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Analysis on Rotational Speed and Material of Twist Drill to Its Worn and Burr Formation in Drilling Ti-6Al-4V

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Abstract. Ti-6Al-4V is a material that is mostly used in aerospace. In this industry, especially on stabilizer horizontal structure, minimizing burrs height is important. These structures are assembled and drilled. To be economically viable, it is preferred to minimized or even removed burr during drilling process. Aerospace industry needs to drill component in an operation without reprocessing (disassembled, deburred, and fastened). Burr will lead to distortion of work piece dimension, damage to subsurface, and make difficult to handling and assembling of part. Burr occurs during machining because of inoptimum choice of material, tool, and cutting speed. This research uses experimental method by varying rotational speed and material and type of twist drill to find the optimum choice of the parameter and tool for drilling process of Ti-6Al-4V. The quality of drilling process was measured by the height of burr and wear on the tool. The result shows that the lowest burr is 0,085 mm by using HSS-Co twist drill in 500 rpm of speed. The use of HSS-Ti and HSS-Co in high speed will cause chipping worn. Therefore, it is unsuitable to minimize the burr height.

1. Introduction

Manual of Ti-6Al-4V has been widely used in aerospace industry and medical [1]. Ti-6Al-4V has mechanical characteristics of high impact and tensile strength, low density, and the most important is high corrosion resistance [2]. Moreover, it has low conductivity and reactivity to cutter material [3]. Titanium alloys are difficult to be treated with machining process in term of cutting speed parameter, feed rate, and cutting depth [4].

Quality of machine components in aerospace industry and automotive have been increasingly important in recent years as the tolerance is more stringent. Therefore, these components or parts need higher quality in minimum tolerance. One of the airplane parts that need this qualified tolerance is horizontal stabilizer of commercial plane. Structuring this horizontal stabilizer is by assembling and drilling. Yet, main machining operation is drilling. There is consequence if assembling conducted before drilling, the burr formed between the adjacent materials. The procedure needed is drilling components in an operation without reprocessing (disassembled, deburred, and fastened). Despite the forming burr cannot be avoided completely, the burr minimizing or predicting burr size is still very important. It is because the burr height is a problem in aerospace industry [5].

Burr is a rough edge on material as the result of tool machining, it sticks on the surface [6]. The burr height in drilling will increase following the spindle speed and the increasing feed speed. The lowest burr height is 17,8 μm on 800 rpm of spindle speed [7]. The height and the thickness of burr decreases if drilling used helix angle and wide main angle of twist drill [8].



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2. Method

This research uses experimental method based on related references. Material uses in this research is Ti-6Al-4V. Drilling process uses rotational speed variation and twist drill material. Procedure in conducting this experimental study is simply explained in the below diagram of Figure 1.

