Tool wear investigation in drilling titanium alloy

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Abstract. During the process of drilling a titanium alloy it can lead to several sources of difficulties. At tall temperatures, titanium can converted chemically lively besides will tend to react with most tool materials such as steel, copper, and other objects. In this study, solid carbide drill will be accustomed drill titanium alloys using different cutting parameters. This research is an experimental study in which to show a relationship between cutting constraints for example feed speed and spindle speed during tool wear and to see developments in the study of wear of solid carbide bit drill bits. The experiment was carried out using a CNC milling machine when drilling on titanium alloys with dry cutting conditions. The three types of testing will be carried out using different cutting parameters namely spindle rapidity of 2387 rpm, 3183 rpm and 3979 rpm then food speed of 29 mm / minute, 48 mm / min, and 72 mm / min have been used with the same type of swivel solid carbide drill. The results show that by applying different or thrilling cutting parameters for spindle speed and feed speed is very influential on the presentation of the bit tool when drilling titanium alloys. Experiment 1 shows the best tool life performance results after drilling Titanium in lower cutting parameters 2387 rpm and 29 mm / minute. Based on observations, it shows that lower cutting parameters must be used once drilling the Ti-6Al-4V to achieve a better act than before.

1. Introduction
Titanium alloy as a material that is very often used because of its excellent properties is usually used in the automotive, aerospace, marine applications and even in the biomedical industry of medicine. Titanium remain currently very extensively used in the space manufacturing because they have very good properties compared to previous materials. In the aerospace industry, the drilling process is a technique that has a very important role in which it is estimated that 45% to 60% is used for the process of removing material as hole making. In the machining process, Ti-6Al-4V will cause several other difficulties. At in height temperatures, it will be converted chemically lively and incline to have a reaction with most tools such as steel, copper and other materials. Titanium alloys are an alloy that is extensively castoff in the space commerce, this is outstanding to a grouping of tall strong point at high temperatures, small density, special confrontation and erosion struggle chattels [1].
show that 60% of manufacture period develops less efficient due to the failure of the tool, once the cutting tool must continue toward change and develop throughout the manufacture procedure in titanium alloy drilling. Therefore, making changes to cutting tools will often increase production costs and can reduce the level of production. The drilling process affects 40% to 60% of the total solid neglect process besides this is an important system in the space manufacturing. Drilling is a machining process that is widely used and has considerable economic importance because it is one of the ending stages in making a powered segment.

Though, throughout the machining procedure, Ti-6Al-4V will cause several difficulties. Titanium alloys have little current conductivity and can cause in height critical temperatures [2]. On high temperatures, it develops chemically lively then inclines to respond by greatest tool materials such as steel, and others. Shattering shake is the result of the failure of an inhomogeneous and initial tool which causes tool wear due to variable cutting forces. Throughout the process on titanium alloys, the properties of cutting limits such as the feed rate and cutting speed, greatly affect the harm to tool wear disaster. Using titanium and its alloys will continuously be a problem not at all substance what technique is hammered toward turn this solid into chips [3].

Numerous previous studies have remained carried out to progress machinability in titanium using alloys, specially in turning and milling processes nonetheless lone minor parts have been carried out in titanium alloy drilling processes especially in Ti-6Al-4V [6-9]. Previous research on drilling Ti-6Al-4V with drill bit carbide no layers of various types of geometry below numerous cutting speeds and drilling procedures showed that hole drilling brought more impressive results compared to direct drilling in terms of live tools because drilling holes helped to remove the heat released and remove the chip [4]. The application of extreme cutting parameters will affect the tool bit performance when titanium alloy drilling is performed. Therefore, this study wants to show the determination of the appropriate drilling parameters to reduce tool uniform that is happening the tool bit.

2 Methodology
Titanium alloys (Ti-6Al-4V) are alloy workpieces used cutting-edge the research process, using parameters dimensions of 400mm x 60mm x 6mm. The drilling experiment was carried out on Deckel Macho DMC 635 V CNC machining and solid carbide DR 30 twist Ø2 mm drills as exposed in Figure 1 and Figure 2 demonstrations the type of cutting tools used are 2 mm diameter solid carbide drill bits with constant geometry for three stage tests with dry cutting conditions. The geometry of the drill and detailed specifications are exposed in Table 1. The mechanical belongings and natural arrangement of the workpiece solid are exposed in Table 2 and Table 3 singly. Checking drilling consists of three tests namely Test 1, Test 2 and Test 3 consisting of various cutting parameters as shown in Table 4.
Table 1. Solid Carbide DR 30 Twist Drills

| Category of drill | Diameter (mm) | Shank length (mm) | Flute length (mm) | Point angle | Helix angle |
|-------------------|---------------|-------------------|-------------------|-------------|------------|
| 4-facet           | 2             | 28                | 12                | 140°        | 30°        |

