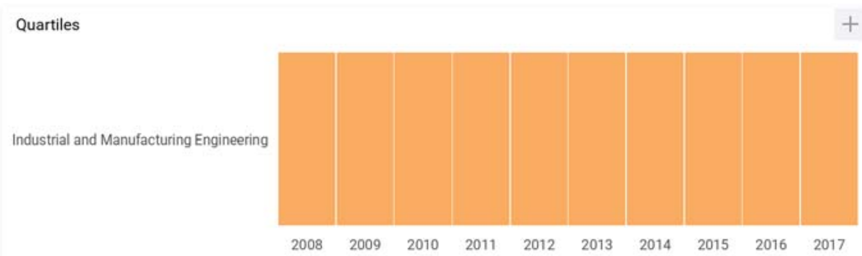
Lecture Notes in Electrical Engineering

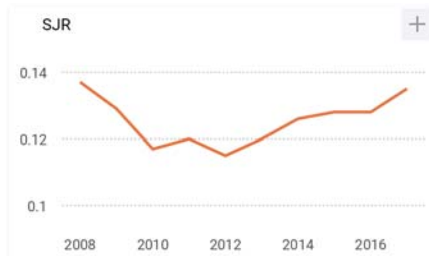
Country	Germany - SIR Ranking of Germany
Subject Area and Category	Engineering Industrial and Manufacturing Engineering
Publisher	Springer Verlag
Publication type	Book Series
ISSN	18761100
Coverage	2008-ongoing

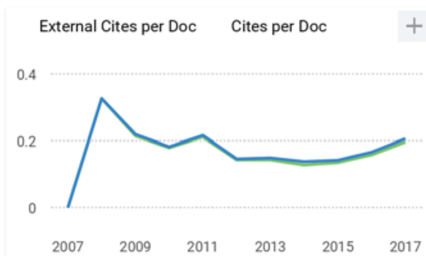
Join the conversation about this journal

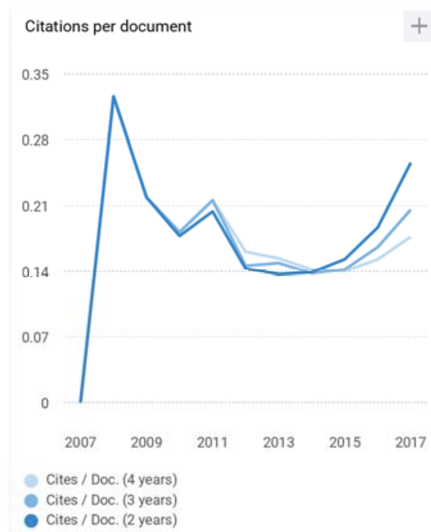
22

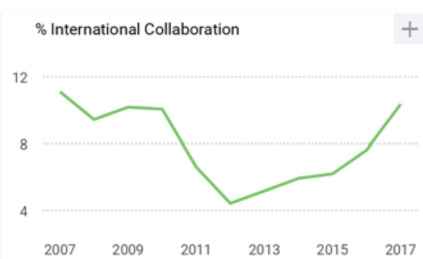
H Index

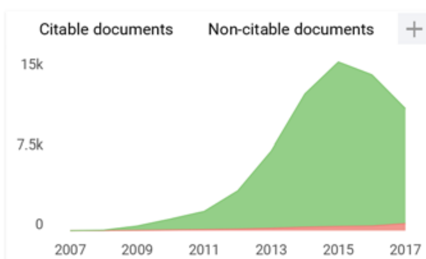


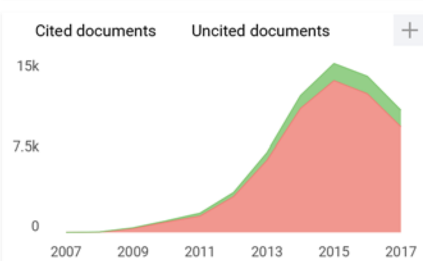












← Show this widget in your own website

Just copy the code below and paste within your html code:

<a href="https://www.scim

S

Sanjoy Kumar Debnath 2 months ago

My name appeared in Book wrongly.What can I do?

