



UNIVERSITI PUTRA MALAYSIA

**OPTIMIZATION OF MICRO-END MILLING PROCESS PARAMETERS OF
TITANIUM ALLOY USING NON-DOMINATED SORTING GENETIC
ALGORITHM**

ABOLFAZL GOLSHAN

FK 2013 49



**OPTIMIZATION OF MICRO-END MILLING PROCESS PARAMETERS OF
TITANIUM ALLOY USING NON-DOMINATED SORTING GENETIC
ALGORITHM**

By

ABOLFAZL GOLSHAN

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in
Fulfilment of the Requirements for the Degree of Master of Science**

November 2013

COPYRIGHT

All material contained within the thesis, including without limitation text, logos, icons, photographs and all other artwork, is copyright material of Universiti Putra Malaysia unless otherwise stated. Use may be made of any material contained within the thesis for non-commercial purposes from the copyright holder. Commercial use of material may only be made with the express, prior, written permission of Universiti Putra Malaysia.

Copyright © Universiti Putra Malaysia



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

**OPTIMIZATION OF MICRO-END MILLING PROCESS PARAMETERS OF
TITANIUM ALLOY USING NON-DOMINATED SORTING GENETIC
ALGORITHM**

By

ABOLFAZL GOLSHAN

November 2013

Chair: B.T. Hang Tuah Bin Baharudin, PhD

Faculty: Engineering

The selection of optimal cutting parameters has always presented a critical quality concern in the micromachining process. This study examines the effects of three process parameters which are spindle speed, feed rate and depth of cut on the process outputs. The outputs are the surface area roughness and burr formation in micro-end milling of Ti-6Al-4V titanium alloy. Response surface methodology was utilized to develop mathematical models of the process outputs. In addition, analysis of variance and confirmation runs were employed to verify the precision of the mathematical models. Finally, non-dominated sorting genetic algorithm-II as evolutionary optimization approach was used for multi-objective optimization of the micro-end milling process. The optimization results demonstrate the high performance of this method to obtain the Pareto optimal set of solutions in the micro-end milling process. With the optimal parameter sets, an operator can select a suitable combination of variables to obtain a better surface finish or lower burr formation. Optimal machining parameters were the spindle speed of 40000 rpm, the feed rate of 61-75 mm/min, and the depth of cut of 86-92 μm .

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

**PENGOPTIMUMAN PARAMETER PROSES PEMESINAN MIKRO
TERHADAP ALOI TITANIUM MENGGUNAKAN ALGORITMA GENETIC
PENGISIHAN TIDAK DIDOMINASI**

Oleh

ABOLFAZL GOLSHAN

November 2013

Pengerusi: B.T. Hang Tuah Bin Baharudin, PhD

Fakulti: Kejuruteraan

Pemilihan parameter pemotongan optimum sentiasa menjadi punca kebimbangan tentang kualiti yang kritikal dalam proses pemesinan mikro. Kajian ini mengkaji kesan kepada hasil proses oleh tiga parameter proses iaitu kelajuan gelendong, kadar suapan dan kedalaman pemotongan. Hasil pemesinan adalah kekasaran kawasan permukaan dan pembentukan duri dalam pengilangan mikro-akhir aloi titanium. Kaedah gerak balas permukaan telah digunakan untuk membangunkan model matematik hasil proses. Di samping itu, analisis varians dan pengesahan telah digunakan untuk mengesahkan ketepatan model matematik tersebut. Akhirnya, kaedah penyusunan bukan didominasi genetik algoritma-II digunakan sebagai pendekatan pengoptimuman evolusi untuk pengoptimuman pelbagai objektif proses pengilangan mikro-akhir tersebut.. Keputusan pengoptimuman menunjukkan prestasi yang tinggi dicapai oleh kaedah ini untuk mendapatkan set optimum Pareto untuk penyelesaian dalam proses pengilangan mikro-end. Dengan set parameter optimum, pengendali boleh memilih kombinasi pembolehubah yang sesuai untuk mendapatkan kemas permukaan yang lebih baik atau lebih rendah pembentukan duri. Parameter pemesinan yang optimum adalah pada kelajuan gelendong 40000 putaran seminit dengan, kadar suapan 61-75 mm / min dan kedalaman pemotongan 86-92 μm .

ACKNOWLEDGEMENTS

With great devotion we acknowledge the Grace of Allah for the successful completion of this research. I dedicated my beloved parents; Mr. Mohammadreza Golshan and Madam Mahnaz Gandomi who always encouraged and motivate me in many ways. I have been blessed with their guidance, inspiration and support.

