

http://www.qir-ftui.com

NTERNATIONAL CONFERENCE ALITY in RESEARCH (QiR)

Justrial, Material Engineering, emerilahagement OL II

Depok, 6 - 7 September 2006



JNIVERSITY OF INDONESIA ACULTY OF ENGINEERING

FOREWORDS from

Dean of Faculty of Engineering, University of Indonesia

The Conference on Quality in Research (QIR) is annual event organized by the Faculty of Engineering, University of Indonesia. Since started in 1998, it has become an excellent forum of discussion for all researchers from research institutions and universities all over the country of Indonesia. The 1st and 6th conference on QIR had been successfully organized as a high quality national conferences, and starting from 7th conference on QIR, the conference has been organized to invite presentations of research papers internationally.

The 9th International Conference on Quality in Research having a theme of "Gaining Competitive Advantages Through Engineering Research" is to provide an international forum for exchange of the knowledge, information, experience and results as well as the review of progress and discussion on the state of the art and future trend various issues and developments in the multifield of scientific and technology. The main purposes of this conference are to provide a forum for free discussion of new ideas, development and applications, including techniques and methods to stimulate and inspire pioneering work, to provide a meeting that will enforce progress, stimulate growth and advance the state of knowledge in the multifield of science and technology.

We would like to express our heartiest to thank to all authors and participants for their active participations in the 9th International Conference on Quality in Research – QIR 2006, and also to all the paper reviewers, member of the technical committees, and member of the organizing committees, for their support to the success of this conference. Last but not least, we would also like to invite all participants to the next conference on Quality in Research – QIR 2007.

Faculty of Engineering, University of Indonesia Dean.

Rinaldy Dalimi, Ph.D

Yanvar Abu Fairuz

FOREWORDS

The 9th International Conference on Quality in Research (QIR) having a theme of "Gaining Competitive Advantages Through Engineering Research" being the third time to go internationally, has invited limited papers from other country like Japan and Malaysia. The conference is organized in parallel session focusing on the 6 (six) research areas such that many researchers and peer groups may focus their discussion on the relevant topics. All submitted papers had been reviewed by the technical committees appointed and had been arranged in to 6 (six) sub-themes according to the following fields:

- Energy, Process and Environmental Engineering and Management

Energy and environmental issues, combustion technology, fluid mechanics and thermal fluid machinery, thermodynamics and heat transfer, geotechnical and environmental engineering, etc

- Industrial, Manufacturing, Material Engineering, and Management Production Engineering, Supply Chain Management, Innovation System, Maintenance System, Quality Management System, Human Factors Engineering, Organizational System, Fabrication and Industrial Automation, Manufacturing System: Control Management and Information Technology, CAD/CAM/CIM, etc

- Biomaterial, Biomedical Engineering and Biotechnology Biomedical numerical modeling, Biomaterial, Biosensor, Biocompatibility, Biomechanics, Biotechnology, Biomedical Instrumentation, Biomedical Imaging
- Design and Infrastructure Engineering and Management Product design and development, composite: materials and applications, structural dynamics, mechanics of materials, Construction Management, Public Infrastructures and Services, Structural Engineering, etc
- Information and Computation Engineering
- Nanotechnology

Nano structured material, Nanotechnology, Nanocomposite, Nanoporous Materials, MEMS, Self Assembled Monolayer, Thin Film, Nanomagnetic Materials, Etc

The main purposes of this conference are to provide a forum for free discussion of new ideas, development and applications, including techniques and methods to stimulate and inspire pioneering work, to provide opportunities for students and young engineers to meet their experienced peer and to provide a meeting that will enforce progress, stimulate growth and advance the state of knowledge in the multifield of science and technology.

