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OPTIMIZING FEED AND RADIAL FORCES IN CNC MACHINING OF P-20 TOOL STEEL THROUGH TAGUCHI'S PARAMETER DESIGN APPROACH

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ABSTRACT

The objective of the paper is to obtain an optimal setting of CNC machining process parameters, cutting speed, feed rate resulting in optimal values of the feed and radial forces while machining P – 20 tool steel with TiN coated tungsten carbide inserts. The effects of the selected process parameters on the chosen characteristics and the subsequent optimal settings of the parameters have been accomplished using Taguchi's parameter design approach.

The process parameters considered are – Cutting speed 3000rpm, 2500rpm and 2000rpm. Feed rate 200mm/min, 300mm/min and 400mm/min and depth of cut is 0.2mm, 0.3mm and 0.4mm.The effect of these parameters on the feed force, radial force are considered for analysis. The analysis of the results shows that the optimal settings for low values of feed and radial forces are high cutting speed, low feed rate and depth of cut. The thrust force and feed force are also taken experimentally using dynamometer for above Cutting speeds, feed rate and depth of cut. The optimal values for speed, feed rate and depth of cut are taken using Taguchi technique in Minitab software.

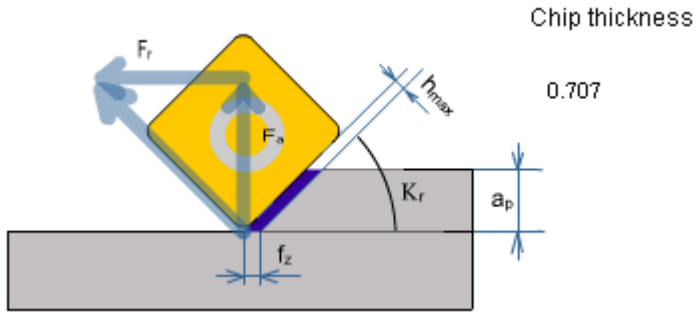
INTRODUCTION

Milling is the machining process of using rotary cutters to remove material from a work piece by advancing (or feeding) in a direction at an angle with the axis of the tool. It covers a wide variety of different operations and machines, on scales from small individual parts to large, heavy-duty gang milling operations. It is one of the most commonly used processes in industry and machine shops today for machining parts to precise sizes and shapes.

Milling can be done with a wide range of machine tools. The original class of machine tools for milling was the milling machine (often called a mill). After the advent of computer numerical control (CNC), milling machines evolved into machining centers (milling machines with automatic tool changers, tool magazines or carousels, CNC control, coolant systems, and enclosures), generally classified as vertical machining centers (VMCs) and horizontal machining centers (HMCs). The integration of milling into turning environments and of turning into milling environments, begun with live tooling for lathes and the occasional use of mills for turning

operations, led to a new class of machine tools, multitasking machines (MTMs), which are purpose-built to provide for a default machining strategy of using any combination of milling and turning within the same work envelope.

TOOL CUTTING EDGE ANGLE



Influence on chip thickness: $h_{max} = f_z \times \sin K_r$

D: Depth of cut, mm.
W: Width of cut, mm.
F: Feed rate, mm/min
MRR = D x W x F cc/min.

LITERATURE SURVEY

PAPER 1 - Modeling of the Influence of Cutting Parameters on the Surface Roughness, Tool Wear and Cutting Force in Face Milling in Off-Line Process Control by Dražen Bajić* – Luka Celent – Sonja Jozić, University of Split, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, Croatia

PAPER 2 - OPTIMIZATION OF SURFACE ROUGHNESS IN FACE TURNING OPERATION IN MACHINING OF EN-8 by K. Adarsh Kumar, Ch.Ratnam, BSN Murthy, B.Satish Ben, K. Raghu Ram Mohan Reddy

PAPER 3 - Effect of machining conditions on MRR and surface roughness during CNC Turning of different Materials Using TiN Coated Cutting Tools – A Taguchi approach by H. K. Dave, L. S. Patel, H. K. Raval

PAPER 4 - Optimization of surface roughness in CNC end milling using response surface methodology and genetic algorithm by B. Sidda Reddy, J. Suresh Kumar, and K. Vijaya Kumar Reddy

PAPER 5 - PREDICTION OF SURFACE ROUGHNESS IN END MILLING WITH GENE EXPRESSION PROGRAMMING by Yang Yang, Xinyu Li, Ping Jiang, Liping Zhang