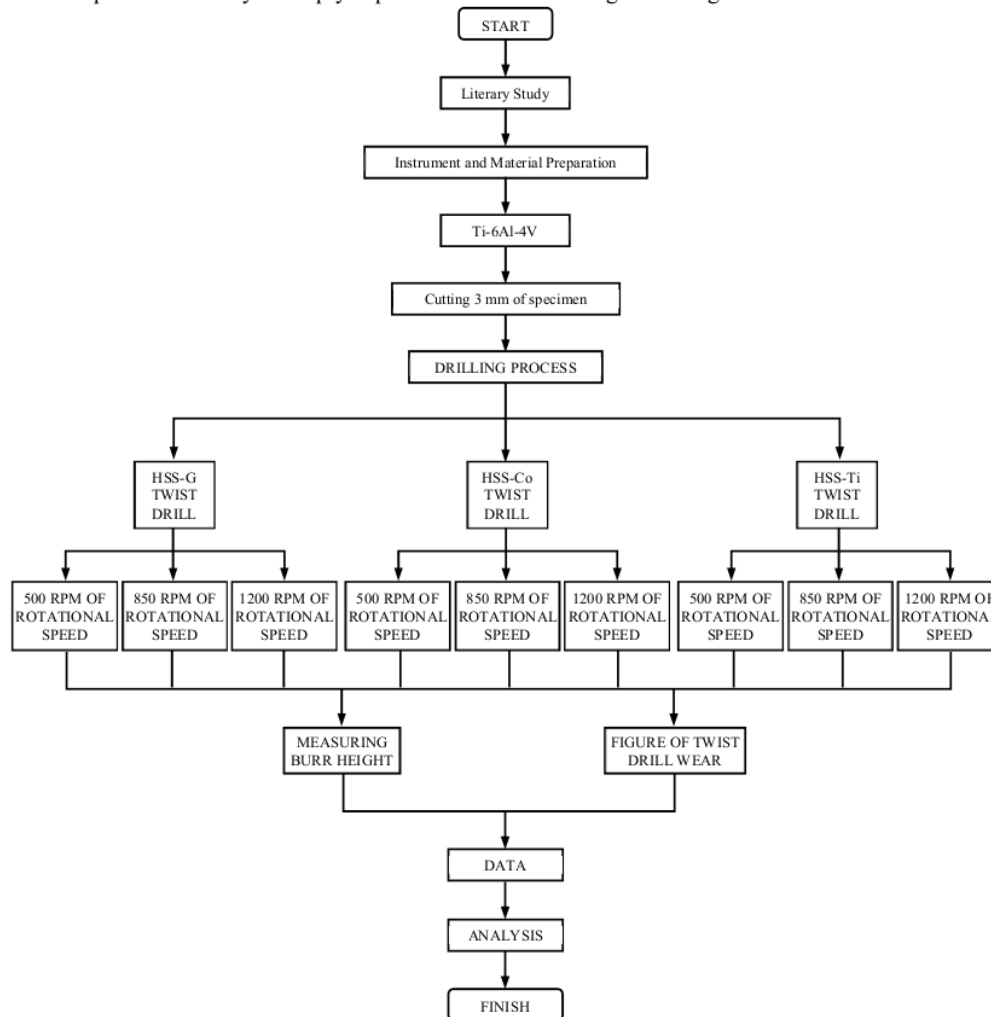


Figure 1. Research procedure

2.1 Research Location

This research uses EDM cutting wire to cut the specimen. This device is on State Polytechnic of Malang. Drilling, measuring burr height, and macro photo were conducted in University of Muhammadiyah Malang.

2.2 Material and Devices

Material selected for this research is Ti-6Al-4V. Devices used were K 15-47 530225 series, HSS-G twist drill, HSS-Co twist drill, HSS-Ti twist drill, dial indicator, macro camera.

3. Result and discussion

3.1 Measuring Burr

The burr height of drilling was measured four times on different drilled holes. Each was drilled with different material of the twist drill and different rotational speed.

Table 1. Burr height measurement

No	Material of twist drill	Rotational speed (Rpm)	Burr Height of four drilled holes (mm)				Average (mm)
1	HSS-G	500	0.11	0.04	0.11	0.08	0.085
2		850	0.18	0.14	0.16	0.17	0.1625
3		1200	0.2	0.18	0.2	0.8	0.345
4	HSS-Co	500	0.04	0.035	0.07	0.08	0.05625
5		850	0.34	0.26	0.31	0.3	0.3025
6		1200	0.74	1.04	1.32	1.45	1.1375
7	HSS-Ti	500	0.32	0.23	0.2	0.19	0.235
8		850	0.17	0.34	0.28	0.31	0.275
9		1200	0.82	0.84	0.82	0.88	0.84

From different materials of twist drill, it resulted different value of burr height with three variations of rotational speed. HSS-Co shows the highest value of burr height in the highest rotational speed of 1200 rpm than HSS-G and HSS-Ti. While in the lowest rotational speed of 500 rpm, HSS-Ti resulted the highest burr height than HSS-G and HSS-Co. It is as depicted in figure 2.