The Organizing Committee, Chairman,

Gunawan Wibisono, Ph.D

LIST OF CONTENTS

FOREWORDS from Dean of Faculty of Engineering - University of Indonesia FOREWORDS from Chairman of 9th International Conference on Quality in Research List of Contents The Committee of 9th International Conference on Quality in Research Keynote Speech : How can we control the electronic structures of condensed materials? - An approach from energy dissipation processes - by: M. Mabuchi, M. Yamaguchi, Y. Hailong, K. Obara Keynote Speech : The Application of High Power Lasers in Surface Modification of Titanium I - 6 by: Shahjahan Mridha Industrial, Manufacturing, Material Engineering and Management Investigation of Optimum Cutting Condition when End Milling Titanium Alloy TI-6AI- Vy: S.S. Mohruni, S. Sharif, M.Y. Noerdin, V.C. Venkatesh The Effect of Composition Variation of LTP on a Quenched Windows Glasses Istudy on Graphite Composite as Bipolar Plate Influenced by Temperature Setting by: Andi Suhandi, Nanik Indayaningah, Bambang Prihandoko, Perdamen Sebayang Recognition of Molten Pool during Aluminum Pipe TIG Welding using Vison Sensor IMM 05 / Synthesis and Characterization of TiO2 Added-ZnFe2O4 Ceramics for NTC Thermistors by: Dani Gustaman Syarif, Wiendartun, Mimin Sukamin Using Graded Channel MOSFET as IR Det	
FOREWORDS from Chairman of 9th International Conference on Quality in Research List of Contents The Committee of 9th International Conference on Quality in Research Keynote Speech : How can we control the electronic structures of condensed materials? - An approach from energy dissipation processes - by: M. Mabuchi, M. Yamaguchi, Y. Hailong, K. Obara Keynote Speech : The Application of High Power Lasers in Surface Modification of Titanium Industrial, Manufacturing, Material Engineering and Management Investigation of Optimum Cutting Condition when End Milling Titanium Alloy TI-6Al- V Vp: A.S. Mohuni, S. Shaif, M.Y. Noordin, V.C. Venkatesh The Effect of Composition Variation of LTP on a Quenched Windows Glasses IMM 027 by: And Suhandi, Nanik Indayaningsh, Bambang Prihandoko, Purdamean Sebayang Recognition of Molten Pool during Aluminum Pipe TIG Welding using Vison Sensor by: Anal Suhand, Nanik Indayaningsh, Bambang Prihandoko, Purdamean Sebayang Stress Analysis on Chasis Structure of Hybrid Vehicle Using Finite Element Method by: Anal Suhard Agus Fahan Synthesis and Characterization of TiO2 Added-ZnFe2O4 Ceramics for NTC Imeristics by: Bani Gustaman Synth, Wiendaruun, Mirnin Sukarmin Using Graded Channel MOSFET as I	
List of Contents The Committee of 9th International Conference on Quality in Research Keynote Speech: How can we control the electronic structures of condensed materials? - An approach from energy dissipation processes - by: Mabuchi, M. Yamaguchi, Y. Hailong, K. Obara Keynote Speech: International Conference Modification of Titanium I - 6 by: Shahjahan Mridha Industrial, Manufacturing, Material Engineering and Management Investigation of Optimum Cuiting Condition when End Milling Titanium Alloy Ti-6Al- 4V by: A.S. Mohruni, S. Sharif, M.Y. Noordin, V.C. Venkatesh The Effect of Composition Variation of LTP on a Quenched Windows Glasses IMM 02 / by: Bambang Prihandoko, Priyo Sardjono, Anne Zulfa dan Eddy Siredj Study on Graphite Composite as Bipolar Plate Influenced by Temperature Setting by: Andi Suhandi, Nanik Indayaningsih, Bambang Prihandoko, Purdamean Sebayang Recognition of Molten Pool during Aluminum Pipe TIG Welding using Vison Sensor IMM 04 / by: Anio Sunar Baskoro, Yasuo Suga IMM 05 / Stress Analysis on Chasis Structure of Hybrid Vehicle Using Finite Element Method by: Danardono A.S, Muhamad Agus Farhan Synthesis and Characterization of TiO2 Added-ZnFe2O4 Ceramics for NTC Thermistors by: Dani Gustaman Syarif, Wiendartun, Mimin Sukarmin Using Graded Channel MOSFET as IR Detector	