Table 2. Motorised possessions of Ti-6Al-4V

| Properties          | Value     |
|---------------------|-----------|
| Yield Strength (MPa)| 820       |
| Tensile Strength (MPa)| 960-1270 |
| Elongation (%)      | ≥8        |
| Reduction In Area (%) | ≥25     |
| Density (g/cm³)     | 4.42      |
| Modulus of Elasticity| 100-130  |
| Tension (GPa)       |           |
| Hardness (HV)       | 330-370   |

Table 3. Chemical properties of Ti-6Al-4V

| Al  | V  | Fe | C   | Mo | Mu | Si | Balance |
|-----|----|----|-----|----|----|----|---------|
| 6.37| 3.89| 0.16| 0.002| <0.01| <0.01| <0.01|         |

After experiments on 10 holes for each test, the cutting tool was analyzed to measure tool wear using the Hitachi SU3500 Scanning Electron Microscope (SEM) with a resolution of 15kV and 150x magnification. The experiment was carried out at a stop when the cutters fulfilled the equipment life criteria for maximum wing wear> 0.3 mm which was determined based on ISO 8688-2: 1989E under the life test equipment in using the final milling machine. Through this research, cutting tools were prepared to be an analysis material in studying the development of wear of solid carbide drill bits and all illustrations from developments were observed using SEM. The stereomicroscope is used for observation and measurement of the diameter of the hole being drilled after all stages of the drilling process are completed. Only the first and last trials were measured for each test at 4.5x magnification.

3 Result and Discussion

3.1 Influence of cutting parameter on tool wear

Table 4 produces the number of holes in various cutting parameters for the three tests. The life of the cutting tool is significantly reduced by an upsurge in cutting parameters because of increased heat generated and pressure circumstances resulting in development of tool wear. Feed speed and cutting speed are the key influences of the level of wear of cutting tools. By cumulative the feed rate, wear of the tool will increase, and the lifetime of the cutter will decrease. As with cutting speeds, small changes in cutting speed can cause drastic changes in tool wear rates. The findings are in line with other researchers reporting that tool wear is very simple at from top to bottom cutting speeds but increases intensely because the speed decreases [5].

Table 5 shows the SEM image of the first hole and the last fleabag distance for each test. Applying risky cutting limits will likewise disturb the workpiece hole diameter. When the cutting tool wears out, the coating and geometry of the cutting tool will be lost so that it will decrease the diameter of the cutting tool. The hole drilling becomes worse because the cutting speed and feed rate increase [5]. This issue will decrease the diameter of the hole. As a result, the tool uses increased spines, which are clearer in the last hole. The effect of the rate of bait on thorns is when the feed rate is lower, this will result in a greater withdrawal opening. The thorn tallness is relational to the shove for the similar bait level. By way of the cutting speed rises, the tallness of the stern will also upsurge. Large cutting speeds, inferior feed rates and longer tool appointment times determination reason inferior grinding.
Table 4. Consequence amount of holes at dissimilar cutting limits solid carbide

| Test  | Test 1 | Test 2 | Test 3 |
|-------|--------|--------|--------|
| Spindle (rev/min) | 2387 | 3183 | 3979 |
| Cutting speed, Vc (m/min) | 15 | 20 | 25 |
| Feed per rev, v | 0.012 | 0.015 | 0.018 |
| Feed Speed (mm/min) | 29 | 48 | 72 |
| Total Holes number | 400 | 93 | 56 |

Table 5. Consequence of the dissimilar amongst first hole and last holes diameter

| Trial | Primary Hole | Past Hole |
|-------|--------------|-----------|
| Trial 1 | ![Image](image1.png) | ![Image](image2.png) |
| Trial 2 | ![Image](image3.png) | ![Image](image4.png) |
| Trial 3 | ![Image](image5.png) | ![Image](image6.png) |

