Óbuda University
Doctoral School of Material Sciences and Technology

Optimization of ball end milling tool path in case of free form milling

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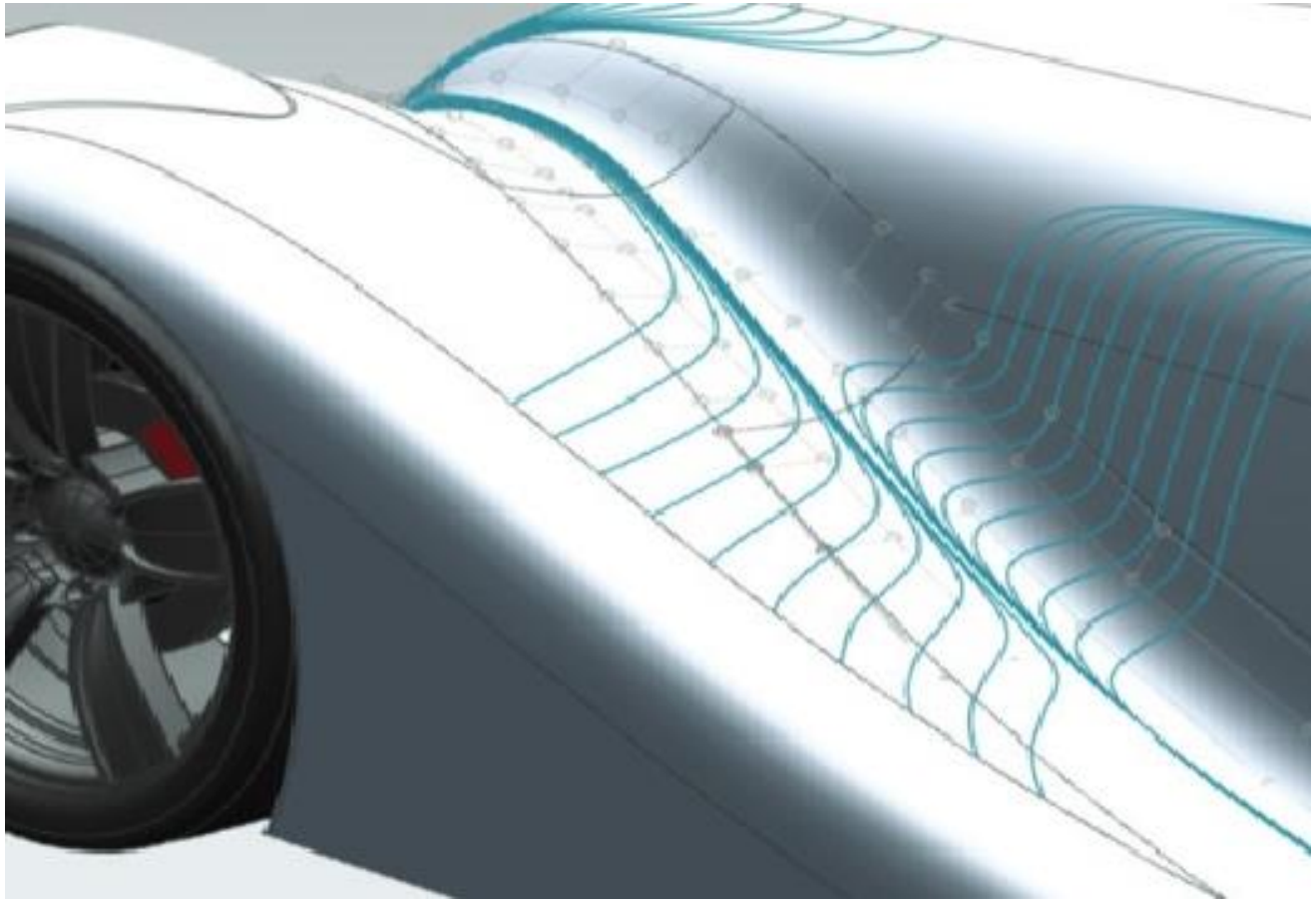
Freeform Surfaces



- Freeform surfaces are defined as surfaces those have one or more nonplanner, nonquadratic surfaces that represented by parametric and/or tessellated models.

Machining freeform surfaces

- Roughing
- Semi-finishing
- Finishing
- Clean-up

Ball-end toll

- Ball end mills are used for milling contoured surfaces, slotting and pocketing

The aim of this research is to find a new tool path planning strategy for freeform surfaces using ball end tool.

Results of the actual semester

- In this semester a study of the previous researches that concerns in Design of Experiments which allows to collect required date those are suitable for further statistical analyses resulting in valid and objective conclusions, and researches that related with ball-end milling which is the technology that will be used in this research, have been done.
- Courses completed

1. Manufacturing process planning
2. Experimental design

Design of experiments

Full factorial design

- Full factorial design: In this method, all the factors and their interactions are investigated. The number of the experiments that should be done is determined by n^k, where k is the number of the factors, and n the number of level of each factor

Author/year	Work piece Material	No. Factors	Input Factors	No. levels	Response
R. Noorani, Y. Farooque, T. Ioi / 2009	Aluminium Alloy 6061	4	Spindle Speed Depth of Cut Feed Rate Tool Size	Each factor has 2 levels	Surface roughness
V V K Lakshmi, Dr.K.Venkata Subbaiah / 2012	En24 alloy steel	3	cutting speed feed rate depth of cut	Each factor has 3 levels	Surface roughness
D S Sai Ravi Kiran S Phani Kumar / 2013	AISI 304 Stainless Steel	3	cutting speed feed rate depth of cut	Each factor has 3 levels	Tool Life