The Committee of 9th International Conference on Quality in Research Keynote Speech : How can we control the electronic structures of condensed materials? - An approach from energy dissipation processes - by: M. Mabuchi, M. Yamaguchi, Y. Hailong, K. Obara Keynote Speech : The Application of High Power Lasers in Surface Modification of Titanium by: Shahjahan Midha Industrial, Manufacturing, Material Engineering and Management Investigation of Optimum Cutting Condition when End Milling Titanium Alloy Ti-6Al- 4V ty: A.S. Mohruni, S. Sharif, M.Y. Noordin, V.C. Venkatesh The Effect of Composition Variation of LTP on a Quenched Windows Glasses IMM 02 / by: Andi Suhandi, Nanik Indayaningsih, Bambang Prihandoko, Purdamean Sebayang Recognition of Molten Pool during Aluminum Pipe TIG Welding using Vison Sensor IMM 05 / by: Ania Suhand Agus Farhan Stress Analysis on Chasis Structure of Hybrid Vehicle Using Finite Element Method by: Danidous A.S. Muhamad Agus Farhan Synthesis and Characterization of TiO2 Added-ZnFe2O4 Ceramics for NTC Thermistors by: Danid Gustaman Syarif, Wiendartun, Mirnin Sukarmin Using Graded Channel MOSFET as IR Detector	
Keynote Speech : 1 - 5 How can we control the electronic structures of condensed materials? 1 - 5 - An approach from energy dissipation processes - by: M. Mabuchi, M. Yamaguchi, Y. Hailong, K. Obara Keynote Speech : 1 - 6 The Application of High Power Lasers in Surface Modification of Titanium 1 - 6 by: Shahjahan Mridha 1 - 6 Industrial, Manufacturing, Material Engineering and Management Inwestigation of Optimum Cutting Condition when End Milling Titanium Alloy Ti-6Al- Investigation of Optimum Cutting Condition when End Milling Titanium Alloy Ti-6Al- IMM 01 / 4V by: A.S. Mohruni, S. Sharif, M.Y. Noordin, V.C. Venkatesh IMM 02 / by: Bambang Prihandoko, Prive Sardjono, Anne Zulfia dan Eddy Siradj Study on Graphite Composite as Bipolar Plate Influenced by Temperature Setting by: Andi Suhandi, Nanik Indayaningsih, Bambang Prihandoko, Perdamean Sebayang IMM 03 / by: Andi Suhandi, Nanik Indayaningsih, Bambang Prihandoko, Perdamean Sebayang Recognition of Molten Pool during Aluminum Pipe TIG Welding using Vison Sensor IMM 04 / by: Danardono A.S, Muhamad Agus Farhan Synthesis and Characterization of TiO2 Added-ZnFe2O4 Ceramics for NTC IMM 06 / Thermistors by: Dani Gustaman Syanf, Wiendartun, Mimin Sukarmin Using Graded Channel MOSFET as IR Detector IMM 07 / by: Hartono Siswono	
Keynote Speech : 1 - 6 The Application of High Power Lasers in Surface Modification of Titanium 1 - 6 by : Shahjahan Mridha 1 - 6 Industrial, Manufacturing, Material Engineering and Management IMM 01 / 4V Investigation of Optimum Cutting Condition when End Milling Titanium Alloy Ti-6Al- IMM 01 / 4V by : A.S. Mohruni, S. Sharif, M.Y. Noordin, V.C. Venkatesh IMM 02 / by : Barnbang Prihandoko, Priye Sardjono, Anne Zulfa dan Eddy Siredj Study on Graphite Composite as Bipolar Piate Influenced by Temperature Setting by : Andi Suhandi, Nanik Indayaningsih, Bambang Prihandoko, Purdamean Sebayang IMM 03 / by : Andi Suhandi, Nanik Indayaningsih, Bambang Prihandoko, Purdamean Sebayang Recognition of Molten Pool during Aluminum Pipe TIG Welding using Vison Sensor IMM 04 / by : Danardono A.S, Muhamad Agus Farhan Synthesis and Characterization of TiO2 Added-ZnFe2O4 Ceramics for NTC IMM 06 / Thermistors by : Dani Gustaman Syarif, Wiendartun, Mimin Sukarmin Using Graded Channel MOSFET as IR Detector IMM 07 / by : Hatrono Siswono	r St
Industrial, Manufacturing, Material Engineering and Management Investigation of Optimum Cutting Condition when End Milling Titanium Alloy Ti-6A!- 4V IMM 01 / 4V by: A.S. Mohruni, S. Sharif, M.Y. Noordin, V.C. Venkatesh IMM 02 / 50 (2000) The Effect of Composition Variation of LTP on a Quenched Windows Glasses IMM 02 / 50 (2000) by: Barnbang Prihandoko, Priyo Sardjono, Anne Zulfia dan Eddy Siradj IMM 03 / 50 (2000) Study on Graphite Composite as Bipolar Plate influenced by Temperature Setting by: Andi Suhandi, Nanik Indayaningsih, Bambang Prihandoko, Purdamean Sebayang IMM 03 / 50 (2000) Recognition of Molten Pool during Aluminum Pipe TIG Welding using Vison Sensor IMM 04 / 50 (2000) Stress Analysis on Chasis Structure of Hybrid Vehicle Using Finite Element Method by: Danardono A.S, Muhamad Agus Farhan Synthesis and Characterization of TiO2 Added-ZnFe2O4 Ceramics for NTC IMM 06 / 1MM 06 / 1MM 06 / 1MM 07 / 50 (2000) Using Graded Channel MOSFET as IR Detector by: Hatono Siswono IMM 07 / 1000 (2000)	
