer was about 1.3 mm because of swell of molten plastic extruded from the nozzle. The diameter, density and tensile strength of the carbon fibre were 6 Pm, 1.82 g/cm 3 and 5.3GPa, respectively, and bundled 9,000 and 18,000 fibres having 70 mm in length were sandwiched for static and fatigue specimens, respectively. The volume percentages of the carbon fibres in the parallel sections of the static and fatigue specimens were 1.4% and 1.6%, respectively. The static and fatigue specimens manufactured by 3D printing are shown in Fig. 3. The surface of the specimens is wavy due to the deposition of extruded plastic wires. The numbers of layers of the lower and upper plates are 2, respectively. The static and fatigue specimens are different, respectively.

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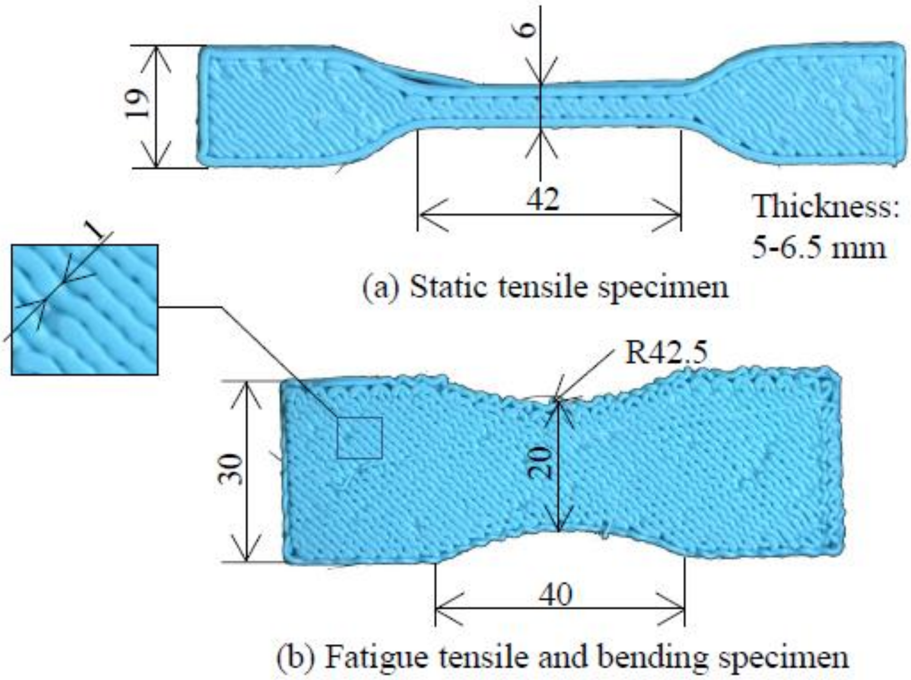

Fig. 3. Static and fatigue specimens manufactured by 3D printing.

3. Results Of Static And Fatigue Tests

The force-stroke curve measured from the static tensile test of the specimen manufactured by 3D printing is illustrated in Fig. 4. Even if the carbon fibres are included in the specimen, the strength without thermal bonding with the plastic is not high. The strength is increased to almost double by thermal bonding.

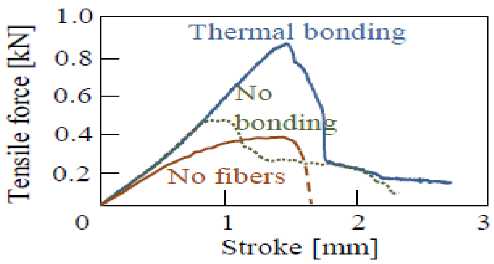

Fig. 4. Force-stroke curve measured from static tensile test of specimen manufactured by 3D printing.

The ruptured tensile specimens without and with thermal heating are given in Fig. 5. Without thermal bonding, the carbon fibres were slipped from the plastic, and thus the strength did not increase. The sufficient bond between the carbon fibres and plastic is important for the increase in