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MODELING OF CUTTER AND WORKPIECE ASSEMBLY

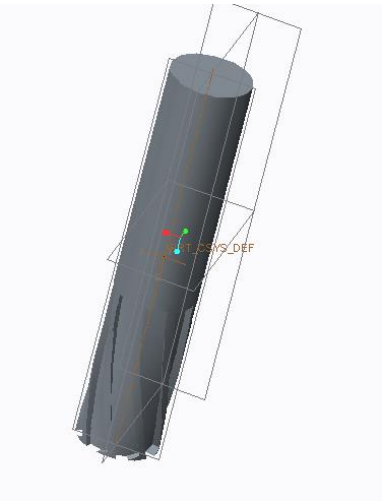

Fig – Tool drawn in creo

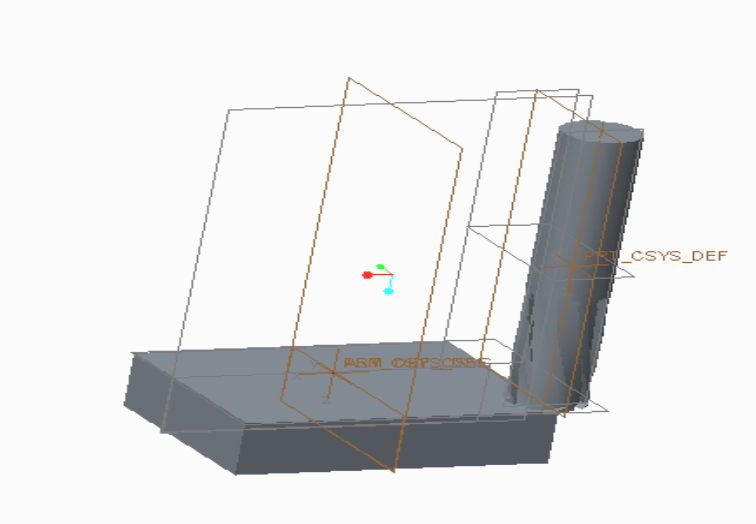

Fig –assembly of cutter and workpiece

THRUST FORCE, TORQUE AND TEMPERATURE CALCULATIONS
MATERIAL – P 20 TOOL STEEL

Cutter dia = 25R5
Width of Workpiece = 75mm
No of Teeth on cutter = 4 = n_c
Depth of Cut = d = 0.2mm
Width of Cut = b = 5mm

Width of chip = b_c = 5mm
V = Cutting Velocity
r_t = Chip Thickness Ratio
$r_t = \frac{t}{tc} = \frac{vc}{v} = \frac{lc}{l}$
L_C = Length of Chip = 7mm
L = Uncut Chip Length = 75mm
$\propto$ = Rake Angle = 20°
β = Friction Angle = 40
$\emptyset$ = Shear Angle