M.S. Kasim,et.al. 2014	Aluminium Alloy 6061-T6	3	cutting speed feed rate depth of cut	Each factor has 2 levels	Tool life
Hamzeh Shahrajabian Masoud Farahnakian / 2015	carbon fibre-reinforced plastics	3	cutting speed feed rate depth of cut	Each factor has 3 levels	surface roughness and machining force
K. Vipindas, B. Kuriachen, Jose Mathew / 2016	titanium alloy Ti-6Al-4V	3	Spindle speed Feed rate Depth of cut	Each factor has 3 levels	surface roughness and top burr formation
Adel Taha Abbas,et.al / 2016	high strength steel	3	Spindle speed Depth of cut Feed rate	Each factor has 4 levels	surface roughness
Satypal T. Warghat Dr. T. R. Deshmukh / 2017	AISI 1020 Mild Steel	3	Cutting speed Depth of cut Feed rate	Each factor has 3 levels except cutting speed has 4 levels	Surface roughness and Material Removal Rate
Gururaj BolarArgha DasShrikrishna N. Joshi / 2018	Aluminum 2024-T35	4	Tool diameter Feed rate (fz) Axial depth of cut Radial depth of cut	Each factor has 3 levels	Surface roughness and cutting force
Balázs Mikó / 2019	C45	3	tool’s corner radius feed rate depth of cut	Each factor has 2 levels	Surface roughness

Fractional factorial Design

- Time, resources and budget are very important in industry. That makes running full factorial experiments is unavailable when the number of the factors is large. Instead fractional factorial design is implemented, in this approach less number of experiments can be run to get the information of the main effects and desired interactions effects, in other ward some interactions are considered unimportant will not be investigated.

Author/ year	Work piece Material	No. Factors	Input Factors	No. levels	Response Variable/s
L.D.K.Catherine R.A. R. Ma'arof S. Suresh /2015	Polyurethane board	5	Depth of cut Feed rate Step-over Spindle speed Plunge rate	2 (Half fractional)	Half fractional
D. Kumar G. Rajamohan 2015	AluminiumalloyAl6063-T6	4	Spindle speed Feed rate Axial depth of cut Radial depth of cut	5	Surface roughness and flatness
Tzu-Liang Tseng Udayvarun Konada Yongjin Kwon 2015	Aluminium 6061 T6 Al	5	Cutting Speed Feed rate Depth of cut Nose radius Cutting fluid	2 (Half fractional)	Surface roughness
Benjamin ClaußAndreas NestlerAndreas Schubert2016	Aluminium alloy	3	cutting speed Feed per tooth Kinematics	2-levels for Kinematics and 5-levels for others	Surface roughness surface imperfec-tions Residualstress state
Yasmine El Taybany Mohab Hossam Hassan El-Hofy 2017	Soda glass	5	Rotational Speed Feed Rat Depth of Cut Ultrasonic Vibra-tion Grain Structure Cutting Fluid	2 (Half fractional)	Cutting forces and the moment

Taguchi Method

- In his approach, Dr Taguchi put a set of standard orthogonal arrays. These arrays determine the number of the experiments that should be implemented.
- Noise or uncontrollable factors were part of Taguchi’s method. These factors usually ignored for an economic reason and because the small effect that they have on the response of the process

Author/ year	Work piece Material	No. Factors	Input Factors	No. levels	Response Variable/s	Orthogonal Matrix
Devesh Pratap Singh, R. N. Mall /2015	Aluminium	3	Cutting speed Feed Rate Depth of Cut	Each factor has 3 levels	Surface Roughness	L_9
K. Ramesh /2015	STAINLESS STEEL AISI 304	3	Spindle speed Feed Rate Depth of Cut	Each factor has 3 levels	Surface Roughness and cycle time	L_9
Malay, Kishan Gupta, et.al. /2016	Al 6351	3	Spindle speed Feed Rate Depth of Cut	Each factor has 3 levels	Surface Roughness	L_9
Sachin Ghalme1 Ankush Mankar J. Bhalerao /2016	GFRP	3	Spindle speed Feed Rate Depth of Cut	Each factor has 3 levels	Surface Roughness	L_9
Ch. Ratnam K. Arun Vikram B.S. Ben, B.S.N. Murthy \2016	AISI 1040 steel	3	Tool speed Feed Rate Depth of Cut	Each factor has 4 levels	Surface roughness, Surface hardness and Tool Vibrations	L_{16}

Anand Gupta, C.M. Krishna, S. Suresh /2017	Aluminium silicon carbide composite	4	Spindle speed Feed Rate Depth of Cut Step over ratio	Each factor has 3 levels	Flatness	L_9
Atul Kumar, et.al /2017	Al2024-SiC	4	Spindle speed Feed Rate Depth of Cut Number of Flutes	Each factor has 3 levels	Surface Roughness and cycle time	L_{27}
Prakash B.Sosa, Rishabh D.Makwana, G.D. Acharya /2108	Medium carbon steel material	3	Spindle speed Feed Rate Depth of Cut	Each factor has 5 levels	Cutting force surface roughness Material removal rate	L_{25}
Eun Jung Kim Choon Man Lee /2019	Inconel 718	3	Spindle speed Feed Rate Depth of Cut	Each factor has 3 levels	Cutting force surface roughness and tool wear	L_9
Shofique U. Ahmed Rajesh Arora /2019	low carbon steel A36 K02600	4	Spindle speed Feed Rate Depth of Cut Cutting speed	Each factor has 3 levels	surface roughness and energy consumption	L_9

Conclusion


Spindle Speed
Depth of cut
Feed rate
Cutting Speed
Finishing Using End-ball Tool
Surface Roughness

Future Work

- Implementation calculation of working diameter in Matlab

- Courses
  1. Characterisation of surface microgeometry and microtopography
  2. Metal cutting theory