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strength

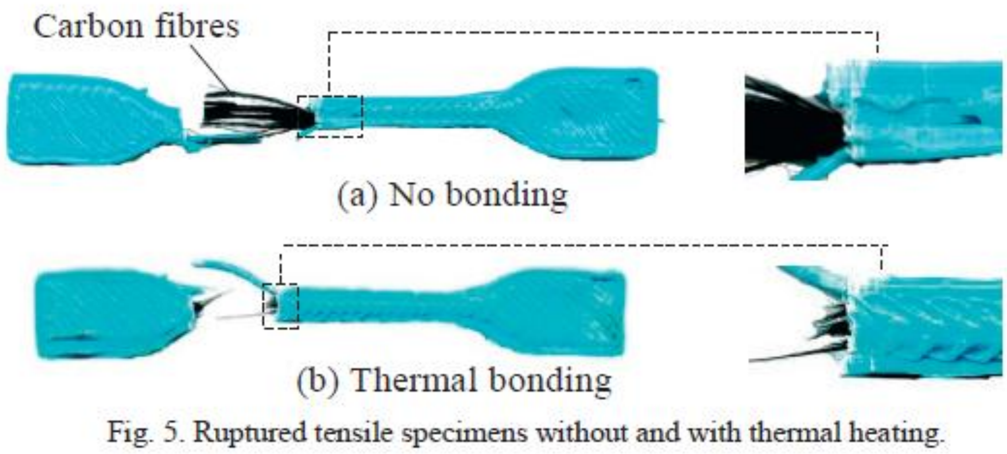

Fig. 5. Ruptured tensile specimens without and with thermal heating.

The strengths measured from the fatigue tensile and bending tests are illustrated in Fig. 6. The fatigue strength of the carbon fibre reinforced plastic is higher than that without the fibres as well as the static tensile strength shown in Fig. 4.

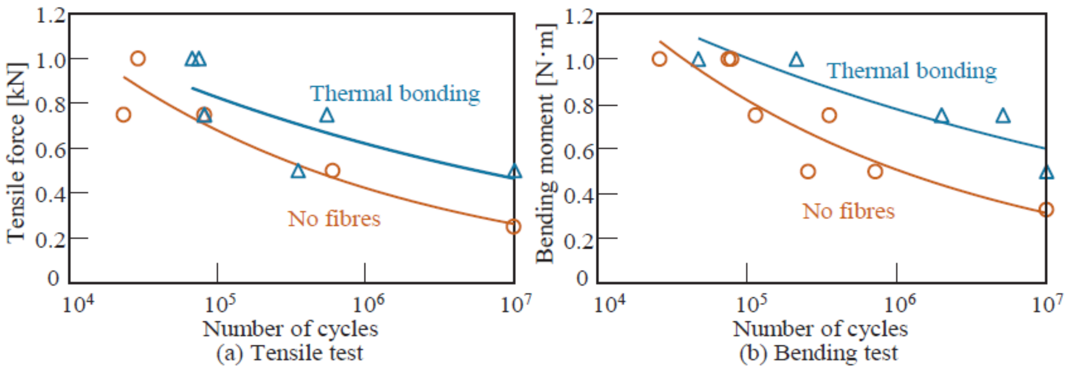

Fig. 6. Strengths measured from the fatigue tensile and bending tests.

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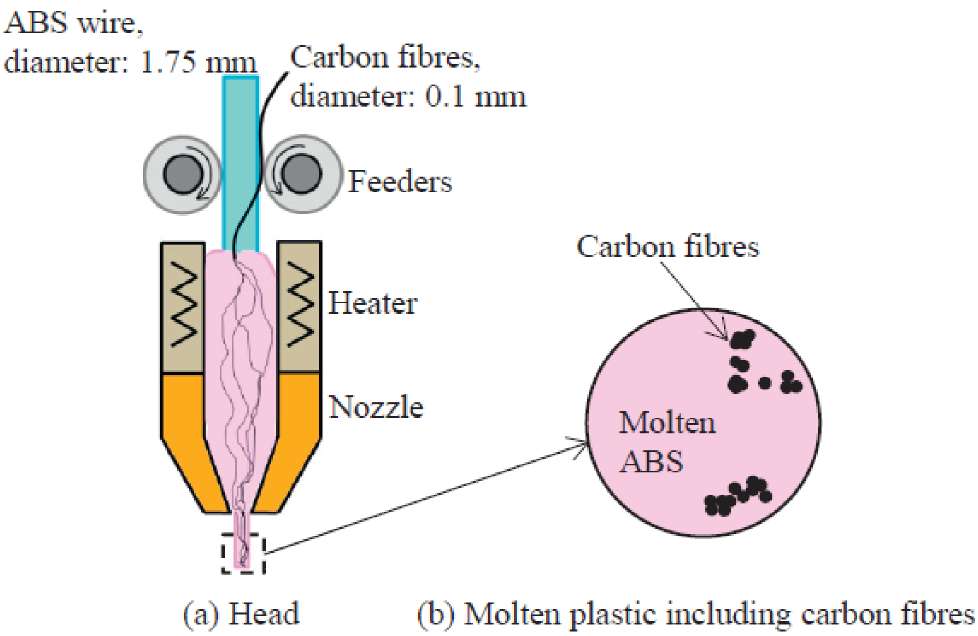

Fig. 7. Inclusion of carbon fibre in molten plastic.