Investigation of Optimum Cutting Condition when End Milling Titanium Alloy Ti-6A!- 4V by : A.S. Mohruni, S. Sharif, M.Y. Noordin, V.C. VenkateshIMM 01 / 4VThe Effect of Composition Variation of LTP on a Quenched Windows Glasses by : Bambang Prihandoko, Priyo Sardjono, Anne Zulfia dan Eddy SiredjIMM 02 / by : Bambang Prihandoko, Priyo Sardjono, Anne Zulfia dan Eddy SiredjStudy on Graphite Composite as Bipolar Plate influenced by Temperature Setting by : Andi Suhandi, Nanik Indayaningsh, Bambang Prihandoko, Purdamean SebayangIMM 03 / by : Andi Suhandi, Nanik Indayaningsh, Bambang Prihandoko, Purdamean SebayangRecognition of Molten Pool during Aluminum Pipe TIG Welding using Vison Sensor by : Anio Sunar Baskoro, Yasuo SugaIMM 05 / IMM 05 / IMM 05 / stress Analysis on Chasis Structure of Hybrid Vehicle Using Finite Element Method by : Danardono A.S, Muhamad Agus Farhan Synthesis and Characterization of TiO2 Added-ZnFe2O4 Ceramics for NTC Thermistors by : Dani Gustaman Syarif, Wiendartun, Mimin SukarminIMM 07 / imm 07 / 	
The Effect of Composition Variation of LTP on a Quenched Windows Glasses by: Bambang Prihandoko, Priyo Sardjono, Anne Zulfia dan Eddy SiradjIMM 02 /Study on Graphite Composite as Bipolar Plate Influenced by Temperature Setting by: Andi Suhandi, Nanik Indayaningsih, Bambang Prihandoko, Purdamean SebayangIMM 03 /Recognition of Molten Pool during Aluminum Pipe TIG Welding using Vison Sensor by: Ario Sunar Baskoro, Yasuo SugaIMM 04 /Stress Analysis on Chasis Structure of Hybrid Vehicle Using Finite Element Method by: Danardono A.S, Muhamad Agus Farhan Synthesis and Characterization of TiO2 Added-ZnFe2O4 Ceramics for NTC Thermistors by: Dani Gustaman Syarif, Wiendartun, Mimin SukarminIMM 07 /Using Graded Channel MOSFET as IR Detector by: Hartono SiswonoIMM 07 /	- 4
Study on Graphite Composite as Bipolar Piate Influenced by Temperature Setting IMM 03 / by : Andi Suhandi, Nanik Indayaningsih, Bambang Prihandoko, Perdamean Sebayang IMM 04 / Recognition of Molten Pool during Aluminum Pipe TIG Welding using Vison Sensor IMM 04 / by : Ario Sunar Baskoro, Yasuo Suga IMM 05 / Stress Analysis on Chasis Structure of Hybrid Vehicle Using Finite Element Method IMM 05 / by : Danardono A.S, Muhamad Agus Farhan IMM 06 / Synthesis and Characterization of TiO2 Added-ZnFe2O4 Ceramics for NTC IMM 06 / Thermistors by : Dani Gustaman Syarif, Wiendartun, Mimin Sukarmin IMM 07 / Using Graded Channel MOSFET as IR Detector IMM 07 / by : Hartono Siswono IMM 07 /	- 5
Recognition of Molten Pool during Aluminum Pipe TIG Welding using Vison Sensor IMM 04 / by : Ario Sunar Baskoro, Yasuo Suga IMM 05 / Stress Analysis on Chasis Structure of Hybrid Vehicle Using Finite Element Method IMM 05 / by : Danardono A.S, Muhamad Agus Farhan IMM 06 / Synthesis and Characterization of TiO2 Added-ZnFe2O4 Ceramics for NTC IMM 06 / Thermistors by : Dani Gustaman Syarif, Wiendartun, Mimin Sukarmin Using Graded Channel MOSFET as IR Detector IMM 07 / by : Hartono Siswono IMM 07 /	- 4
IMM 05 / Stress Analysis on Chasis Structure of Hybrid Vehicle Using Finite Element Method by : Danardono A.S, Muhamad Agus Farhan Synthesis and Characterization of TiO2 Added-ZnFe2O4 Ceramics for NTC Thermistors by : Dani Gustaman Syarif, Wiendartun, Mimin Sukarmin Using Graded Channel MOSFET as IR Detector by : Hartono Siswono	- 5
by : Danardono A.S., Muhamad Agus Farhan Synthesis and Characterization of TiO2 Added-ZnFe2O4 Ceramics for NTC Thermistors by : Dani Gustaman Syarif, Wiendartun, Mimin Sukarmin Using Graded Channel MOSFET as IR Detector by : Hartono Siswono	- 5
Using Graded Channel MOSFET as IR Detector IMM 07 /	- 5
Using Graded Channel MOSFET as IR Detector IMM 07 / by : Hartono Siswono	
	- 5
Feedback Active Engine Mounting Control Algorithm Using PD Controller IMM 087	- 5
Development of High-Temperature Materials Fe-Al Based Alloys by Using Powder IMM 097 Metallurgy	- 5
The Development of Spline Generator Algorithm Based on CI -Curve for 5-Axis	- 4

