

ADVANCED MACHINING  
TOWARDS IMPROVED  
MACHINABILITY OF  
DIFFICULT-TO-CUT  
MATERIALS

---

Edited by:  
A.K.M. Nurul Amin (Chief Editor)  
Dr. Erry Yulian Triblas Adesta  
Dr. Mohammad Yeakub Ali



IIUM PRESS

INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

**ADVANCED MACHINING**  
**TOWARDS IMPROVED MACHINABILITY OF**  
**DIFFICULT-TO-CUT MATERIALS**

*Edited by:*

*A.K.M. Nurul Amin (Chief Editor)*

*Dr. Erry Yulian Triblas Adesta*

*Dr. Mohammad Yeakub Ali*



**IIUM Press**

Published by:  
IIUM Press  
International Islamic University Malaysia

First Edition, 2011  
©IIUM Press, IIUM

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without any prior written permission of the publisher.

Perpustakaan Negara Malaysia

Cataloguing-in-Publication Data

Advanced Machining Towards Improved Machinability of Difficult-To-Cut Materials: A.K.M.  
Nurul Amin, Erry Yulian Triblas Adesta & Mohammad Yeakub Ali

ISBN: 978-967-418-175-8

Member of Majlis Penerbitan Ilmiah Malaysia – MAPIM  
(Malaysian Scholarly Publishing Council)

Printed by :  
**IIUM PRINTING SDN.BHD.**  
No. 1, Jalan Industri Batu Caves 1/3  
Taman Perindustrian Batu Caves  
Batu Caves Centre Point  
68100 Batu Caves  
Selangor Darul Ehsan  
Tel: +603-6188 1542 / 44 / 45 Fax: +603-6188 1543  
EMAIL: iiumprinting@yahoo.com

Published by:  
IIUM Press  
International Islamic University Malaysia

First Edition, 2011  
©IIUM Press, IIUM

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without any prior written permission of the publisher.

Perpustakaan Negara Malaysia

Cataloguing-in-Publication Data

Advanced Machining Towards Improved Machinability of Difficult-To-Cut Materials: A.K.M. Nurul Amin, Erry Yulian Triblas Adesta & Mohammad Yeakub Ali

ISBN: 978-967-418-175-8

Member of Majlis Penerbitan Ilmiah Malaysia – MAPIM  
(Malaysian Scholarly Publishing Council)

Printed by :  
**IIUM PRINTING SDN.BHD.**  
No. 1, Jalan Industri Batu Caves 1/3  
Taman Perindustrian Batu Caves  
Batu Caves Centre Point  
68100 Batu Caves  
Selangor Darul Ehsan  
Tel: +603-6188 1542 / 44 / 45 Fax: +603-6188 1543  
EMAIL: iiumprinting@yahoo.com

<b>SECTION A: HEAT ASSISTED MACHINING</b>	<b>1</b>
1. <b>CHAPTER 1: INFLUENCE OF WORKPIECE PREHEATING ON CHATTER AND MACHINABILITY OF TITANIUM LOY - TI6AL4V</b>	<b>1</b>
2. <b>CHAPTER 2: MACHINABILITY IMPROVEMENT IN END OF MILLING TITANIUM ALLOY TI-6AL-4V THROUGH PREHEATING</b>	<b>9</b>
3. <b>CHAPTER 3: SOME ASPECTS OF IMPROVED MACHINABILITY IN PREHEATED MACHINING OF TITANIUM ALLOY TI-6AL-4V</b>	<b>19</b>
4. <b>CHAPTER 4: MACHINABILITY ASPECTS IN HEAT ASSISTED MACHINING OF HARDENED STEEL AISI H13 USING COATED CARBIDE TOOL</b>	<b>27</b>
5. <b>CHAPTER 5: TOOL WEAR AND SURFACE ROUGHNESS ASPECTS IN HEAT ASSISTED END MILLING OF AISI D2 HARDENED STEEL</b>	<b>35</b>
6. <b>CHAPTER 6: MODELING IN PREHEATED MACHINING OF AISI D2 HARDENED STEEL</b>	<b>43</b>
7. <b>CHAPTER 7: RELATIVE PERFORMANCES OF PREHEATING, CRYOGENIC COOLING AND HYBRID TURNING OF STAINLESS STEEL AISI 304</b>	<b>49</b>
<b>SECTION B: CHATTER AND SELECTED METHODS OF CHATTER SUPPRESSION</b>	<b>57</b>
8. <b>CHAPTER 8: ROLE OF THE FREQUENCY OF SECONDARY SERRATED TEETH IN CHATTER FORMATION DURING TURNING OF CARBON STEEL AISI 1040 AND STAINLESS STEEL</b>	<b>57</b>
9. <b>CHAPTER 9: INFLUENCE OF THE ELASTIC SYSTEM AND CUTTING PARAMETERS ON CHATTER DURING MACHINING OF MILD STEEL</b>	<b>65</b>
10. <b>CHAPTER 10: INFLUENCE OF CHATTER ON TOOL LIFE DURING END MILLING OF ALUMINIUM AND ALUMINIUM ALLOY ON VMC</b>	<b>75</b>