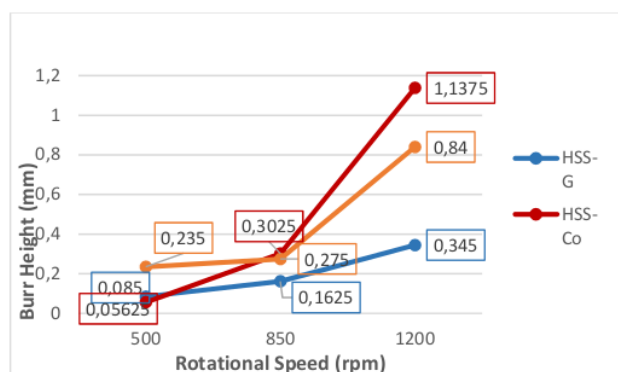


Figure 2. Analysis on rotational speed and materials of twist drill to the burr height of Ti-6Al-4V

The above figure 2 the correlation of burr height and rotational speed of the twist drill. The higher of twist drill rotational speed, the higher the burr height value [8]. The lowest burr height is 0,05626 mm in 500 rpm rotational speed with HSS-Co twist drill, while the lowest burr height in 850 rpm rotational speed is 0,1625 mm with HSS-G twist drill. It shows a better result than the research by Waqar. The lowest burr height in 1200 rpm speed is 0,345 mm with HSS-G twist drill.

Drilling process with HSS-Ti and HSS-Co in 1200 rpm rotational speed resulted no holes as the rotational speed is high. Therefore, it gives high friction and temperature during machining process.

High cutting speed will cause high temperature in drilling [9]. The burr height of drilling process is as shown in figure 3.

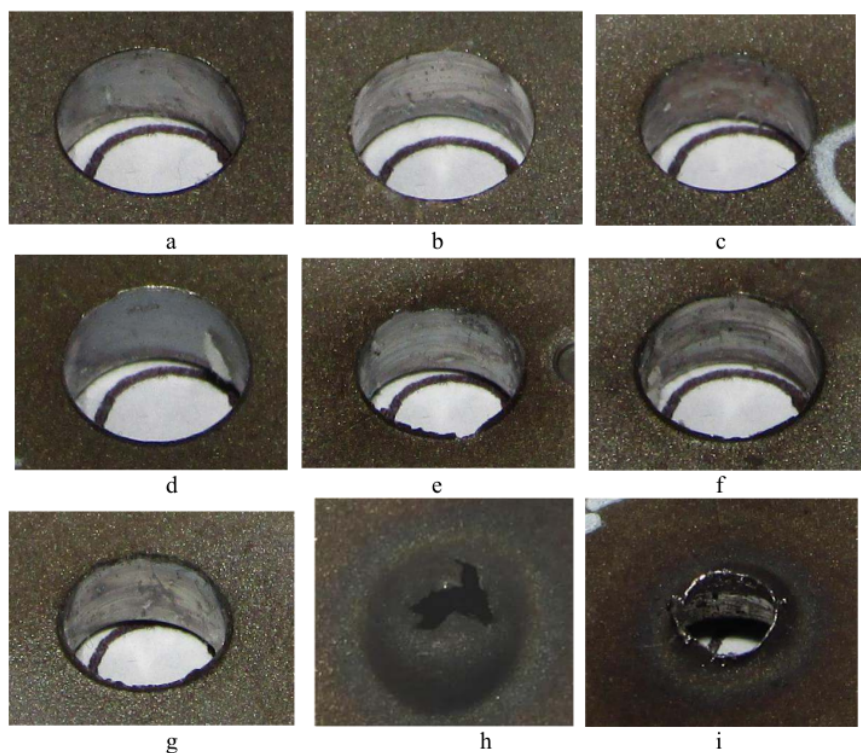


Figure 3. Burr (a) HSS-G with 500 rpm; (b) HSS-Co with 500 rpm; (c) HSS-Ti with 500 rpm; (d) HSS-G with 850 rpm; (e) HSS-Co with 850 rpm; (f) HSS-Ti with 850 rpm; (g) HSS-G with 1200 rpm; (h) HSS-Co with 1200 rpm; (i) HSS-Ti with 1200 rpm