4. Inclusion Of Carbon Fibres In Plastic Wire

To increase the strength of the specimen, the carbon fibres were included in the molten plastic as shown in Fig. 7. The bundled 280 carbon fibres were inserted with the ABS wire in the entry of the nozzle, and the fibres were bonded with the plastic by heating during passing through the nozzle. The second layer of the lower plate and the first layer of the upper plate include the fibres. The volume of the additional carbon fibres included in molten plastic in the parallel section of the specimen was 0.2%. The extruded ABS wire including the carbon fibres without disposition is shown in Fig. 8. The carbon fibres are scattered during extrusion and are successfully included in the wire.

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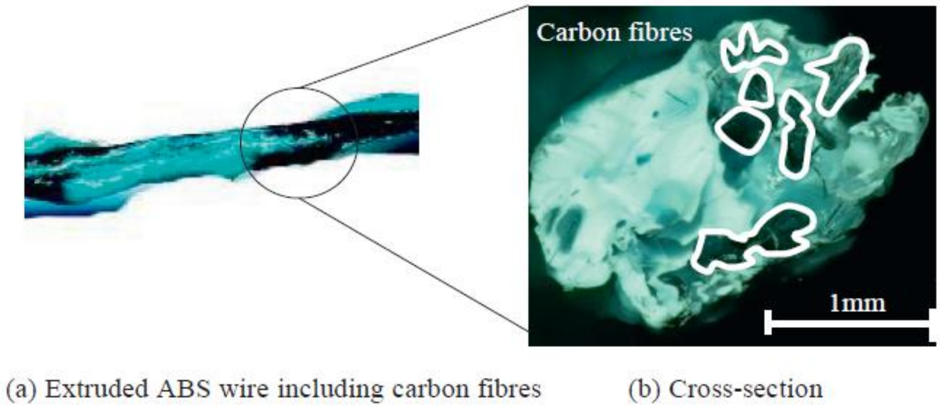

Fig. 8. Extruded ABS wire including carbon fibres without disposition.

The static specimen manufactured by 3D printing of the extruded ABS wire including the carbon fibres is shown in Fig. 9. In this specimen, the orientation of carbon fibres in the extruded wire is 45o with respect to the force direction and influences the strength of the product.

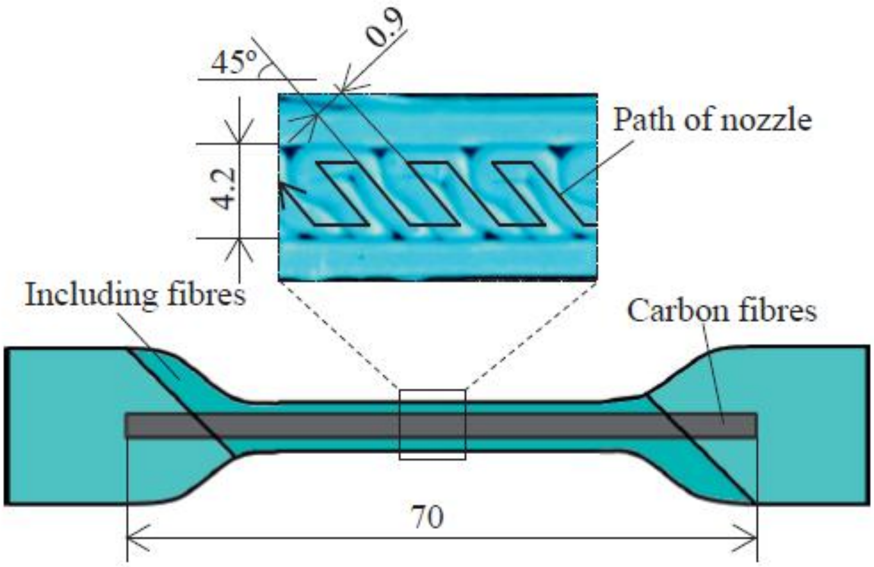

Fig. 9. Specimen of static tensile test manufactured by 3D printing of extruded ABS wire including carbon fibres.