11	<b>CHAPTER 11: A NEW METHOD FOR CHATTER SUPPRESSION AND IMPROVEMENT OF SURFACE ROUGHNESS IN END MILLING OF MILD STEEL</b>	83
12	<b>CHAPTER 12: APPLICATION OF PERMANENT ELECTROMAGNET FOR CHATTER CONTROL IN END MILLING OF MEDIUM CARBON STEEL</b>	91
13	<b>CHAPTER 13: APPLICATION OF PERMANENT ELECTROMAGNET FOR CHATTER CONTROL IN END MILLING OF TITANIUM ALLOY - Ti6Al4V</b>	99
14	<b>CHAPTER 14: CHATTER SUPPRESSION IN END MILLING OF TITANIUM ALLOY Ti6Al4V APPLYING PERMANENT MAGNET CLAMPED ADJACENT TO THE WORKPIECE</b>	107
	<b>SECTION C: MODELING AND OPTIMIZATION IN MACHINING</b>	117
15	<b>CHAPTER 15: A COUPLED ARTIFICIAL NEURAL NETWORK AND RSM MODEL FOR THE PREDICTION OF CHIP SERRATION FREQUENCY IN END MILLING OF INCONEL 718</b>	117
16	<b>CHAPTER 16: APPLICATION OF RESPONSE SURFACE METHODOLOGY COUPLED WITH GENETIC ALGORITHM FOR SURFACE ROUGHNESS OF INCONEL 718</b>	123
17	<b>CHAPTER 17: DEVELOPMENT OF A MATHEMATICAL MODEL FOR THE PREDICTION OF SURFACE ROUGHNESS IN END MILLING OF STAINLESS STEEL SS 304</b>	133
18	<b>CHAPTER 18: DEVELOPMENT OF AN ARTIFICIAL NEURAL NETWORK ALGORITHM FOR PREDICTING THE CUTTING FORCE IN END MILLING OF INCONEL 718 ALLOY</b>	143
19	<b>CHAPTER 19: DEVELOPMENT OF AN ARTIFICIAL NEURAL NETWORK ALGORITHM FOR PREDICTING THE SURFACE</b>	149
20	<b>CHAPTER 20: DEVELOPMENT OF TOOL LIFE PREDICTION MODEL OF TiAlN COATED TOOLS DURING PART C: HIGH SPEED HARD MILLING OF AISI H13 STEEL</b>	155
21	<b>CHAPTER 21: MODELING FOR SURFACE ROUGHNESS IN END-MILLING OF TITANIUM ALLOY Ti-6Al-4V USING UNCOATED WC INSERTS</b>	161

