# PERFORMANCE EVALUATION OF UNCOATED AND COATED CARBIDE TOOLS WHEN DRILLING TITANIUM ALLOY

ERWEEN BIN ABD. RAHIM

UNIVERSITI TEKNOLOGI MALAYSIA

PSZ 19:16 (Pind. 1/97)

UNIVERSITI TEKNOLOGI MALAYSIA

# BORANG PENGESAHAN STATUS TESIS♦

JUDUL: PERFORMANCE EVALUATION OF UNCOATED AND COATED CARBIDE TOOLS WHEN DRILLING TITANIUM ALLOY

SESI PENGAJIAN: [illegible]

Saya ERWEEN BIN ABD. RAHIM
(HURUF BESAR)

mengaku membenarkan tesis (PSM/Sarjana/Doktor Falsafah)* [illegible]
Universiti Teknologi Malaysia dengan syarat-syarat [illegible]

1. Tesis adalah hakmilik Universiti Teknologi Malaysia.
2. Perpustakaan Universiti Teknologi Malaysia dibenarkan [illegible] pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis [illegible] institusi pengajian tinggi.
4. **Sila tandakan (✓)

| | | |
|---|---|---|
| ☐ | SULIT | (Mengandungi maklumat [illegible] Kepentingan Malaysia [illegible] AKTA RAHSIA RASMI 1972) |
| ☐ | TERHAD | (Mengandungi maklumat TERHAD [illegible] oleh organisasi/badan [illegible]) |
| ✓ | TIDAK TERHAD | |

(TANDATANGAN PENULIS) (TANDATANGAN PENYELIA)

Alamat Tetap:
FAKULTI KEJ. MEKANIKAL & PEMBUATAN, KUITTHO, 86400 BATU PAHAT, JOHOR

PM. DR. SAFIAN SHARIF

Tarikh: [illegible] Tarikh: [illegible]

"We hereby declare that we have read this thesis and in our opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Master of Engineering (Mechanical)"

Signature : 

Name of Supervisor I : Assoc. Prof. Dr. Safian Sharif

Date : 5/9/05

Signature : 

Name of Supervisor II : Assoc. Prof. Zainal Abidin bin Ahmad

Date : 5/9/05

**BAHAGIAN A – Pengesahan Kerjasama***

Adalah disahkan bahawa projek penyelidikan tesis in telah dilaksanakan melalui kerjasama antara____________________dengan______________________________

Disahkan oleh:

Tandatangan : .............................................. Tarikh : ..................

Nama : ..............................................

Jawatan : ..............................................
(Cop rasmi)

* *Jika penyediaan tesis/projek melibatkan kerjasama.*

---

**BAHAGIAN B – Untuk Kegunaan Pejabat Sekolah Pengajian Siswazah**

Tesis ini telah diperiksa dan diakui oleh:

Nama dan Alamat
Pemeriksa Luar :**Prof. Madya Dr. Wan Mansor Bin Wan Muhammad**
Fakulti of Mechanical Engineering
University of College of Engineering & Technology
Malaysia, 25200 Kuantan, Malaysia

Nama dan Alamat
Pemeriksa Dalam :**Prof. Madya Hamidon Bin Musa**
Fakulti Kejuruteraan Mekanikal
Universiti Teknologi Malaysia, Skudai, Johor

Nama Penyelia Lain (jika ada) :

Disahkan oleh Penolong Pendaftar di SPS:

Tandatangan : .......................................... Tarikh : ..................

Nama : ..........................................

# PERFORMANCE EVALUATION OF UNCOATED AND COATED CARBIDE TOOLS WHEN DRILLING TITANIUM ALLOY

ERWEEN BIN ABD. RAHIM

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Engineering (Mechanical)

Faculty of Mechanical Engineering
Universiti Teknologi Malaysia

SEPTEMBER 2005

"I declare that this thesis entitled *"Performance Evaluation of Uncoated and Coated Carbide Tools When Drilling Titanium Alloy"* is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any degree"

Signature : ...................................................

Name of Candidate : ERWEEN BIN ABD. RAHIM

Date : 5/9/05

# ACKNOWLEDGEMENT

**In the name of Allah, the most Gracious and most Compassionate**

The author would like to thank Allah Almighty for blessing and giving me strength to accomplish this thesis. The author would like to acknowledge Assoc. Prof. Dr. Safian Sharif and Assoc. Prof. Zainal Abidin Ahmad for their guidance, help and relentless encouragement. Many of my accomplishments would not have been realized without his dedication to hard work. The author is also grateful to Kolej Universiti Teknologi Tun Hussein Onn for providing the financial assistant to the author throughout the study.