The force-stroke curve measured from the static tensile test of the specimen made of the extruded ABS wire including the carbon fibres is shown in Fig. 10. By including the carbon fibres in the extruded ABS wire, not only the force but also the final elongation increases due to the prevention of occurrence of local necking.

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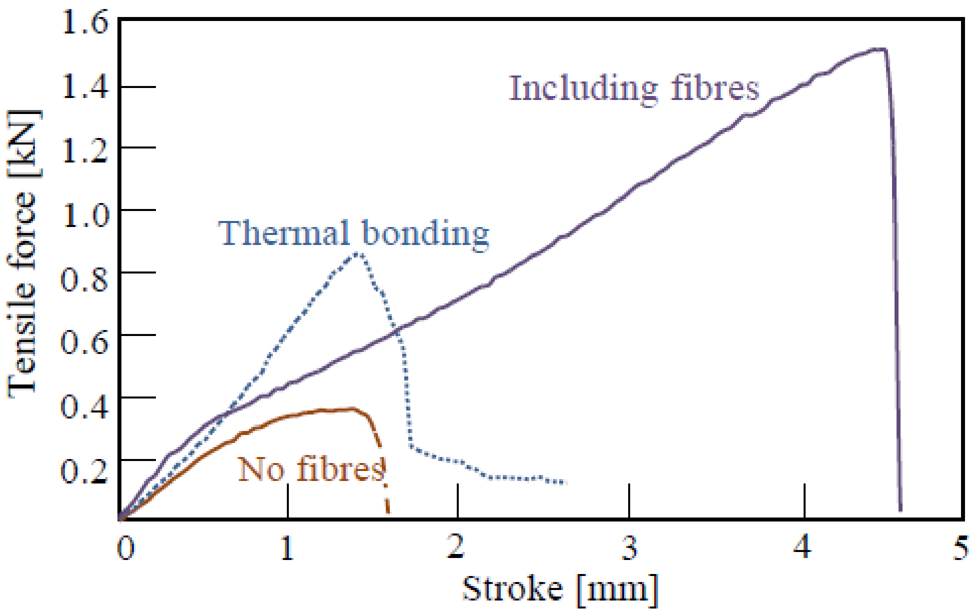

Fig. 10. Force-stroke curve measured from static tensile test of specimen made of the extruded ABS wire including the carbon fibres.

The ruptured static tensile specimens without and with including the carbon fibres in the the extruded ABS wire are given in Fig. 11. Although the specimen without including was ruptured by the occurrence of the 1st crack, the 1st crack was stopped by the carbon fibres in the extruded ABS wire and the specimen with including was ruptured by the occurrence of the 2nd crack. It was found that the circumstances of inclusion of the carbon fibres have a great influence on the strength of products.

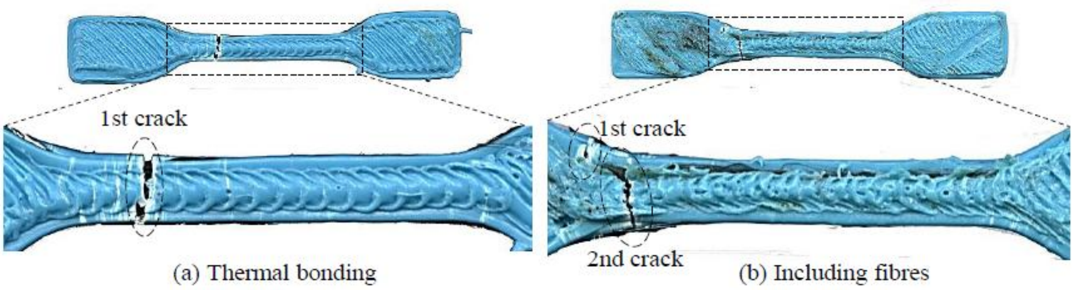

Fig. 11. Ruptured static tensile specimens without and with including carbon fibres in extruded ABS wire.

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5. Conclusions

The application of 3D printers increasingly expands as a small-lot production process. The inclusion of carbon fibres in the plastic is attractive in increasing the strength of products. It is desirable to develop approaches for increasing the amount of carbon fibres and the bonding force between the carbon fibres and plastic and for controlling the orientation of carbon fibres.

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