Speeds (rpm)	Feed(mm/min)
1. 3000	200
2. 2500	300
3. 2000	400

ANALYSIS OF CUTTING TOOL AND WORKPIECE ASSEMBLY

STRUCTURAL ANALYSIS OF P20 TOOL STEEL

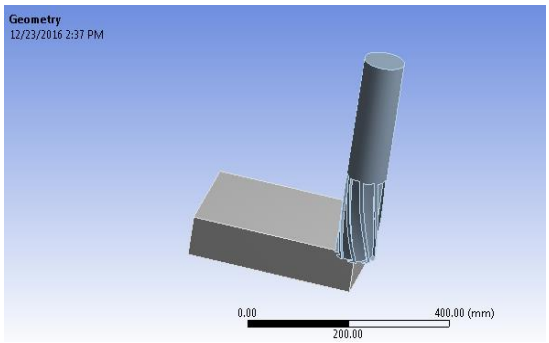

Fig – Imported Model

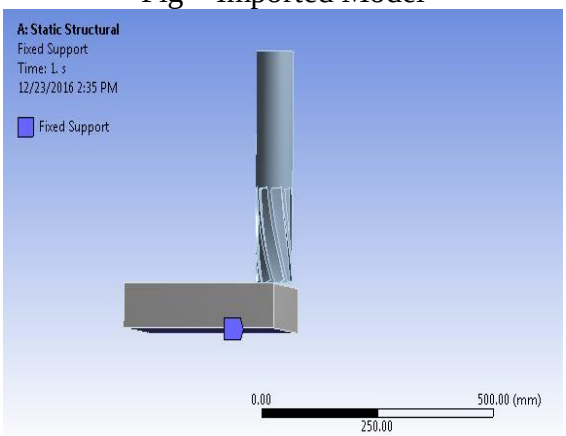

Fig – Fixed Support

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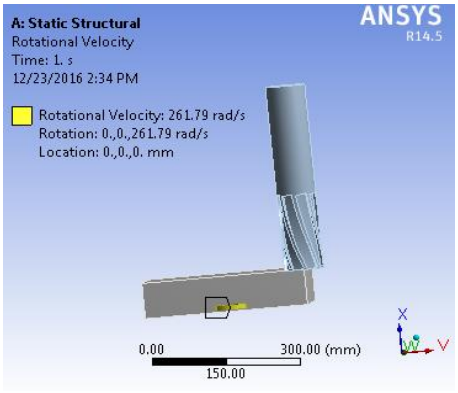

Fig – Rotational Velocity

RESULTS TABLE

Speed (rpm)	3000	2500	2000
Total deformation (mm)	74.529	51.756	33.123
Stress (MPa)	37.205	25.837	16.535
Strain	0.18603	0.12918	0.082675

TAGUCHI PARAMETER DESIGN FOR CNC MILLING PROCESS

In order to identify the process parameters affecting the selected machine quality characteristics of CNC milling, the following process parameters are selected for the present work: cutting speed (A), feed rate (B) and depth of cut (C). the selection of parameters of interest and their ranges is based on literature review and some preliminary experiments conducted.

Selection of Orthogonal Array

The non-linear relationship among the process parameters, if it exists, can only be revealed if more than two levels of the parameters are considered. Thus, each selected parameter was analyzed at three levels. The process parameters and their values are given in table. It was also decided to study the three – factor interaction effects of process parameters on the selected characteristics while milling. These interactions were considered between cutting speed and feed rate (AXB), feed rate and depth of cut (BXC), cutting speed and depth of cut (AXC).

FACTORS	PROCESS PARAMETERS	LAVEL1	LEVEL2	LEVEL3
A	CUTTING SPEED(rpm)	3000	2500	2000
B	FEED RATE (mm/rev)	200	300	400
C	DEPTH OF CUT(mm)	0.2	0.3	0.4

Table – Process parameters and their values

The experimentation is done by specifying process parameters for each job as per L9 orthogonal array using Taguchi technique.

JOB NO.	SPINDLE SPEED	FEED RATE	DEPTH OF CUT

	(rpm)	(mm/rev)	(mm)
1	3000	200	0.2
2	3000	300	0.3
3	3000	400	0.4
4	2500	200	0.3
5	2500	300	0.4
6	2500	400	0.2
7	2000	200	0.4
8	2000	300	0.2
9	2000	400	0.3

The feed forces are experimentally determined using a dynamometer.

Job no.	Feed Force 1 (N)	Feed Force 2 (N)
1	1896	1636
2	1762	1762
3	1150	1285
4	1200	1369
5	1275	1432
6	1542	1542
7	1172	1056
8	1222	1581
9	1096	1364

The radial forces are experimentally determined using a dynamometer.

Job no.	Radial Force 1 (N)	Radial Force 2 (N)
1	415	421
2	456	498
3	423	478
4	393	405
5	434	476
6	451	386
7	443	429
8	395	399
9	465	436

OPTIMIZATION OF PROCESS PARAMETERS USING TAGUCHI METHOD TO MINIMIZE FORCES

Design of Orthogonal Array

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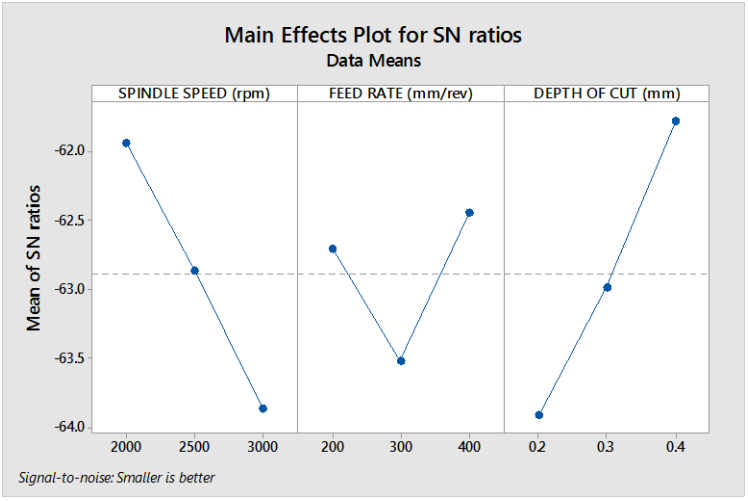

