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# Effect of cutting parameter on tool wear of HSS tool in drilling of Kevlar composite panel

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**Abstract.** The paper reports the tool wear in the drilling of composite panel in various cutting conditions. The drilling process was applied to 4mm thickness Kevlar composite panel by using HSS drill tool (2 flutes, 12 mm diameter, 17 mm length and 118° drill point angle). The process was conducted by using a vertical machining center. The tool wear was measured by using an optical microscope with the max precision 0.01  $\mu\text{m}$ . The drilling process was conducted with a constant feed rate (75 mm/min) and three levels of spindle rotation speeds (1000, 3000 and 5000 rpm). Each cutting condition was applied to two different drill tools. In order to investigate the wear rate, the tool wear was measured in several levels of cutting time (i.e., after drilling of 5, 10, 20 and 30 drill holes). The result of the experiment shows that the cutting speed gives significant effect to the tool wear of HSS drill tool when drilling Kevlar composite panel. Higher cutting speed produced higher tool wear at any cutting time level. The result of the experiment also shows the effect of continuous/ discontinuous cutting. Higher tool wear was found in a direct 20 holes drilling, compare to paused drilling (i.e., start with 10 holes, pause for 20 minutes then continue with other 10 holes).

## 1. Introduction

Composite is a combination of two or more materials with different phase become a new material with better properties [1]. Composite is reinforced either by synthetic or natural fiber. Natural fiber (jute, knaf, banana, etc.) has some benefit compare to synthetic fiber, i. e. lower production cost and environmentally friendly. However, its lower strength and un-uniform size (compare to synthetic fiber), make natural fiber has limited application as the end product [2]. The most popular synthetic fibers are glass fiber and carbon fiber, because of their strength and economical production cost [3, 4]. Kevlar is synthetic fiber with better properties but relatively more expensive compare to glass and carbon fiber.

Kevlar is a registered trademark for aramid synthetic that related to Numex and Technora. Kevlar (Poly-para phenylene terephthalamide) was first developed by Stephanie Kwolek in 1965 at DuPont Company. Then Kevlar was further developed to be synthetic fiber and other product by DuPont [1]. Kevlar was firstly used as commercial material in 1970 to replace steel fiber in racing tyres. Its tensile strength was five times higher than steel fiber. Since then, due to its mechanical strength, impact absorption, flexibility, and lightweight, Kevlar has been further commercially developed to ship sail,

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armor and composite panel [5]. Kevlar composite panel has been used as hard, strength, flexible and lightweight component in aerospace and aircraft product [6].

Like any other composite panel, Kevlar required some drilling process to become an end product. Drilling Kevlar composite panel would be a difficult machining process. Its hardness generates a high cutting temperature during the friction between drill tool's cutting surface and hole's surface. High cutting temperature and chemical substance of composite panel lead to an internal heating process that reduces the strength of the cutting tools [7]. Furthermore, its flexibility generates more vibration during the drilling process. Both of the problems increase the wear progress of the drill tool. Since the tool cost and tool replacement time consumes significant production cost and production time, minimizing of the tool wear has been an important issue in machining composite panel. However, the tool wear is not affected only by the nature of the material. The tool wear could be minimized if the correct cutting condition was applied during the machining process [8, 9, 10, 11, 12].

This research aims to investigate the flank wear of HSS drill tool when drilling Kevlar composite panel. A set of experiment was conducted to study the effect of cutting parameter, i. e. spindle speed to the tool wear. The experiment also conducted to investigate the progressive wear rate by drilling several sets of holes and measure the wear separately. The result of the experiment would be used as a reference for machining industry/ workshop in order to minimize the tool cost while maintaining the machining productivity.

## 2. Methods

The Kevlar composite with 4 mm thickness was prepared as the material of the experiment. The Kevlar composite was cut to rectangle form with 700 mm length and 500 mm width. The material was design to be drilled with 10 rows of holes with 35 mm distance between the center of the rows. Each row consisted of 13 holes with 50 mm distance between the center of the holes. With the particular design, the total of 130 holes could be drilled on the material. The Kevlar composite panel was drilled by using High-Speed Steel (HSS) drill tool. The drill tool was manufactured by Nichi, with 2 flutes, 12 mm diameter, 17 mm tool length and 118° drill point angle. The tools used in the experiment were originally a new tool without any defect or initial wear.

