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Experimental assessment of the 3-axis filament winding machine performance

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ABSTRACT

This paper presents the experimental evaluation method analysis of 3-axis filament winding machine performance. Winding circular test is a sufficient method to evaluate machine performance on winding circular repeatability and winding angle quality. It was concluded that the portable 3-axis filament winding machine had a good winding circular repeatability result, which offered 0.83–1.13 mm winding circular distance with 1.75–3.13% standard deviation. It was provided a good winding angle quality, which relied on 0.35–0.62° difference value with 2.25–8.68% standard deviation. It is indicated that winding circular test and winding angle measurement methods could be used as the experimental assessment to evaluate winding machine or relevant equipment on winding performance and manufacturing capability.

1. Introduction

Filament winding technique has been developed by numerous industries and researchers as one of commercial composite fabrication methods with low-cost, high-repeatable and high-flexible characteristics [1]. Filament winding machine has evolved from 2-axis classical lathe-type machine towards winding machine with higher degrees of freedom [2]. In order to advance innovative equipment, various researchers have studied, designed and fabricated different axial filament winding machines [3–7]. However, there are still limited reports on experimental assessment about winding performance of current developed filament winding machines. Therefore, this paper is to adopt winding circular test to evaluate machine performance on winding circular and angle qualities based on the portable 3-axis filament winding machine.

2. Methods

The winding circular test is defined to measure the winding fibre distance between the first and second circles, and it is performed to assess winding circular repeatability, which is used the portable 3-axis filament winding machine [8], as shown in Fig. 1 a. Filament wound carbon/epoxy tubes are presented in Fig. 1 b, which performs winding angle quality analysis. 3K carbon fibre spool is supplied by Mitsubishi Rayon Co., Ltd, which offers 3 mm width, 7 μm filament diameter and 1.79 g/cm^3. Filament wound composite tubes with four winding angles (±30°, ±45°, ±60° and ±75°) are fabricated to evaluate winding angle quality. The schematic overview of winding circular test is presented in Fig. 2 a, which measures the contiguous fibre tow distance. Fig. 2 b presents the winding angle measurement test setup of using AM4815 Dino-lite edge microscope.

3. Results and discussion

Results of winding circular test and winding angle measurement test were discussed in this study, which generally was used to evaluate winding machine winding quality. Table 1 illustrated the winding circular test results, and each winding angle was measured six times to obtain accurate results respectively. It was obtained that winding circular distance average value was 1.13 mm with ±30° winding angle, 1.05 mm with ±45° winding angle, 1.00 mm with ±60° winding angle and 0.83 mm with ±75° winding angle. Winding quality ratio is defined as the value of winding circular distance divides fibre width, and the lower value represents higher winding quality. It was concluded that with

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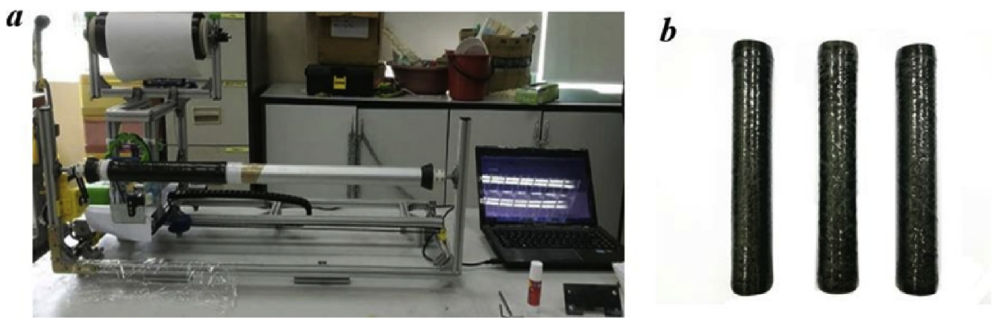

Fig. 1. The overview of equipment schematic: (a) the portable 3-axis filament winding machine; (b) filament wound carbon reinforced plastic tubes [8].