3.2. Analysis on wear of twist drill

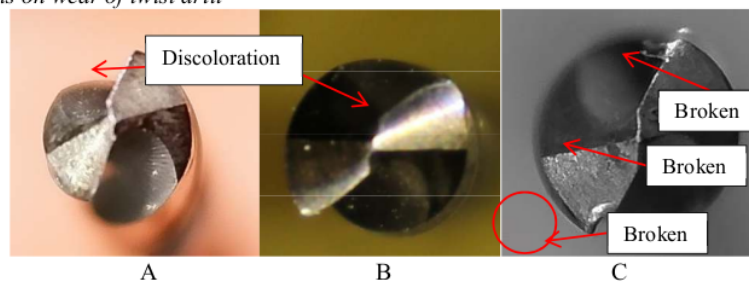


Figure 4. The twist drill wear from the front. It occurs on 500 rpm rotational speed. (a) HSS-G; (b) HSS-Co; (c) HSS-Ti

Figure 4 and figure 5 shows the comparison of twist drill wear with different materials. The wear is obviously occur to HSS twist drill with Ti coating in outside angle position and the edge (chisel).

HSS-G and HSS-Co do not show the significant wear, but there is discoloration on the flank face color. The discoloration occurred by heat as the result of friction between Ti-6Al-4V and HSS-G and HSS-Co twist drills.

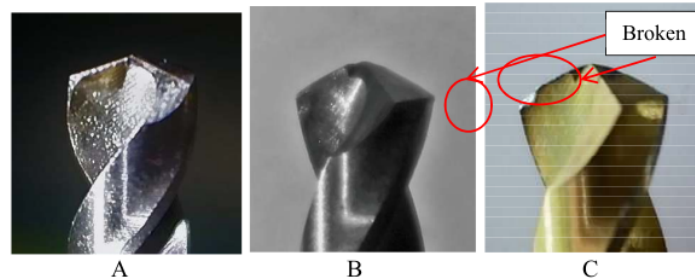


Figure 5. The twist drill wear from the side position. It occurs on 500 rpm rotational speed. (a) HSS-G; (b) HSS-Co; (c) HSS-Ti

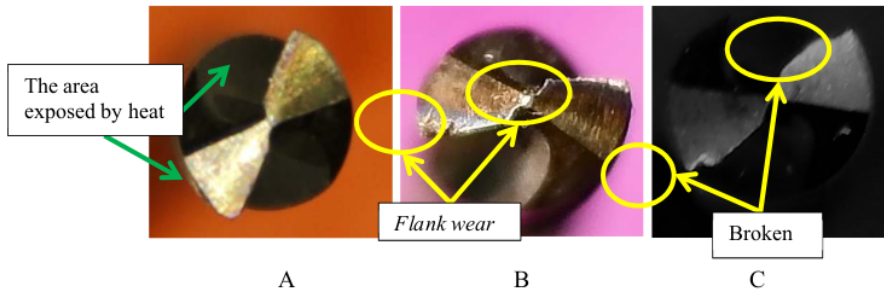


Figure 6. The twist drill wear from the front. It occurs on 850 rpm rotational speed. (a) HSS-G; (b) HSS-Co; (c) HSS-Ti

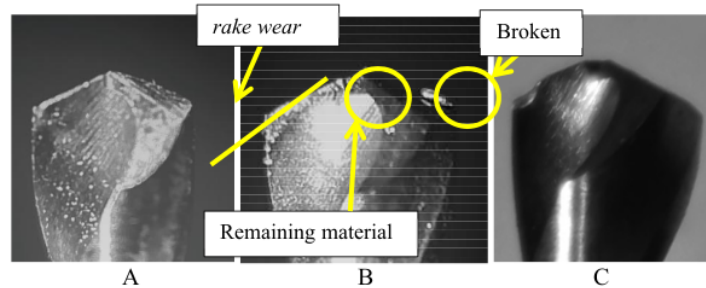


Figure 7. The twist drill wear from the side position. It occurs on 850 rpm rotational speed. (a) HSS-G; (b) HSS-Co; (c) HSS-Ti