The spindle speed has been selected as the independent variable of the experiment. Three levels of spindle speed have been determined, i. e. 1000, 3000 and 5000 rpm. The feed rate of the drilling process remains constant as 75 mm/min. The drilling process was conducted by using machining center (Agma type A-8 and max spindle speed 8000 rpm) at Laboratorium of Design and Manufacture, Department of Mechanical and Industrial Engineering, Faculty of Engineering, Syiah Kuala University, Banda Aceh, Indonesia. In order to measure the progress of the flank wear, several sets of the holes were set to be drilled continuously, i. e. 5, 10, 20 and 30 holes. After drilling a set of holes, the drilling process took a halt, and the flank wear of the tool was measured and recorded. The tool then used to drill another set of the holes, and similar flank wear was measured and recorded. Two drill tools were used to provide the drilling process for each spindle speed with a different set of holes. The result was compared in order to investigate the effect of the continuous/ discontinuous drilling process on the progress of flank wear.

The flank wear was measured by using an optical microscope (Olympus GX-71 with the max precision 0.01  $\mu\text{m}$ ). A special fixture was designed and fabricated to hold the tool during the measurement process. The angle of fixtures could be set to secure the surface of the cutting edge, to make sure that the microscope give a correct reading and the similar position could be repeated precisely. The original tool was put under the microscope before the first drilling process started to identify the original line and surface of the cutting edge. The wear measurement (after drilling) was conducted at a similar original position. The setup of the experiment was shown in Figure 1.

### 3. Result and Discussions

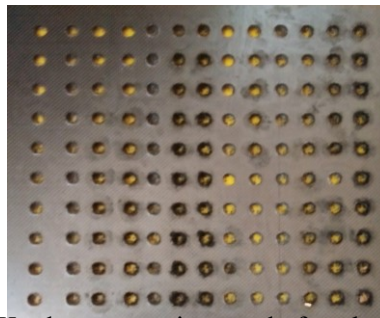
The NC programming was developed according to the cutting condition and holes position in the design of the experiment. The Kevlar composite panel after drilling experiment was shown in Figure 2. Each of cutting speed used 2 cutting tools. The first one was used to drill 10 + 10 + 10 holes.

Consequently, the experiment produced tool wear data after drilling 10 holes, 20 holes and 30 holes. The second drill tool was used to drill 5 + 15 holes. The data would be the tool wear after drilling 5 holes and 20 holes.

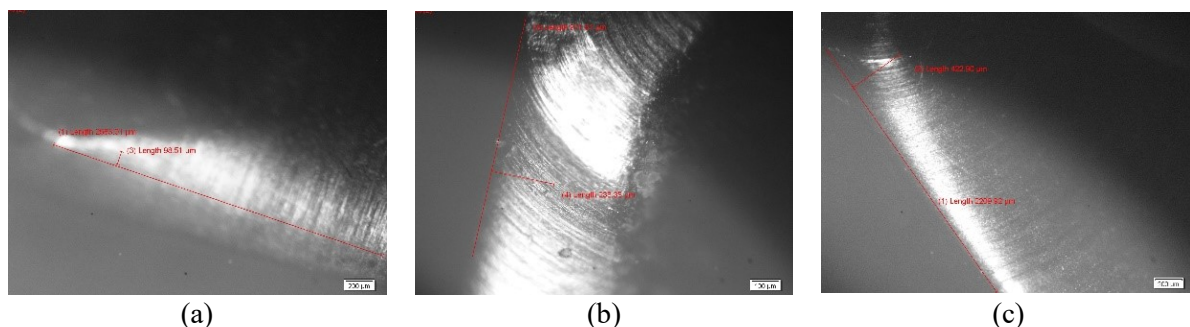
The tool was observed under the optical microscope. The tool wears were captured by the digital camera of the microscope and were further investigated. The images of the tool wear from different spindle speed were shown in Figure 3, 4 and 5. The bright side was the flank wear of the tool. There were some difficulties during the measurement since the original surface has been removed during the drilling process. However, the initial surface has been recognized and recorded before the drilling process. The red line in Figure 3, 4 and 5 was the imaginer edge of the initial cutting surface.