Fig Graph - Effect of milling parameters on feed forces for S/N ratio

The above graph shows the effect of each parameter Spindle Speed, Feed Rate and Depth of Cut on the feed forces. By observing, the S/N ratio is maximum at Spindle Speed 2000rpm, Feed Rate 400mm/rev and Depth of Cut 0.4mm.

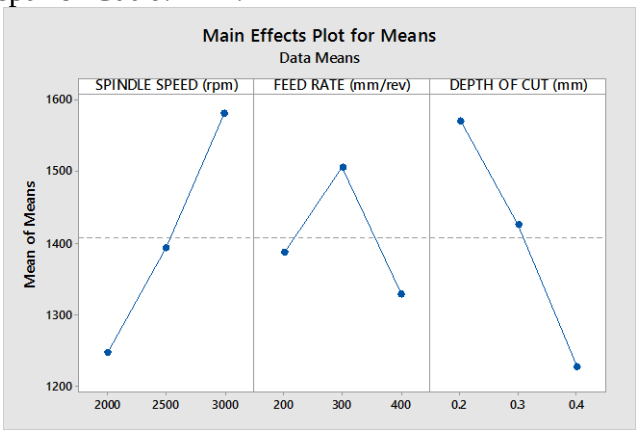

Fig Graph - Effect of milling parameters on feed forces for Means

ANALYSIS AND DISCUSSION

Regardless of the category of the performance characteristics, a greater S/N value corresponds to a better performance. Therefore, the optimal level of the machining parameters is the level with the greatest value.

Spindle Speed: - The effect of parameters spindle speed on the feed force is shown above figure for S/N ratio. The optimum spindle speed is 2000 rpm.

Feed Rate:- The effect of parameters Feed Rate on the feed force is shown above figure S/N ratio. The optimum Feed Rate is 400 mm/rev.

Depth of Cut:- The effect of parameters Depth of Cut on the feed force is shown above figure S/N ratio. The optimum Depth of Cut is 0.4 mm

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MINIMIZATION OF RADIAL FORCE

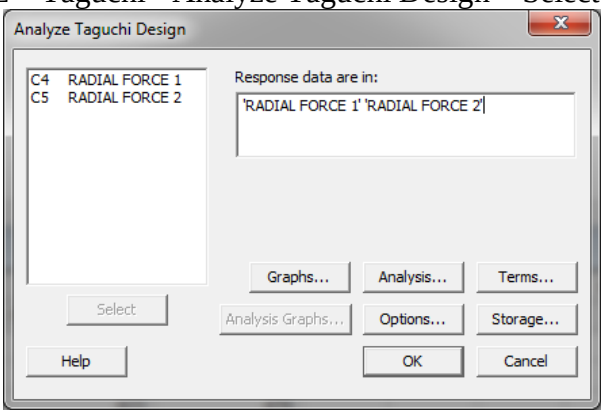
Enter radial force values in the table

Worksheet 1 ***

↓	C1	C2	C3	C4	C5
	SPINDLE SPEED (rpm)	FEED RATE (mm/rev)	DEPTH OF CUT (mm)	RADIAL FORCE 1	RADIAL FORCE 2
1	3000	200	0.2	415	421
2	3000	300	0.3	456	498
3	3000	400	0.4	423	478
4	2500	200	0.3	393	405
5	2500	300	0.4	434	476
6	2500	400	0.2	451	386
7	2000	200	0.4	443	429
8	2000	300	0.2	395	399
9	2000	400	0.3	465	436