Figure 6B shows the flank wear on HSS-Co and the rake face wear shown in Figure 7B. HSS-Ti twist drill has outer corner wear. It has high influence to burr as, basically, the outer corner wear influences geometrical of twist drill main angle. Height and thickness of burr would be lessen by using helix angle and wide angle [8]. HSS-G is not worn, but it has discoloration on flank face as the result of work-piece (Ti-6Al-4V) friction. The friction causing heat on this area.

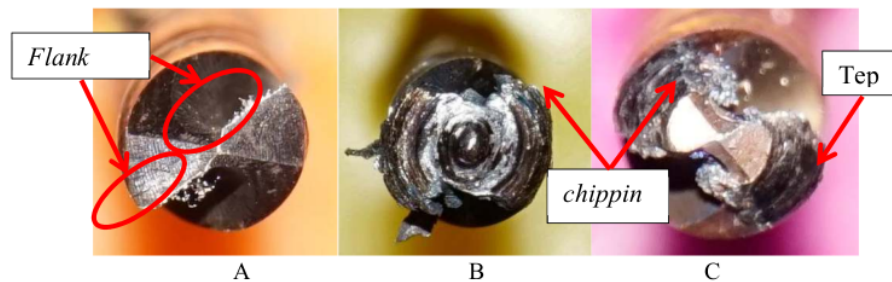


Figure 8. The twist drill wear from the front. It occurs on 1200 rpm rotational speed. (a) HSS-G; (b) HSS-Co; (c) HSS-Ti

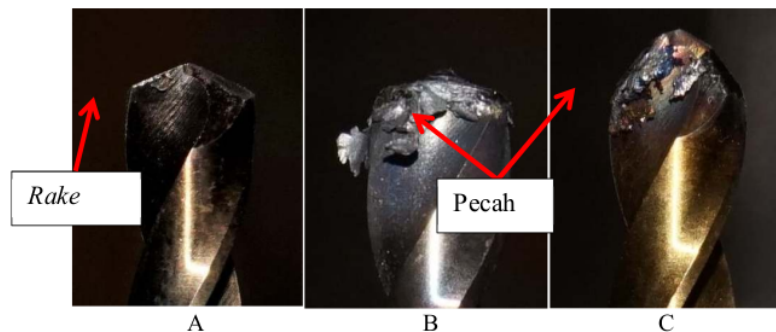


Figure 9. The twist drill wear from the side position. It occurs on 1200 rpm rotational speed. (a) HSS-G; (b) HSS-Co; (c) HSS-Ti

Figure 8 and figure 9 show the incapability of HSS-Co and HSS-Ti to drill with 1200 rpm of rotational speed. The wear of HSS-Co and HSS-Ti is chipping. For HSS-Ti, the chisel structure is still complete. For HSS-G, the geometrical structure of main angle is still complete but there is flank wear and rake wear.

3.3. Discussion on the wear form of the twist drill

The twist drills with different materials are mostly worn, but the wear is clearly shown by HSS-Ti and HSS-Co on 1200 rpm of rotational speed. It occurs during high rotational speed, that the cutting speed is high. The high cutting speed will cause high friction between the twist drill and Ti-6Al-4V, that furthermore, it causes twist drill wear [10]. Comparing the three twist drills in 1200 rpm rotational speed, the worst wear is on HSS-Ti and HSS-Co. Basically, HSS with Ti coating is weak toward friction [6]. The weak of Ti coating causes friction and wear on the twist drills. Moreover, it also causes chipping wear [11]. The wear on HSS-Co is as a result of recommendation rotational speed setting in 500 rpm for drilling Ti. HSS-G is the best material of twist drill for drilling Ti in high speed.

