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Experimental study on composite 3D printing process with pam 3D print

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Abstract

Recently, a paradigm shift towards high efficiency and high performance is taking place due to policies and regulations such as improving fuel efficiency and reducing carbon emissions in automotive, aerospace, and shipbuilding industry. Among them, a method of manufacturing parts by mixing a composite material with an existing base material by applying a 3D printer capable of realizing a complex shape is attracting attention. However, there are many difficulties in selecting process conditions in consideration of material characteristics when laminating composite materials, and problems such as deterioration of the laminated material quality occur. Therefore, it is necessary to develop various process technologies to solve such problems. In this study, a composite material additive manufacturing process monitoring study is conducted using PAM (Pellet Additive Manufacturing) dedicated to composite materials. To monitor the additive manufacturing process, a current sensor, IR camera, and vision are installed to establish a monitoring system. Based on the sensor data, the correlation between the quality of the laminated material and the process conditions is analyzed. As a result, the correlation between monitoring factors affecting material quality is identified, and additional process research and optimization can be performed on this in the future.

Keywords: PAM 3D printer, Process Monitoring, Current Sensor, IR Camera

1. Introduction

The additive manufacturing is rapidly emerging as it is applied to various industries. Recently, the paradigm is changing to high efficiency and high performance in industries such as automobiles, aerospace, and shipbuilding due to government policies and regulations such as improvement of fuel efficiency and reduction of carbon emission. Among them, the method for a part manufacturing by mixing composite materials with existing materials by applying 3D printers capable of realizing complex shapes is attracting attention[1-4].

However, it is difficult to select appropriate process conditions when laminating composite materials, which causes problems such as void in the material and deterioration of surface quality. Therefore, in order to solve these problems, it is necessary to develop various process technologies [5].

In this study, additive manufacturing process monitoring research was conducted by using a PAM (Pellet Additive Manufacturing) dedicated to composite materials. In order to do experiments, various sensors such as an IR camera, vision, acceleration sensor, etc. were installed. And then, the experiment was designed and conducted at three levels for each stacking temperature and extrusion amount variable.

2. Experimental Setup

The experimental setup and monitoring system used in the study are illustrated in Figure 1. The monitoring system consisted of an IR camera (A325sc, FLIR), vision (acA3088-16gm, Basler), and acceleration sensor (607A61, IMI). Various process conditions were considered in the experiment, with the two most important factors in the screw-based lamination method, i.e., melting system temperature and screw motor speed, selected for investigation. These two factors were chosen as they were found to have a significant impact on the lamination quality through preliminary experiments. The experiment was designed with three levels of melting system temperature (230, 240, 250 °C) and screw motor speed (130, 140, 150 rev/min). For more information on the experimental conditions, refer to Table 1.

