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Speed Controlled Composite Fabrication Using DC Motor

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Abstract

Fabrication process determines the composite quality. Conventional method such as dry- and hand lay-up are commonly used. Dry lay-up method has known to be more controllable and produce less defect composites with good mechanical property. However, this method is more expensive. On the other hand, hand lay-up which is more simple and less expensive, is uncontrollable as well as produces more defect and poorer mechanical properties of composites. In this study, we create instrument which can control wet lay-up fabrication process of Fiber Reinforced Composite Material (FRCM). Instead of using uncontrollable human hands, this instrument utilizes speed controllable paint roller which distributes the resin though all matrices. The result shows that the produced composites have more homogenous resin distribution, smaller size defects, and exhibits stronger mechanical properties compare to the one produced by hand lay-up method. This study is expected to open further innovations on low-cost composite fabrication.

Keywords: Composite; controllable wet lay up; resin distribution; mechanical properties

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1. Introduction

Composite is a material which consists of matrix and its reinforcement combining macroscopically [1,2]. Fiber Reinforced Composite Material (FRCM) is composite which the matrix is made from a fiber while the reinforcement is usually made from resin [3]. Due to its elasticity, mechanical strength, light weight, and anti-corrosive properties, this type of composite has been applied widely in automotive industries, plane industries, and sport equipment [2]. The FRCM has been also widely applied in civil infrastructure and reported to perform outstanding durability, sustainability, and cost effective [4]. Besides, the FRCM can replace the conventional materials which have lack of flexibilities [5]. Various types of fibers determine the FRCM properties and their application in infrastructure [6]. Furthermore, the FRC is also a good candidate to replace the anterior or posterior teeth [7]

In addition to the raw material quality, the fabrication process is also crucial in determining the quality of FRCM [8]. The non-homogenous resin distribution is suspected to affect the mechanical properties [9]. Conventionally, dry lay-up method which the prepreg material is manufactured in high cost and controllable factory, gives high quality composites [10]. In this method, the curing time and temperature are the crucial factor determining the mechanical properties. Another low-cost fabrication approach is the hand lay-up which the resin is coated on the fiber manually using the human hand. However, it produces lower quality FRCM with large size defects or higher porosity [11]. The mechanical properties of wet layup fabricated composite is reported to be dependent to the number of plies and be strongly affected by environment induced hygrothermal aging [12]. A resin transfer molding controllable wet lay-up was reported to have better mechanical properties [13].

In this study we create a simple instrument to control resin distribution in FRCM. Instead of using human hands, the instrument utilizes the roller paint which the speed of resin distribution through all matrix is controlled by microcontroller Arduino Uno ATMega328. It is found that the instrument produced composite with larger tensile strength compared to the ones fabricated using dry- and wet layup. Furthermore, the slow speed fabrication created larger tensile strength and %elongation.

2. Experimental Method

To achieve our goal, we designed a speed-controlled instrument for resin lamination on fiber glass material. The schematic diagram of the instrument is presented in Fig. 1

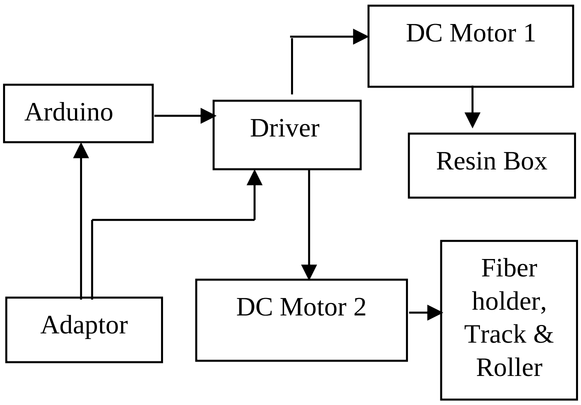
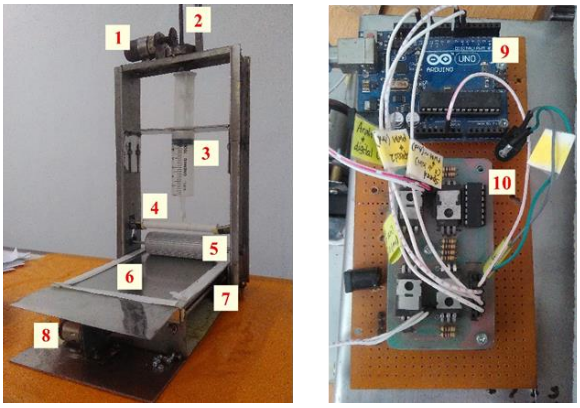


Fig. 1. Schematic diagram of the instrument.

The schematic diagram of the instrument is shown in Fig. 1. It mainly consists of resin box, fiber holder, track, paddle roller, H-bridge dc motor, driver, microcontroller Arduino, and adaptor. The implementation of the instrument is shown in Fig. 2. It consists of resin box (1), rotating bar to move the resin injection up and down (2), resin injection tube with 100 ml volume (3), a connector tube to flow the resin from injection tube to roller (4), roller (5), fiber holder (6), roller track (7), 12V DC motor with 5.2 kg/cm torsion to control roller movement (8), Arduino uno (9), dan motor driver (10). The mechanics parts were made using iron and aluminum. Resin box used 100 ml commercial injection tube. Here we used 12 V H-bridge dc motor and Arduino Uno Atmega 328 which the specification is shown in Table 1.