3.4. Discussion on the Gram

Gram resulted by 500 rpm speed with HSS-G shows spiral-cone form in the end, but it is wad afterward as there is no heat in the beginning of drilling process. Heat distribution on drilling process is higher when it is getting deeper [10]. The form of gram is discontinue. It is as depicted in figure 10(a). Figure 10(b) shows spiral-cone form of gram from the beginning to the end. This form achieved because of twist drill material and the sharp edge of twist drill top [11]. Gram is continued and attached during machining process. Gram on HSS-Ti with 500 rpm speed shows continued form but it is not attached. If it is compared with HSS-G and HSS-Co gram on 500 rpm, the gram of HSS-Ti is thinner as it is

depicted in figure 10(c). Figure 10(d) shows discontinued gram and it is attached during drilling process from the beginning to the end of the process. On Figure 10(e), the gram is discontinue and unattached, but it is after some time later. It has spiral-cone form. Figure 10(f) shows continued form of gram and it is unattached on the twist drill. If it is compared to the gram of HSS-G and HSS-Co on 850 rpm of speed, the gram of HSS-Ti is thinner. On Figure 10(g), the gram of HSS-G twist drill with high speed is unattached in the beginning of drilling process, but after some time later, it is attached on the twist drill. The gram is randomly discontinued. Figure 10(h) shows the gram by using HSS-Co twist drill in high speed. Figure 10(i) shows that the gram is attached on the twist drills and is irregularly continued. It used HSS-Ti with high speed. Gram is attached on the twist drill and is irregularly continued. Therefore, the best gram is on HSS-Co in 500 rpm of rotational speed.

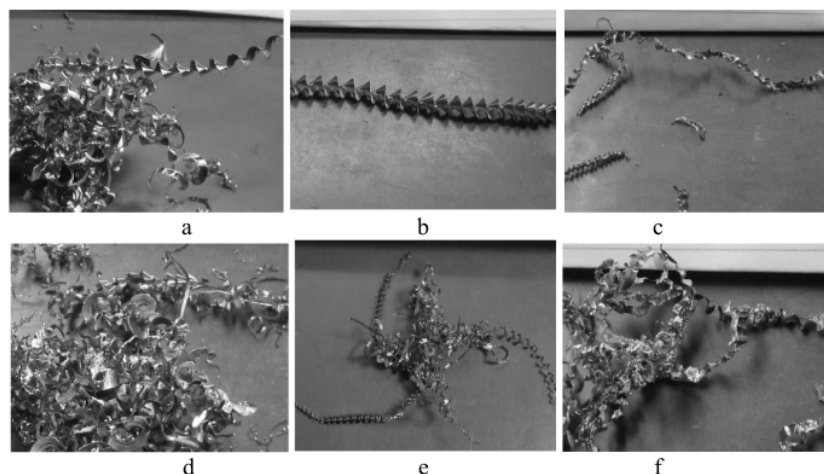


Figure 10. Macro photo of gram: (a): HSS-G with 500 rpm speed; (b): HSS-Co with 500 rpm speed; (c): HSS-Ti with 500 rpm speed; (d): HSS-G with 850 rpm speed; (e): HSS-Co with 850 rpm speed; (f): HSS-Ti with 850 rpm speed; (g): HSS-G with 1200 rpm speed; (h): HSS-Co with 1200 rpm speed; (i): HSS-Ti with 1200 rpm speed

4. Conclusion

Based on the research on the influence twist drill material and rotational speed toward the twist drill wear and burr formation for drilling Ti-6Al-4V has achieved conclusion.

The higher rotational speed, the higher the burr formation. The lowest burr resulted is 0,085 mm by using HSS-Co and it is set on 500 rpm speed. HSS-Ti and HSS-Co twist drill with low rotational speed is very suitable to minimize the burr height. The twist drills of HSS-Ti and HSS-Co set on high speed is unsuitable to minimize the burr height. HSS-Ti and HSS-Co set on high rotational speed will cause the chipping wear.

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