The Development of Spline Generator Algorithm Based on CL-Curve for 5-Axis ^{by}: G. Kiswanto, Christiand

LIST OF CONTENTS

	Page :
Energy Consumption for Electromechanical by : Houtman P. Siregar	IMM 11 / 1 - {
Characterization Isocyanate and Polyol Mix for Polymer Polyurethane Sole by Cup Test and Drop Test Method by : Sibut	IMM 12 / 1 - 4
Mechanical Properties of Recycled PET/HDPE Composite by : I. H. Sahputra	IMM 13 / 1 - :
An Examination of Accuracy Laser And Glass Scale Measuring System by Investigation of Error On The Computer Numerical Control (CNC) Machine by I Kade Wiratama	IMM 14 / 1- 5
The Effect of Compaction Variable On The Modulus Young Of The Composite Al- SiC	IMM 15 / 1 - !
by : Mochamad Zainun, Dedi Phadi, Anne Zunia, Sutopo, Darminto	*
New Approaching in Neutron Absorption on ThxSr2O1.8 Micro Structure with Quantum Dot at Magnetic Quadrupole Enhancement	IMM 16 / 1 - '
by : Moh. Hardiyanto	
Trimaran Fishing Vesel With Seawater Filled Fish Holds	IMM 17 / 1 - :
by : Sunaryo	
Al-Fe Coating on Iron by Mechanical Alloying by : Agus S.W, Suryadi, Agus D, Alfian N, Hubby I, Endang S, Wahyu B.W, Dody W, Nurul T. R.	IMM 18 / 1 - (
Development of Active Power Filter for Power System by : Mr S.Abubakar, M.M.Rashid and Nasruddin AR	IMM 19 / 1 - 4
The rate of the precious group metals from automotive catalyst residue leaching reaction by using NaClO-HCI-H2O2 solution by Sri Harjanto, Yucai Cao, Atsushi Shibayama	IMM 20 / 1 - 4
Identification of Particle shape A!, SiC and Al2O3 According Anisometry and Bulkiness Value by : Widyastuti, Anne Z, Dedi P, Johny W.S, Eddy S. Siradj	IMM 21 / 1 - (·
Structural Characterization of MIG Welded Ateel AISI 1045 after Carbon Nitriding Process by : Winarto	IMM 22 / 1 - {
Castor Oil as an Alternative Base Oil for Heavy Duty Lubricant by : Budiarso, Yanuar, Edbert Andree, Handoko Utama	IMM 23 / 1 - ;
Effects of Cutting Conditions and Chip Formation in Titanium Alloy Machining by : Y. Burhanuddin, C.H. Che Haronw, J.A. Ghani, G.A. Ibrahim, S. Junaidi	IMM 24 / 1 - (
Modification of Microstructure of Low Pressure Die Casting AC4B Alloy by Addition of 0.015 wt. % Sr by : Bondan T. Sofyan, Ragil E. Susanto and Thomas M. Parapat	IMM 25 / 1 - !
A Linear Induction Motor Parameter Determination Method	IMM 26 / 1 - /

HALAMAN PENGESAHAN

Terdaftar di Lembaga Penelitian Universitas LampungNo.//2009Tanggal://2009

Judul

: Effects of Cutting Conditions and Chip Formation in Titanium Allov Machining.

Prosiding

Alloy Machining. : Proceeding of The 9th International Conference on Quality Research, Vol. II: Industrial, Manufacturing, Material

Engineering and Management, Depok, Indonesia, 2007.

Penulis NIP Pangkat/Golongan Jabatan

: Yanuar Burhanuddin : 19640506 200003 10001 1 : Penata Tk. I/IIIa : Asisten Ahli

Bandar Lampung,31 Desember 2009



Ketua Jurusan Teknik Mesin

Dr. Asnawi Lubis NIP 19700412 199703 1006



PERNYATAAN

Saya yang bertanda tangan di bawah ini:

Nama NIP Fakultas/Jurusan Institusi Alamat Telepon/Fax : Ir. Yanuar Burhanuddin, M.T.
: 19640506 200003 20001 1
: Teknik/Teknik Mesin
: Universitas Lampung
: Jl. Soemantri Brodjonegoro No. 1
: 0721-704947

Dengan ini menyatakan sebenarnya bahwa artikel saya yang berjudul: "Effects of Cutting Conditions and Chip Formation in Titanium Alloy Machining" adalah benar telah terbit pada Proceeding of The 9th International Conference on Quality Research, Vol. II: Industrial, Manufacturing, Material Engineering and Management, Depok, Indonesia, 2007.

Dalam artikel Prosiding ini, saya sebagai penulis ke satu. Demikian surat pernyataan ini saya buat dengan sebenarnya

Bandar Lampung, 31 Desember 2009

Ir. Yanuar Burhanuddin, M.T. NIP 19640506 200003 J001 1

Effects of Cutting Conditions and Chip Formation in Titanium Alloy Machining

Y. Burhanuddin, C.H. Che Haron[•], J.A. Ghani, G.A. Ibrahim, S. Junaidi Deparment of Mechanical and Material Engineering Universiti Kebangsaan Malaysia 43600 Bangi, Selangor, Malaysia

Abstract--Tool life is the one of the most important arameters in the machining research area. Most esearchers have dealt the effect of cutting variables on tool fe by the one-variable-at-a-time method. This approach eeds a separate set of tests for each combination of cutting ondition and cutting tool. The approach required large mount of cost and cannot consider the combined effect of utting conditions on response. The purpose of this research ; to develop tool life model which take into account the ombined effect of cutting variables (cutting speed, feed rate, nd depth of cut) by using design of experiment. The effects f cutting variables are investigated by the application of actorial design method. The first-order of tool life model are enerated. The cutting tests are conducted using Cubic foron Nitride (CBN) as cutting too! when turning of itanium in dry cutting condition.