Special thank and appreciations goes to all the friends and technicians in Production Laboratory, Machine Shop and Material Laboratory, Faculty of Mechanical Engineering for their help at various occasions. In particular, thanks to Mr. Amrifan for his help and useful discussion.

My warmest thanks go to my parent and parent-in-law for their support. My highest appreciation goes to my wife and my son for their unconditional support and love that continuously fed my strength desire to succeed.

## ABSTRACT

Titanium alloys are widely used in the 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 thought to be difficult-to-machine material due to their poor thermal properties and highly chemical reactivity. In this study, Ti-6Al-4V has been drilled using single-layer PVD-HIS-TiAlN coated carbide, Type A (T12-A) and Type C (T12-C and T13-C), multi-layer PVD-HIS-Supernitride coated carbide, Type A (S13-A) and Type C (S12-C and S13-C) and uncoated carbide Type B (U12-B and U13-B) and Type C (U12-C and U13-C) drills with different drill point geometry under various cutting speeds and constant feed rate. The tool performance, tool failure modes and tool wear mechanisms were analyzed under various cutting speeds. On the other hand, the cutting forces and the surface roughness were measured. 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 low cutting speed of 25 m/min, the uncoated carbide tool of U12-C drills demonstrated the longest tool life, which resulted in low tool wear rate. The excellent improvement of both coated drills were mainly due to their ability of maintaining oxidation resistance and high hardness especially at elevated temperatures. On the other hand, poor performance of Type B drills was mainly due to premature tool failure caused by severe chipping and breakage. Non-uniform flank wear, chipping, cracking 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 25 m/min should be employed in order to achieve high performance in drilling Ti-64.

# ABSTRAK

Aloi titanium telah digunakan dengan meluas di dalam industri aero-angkasa untuk 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 mempunya tahap tindak balas kimia yang tinggi. Di dalam kajian ini, Ti-6Al-4V telah digerudi menggunakan gerudi disalut selapis TiAlN pada karbida, Jenis A (T12-A) dan Jenis C (T12-C dan T13-C), disalut berlapis-lapis Supernitride pada karbida, Jenis A (S13-A) dan Jenis C (S12-C dan S13-C) dan karbida tanpa disalut, Jenis B (U12-B dan U13-B) dan Jenis C (U12-C dan U13-C) pada pelbagai halaju pemotongan dan kadar suapan malar. Prestasi mata gerudi, mod kegagalan mata alat, dan mekanisma kehausan mata alat telah dianalisa pada keadaan penggerudian yang basah. Daya pemotongan dan kekasaran permukaan pada dinding lubang juga telah diukur. 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 25 m/min, gerudi karbida tanpa disalut, U12-C mempamerkan jangka hayat yang lama dan kadar kehausan mata gerudi yang rendah. Peningkatan prestasi bagi gerudi karbida yang disalut adalah disebabkan oleh keupayaan gerudi tersebut untuk menangani pengoksidaan dan mempunyai kekerasan yang tinggi pada suhu yang melampau. Prestasi yang buruk ditunjukkan oleh gerudi Jenis B adalah kerana kegagalan pra-matang disebabkan oleh sumbing yang ketara dan mata alat patah. 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 25 m/min bagi mencapai prestasi penggerudian yang optimum untuk menggerudi Ti-6Al-4V.

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

## LIST OF SYMBOLS

| | | |
|---|---|---|
| $\alpha$ | - | Tool rake angle |
| $b$ | - | Width of cut |
| $\beta$ | - | Friction angle |
| $C_T$ | - | Chisel edge wear (depth) |
| $C_M$ | - | Chisel edge wear (width) |
| 2d | - | Drill diameter |
| $F_f$ | - | Component of parallel frictional force |
| $F_p$ | - | Component of horizontal force |
| $F_s$ | - | Component of horizontal shear force |
| $F_t$ | - | Component of vertical force |
| $i$ | - | Inclination angle |
| $K_M$ | - | Crater wear |
| $L$ | - | Lead length of the helix |
| $M_w$ | - | Margin wear |
| $N_f$ | - | Component of normal frictional force |
| $N_s$ | - | Component of normal shear force |
| $P_M$ | - | Chipping (width) |
| $P_T$ | - | Chipping (depth) |
| 2p | - | Drill point angle |
| $R_a$ | - | Arithmetical mean deviation |
| $R_{max}$ | - | Maximum height of the profile |
| $R_z$ | - | Height of the profile irregularities in ten points |
| $r$ | - | Drill radius |
| $t_c$ | - | Undeformed chip thickness |
| $V_b$ | - | Flank wear |