

**EFFECT OF DRILL GEOMETRY OF UNCOATED TOOL WHEN  
DRILLING TITANIUM ALLOY, Ti-6Al-4V**

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## ABSTRACT

Titanium alloys are widely used in various applications such as in aerospace industry, especially in airframes and engine components due to their high strength-weight ratio that is maintained at elevated temperature and their exceptional corrosion resistance. Nevertheless, titanium and its alloys are difficult-to-machine material due to their poor thermal properties and highly chemical reactivity. In this study, Ti-6Al-4V had been drilled using different drill point geometry under various cutting speeds and feed rate. The tools are Tool A (spiral point), Tool B (3 facet) and Tool C (4 facet). The tool life, tool wear and surface roughness were analyzed under various cutting speeds and feed rates. In this study, Type C drills outperformed Type A and B drills in terms of tool life for almost all the cutting conditions tested. At the lowest cutting speed of 50 m/min and lowest feed rate, 0.05 mm/rev, Tool C demonstrated the longest tool life, which resulted in low tool wear rate. The excellent improvement of Tool C give higher tool life compared to Tool A and Tool B when drilling at higher cutting speeds. Its due to its multi-faceted geometry and web thickness. Non-uniform flank wear, chipping and catastrophic failure were the dominant failure modes of all tools under most cutting conditions tested. These failure modes were mainly associated with adhesion, diffusion and plastic deformation wear mechanisms. Based from the results obtained, it can be suggested that Type C drill was recommended and the lower cutting speed of 50 m/min should be employed in order to achieve high performance in drilling titanium alloy, Ti-6Al-4V.

## ABSTRAK

Aloi titanium telah digunakan dengan meluas di dalam pelbagai aplikasi seperti dalam industri aero-angkasa terutamanya dalam membuat kerangka pesawat dan komponen enjin disebabkan oleh nisbah diantara kekuatan-berat yang tinggi serta mampu bertahan pada suhu yang melampau dan tahan karat. Tambahan lagi, aloi titanium adalah sukar untuk dimesin kerana sifat termalnya yang lemah dan mempunyai tahap tindak balas kimia yang tinggi. Di dalam kajian ini, Ti-6Al-4V telah digerudi menggunakan mata gerudi yang berbeza jenis geometri mata gerudi pada pelbagai halaju pemotongan dan kadar suapan. Mata gerudi tersebut adalah Jenis A (“spiral point”), Jenis B (“3 facet”) dan Jenis C (“4 facet”). Jangka hayat, mod kegagalan mata alat, dan kekasaran permukaan telah dianalisa pada pelbagai halaju pemotongan dan kadar suapan. Di dalam kajian ini, gerudi Jenis C adalah lebih baik jika dibandingkan dengan Jenis A dan B dari aspek jangka hayat gerudi tersebut bagi hampir kesemua keadaan pemotongan. Pada halaju pemotongan yang terendah, 50 m/min dan juga kadar suapan yang terendah, 0.05 mm/rev, gerudi Jenis C mempamerkan jangka hayat yang paling lama dan kadar kehausan mata gerudi yang rendah. Peningkatan prestasi bagi gerudi Jenis C adalah memberikan jangka hayat paling lama berbanding dengan Jenis A dan B apabila digerudi dengan halaju pemotongan yang tinggi. Ia adalah kerana “multi-faceted” geometrid dan ketebalan web. Kehausan rusuk yang tidak seragam, sumbing, retakan dan kegagalan bencana merupakan mod kegagalan yang utama bagi semua mata alat pada hampir kesemua keadaan penggerudian. Mod-mod kegagalan ini boleh jadi berkaitan dengan rekatan, resapan dan perubahan bentuk plastik. Berdasarkan kepada keputusan yang dicerap, gerudi Jenis C telah disyorkan dengan halaju pemotongan pada 50 m/min bagi mencapai prestasi penggerudian yang optimum untuk menggerudi aloi titanium, Ti-6Al-4V.

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## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 Introduction**

Today's competitive environment has created many challenges in the development of making new materials. Lightweight materials such as titanium alloys are now used in modern aerospace structure due to their best combination of metallurgical and physical properties. Each class of titanium alloy has their advantages and disadvantages. Titanium's advantages are high strength-to-weight ratio, low density, excellent corrosion resistance, excellent erosion resistance and low modulus of elasticity.

Titanium alloys are metallic materials which contain a mixture of titanium and other chemical elements. Such alloys have very high tensile strength and toughness at extreme temperatures or low temperature, light weight, extraordinary corrosion resistance, and ability to withstand extreme temperatures. However, the high cost of both



raw materials and processing limit their use to military applications, aircraft, spacecraft, medical devices, and some premium sports equipment and consumer electronics.

The main problems of machining titanium are that the tool life is short. Permissible rate of metal removal are low, in spite of the low tool forces. It is the high temperatures and unfavourable temperature distribution in tool used to cut titanium. When machining commercially pure titanium, although the tool forces are low, the stress on the rake face is high. Furthermore, the highly stressed region near the tool edge is at a very high temperature. This is the problem that leads to deformation of the tool edge and rapid failure, with the formation of a new heat source on the deformed and worn flank. With prolong machining, failure is initiated at the nose radius of the tool (E.M. Trent and P.K Wright, 2000). So to solve this problem, the following are example general guidelines that should be followed in machining titanium alloys:

- Low cutting speeds should be used to limit cutting temperature;
- High feed rates should be maintained to avoid surface damage;
- High coolant volumes should be maintained to reduce temperatures and clear chips; and
- Dwelling of the tool against the work piece should be avoid to reduce surface damage;

## 1.2 Problem Statement

Cantero *et al.* (2005) studied the dry drilling of alloy Ti-6Al-4V using different conditions in coolant system. They concluded that temperature due to machining process is the most important magnitude affecting material damage and tool wear. As such addition the establishment of proper cutting conditions and parameters of machining operations would be an important future work when dealing with titanium alloys.

Titanium alloy are extremely difficult to machine material. So, by considering the observations of titanium microstructure, the main problems of machining titanium are that tool life is short. Permissible rate of metal removal are low, in spite of the low tool forces. It is the high temperatures and unfavourable temperature distribution to tool when used to cut titanium. The cutting condition and tool geometry are very important to cut titanium alloy to improve tool life of the cutting tool.

Selection of drilling tool and machining conditions such as cutting speeds, feed rate and coolants system are discussed in detail towards the scope and objectives that were being set up.

### 1.3 Objectives .of Study

The specific objectives of this study;

- i. To evaluate the effect of drill point geometry on the drilling performance of uncoated carbide tool when drilling Ti-6Al-4V at various of cutting parameters.
- ii. To evaluate the effect of drilling modes on the drilling performance which include tool wear, tool life and surface roughness.

### 1.4 Scope of Study

- i. Material used in this research was titanium alloy, Ti-6Al-4V.
- ii. Drilling experiments was carried out using Mazak CNC milling machine at UTHM.
- iii. Uncoated tungsten carbide drills were used which consist of 3 types; spiral point, 3 facet and 4 facet.
- iv. Cutting parameters were as follows:
  - Cutting speed of 50 m/min, 60 m/min and 70 m/min.
  - Feed rate of 0.05 mm/rev and 0.1 mm/rev.
  - Water soluble coolant.
  - The machining responses of this study were tool wear, tool life and surface roughness.
  - The types of drilling modes conducted were peck and direct drilling.

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