Keyword-tool life, fractional factorial, CBN, dry urning, titanium 6A1-4V

I. INTRODUCTION

Titanium and titanium alloy products is used mainly n the aerospace industry due to the exceptional strengtho-weight ratio, elevated temperature performance and orrosion resistance. The applications of titanium are nostly in jet engine and airframe components where those re subjected to temperatures up to 600°C and for other ritical structural parts. The usage is widespread in both commercial and military aircrafts. Titanium alloys fall nto four major groups, classified by their alloying elements and microstructures: pure titanium, alpha, alpha beta and beta phases. The most commonly used alloys are the alpha-beta group. Titanium 6Al-4V, member of this group, comprises more than 50 percent of all titanium alloys used today.

Titanium alloys has some certain characteristics that limits on its machinability. Some of these are given as follows: low thermal conductivity, chemical reactivity with the cutting tools materials at tool operating temperatures, a relatively low modulus of elasticity. Due to those characteristics, titanium has been generally turned with uncoated carbide, CBN/PCBN and Poly Crystalline Diamond (PCD). Uncoated carbide tools are suitable at low speed machining conditions while CBN/PCBN are employed at high speed machining (Che Haron 2001,Ezugwu et al 2003).

Machinability data of titanium is usually acquired from the experimental studies. For saving the time and cost, the experimenters used statistical design of experiment. Statistical design of experiment is the process of planning the experiments so that the appropriate data should be collected which may be analysed by statistical methods resulting in valid and objective conclusions (Montgomery 1991). Statistical design of experiment will produced the data uniformity and reduces the total number of experiments.

The objective of the study is to establish the tool life model of CBN cutting when turning Titanium 6AI-4V. It is necessary to employ theoretical models making it feasible to do predictions in function of operation conditions such as spindle speed, feed rate, cutting depth, tool geometry and so on. The study will investigate the wear progression, the failure mode of cutting tool and the significant factors that affect the CBN tool life.

II. RESEARCH METHODOLOGY

A. DESIGN OF EXPERIMENTS

The present study takes into account the simultaneous variation of speed, feed, depth of cut and CBN contents as variables. The result will produce the tool life as a response. Factorial designs are used widely in experiments involving several factors where it is necessary to study the combined effect of these factors on responses. The meaning of factorial design is that each complete trial or replication of all the possible combinations of the levels of the factors is investigated.

^{*} Corresponding author: Tel.:(60)3-8921 6516; E-mail:chase@vlsi.eng.ukm.my

9th Int'l QIR Proceeding, 6-7 Sept 2006

The proposed relationship between the machining responses (tool life, cutting forces) and machining independent variables can be represented by the following:

$$T = C(V^w f^y d^x) \tag{1}$$

where T is the tool life in minutes, V, f, and d are the cutting speeds (m/min), feed rates (mm/rev), and depths of cut (mm) respectively, and C, /, m, n are constants. Eq. (1) can be written in the following logarithmic form:

$$\ln T = \ln C + l \ln V + m \ln f + n \ln d \tag{2}$$

The first-order model can be expressed as:

$$y = b_0 x_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 \tag{3}$$

where y is the measured tool life to a logarithmic scale, $x_0 = 1$ (dummy variable), $x_1 = \ln V$, $x_2 = \ln f$, $x_3 =$ In d, $b_0 = \ln C$, and b_1 , b_2 and b_3 are the model parameters. In the present study, the parameters of Equation (3) will be estimated by using a computer package. To develop the first-order model, 2^{4-1} partial factorial design will be used. A design consisting of 8 experiments was conducted.

 TABLE 1

 LEVEL DESIGNATION OF DIFFERENT PROCESS VARIABLES

Level	V (m/min)	F (mm/rev)	D (mm)	CBN content
-1 (Low)	180	0.05	0.1	Low
l (High)	300	0.25	1.00	High

B. Work piece material, Machine and cutting inserts

A 150 mm diameter x 300 mm long bar of Titanium 6AI-4V was used for the tests. The machining tests were carried out on a Cincinnati Avenger 200T CNC lathe. A MCLNR 2020K09 tool holder was used to provide an 85° cutting edge angle and - 5° rake angles. The cutting tools used were Kennametal grade KD050 and KD081 designated CNGA 120408S1020, in order to investigate the influence of CBN content. All of the experiments were conducted in dry condition. Depending on the cutting condition and wear rate, machining was stopped at various interval of time varying from 5 sec to 1 min to record the wear of the insert. Flank wear was considered as the criteria of tool failure and the wear was measured using a Mitutoyo toolmaker's microscope. The machining was stopped when an average flank wear was greater than 0.30 mm or fracturing happened.

III. RESULTS AND DISCUSSIONS

A. Statistical Analysis

Table 2 shows the experimental conditions together with the measured tool life values. The results were transformed to half-normal probability plot as in Figure 1. The figure shows the factors (depth of cut, cutting speed, feed rate) and the interaction (cutting speed-cutting depth), which may have an effect to cutting tool life.

Then, analysis of variance (ANOVA) was applied to calculate the main effects of cutting speed (V), feed rate (f), depth of cut (d), and CBN content together with their two-level interaction effects on tool life. The ANOVA output and the calculated F ratios are shown in Table 3 for each significant effect.