22	<b>CHAPTER 22: MODELING OF SURFACE ROUGHNESS DURING END MILLING OF AISI H13 HARDENED TOOL STEEL</b>	<b>167</b>
23	<b>CHAPTER 23: MODELING OF TOOL LIFE USING RESPONSE SURFACE METHODOLOGY IN HARD MILLING OF AISI D2 TOOL STEEL</b>	<b>175</b>
24	<b>CHAPTER 24: OPTIMIZATION OF SURFACE ROUGHNESS IN HIGH SPEED END MILLING OF TITANIUM ALLOY Ti-6Al-4V UNDER DRY CONDITION</b>	<b>181</b>
25	<b>CHAPTER 25: COMPARISON OF SURFACE ROUGHNESS IN END-MILLING OF TITANIUM ALLOY Ti-6Al-4V USING UNCOATED WC-CO AND PCD INSERTS THROUGH GENERATION OF MODELS</b>	<b>189</b>
26	<b>CHAPTER 26: ASSESSMENT OF PERFORMANCE OF UNCOATED AND COATED CARBIDE INSERTS IN END MILLING OF Ti-6Al-4V THROUGH MODELLING</b>	<b>195</b>
	<b>SECTION D: CRYOGENIC AND HIGH SPEED MACHINING OF METALS AND NON METALS</b>	<b>203</b>
27	<b>CHAPTER 27: THE EFFECT OF CRYOGENIC COOLING ON MACHINABILITY OF STAINLESS STEEL DURING TURNING</b>	<b>203</b>
28	<b>CHAPTER 28: COMPARISON OF MACHINABILITY OF CERAMIC INSERT IN ROOM TEMPERATURE AND CRYOGENIC COOLING CONDITIONS DURING END MILLING INCONEL 718</b>	<b>209</b>
29	<b>CHAPTER 29: HIGH SPEED END MILLING OF SINGLE CRYSTAL SILICON SING DIAMOND COATED TOOL</b>	<b>217</b>
30	<b>CHAPTER 30: IMPLEMENTATION OF HIGH SPEED OF SILICON USING DIAMOND COATED TOOLS WITH AIR BLOWING</b>	<b>225</b>
31	<b>CHAPTER 31: ELIMINATION OF BURR FORMATION DURING END MILLING OF POLYMETHYL METHACRYLATE (PMMA) THROUGH HIGH SPEED MACHINING</b>	<b>233</b>
32	<b>CHAPTER 32: WEAR MECHANISMS IN END MILLING OF INCONEL 718</b>	<b>239</b>

<b>33</b>	<b>CHAPTER 33: PERFORMANCE OF UNCOATED WC-CO INSERTS IN END MILLING OF ALUMINUM SILICON CARBIDE (ALSiC)</b>	<b>247</b>
<b>34</b>	<b>CHAPTER 34: APPLICATION OF PCD INSERTS IN END MILLING OF ALUMINUM SILICON CARBIDE (ALSiC)</b>	<b>253</b>
<b>35</b>	<b>CHAPTER 35: EFFECTS OF SCRIBING WHEEL DIMENSIONS ON LCD GLASS CUTTING</b>	<b>259</b>



# Application of Permanent Electromagnet for Chatter Control in End Milling of Titanium Alloy - Ti6Al4V

A.K.M. Nurul Amin<sup>1</sup>, Ahmad Farhan B Zakaria<sup>2</sup>, Syadatul Akma<sup>3</sup>  
<sup>1,2,3</sup>Faculty of Engineering, International Islamic University Malaysia

c-mail address of corresponding author: *akamin@iiu.edu.my*

---

## 1.0 INTRODUCTION

Chatter is a vibration that occurs during machining operations resulting from instability of the cutting process with system responses of the spindle tool chuck system. One of the most challenging issues in machining process is to know the chatter characteristics. The main problem with chatter is that its mechanics is still not yet fully understood. Chatter is inconsistent in character, making it difficult to analyze and predict. This research work investigates the performance of permanent magnet in suppressing the chatter phenomena in end milling operation. An experiment is designed based on response surface methodology (RSM) approach using DESIGN EXPERT software. The experiments are done under two different conditions. The first condition is without the presence of magnet while the other is with the presence of magnet. Titanium alloy (ti-6al-4v) WAS used as a work material. Chatter or vibration with high amplitude appears in the system during end milling at cutting speed 70 m/min when the frequency of chip formation instability, associated with the formation of serrate chip. Cutting under the existence of magnet did suppress the chatter about 40% and the surface roughness is much better and smoother with the magnet compared to the cutting under room temperature in general. Machining of metal is usually accompanied by a violent relative vibration between work and tool, known as chatter. Chatter arises as a result of resonance caused by the interaction of the vibrations due to the instability of chip formation and natural vibrations of the system components. Campa et al. [1] described chatter as a dynamic problem at high removal rate condition. In addition Quintana et al. [2] specified that chatter can be obviously predicted from the loud noise and the poor surface integrity due to the chatter mark. In machining process, there are some problems that propagate the end of result especially in metal cutting. Y. Altintas and Philips K. Chan [3] stated that one of the major limitations on productivity in metal cutting is chatter vibration, which cause poor surface finish and tool damage. Kim et al. [4] explained that most of the drawbacks comes from chatter is causes excessive tool wear, noise, tool breakage, and deterioration of the surface quality. According to Patwari et al. [5] chatter is a very important phenomenon that needs to be taken into consideration whenever machining process is being performed. Amin et al. [6] and Patwari et al. [7] found that the root cause of chatter lies in the coincidence of the frequency of instability of chip formation with one of the natural frequencies of the machine-spindle-tool system components during end milling machining operation