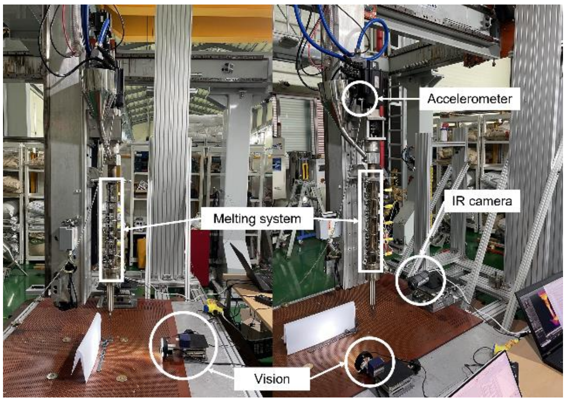


Figure 1. Experimental setup

Table 1 Experimental condition

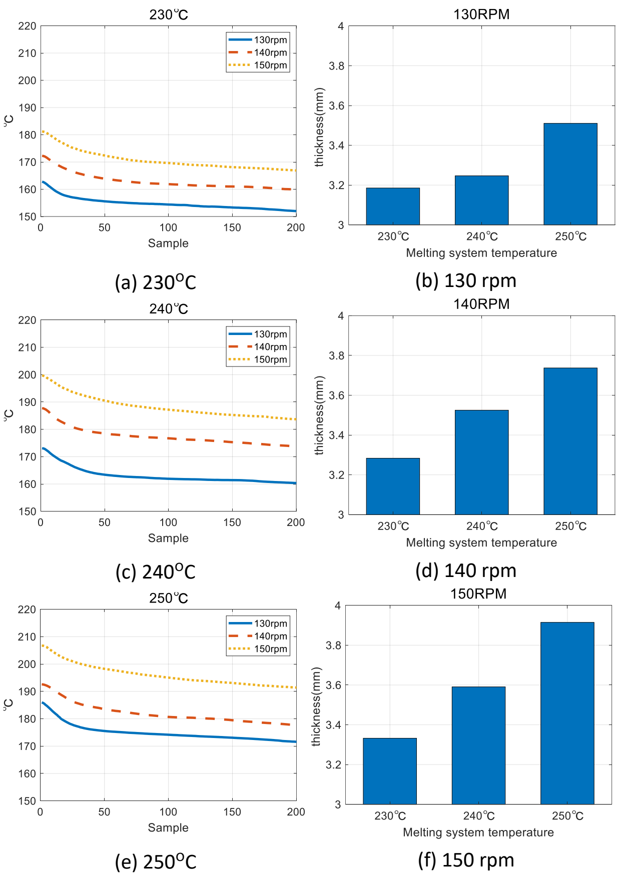
Material	ABS + sCFRP 20 % (Sabic)
Nozzle diameter	6 mm
Extrusion head capacity	50 kg/h
Extrusion head speed	2000 mm/min

Melting system temperature	230, 240, 250 C°
Screw motor speed	130, 140, 150 rev/min
Layer height	3 mm
Layer width	7 mm

3. Experimental Results

To analyze the stacking conditions and AM process monitoring signals, the researchers studied the stacking cross-section, IR camera, and vision data. The IR camera was used to monitor the temperature during extrusion, and the vision system was used to measure the stack height. For temperature, the temperature measured by the vision system during lamination was extracted as time-temperature data. The vision system also measured the height of one layer five times during printing and provided the average height.

Fig.2(a,c,e) are the thermal imaging camera results, and Fig.2(b,d,f) are the vision data extraction results. As a result, it was confirmed that the lamination temperature increased when the screw motor speed increased, and the extrusion amount increased when the lamination temperature increased. It was confirmed that the extrusion amount increased by about 4 to 11% at the same printing temperature. Also, when the amount of extrusion increases at the same melting temperature, it was confirmed that the printing temperature increased by about 11 to 14%.



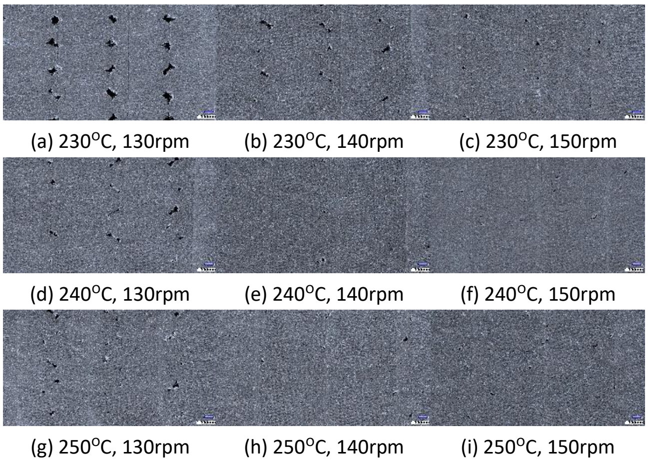
(a) 230°C (b) 130 rpm

(c) 240°C (d) 140 rpm

(e) 250°C (f) 150 rpm

Figure 2. Extracting data from an IR camera and Vision

The cross-section of the laminate was measured using a microscope (VHX-7000, KEYENCE). As a result of measuring the void width of the material, the maximum void area was 8.6mm^2 and the minimum void area was 0.59mm^2 at a melting temperature of 230C° and a screw motor speed of 130rev/mm. The cross-section measurement results according to each stacking condition can be seen in Fig.3.



(a) 230°C, 130rpm (b) 230°C, 140rpm (c) 230°C, 150rpm

(d) 240°C, 130rpm (e) 240°C, 140rpm (f) 240°C, 150rpm

(g) 250°C, 130rpm (h) 250°C, 140rpm (i) 250°C, 150rpm

Figure 3. The cross-section measured results using the microscope

4. Conclusion and further research

In this paper, two main factors affecting the quality of the PAM printing process were tested. The results can be seen in two ways. First, the monitoring data analysis confirmed a linear relationship between the printing temperature and the motor speed, as the heat accumulation of the material increased with the extrusion amount. Second, the measurement of the stacking cross-section showed a decrease in voids with an increase in stacking temperature, likely due to the material's viscosity at different temperatures. In the near future, the difference in material viscosity inside the screw will be analyzed based on the current signal of the screw motor. This analysis will enable the optimization of stack quality.

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