reply

Springer

Proceedings of Second International Conference on Electrical Systems, Technology and Information 2015 (ICESTI 2015)

Editors (view affiliations)

Felix Pasila, Yusak Tanoto, Resmana Lim, Murtiyanto Santoso,

Nemuel Daniel Pah

Conference proceedings

Part of the Lecture Notes in Electrical Engineering book series (LNEE, volume 365)

Papers | **About**

Introduction

This book includes the original, peer-reviewed research papers from the 2nd International Conference on Electrical Systems, Technology and Information (ICESTI 2015), held in September 2015 at Patra Jasa Resort & Villas Bali, Indonesia. Topics covered include: Mechatronics and Robotics, Circuits and Systems, Power and Energy Systems, Control and Industrial

Automation, and Information Theory.

It explores emerging technologies and their application in a broad range of engineering disciplines, including communication technologies and smart grids. It examines hybrid intelligent and knowledge-based control, embedded systems, and machine learning. It also presents emerging research and recent application in green energy system and storage.

It discusses the role of electrical engineering in biomedical, industrial and mechanical systems, as well as multimedia systems and applications, computer vision and image and signal processing.

The primary objective of this series is to provide references for dissemination and discussion of the above topics. This volume is unique in that it includes work related to hybrid intelligent control and its applications. Engineers and researchers as well as teachers from academia and professionals in industry and government will gain valuable insights into interdisciplinary solutions in the field of emerging electrical technologies and its applications.

Keywords

Embedded Systems Energy Storage Energy System

Hybrid Intelligent Control ICESTI 2015

Industrial Automation Information Theory

Machine Learning Smart Grid

Editors and affiliations

Felix Pasila (1)

Yusak Tanoto (2)

Resmana Lim (3)

Murtiyanto Santoso (4)

Nemuel Daniel Pah (5)

1. Electrical Engineering Department, Petra Christian University, , Surabaya, Indonesia
2. Petra Christian University, , Surabaya, Indonesia
3. Electrical Engineering Department, Petra Christian University, , Surabaya, Indonesia
4. Electrical Engineering Department, Petra Christian University, , Surabaya, Indonesia
5. University of Surabaya, , Surabaya, Indonesia

Bibliographic information

DOI

https://doi.org/10.1007/978-981-287-988-2

Publisher Name

Springer, Singapore

eBook Packages

Engineering

Print ISBN

978-981-287-986-8

Online ISBN

978-981-287-988-2

Series Print ISSN

1876-1100

Series Online ISSN

1876-1119

Buy this book on publisher's site

Springer

Proceedings of Second International Conference on Electrical Systems, Technology and Information 2015 (ICESTI 2015)

Editors (view affiliations)

Felix Pasila, Yusak Tanoto, Resmana Lim, Murtiyanto Santoso,

Nemuel Daniel Pah

Conference proceedings

Part of the Lecture Notes in Electrical Engineering book series (LNEE, volume 365)

Papers About

Page 1 of 2

Search within book

Chapter 44
The Influence of Depth of Cut, Feed Rate and Step-Over on Surface Roughness of Polycarbonate Material in Subtractive Rapid Prototyping

The Jaya Suteja

Abstract Rapid prototyping is fast and automatic three dimensions physical modeling that uses computer aided design model as the input. One of the important requirements in various products is the surface quality. Therefore, the aim of this research is to study and then develop a model that shows the influence of depth of cut, feed rate, and step-over on the vertical and horizontal surface roughness of polycarbonate material in subtractive rapid prototyping. The subtractive rapid prototyping process is performed by using Roland MDX 40 machine assisted by CAM Modela Player 4.0 software. This research implements response surface methodology to develop the model and then followed by the residual tests. The result shows that the increase of the depth of cut and the interaction between the step-over and the depth of cut will increase the horizontal surface roughness. Meanwhile, the vertical surface roughness will be affected mostly by the step-over. This research provides an insight on how to rapid prototype the polycarbonate material in order to achieve the surface requirement. The result of this research is the basis for achieving the main purpose of subtractive rapid prototyping which are maximum material rate removal and the minimum surface roughness.