The 5 per cent level for testing the significance of the main effects and the interaction was used. Table 3 shows that depth of cut is most significant, and followed by cutting speed and cutting speed-depth of cut interaction. Feed rate is not significant because its "Prob > F" values greater than 0.1. Even if the feed rate has a greater value than 0.1, this term will not be neglected in order to take into account the feed rate contribution to tool life. While the CBN content does not have any effect to tool life absolutely.

TABLE 2 EXPERIMENTAL CONDITIONS AND RESULTS

		Facto		Tool	
Run	Cutting speed (m/min)	Feed rate (mm/rev)	Cutting depth (mm)	CBN content	life (sec)
	А	В	С	D	
1	300	0.05	1.0	Low	40
2	180	0.05	0.1	Low	1740
3	180	0.25	0.1	High	820
4	300	0.25	0.1	Low	130
5	180	0.05	1.0	High	150
6	180	0.25	1.0	Low	10
7	300	0.05	0.1	High	420
8	300	0.25	1.0	High	10

9th Int'l QIR Proceeding, 6-7 Sept 2006



Fig. 1 Half normal % probability plot

 TABLE 3

 ANOVA FOR SELECTED FACTORIAL MODEL [PARTIAL SUM OF SQUARES]

Source	Sum of Squares	DF	Mean Squar	e F	Prob > F	
		Value			:	
Model	2,302,000	4	575,600	7.27	0.0675	
Á	561,800	1	561,800	7.10	0.0761	
B	238,000	1	238,000	3.01	0.1813	
С	1,051,000	1	1,051,000	13.28	0.0356	
AC	451,300	1	451,300	5.70	0.0969	
Residual	237,500	3	79150.00			
Corr Total	2,540,000	7				

The CBN content seems to be suitable for interrupted cutting than continuous cutting as in this experiment. The R-squared statistic indicates that the first-order model explains 90.65 % of the variability in tool life (T). The calculation also indicates that the model has an adequate signal to noise ratio.

The normal probability plots of the residuals and the plots of the residuals versus the predicted response for tool life are shown in Figures 2 and 3, respectively. A check on the plots in Figures 2 and 3 revealed that the residuals generally fall on a straight line implying that the errors are distributed normally.



Fig. 2. Normal plot of residuals for tool life data

This implies that the models proposed are adequate and there is no reason to suspect any violation of the independence or constant variance assumption. It means that the proposed model using partial factorial design is suitable for running the experiment. But, in order to obtain a more precise result, the second-order model is proposed.

B. Tool wear and tool life

Figure 4 shows the flank wear progression curves of CBN tool at the different cutting conditions. The flank wear progressions were generally divided into three stages: the rapid initial, the relative steady state and finally the abrupt of wear.

The flank wear rate was rapid at higher cutting speeds, feed rates and depth of cuts. There are several types of wear mechanisms that can influence the tool wear and subsequently the tool life. The observed wear mechanisms were abrasion, attrition, adhesion, diffusiondissolution, chipping and fracture.



Fig. 3. Residuals vs predicted responses plot

Figure 5(a) show clearly rubbing and attrition wear mechanism. At the lower cutting speed, temperatures are low so that the wear based on plastic shear or diffusion does not occur. The flow of metal past the cutting edge is more irregular, laminar, a built-up edge may be formed and contact with the tool may be less continuous. Under these conditions larger fragments may be torn intermittently from tool surface (Trent 1991). But in this test, the well-defined built-up edge has not appeared.

Beside the abrasion and attrition, cutting tool wear can also be ascribed to the chemical reaction and adhesion between the tool and work materials. During the processing, especially dry cutting, the temperature increases rapidly. The increasing temperature will induce the tendency for the titanium to weld to the tool during



Fig. 4. Flank wear progression curves

9th Int'l QIR Proceeding, 6-7 Sept 2006

IMM-24

ISSN 141

machining. If the material welded to the tool received dynamical stress, this eventually results in chipping severe failure. Figures 5(b) and 6(b) show the n surface of CBN tool due to severe failure.

Another wear mechanism which present in the experiment is dissolution and diffusion of the cutting to The dissolution-diffusion mechanism caused the craft formation in the chamfered edge land. Figures 5(a) and 6(a) show the formed crater obviously.

Figure 7 also show results of cutting tool life on some cutting parameters at different depth of cut. Based on the figure, depth of cut is the most influencing factor to the tool life, followed by cutting speed and feedrate.