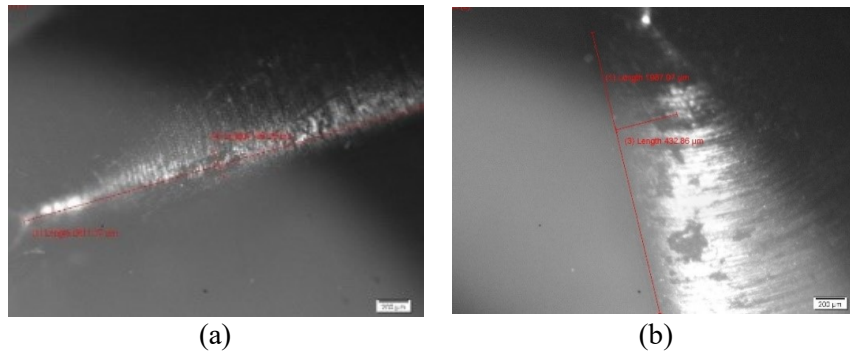
**Figure 1.** Setup of the experiment (a) drilling process (b) tool wears measurement process.



**Figure 2.** The Kevlar composite panel after the drilling process.



**Figure 3.** Figure Tool wears after drilling process with 1000 rpm spindle speed (a) after drilling 10 holes (b) 20 holes (c) 30 holes.

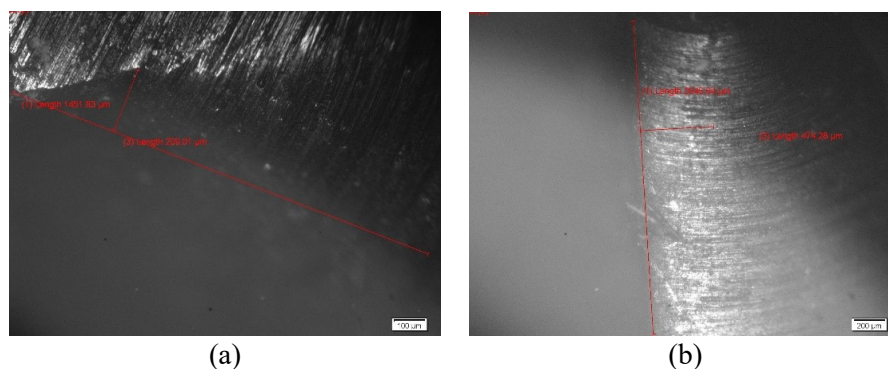


**Figure 4.** Tool wear after drilling process with 3000 rpm spindle speed (a) after drilling 10 holes (b) 20 holes.

The result of the experiment was recorded in Table 1. The maximum tool wear of 500  $\mu\text{m}$  has been considered as the limit of the tool life [13]. The tool wear greater than 500  $\mu\text{m}$  was not shown in Table 1 since at that point the tool wear has exceeded the limit and the tool could not be used anymore. Most of the tool exceeded the tool life limit when drilling the 30 holes. Only the drilling with 1000 rpm spindle speed was able to drill 30 holes without exceeding the tool life limit.

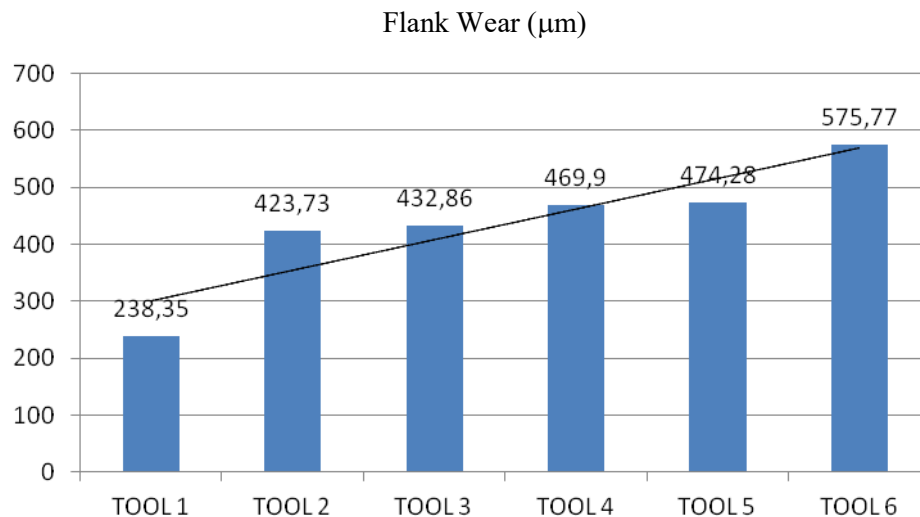
**Tabel 1.** The tool wear data of the HSS tool after drilling experiment