Fig– Observed radial Force Values

Stat – DOE – Taguchi - Analyze Taguchi Design – Select Responses



Fig– Selecting Responses

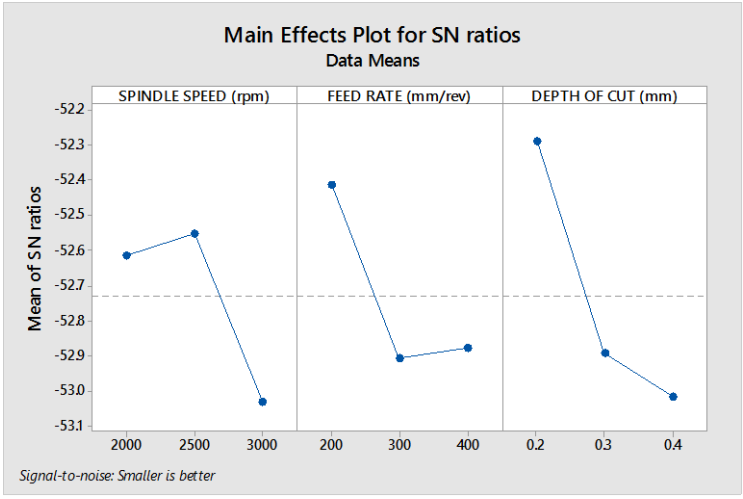


Fig Graph - Effect of milling parameters on radial forces for S/N ratio

The above graph shows the effect of each parameter Spindle Speed, Feed Rate and Depth of Cut on the feed forces. By observing, the S/N ratio is maximum at Spindle Speed 2500rpm, Feed Rate 200mm/rev and Depth of Cut 0.2mm.

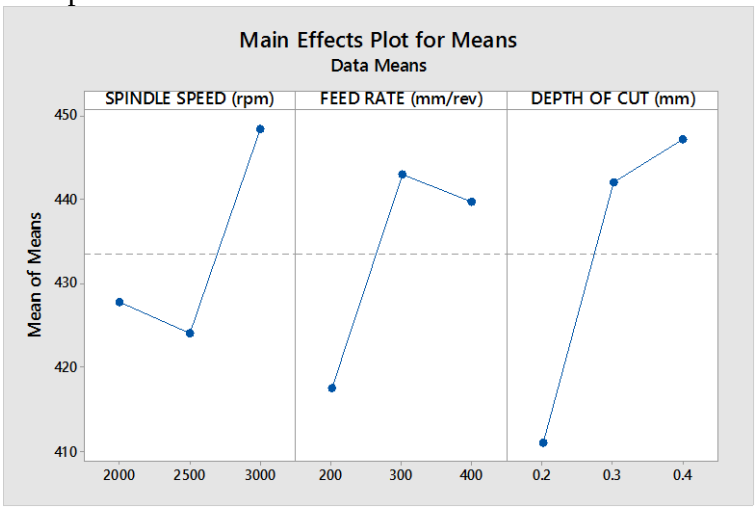


Fig Graph - Effect of milling parameters on radial forces for Means

Analysis and Discussion

Spindle Speed :- The effect of parameters spindle speed on the feed force is shown above figure for S/N ratio. The optimum spindle speed is 2500 rpm.

Feed Rate:- The effect of parameters Feed Rate on the feed force is shown above figure S/N ratio. The optimum Feed Rate is 200 mm/rev.

Depth of Cut:- The effect of parameters Depth of Cut on the feed force is shown above figure S/N ratio. The optimum Depth of Cut is 0.2 mm.

CONCLUSION

P20 Tool Steel is considered for milling process which is used in die casting process and the influence of cutting parameters spindle speed, feed rate and depth of cut on thrust force and torque for the material is done theoretically using calculations and experimentally using Taguchi technique.

The parameters considered are cutting speed, feed rate and depth of cut. The cutting speeds are 3000rpm, 2500rpm and 2000rpm. The feed rates are 200mm/min, 300mm/min and 400mm/min and depth of cut is 0.2mm. From the analysis results, the displacement and stress values are less for all speeds. The stress values are very less compared with its yield stress value. So we can conclude that using P20 tool steel for die casting process is suitable.

Feed force and radial forces are taken experimentally using dynamometer by considering parameters cutting speed, feed rate and depth of cut. The optimal values for speed, feed rate and depth of cut are taken using Taguchi technique.

The optimal settings of various process parameters for CNC machined parts to yield optimal forces are: Speed – 2000rpm, Feed rate – 400mm/min, Depth of cut – 0.4mm when thrust force is taken (i.e.) feed force and when torque (i.e.) radial force is taken the optimal values are Speed – 2500rpm, Feed rate – 200mm/min, Depth of cut – 0.2mm.

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