# Mechanical properties of direct composite 3D printing on metal plate for multi-material applications

Ryunosuke OTSUKI [1], Takuma TAKEMURA [1], Ryosuke MATSUZAKI [1]
*1 : Department of Mechanical Engineering, Tokyo University of Science, Yamazaki 2641, Noda-shi, Chiba, 278-8510 Japan*

## Introduction

The development of carbon fiber reinforced plastic (CFRP) materials has led to the use of multi-materials in transportation equipment such as automobiles and aircraft to reduce weight. Compared to metals, CFRP has superior specific strength and specific rigidity, but due to its low interlaminar strength, delamination is easily caused by external impact. Therefore, CFRP is used for the parts with relatively little impact damage in lightweight and high-grade automobiles, while metal is used for the parts where impact and wear occur, such as joints between different parts[1]. Thus, when aiming for weight reduction while meeting strength standards, multi-materialization of metal and CFRP is effective.

However, improving the interfacial strength of the joint surface is an issue in the multi-materialization of CFRP and metal. To solve this problem, we focused on 3D printing technology. 3D printing technology has the advantage of being excellent for complex three-dimensional modeling. Therefore, it is expected to be possible to print carbon fiber reinforced thermoplastics (CFRTP) filaments[2][3] that are optimal for various metal joint shapes.

Based on the above research background, this study proposes a method of 3D printing filaments of metal impregnated with continuous carbon fibers directly by fused deposition modeling (FDM) method to create multi-materials of CFRP and metal. In addition, continuous carbon fiber filaments are 3D printed directly on metals with various surface geometries to evaluate the interface strength between CFRP and metal.

## 3D printing of CFRTP on metal plate

*Fabrication of a 3D printer for CFRTP and CF/metal test specimen preparation*

The 3D printer used in this study is a 3D printer for resin using the FDM method. The resin filament has a diameter of 1.75 mm, while the continuous carbon fiber filament used in this study has a diameter of 0.36 mm. Therefore, the roller and nozzle were changed so that continuous carbon fiber filaments could be sent out. An auto-leveling sensor (Fig. 1) was installed to detect the thickness of the metal and print a continuous carbon fiber filament.

In this study, aluminum alloy (A2017) is used as metal, and continuous carbon fiber filament impregnated with resin (PA6) is made by Markforged. Continuous carbon fiber filaments are 3D printed and bonded directly to aluminum alloy (A2017) (Fig. 1).

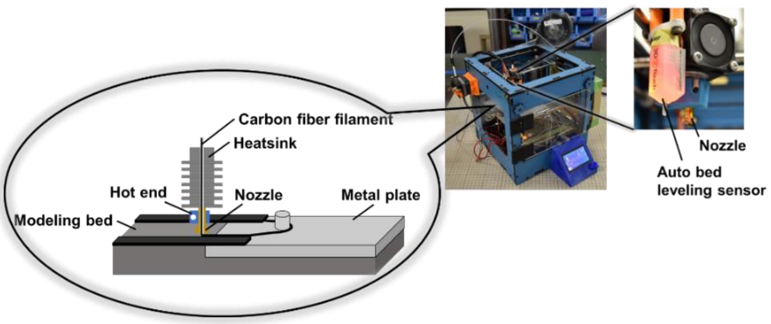


*Fig.1 FDM 3D printer for printing carbon fiber filament and*

*3D printing of carbon fiber filament on a metal plate.*

*Study on the improvement of joint strength by installing pins*

The strength of the filament was improved by placing a pin on the metal plate and hooking the filament to the pin. A screw with a diameter of 5 mm was placed on a metal plate to serve as a pin. The print path was devised so that the parts around the nozzle would not hit the pins and the filament would be caught on the pins without any gaps (Fig. 2).

A tensile test was performed using a specimen with a pin and a test piece without a pin. Although there was not much difference in strength, the specimen with a pin has higher energy because the continuous carbon fiber filament is caught on the pin (Fig. 3).

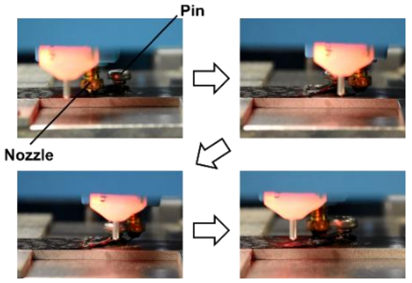


*Fig. 2 Print path adapted to the specimen with pin.*

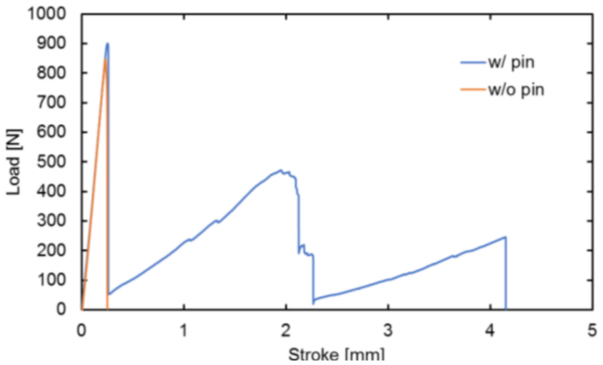


*Fig. 3 Strength comparison between 3D printed CF/metal specimen w/ and w/o pin.*

## Conclusions

We modified a 3D printer for resin to print continuous carbon fiber filaments. We were able to create a print path for the metal plate with the pin and fabricate CF/metal specimen using a modified 3D printer. However, there was not much difference in strength between a specimen with a pin and a test piece without a pin.

## References

[1] Z. Wang, C. Lauter, B. Sanitther, A. Camberg, T. Troester, Manufacturing and investigation of steel-CFRP hybrid pillar structures for automotive applications by intrinsic resin transfer moulding technology, Int. J. Automot. Compos. 2 (2016) 229–243.

[2] Y. Hoshikawa, K. Shirasu, J. Tsuyuki, T. Okabe, R. Higuchi, K. Yamamoto, Y. Hirata, Experimental and Numerical Evaluation of Open Hole Tensile Properties of 3D Printed Continuous Carbon Fiber Reinforced Thermoplastics, (n.d.).

[3] J. Jiao, S. Jia, Z. Xu, Y. Ye, L. Sheng, W. Zhang, Laser direct joining of CFRTP and aluminium alloy with a hybrid surface pre-treating method, Compos. Part B Eng. 173 (2019)