Keywords Polycarbonate · Subtractive rapid prototyping · Surface roughness · Process parameters

44.1 Introduction

Polycarbonate is a strong, tough, and transparent thermoplastic material that is most commonly used and most widely tested in the medical device. As most of the prosthetic products are customized for each patient, the feasible process to fabricate

T.J. Suteja (✉)
Manufacturing Engineering Department, University of Surabaya, Surabaya, Indonesia
e-mail: jayasuteja@staff.ubaya.ac.id

F. Pasila et al. (eds.), *Proceedings of Second International Conference on Electrical Systems, Technology and Information 2015 (ICESTI 2015)*,
Lecture Notes in Electrical Engineering 365, DOI 10.1007/978-981-287-988-2_44

it is by using rapid prototyping. Rapid prototyping is fast and automatic three dimensions physical modeling that uses computer aided design model as the input. Two methods in rapid prototyping are additive and subtractive rapid prototyping. Subtractive Rapid Prototyping implements milling process to cut material with tool that rotates in very high speed (high speed milling). According to Toh, C.K., high speed milling refers to milling process with 10 mm tool diameter that is rotated in 10.000 rpm [1].

Nieminem, I., et al., have investigated the possibility to use high speed milling to fabricate a thin fin of polycarbonate material by changing the depth of cut and step-over [2]. However, Nieminem, I., et al. did not investigate the influence of the depth of cut and the step-over on the important factors such as surface roughness of the polycarbonate material.

As no other research investigate the influence of high speed milling process parameters on the polymer materials, this research conduct a literature review on its influence on metal materials. In this research, studies by Albertí et al. [3], Vivancos [4], and Urbanski [5], are reviewed. In addition, the influence of non-high speed milling process parameters is also reviewed. The studies conducted by Oktem et al. [6], Ardiansyah [7], Suteja [8] are studied. Based on the reviews, it is shown that material removal rate, surface roughness, and dimension accuracy of a material are affected by interpolation type, tool holder type, controller of the machine, computer aided manufacturing software, physical and mechanical characteristics of the material, physical and mechanical characteristics of the tool, vibration, depth of cut, step-over, feed rate, cutting speed, and cut type.

One of the important requirements in various products especially medical device is the surface quality. Therefore, the aim of this research is to study and then develop a model that shows the influence of depth of cut, feed rate, and step-over on the vertical and horizontal surface roughness of polycarbonate material in subtractive rapid prototyping. These three process parameters are selected because these parameters are the dominant factors that influence the main purpose of subtractive rapid prototyping, which are to achieve the maximum material rate removal and the minimum surface roughness.

44.2 Research Design

This research implements response surface methodology to develop a surface roughness model. Then it is followed by conducting three residual tests, which are independence test, constant variance test, and normality test. By applying subtractive rapid prototyping process on the polycarbonate material, this research expects to achieve the final shape shown in Fig. 44.1. The subtractive rapid prototyping process is performed by using Roland MDX 40 machine assisted by CAM Modela Player 4.0 software. The software is used to generate the tool path of Roland MDX 40 machine. The input in order to generate the tool path is a three dimension model in STL format. The cutting tool used in this research is carbide

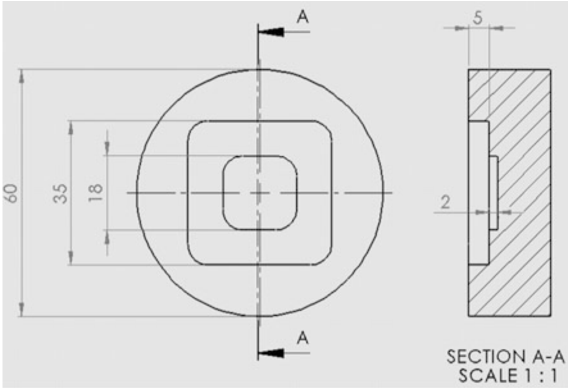


Fig. 44.1 The final shape

solid square end mill with 5 mm diameter. The tool is moved by the software based on the zigzag cut type.