3.2 Cutting tool attire progressions and tool lifetime

Figure 3 shows the stages of development of tool wear for Test Test 1. This shows that there are three areas of wear which are gradual wear, stable wear and damage to satay. This tool gradually uses in the first stage rather than using uniforms to take place before accelerating to use before resting. Test 1 produces the longest tool life of 12244 seconds at a spindle speed of 2387 rpm then a feedspeed of 29 mm / minute. Similar trends occur from the wear area also for Test 2 with the cutting parameters of the spindle speed of 3187 rpm then the feed speed of 48 mm / minute by way of illustrated in Figure above. However, Test 3 experiences significant wear progression and damage at the initial stage which can only be done . Stand for 668 seconds. The results for Test 3 show that the tool wear rate of the cutter is too fast even at that hole 10 has reached maximum plate wear which is> 0.3 mm. This shows that the cutting parameters in Test 3 are not suitable because they can increase production costs. The higher tool life obtained by Test 1 is due to the low cutting parameters which are used to be compared with Test 2 in the intermediate cutting parameters and Test 3 in the high / extreme cutting parameters.

Table 6 shows the SEM image of tool wear from the initial cutting stage to reaching maximum wing wear of 0.3 mm. The illustration is taken in three views, namely from the upper face, the end heel and the pelvic face. Wing wear can be clearly and detailed drawn after the early stage in the incident period up until it influences the disappointment area. Flank wear occurs when cutting lips
may occur because the temperature is very high where it is produced during the drilling process and accelerates the wear of plates from time to time until the tool is resistant to the highest pressure than damage to the tool. Progressive compilation of tool wear for all tests is illustrated in Figure 5.

**Figure 3.** Tool wears progression Test 1 (2387 rpm, 29 mm/min)

**Figure 4.** Test 2 (3183 rpm, 48 mm/min)
| Number of Holes | Test 1 Spindle Speed: 2387 rpm Feed Speed: 29 mm/min |
|-----------------|---------------------------------------------------------|
|                 | Upper Face | Finish Heel | Side Face |
| Original        | ![Image](image1.png) | ![Image](image2.png) | ![Image](image3.png) |
| No:10           | ![Image](image4.png) | ![Image](image5.png) | ![Image](image6.png) |
| Flank wear:     | 102.24μm   |             |           |
| No:50           | ![Image](image7.png) | ![Image](image8.png) | ![Image](image9.png) |
| Flank wear:     | 131.44μm   |             |           |
| No:100          | ![Image](image10.png) | ![Image](image11.png) | ![Image](image12.png) |
| Flank wear:     | 160.71μm   |             |           |
| No:300          | ![Image](image13.png) | ![Image](image14.png) | ![Image](image15.png) |
| Flank wear:     | 201.46μm   |             |           |
| No:400          | ![Image](image16.png) | ![Image](image17.png) | ![Image](image18.png) |
| Flank wear:     | 391.21μm   |             |           |
3.3 Kind of tool wear

According to the results of this learning, plate attire and catastrophic wear is a key tool failure once drilling titanium alloys (Ti-6Al-4V). Though, several additional wears consume remained noticed when observing using the Scanning Electron Microscope (SEM) tool which uses angles, abrasive and fractures. Using the angle Figure 6 (a) occurs it may be due to a higher cutting force on the cutting edge in contact with the sliding wall of the hole leading to the deflection of the tool in the radial direction. Abrasive uniform as illustrated in Number 6 (b) usually leads to negotiating of the tool on the time of observation after the initial fracture at the sharp end intersects Figure 6 (c). This phenomenon applies because when the cutting tool rubs additional often than cutting. Abrasion and fracture are also illustrated as the main wear mode which causes a slow drop in cutter diameter through the steady state phase of progressive tool attire [6].

Figure 6. a Angle wear b Abrasive wear c Breakage of cutting edge
4 Conclusions

1. Test 1 test illustrates the best performance of tools once drilling Ti-6Al-4V on inferior cutting parameters by a spindle speed of 2387 rpm then a feed speed of 29 mm / minute. So, smaller cutting parameters must remain used when drilling Ti-6Al-4V to realize more expected tool lifetime act.

2. In reminding the performance of cutting tools, it is required to use drilling holes in the drilling process to reduce or eliminate the heat caused by the results of solid carbides when drilling Titanium Alloy rather than direct drilling. This method can make the process of increasing the tool lifetime and can decrease the level of uniform of the tool on the cutting tool.

3. Flank wear and catastrophic disappointment is a very main tool failure method; using angles, abrasive wear then fractures were also noticed in the training.

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