(a) (b)

Figure 2. The instruments (a) the mechanical and (b) the electronic parts.

Table 1 Arduino Uno Specification

Microcontroller	Atmega328
Operating Voltage	5V
Input Voltage (recommended)	7-23V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40Ma
DC Current for 3.3 V Pin	50Ma
Flash Memory	32 KB (Atmega328) of which 0.5 KB used by bootloader
SRAM	2 KB (Atmega328)
EEPROM	1 KB (Atmega328)

This instrument is mean to laminate homogenously the mixture of resin epoxy and its hardener to the fiber glass sheet. The ratio between resin and its hardener was 100:38 %weight. In this experiment, 100 ml resin hardener mixture was placed in resin box. A 12 V DC motor with 10.86 kg/cm torsion was used to control the resin flow to roller. A 21 cm fiber glass sheet was placed in fiber holder. The lamination process was conducted by moving the roller back and forth up to 10 plies. A 20 ml resin hardener mixture was laminated for each ply. The mechanical properties of the composites were subsequently tested using ASTM Standard D 638-02 Standart Test Method for Tensile Properties of Polimer Matrix Composite Material [14].

3. Result and Discussion

The resin flow (Q) and the roller speed (V) are controlled by tuning the dc motor pulse width modulation (PWM). The resin flow was found to be linear with PWM as displayed in Fig. 3. (a). The relation between speed and PWM is shown in Fig. 3 (b). In general, the speed is linear with the PWM.

However, there is slightly different speed of 0.4 cm/s between forward and backward movement as a consequence of the track belt system which requires different force to push and pull the roller. Hence, we set different PWM to obtain the same forward and backward speed

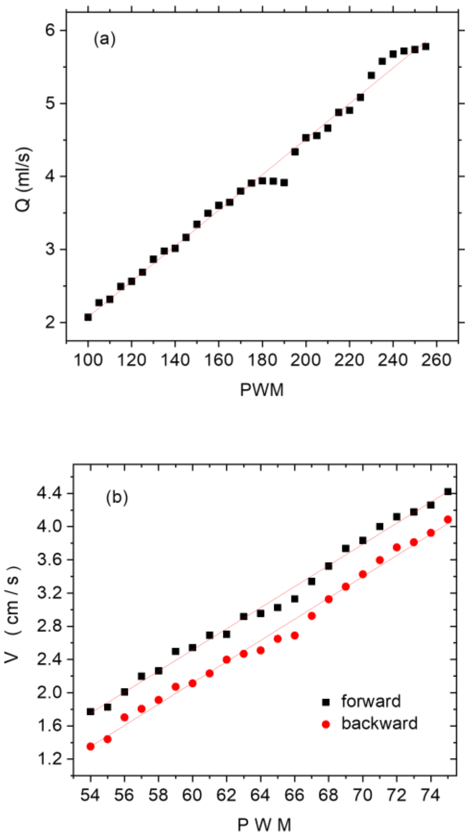
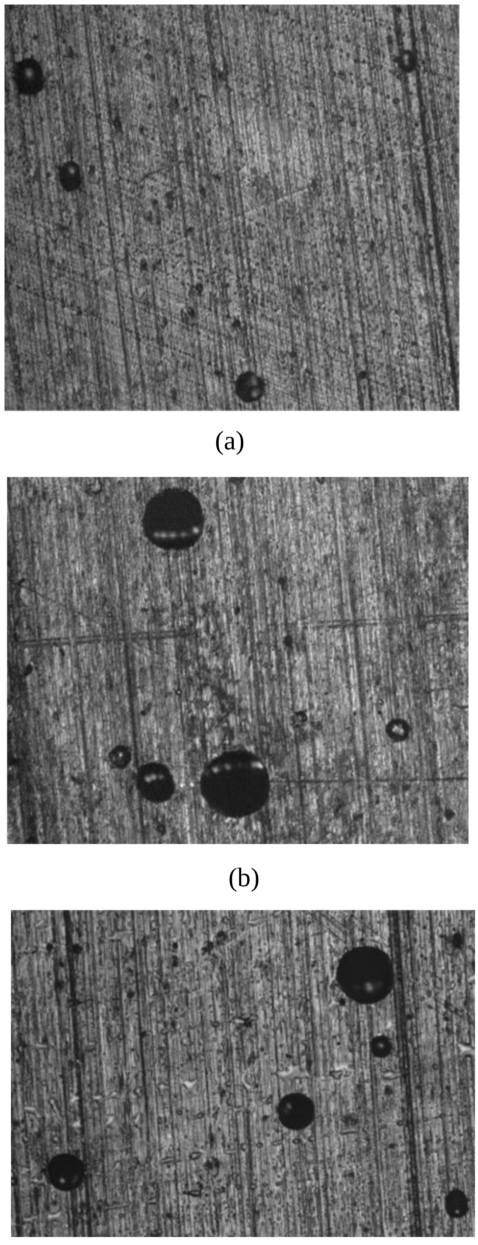


Fig. 3. The relation between PWM and (a) resin flow as well as (b) the roller speed.