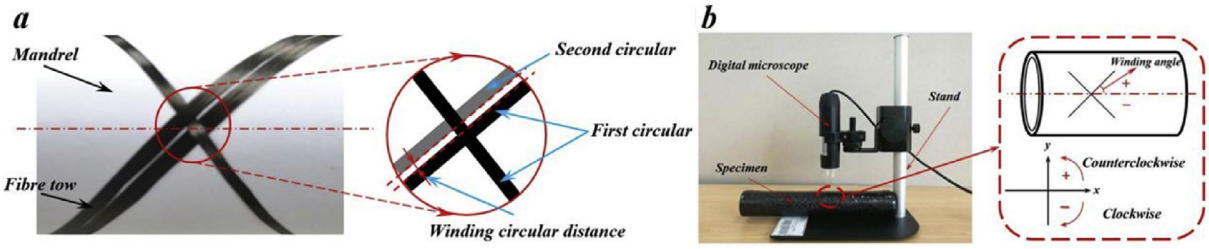

Fig. 2. (a) The schematic overview of winding circular test method; (b) The winding angle measurement experimental setup.

Table 1
Winding circular test results.

Winding angle	±30°	±45°	±60°	±75°
Winding circular distance average value (mm)	1.13	1.05	1.00	0.83
Standard deviation (%)	1.75	1.94	2.92	3.13

winding angle increased, average distance value showed the decreasing trend. Winding quality ratio at ±75° winding angle was 0.27, which indicated that tested machine could offer a better winding repeatability quality between ±45° and 90° winding angles.

Table 2 exhibited winding angle measurement test results, which obtained six measurement numbers. It highlighted that with the winding angle increased, average value of winding angle measurement result provided decreasing trend. Winding angle has positive and negative values, which defined by counter-clockwise and clockwise rotation based on axial direction [9]. is defined as angle It was found that this winding machine showed better winding angle accuracy on higher winding angle.

Table 2
Winding angle measurement test results.

Winding angle	±30°	±45°	±60°	±75°
Winding angle average measurement value (°)	30.62	45.46	60.41	75.35
Standard deviation (%)	8.68	7.72	4.07	2.25

Fig. 3 a exhibited the analysis result of winding circular distance versus measurement time, which includes four winding angle conditions. It was found that tested machine offered better winding circular repeatability quality at ±75° winding angle with 0.83 mm average distance value, which provided a lower winding angle ratio compared to other winding angles. Fig. 3 b presented winding angle measurement test analysis result, which involved winding angle difference value and standard deviation between measurement and expected angles. It was highlighted that with winding angle increased, there was decreasing trends on difference value and standard deviation value. Such as ±75° winding angle, it obtained the 0.35° difference value and 2.25% standard deviation. It is concluded that the portable 3-axis winding machine could offer a better winding circular repeatability and winding angle quality on higher winding angle. Like lower winding angle condition, the tested machine may not offer a stable and accurate winding performance on winding circular repeatability and winding angle qualities.

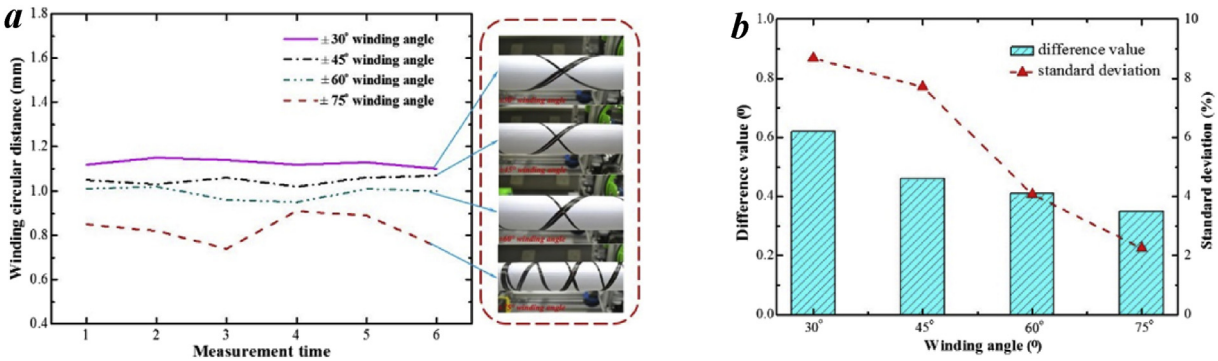

Fig. 3. (a) winding circular test result analysis; (b) winding angle measurement test result analysis.

4. Conclusion

In conclusion, the portable 3-axis filament winding machine shows a relative accurate winding performance on winding circular tests, which obtains 0.83–1.13 mm winding circular distance with 1.75–3.13% standard deviation. It also offers a good winding angle quality, which based on 0.35–0.62° difference value with 2.25–8.68% standard deviation. It is highlighted that winding circular and winding angle measurement tests have great potential to evaluate filament winding machine and equipment in industrial areas.

Conflict of interest

The authors declare no potential conflicts of interest regarding to the research, authorship and publication of this article.

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