I would like to express my deep gratitude and sincere thanks to my supervisor Dr. B.T. Hang Tuah Baharudin and Co.supervisor Dr. Mohd Khairol Anur Ariffin for their thoughtful supervision, steady support and guidance throughout the course of this research.

Lastly, I would like to express my sincere thanks and appreciation to all lecturers and friends for their continual support, generous guidance, help, patience and encouragement in order to finish this research.

I certify that an Examination Committee has met on 08 November 2013 to conduct the final examination of Abolfazl Golshan on his Master of Science thesis entitled "Optimization of Micro-end Milling Process Parameters of Titanium Alloy Using Non-dominated Sorting Genetic Algorithm" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the Master of Science Degree.

Members of the Examination Committee were as follows:

Zulkiflle bin Leman, PhD

Associate Professor,
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Shamsuddin bin Sulaiman, PhD

Professor,
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Azmah Hanim binti Mohamed Ariff, PhD

Senior Lecturer,
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Safian bin Sharif, PhD

Professor,
Faculty of Engineering
Universiti Putra Malaysia
(External Examiner)

NORITAH OMAR, PhD

Associate Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 17 February 2014

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science.

The members of the Supervisory Committee were as follows:

B.T. Hang Tuah Bin Baharudin, PhD

Associate Professor,
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Mohd Khairol Anur Ariffin, PhD

Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

BUJANG BIN KIM HUAT, PhD

Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 20 March 2014

Declaration by graduate student

I hereby confirm that:

- this thesis is my original work;
- quotations, illustrations and citations have been duly referenced;
- this thesis has not been submitted previously or concurrently for any other degree at any other institutions;
- intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from supervisor and the office of Deputy Vice-Chancellor (Research and Innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software.

Signature: _____ Date: _____

Name and Matric No.: _____

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

Signature: _____

Name of
Chairman of
Supervisory
Committee: _____

Signature: _____

Name of
Member of
Supervisory
Committee: _____



TABLE OF CONTENTS

	Page
ABSTRACT	iii
ABSTRAK	iv
ACKNOWLEDGEMENTS	v
APPROVAL	vi
DECLARATION	viii
LIST OF TABLES	xii
LIST OF FIGURES	xiii
LIST OF ABBREVIATIONS	xv
CHAPTER	
1	1
INTRODUCTION	1
1.1 Background	1
1.2 Research problems	3
1.3 Scope and research objectives	3
1.4 Outline of thesis	4
2	5
LITERATURE REVIEW	5
2.1 Micro-milling and its components	5
2.2 Machine tools	6
2.2.1 Types of machine tools	7
2.2.2 High speed spindle specifications	10
2.3 Cutting tools	12
2.3.1 Material and geometry	13
2.3.2 Coated and uncoated micro tools	15
2.3.3 Quality and size accuracy of micro tools	16
2.4 Workpiece materials	16
2.5 Cutting conditions	17
2.6 Overview of machinability research in micro-milling	18
2.6.1 Surface roughness	19
2.6.2 Burr formation	23
2.7 Statistical modeling approach	29
2.8 Optimization approach	30
2.8.1 Evolutionary optimization approach	30
2.8.2 Non-dominating sorting genetic algorithm	31
2.9 Research gaps and current issues	32
3	33
MATERIALS AND METHODS/METHODOLOGY	33
3.1 Experimental	33
3.1.1 Workpiece Material	33

	3.1.2	Tooling	35
	3.1.3	Machine tool and experimental setup	36
	3.1.4	Surface roughness analysis	37
	3.1.5	Burr formation analysis	39
	3.1.6	Cutting conditions	40
	3.1.7	Experimental design	41
	3.2	Process modeling	43
	3.2.1	Response Surface Methodology	43
	3.2.2	Test for significance of the regression model	44
	3.2.3	Test for significance on model coefficients	44
	3.2.4	Test for lack-of-fit	44
	3.3	Process optimization	45
	3.3.1	Multi-objective optimization	45
	3.3.2	Non-dominated sorting genetic algorithm	46
4		RESULTS AND DISCUSIONS	50
	4.1	Experimental results:	50
	4.2	Modeling results	53
	4.2.1	Models summary statistics	53
	4.2.2	Analysis of variance (ANOVA)	54
	4.2.3	Final empirical models	56
	4.2.4	Surface and contour plots of responses	57
	4.2.5	Validation of experimental results	58
	4.3	Multi-objective optimization results	60
5		CONCLUSIONS AND FUTURE WORKS	64
	5.1	Conclusions	64
	5.2	Future works	65
		REFERENCES	66
		APPENDICES	80