Figure 5: SEM micrograph of CBN tools while machining Ti-6Al-4V at cutting speed 180 m/min, feedrate 0.25 mm/rev (a) depth of cut 0.1 mm, (b) depth of cut 1 mm



Fig. 6. SEM micrograph of CBN tools while machining Ti-6Al-4V at cutting speed 300 m/min (a) feedrate 0.25 mm/rev and depth of cut 0.1 mm, (b) feedrate 0.05 mm/rev and depth of cut 1 mm

Page 4 of 6

ISSN 1411-1284



Fig. 8.Chip formed at cutting speed 180 m/min, feed rate 0.25 mm/rev and depth of cut 0.1 mm (a) top view (b) side view



Fig.9. Chip formed at cutting speed 300 m/min, feed rate 0.25 mm/rev and depth of cut 1 mm (a) top view (b) side view

IV. CONCLUSIONS

It has been shown in this work, machining of titanium 6Al-4V with CBN cutting tool, the partial factorial design can be applied in designing the experiments. The design is very helpful in the running of expensive cutting toolmaterial combinations. The work showed that the depth of cut is the most significant factor to tool life, followed by



(a)

1740

2000

1800

1600

1400

180 0.25 High

300 0.05 High

1800.05 Low

Fig. 7 Tool life at different depth of cutting (a) 0.1 mm (b) 1 mm

Figures 5(b) and 6(b) confirmed the influence of depth of cut to tool wear mechanism. In this case, higher depth of cut enlarged the possibility of tool to severe failure and shortens the tool life. It is suggested to use lower depth of cut in finish machining of titanium using CBN tool. It seems that CBN content (grade) give small significance leve! of to tool life. Lower CBN content gave a relatively good performance and it is parallel to the finding of Ezugwu et al (2003).

С. Chip formation

0

Figures 8 and 9 show the differences of two formed chips at the different cutting speeds and depth of cuts. The depth of cut will influence the width of chip, type of flakes and peak shape of flakes. Chip formed in turning at a depth of cut 1 mm has approximately 2.5 times wider than chip formed at depth of cut 0.1 mm. The bigger flake and the smaller flake were formed at a depth of cut 0.1 mm. The smaller flake was formed at the right side. At the depth of cut of 1 mm, the smaller flakes were not formed. The sharper peak shape was formed at the depth of cut 0.1 mm than at the depth of cut 1 mm. While the interval of flakes depend on the cutting speed.

9th Int'l QIR Proceeding, 6-7 Sept 2006

cutting speed and feed rate. The lower depth of cut is more significant to prolong the tool life at the cutting speed range of 180 –300 m/min. It showed that there is no contribution of CBN content to tool life.

CBN tool has three stages of wear process: rapid initially, slowly wear progress and abruptly failure. The dominantly wearing mechanism present was abrasion, attrition, adhesion, diffusion-dissolution, chipping and fracture. The cutting speed induced attrition wear. While chipping and fracture was generated by higher depth of cut. Diffusion-dissolution was induced by increasing temperature during turning operation. Beside the bigger flakes, some smaller flakes were formed when turning at lower depth of cut. The width and height of formed chip are depended on depth of cut while interval between peaks of flakes is depended on cutting speed.

ACKNOWLEDGMENT

The authors would like to thank the Malaysian Ministry of Science, Technology and Environment for sponsoring this work under project IRPA 03-02-02-0062-EA122.

REFERENCES

 Arbizu, I.P. & Pérez, C.J.L. 2003. Surface roughness prediction by factorial design of experiments in turning processes. J. Mat. Processing Tech. 143-144; 390-396

- [2] Bhaumik, S.K., Divakar, C. & Singh, A.K. 1995. Machining Ti-6Al-4V alloy with a wBN-cBN composite tool. Mat. & Design 16(4): 221-226.
- [3] Che-Haron, C.H.. 2001. Tool life and surface integrity in turning titanium alloy. J. Mat. Processing Tech. 118: 231-237
- [4] Choudhury, I.A. & El-Baradie, M.A. 1998. Tool-life prediction model by design of experiments for turning high strength steel (290 BHN). J. Mat. Processing Tech. 77: 319-326.
- [5] D.C. Montgomery. 1991. Design and Analysis of Experiments. John Wiley and Sons: New York.
- [6] E.M. Trent. 1991. Metal Cutting. 3rd ed. Buttreworth-Heinemann; Oxford.
- [7] Ezugwu, E.O. Bonney, J. & Yamane, Y. 2003. An overview of the machinability of aeroengine alloys. J. Mat. Processing Tech. 134: 233-253.
- [8] Lin, Z.C. & Chen, D.Y. 1995. A study of cutting with a CBN tool. J. Materials Proc. Tech. 49:149-164.
- [9] Nabhani, F. 2001. Machining of aerospace titanium alloys. Robotics & Comp. Integ. Manuf. 17: 99-106
- [10] Narutaki, N., Murakoshi, A. & Motonishi, S. 1983. Study on Machining of Titanium Alloys. Annals of the CIRP. 32: 65-69.
- [11] Noordin, M.Y., Venkatesh, V.C., Sharif, S., Elting, S. & Abdullah, A. 2004. Application of response surface methodology in describing the performance of coated carbide tools when turning AISI 1045 steel, J. Mat. Processing Tech. 145: 46-58.
- [12] Zhou, J.M., Walter, H., Andersson, M. & Stahl, J.E. 2003. Effect of chamfer angle on wear of PCBN cutting tool. Int. J. Mach. Tools Manuf. 43: 301-305.