Number of the hole	1000 rpm		3000 rpm		5000 rpm	
	Tool 1	Tool 2	Tool 3	Tool 4	Tool 5	Tool 6
5		57,11 $\mu\text{m}$		80,98 $\mu\text{m}$		114,93 $\mu\text{m}$
10	98,51 $\mu\text{m}$		186,29 $\mu\text{m}$		209,01 $\mu\text{m}$	
20	238,35 $\mu\text{m}$	423,73 $\mu\text{m}$	432,86 $\mu\text{m}$	469,9 $\mu\text{m}$	474,28 $\mu\text{m}$	575,77 $\mu\text{m}$
30	422,9 $\mu\text{m}$					



**Figure 5.** Tool wear after drilling process with 5000 rpm spindle speed (a) after drilling 10 holes (b) 20 holes.

The result of the experiment shows that spindle speed gives a significant effect on the tool wear. As shown in Figure 6 the higher spindle speed increases the tool wear at any number of the holes. This was because the higher speed gives more friction between the cutting surface of the drill tool and the surface of the Kevlar composite panel. More friction generates more heat and reduces the strength of the drill tool material. Finally, the wear resistance decreases and the tool wear increases progressively.



**Figure 6.** Comparison of tool wears after drilling 20 holes.

The experiment also investigated the effect of continuous cutting to the tool wear. As shown in Figure 6, the tool wear was higher in the second drill tool (tool 2, 4 and 6) compare to the first drill tool (tool 1, 3, and 5) at all spindle speed. The first tools were used to drill 5 holes, pause for 30 minutes, then continue to drill 15 holes. The second tools were used to drill 10 holes, pause for 30 minutes, then continue to drill 10 holes. Even though both of the drill tools were used to drill 20 holes, the result showed that they produced different tool wear. This result showed that continuous drilling produces more tool wear compare to discontinuous one. It was because when the drilling stops (in discontinuous drilling), the tool has released the heat to the environmental for 30 minutes. While in the continuous drilling the temperature increases very fast and there was no opportunity to release the heat to the environment until the 15 holes have been drilled completely.

#### 4. Conclusion

The result of the experiment has been discussed. The spindle gives significant effect to the tool wear. The higher spindle speed increases the tool wear at any number of the holes. The comparison between continuous and discontinuous drilling showed that continuous drilling produces more tool wear compare to discontinuous one.

#### 5. References

- [1] Groover M P 2012 *Fundamentals of Modern Manufacturing*, 5th Edition (John Wiley & Sons, Inc).
- [2] Elanchezhian C, Ramnath B V, Ramakrishnan G, Rajendrakumar M, Naveenkumar V and Saranavakumar M K 2018 *Material Today: Proceedings*. **5** 1785
- [3] Jones F R and Huff N T 2018 *Hand Book of Properties of Textile and Technical Fibers* 2<sup>nd</sup> Ed **757**
- [4] Newcomb B A 2016 *Composite Part A: Applied Science and Manufacturing*. **91** P 1 262

- [5] Raja S n, Basu S, Limaye A M, Anderson T j, Hyland C M, Lin L, Alivisatos A P and Ritchie R O 2015 *Material Today Communications*. **2** 33
- [6] Dickson A N, Barry J N, McDonnell K A and Dowling D P 2017 *Additive Manufacturing*. **16** 146
- [7] Parka K H, Bealb A, Kimb D D W, Kwonc P and Lantripd J 2011 *Wear* **271** 2827
- [8] Iqbal M, Akram A and Tadjuddin M 2015. *International Journal of Applied Engineering Research*. **10** N 95 16
- [9] Iqbal M, Konneh M, Hanafi M, Abdallah K A and Binting M F 2015 *International Journal of Mechanical And Production Engineering*. V **3** I 4 62
- [10] Iqbal M, Konneh M, Said A Y M and Zaini A F M 2014 *Applied Mechanics and Materials Journal*. **446 - 447** 275
- [11] Konneh M, Iqbal M and Faiz N M A 2012 *Advanced Materials Research Journal*. **576** 531
- [12] Konneh M, Iqbal M, Kasim M A and Isa N M 2012 *Advanced Materials Research Journal*. **576** 535
- [13] Yong A Y L, Seah K H W and Rahman M 2007 *Int J Adv Manuf Technol*. **32** 638