Figure 4 displays the image of composite fabricated using (a) 2, (b) 3, and (c) 4.2 cm/s velocities, respectively. The black circles indicate the voids while the lines are caused by the paddle roller which has serrations with 3 mm distance. In general, the number of large voids have no significant differences. The detail calculation of the void number and size are reported in our other publication [15]. We should note that the slower speed requires longer fabrication time.



(a)

(b)

(c)

Fig. 4. The images of composite fabricated using (a) 2, (b) 3, an (c) 4.2 cm/s velocities.

To understand the effect of speed to the mechanical properties, the tensile strength and the modulus young were measured, and the results are presented in Fig. 5. The strain-stress curves for roller velocities of 2, 3, and 4.2 cm/s are shown in Fig. 5. (a). The smaller the speed, the larger the tensile strength. Besides, the modulus Young is also influenced by the roller speed.

The tensile strength and modulus Young extracted from Fig. 5 (a) are displayed in Fig. 5. (b). Compared to other fabrication methods [11], the tensile strength of the composites fabricated with this controllable machine are relatively higher. The modulus Young is also clearly dependent on the speed.

The dependence of tensile strength and modulus Young to the roller speed opens possibility for tunable composite fabrication. The number of large voids is also found to be small. However, the paddle roller creates long lines which can influence the mechanical properties of the composite. Further investigation is required to reduce the roller induced lines.

(a)

(b)

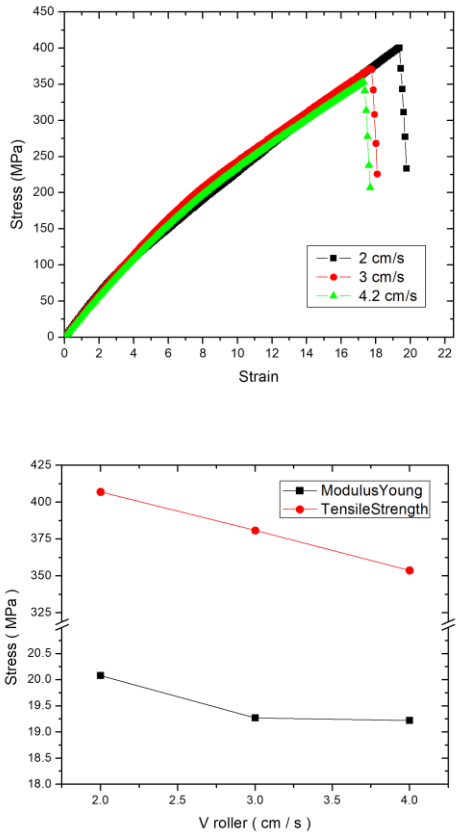


Fig. 5. (a) The strain-stress curve and (b) the tensile strength as well as the modulus Young of the composites fabricated using speed of 2 cm/s, 3 cm/s, and 4.2 cm/s

Fig. 6 shows the composite mechanical property prepared using our instrument and the ones prepared by conventional hand- and dry layup method. It is shown that the composite prepared using our instruments has highest tensile strength of 425 MPa. However, it has lowest facture strain of 19 %. On the other hand, the cheapest hand layup method has lowest tensile strength of 300 MPa and largest facture strain of 24 %. This result is in a good agreement with previous reported study at Ref. [13] which shows that the controlled composite manufacturing process created better mechanical properties.

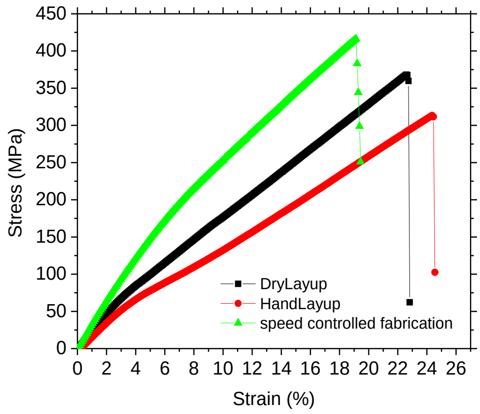


Fig. 6. The strain-stress curves of composites prepared by dry layup (black), hand layup (red), and speed controlled (green) fabrication methods.

4. Conclusions

The speed controlled composite fabrications have been conducted for three speed variation. The instruments were designed so that the velocities of roller movement as well as the resin flow can be controlled using PWM of the DC motor. The composites are found to have a lot of long narrow voids induced by the roller. A small number of large voids are also observed. The modulus Young and the tensile strength decrease with the increasing of the speed. This study shows how the mechanical properties of a composite can be controlled by the speed during the resin lamination processes.

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