In order to fabricate the shape, roughing and finishing processes are required. Each of the processes requires different parameter values. Roughing process is performed by implementing the parameters value shown in Table 44.1. This parameter value is determined based on the machine specification, literature study, and the preliminary experiment. The range of subtractive rapid prototyping parameters value for finishing process used in this research is shown in Table 44.2. The spindle and the entry speed for finishing process are 10,000 rpm and 4 mm/s consecutively. In this research, no coolant is used in performing the subtractive rapid prototyping.

This research takes some assumptions, which are: the polycarbonate material is always homogeneous, the cutting temperature is always constant, and the tool wears after performing three roughing and finishing processes.

Table 44.1 Parameters value for proses roughing

Parameters	Value
Feed rate	12 mm/s
Entry speed	4 mm/s
Spindle speed	8500 rpm
Depth of cut	0.37 mm
Step-over	1 mm

Table 44.2 Range parameters value for finishing process

Parameters	Low value	Middle value	High value
Depth of cut (mm)	0.1	0.235	0.37
Feed rate (mm/s)	12	14.5	17
Step-over (mm)	0.3	0.65	1

In this research, the surface roughness measurement is conducted at Industrial Metrology Laboratory of University of Surabaya. The surface roughness measurement device used in this research is Mitutoyo SJ 210 with 0.01 μm of accuracy. After the measurement process, the measured data is analyzed by using MINITAB release 14 software.

44.3 Results and Discussion

The first order experiment is conducted in implementing response surface methodology. The experiment design and the result of the first order experiment are shown in Table 44.3. By using the experiment result, the first order models of horizontal and vertical surface roughness are developed. However, based on the data analysis, the first order model of horizontal surface roughness is not fit to the horizontal surface roughness values. As a result, the second order experiment must be conducted to develop a better horizontal surface roughness model. Meanwhile, the first order model of vertical surface roughness is fit and can be used to predict the vertical surface roughness values. For that reason, the mathematical model to predict the vertical surface roughness values is shown in Eq. 44.1.

$$Ra_{ver} = 0.250056 + 0.022.F + 11.1214.S + 1.42593.D \quad (44.1)$$

where Ra_{ver} is vertical surface roughness (μm), F is feed rate (mm/s), S is step-over (mm), and D is depth of cut (mm).

Table 44.3 Results of first order experiment

Std order	Run order	Feed rate (mm/s)	Step-over (mm)	Depth of cut (mm)	Ra $_{Hor}$ (μm)	Ra $_{Ver}$ (μm)
11	1	14.50	0.65	0.235	3.13	7.25
13	2	14.50	0.65	0.235	3.22	7.83
2	3	17.00	0.30	0.100	2.53	4.46
12	4	14.50	0.65	0.235	3.18	8.65
7	5	12.00	1.00	0.370	4.88	12.39
9	6	14.50	0.65	0.235	2.89	7.83
3	7	12.00	1.00	0.100	3.64	12.01
5	8	12.00	0.30	0.370	3.00	4.70
10	9	14.50	0.65	0.235	3.55	8.33
6	10	17.00	0.30	0.370	4.18	4.59
1	11	12.00	0.30	0.100	2.81	3.60
4	12	17.00	1.00	0.100	4.30	12.08
8	13	17.00	1.00	0.370	4.49	12.01

The first order model of vertical surface roughness can be used as the best prediction model for vertical surface roughness because analysis of the model shows that its lack-of-fit is not significant. This model shows that the increase of the feed rate, the step-over, and the depth of cut will increase the vertical surface roughness. However, the parameter that has the most influence to the vertical surface roughness is the step-over.

As the first order model of horizontal surface roughness is not fit to the horizontal surface roughness values, the second order experiment must be conducted to develop the prediction horizontal surface roughness model. The experiment design and the result of the second order experiment are shown in Table 44.4. By using the experiment result, the second order models of horizontal surface roughness are developed. The mathematical model to predict the horizontal surface roughness values is shown in Eq. 44.2.

$$\begin{aligned} Ra_{hor} = & 2.44029 + 0.0736795.F - 1.36142.S + 1.36761.D + 1.43091.S^2 \\ & + 12.3338.D^2 - 0.485185.F.D + 3.73016.S.D \end{aligned} \quad (44.2)$$

where Ra_{hor} is horizontal surface roughness (μm), F is feed rate (mm/s), S is step-over (mm), and D is depth of cut (mm).

Table 44.4 Results of second order experiment

Std order	Run order	Feed rate (mm/s)	Step-over (mm)	Depth of cut (mm)	Ra $_{Hor}$ (μm)
18	1	14.5000	0.65000	0.235000	3.64
19	2	14.5000	0.65000	0.235000	3.36
10	3	18.7045	0.65000	0.235000	2.80
15	4	14.5000	0.65000	0.235000	2.74
20	5	14.5000	0.65000	0.235000	2.72
13	6	14.5000	0.65000	0.007958	3.33
14	7	14.5000	0.65000	0.462042	3.90
5	8	12.0000	0.30000	0.370000	3.71
11	9	14.5000	0.06137	0.235000	2.35
8	10	17.0000	1.00000	0.370000	4.29
6	11	17.0000	0.30000	0.370000	3.51
2	12	17.0000	0.30000	0.100000	3.10
9	13	10.2955	0.65000	0.235000	3.28
7	14	12.0000	1.00000	0.370000	5.03
12	15	14.5000	1.23863	0.235000	4.60
4	16	17.0000	1.00000	0.100000	3.48
3	17	12.0000	1.00000	0.100000	3.26
16	18	14.5000	0.65000	0.235000	2.94
1	19	12.0000	0.30000	0.100000	2.95
17	20	14.5000	0.65000	0.235000	3.42

The analysis and the residual plots of the second order model of horizontal surface roughness show that the model is fit and satisfy all the assumptions. As a result, it can be used as the best prediction horizontal surface roughness model. This model shows that the horizontal surface roughness is mostly affected by the depth of cut and the interaction between the step-over and the depth of cut. The increase of the depth of cut and the interaction between the step-over and the depth of cut will increase the horizontal surface roughness.

44.4 Conclusion

This result of this research shows that the increase of the feed rate, the step-over, and the depth of cut will increase the vertical surface roughness with the step-over as the most influenced parameter. In addition, the increase of the depth of cut and the interaction between the step-over and the depth of cut will increase the horizontal surface roughness. The models developed in this research give an insight on how the important parameters of rapid prototyping will influence the surface requirement of a polycarbonate material. The result of this research is the basis for achieving the main purpose of subtractive rapid prototyping which are maximum material rate removal and the minimum surface roughness.

References

1. Toh, C.K.: Surface topography analysis in high speed finish milling inclined hardened steel. Precis. Eng. **28**(4), 386–398 (2004)
2. Nieminen, I., Paro, J., Kauppinen, V.: High-speed milling of advanced materials. J. Mater. Process. Technol. **56**(1–4), 24–36 (1996)
3. Albertí, M., Ciurana, J., Rodriguez, C.A.: Experimental analysis of dimensional error versus cycle time in high-speed milling of aluminium alloy. Int. J. Mach. Tools Manuf **47**(2), 236–246 (2007)
4. Vivancos, J., Luis, C.J., Costa, L., Ortız, J.A.: Optimal machining parameters selection in high speed milling of hardened steels for injection moulds. J. Mater. Process. Technol. **155**, 1505–1512 (2004)
5. Urbanski, J.P., Koshy, P., Dewes, R.C., Aspinwall, D.K.: High speed machining of moulds and dies for net shape manufacture. Mater. Des. **21**(4), 395–402 (2000)
6. Oktem, H., Erzurumlu, T., Kurtaran, H.: Application of response surface methodology in the optimization of cutting conditions for surface roughness. J. Mater. Process. Technol. **170**(1–2), 11–16 (2005)
7. Ardiansyah, S.D.: Pengaruh Parameter Proses Milling terhadap MRR dan Kekasaran Permukaan (Ra) pada Pemotongan Material Polyacetal menggunakan Pahat HSS. B.Eng. thesis, University of Surabaya, Surabaya, Indonesia (2010)
8. Suteja, T.J., et al.: Optimasi Proses Pemesinan Milling Fitur Pocket Material Baja KarbonRendahMenggunakan Response Surface Methodology. Jurnal Teknik Mesin Universitas Kristen Petra **10**(1), 1–7 (2008)