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OPTIMIZATION OF PROCESS PARAMETERS FOR MINIMUM CUTTING TEMPERATURE AND SURFACE ROUGHNESS IN TURNING OF AISI 410 STAINLESS STEEL IMPELLER

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In the present scenario of work, an investigation of experiment on CNC turning of AISI 410 stainless steel impeller has been brought into presentation. Turning parameters such as cutting speed (C_s), feed rate (F_r) and depth of cut (D_c) are taken into investigation and thus modeled for performance characteristics like cutting temperature (C_t) and surface roughness (R_a). The desirability function (D_f) is employed in order to optimize the multi performance characteristics. In correspondence to the highest desirability, C_s: 80 m/min, F_r: 0.12 mm/rev and D_c: 0.59 are considered to be the optimal combination of process parameters. In result of Scanning electron microscopy (SEM), it denotes that the formation relating surface defect on AISI 410 are deposition of tool material particles, scratches and feed marks.

Keywords: AISI 410 stainless steel, turning, impeller, temperature, SEM, surface defect

INTRODUCTION

In the recent span of years it is known that stainless steels have taken up a good position in the fields of industry owing to its corrosion resistance. The ductility and hardenability are the main characteristics features that revolve around it [1]. Tool wear, thermal degradation and expansion of the workpiece is caused by the machining process occurred by the discussed temperature rise. It also affects machining accuracy and quality [2]. When complex industrial problems are taken as a fact, multi objective optimization is said to be an important issue [3]. The adopted optimization technique improves the machining operations so that manufacturing of the product would be high with a low cost [4]. Metal cutting is subjected to high strains so that the energy required for the cutting is converted into heat.

Many causes in machining difficulties in stainless steel are because of discussed heat generation during the machining [5]. Findings toward the generation of heat in workpiece was investigated and therefore also found that the heat transfer among the tool, workpiece are caused due to high speed and shortage time and heat conduction [6]. [7] carried out experimental investigation to analyze the influence of cutting parameters such as cutting speed, feed rate and depth of cut on cutting temperature. Several works have been taken into subject by adopting methods GA, Taguchi, PSO, GRA, DF, etc. in accordance to the cutting parameters in optimization of machining process [8]. The desirability function approach is the choice taken into focus, as it allows the multi objective optimization [9]. Researchers often adopt desirability approach to calculate responses as to the reason of its simplicity weighing flexibility and insertion in statistical software. In accordance to the response calculated by the statistical model, it is noted by the desirability makes the possible estimation. It also brings about a satisfaction of percentage that corresponds to the desired objective [10]. Several factors rely on the machined surface with cutting process topography. To analyze various characteristics of surface and sub finish alteration, advances techniques like Scanning Electron Microscope (SEM) have helped in many ways [3]. Presently, efforts are being made to optimize the parameters such as cutting speed, feed rate and depth of cut on AISI 410 stainless steel

EXPERIMENTAL METHODOLOGY

Experimental setup

CNC Lathe TL20MAX500 Machine was utilized for tuning experimentation. The CNCT20 machine is having maximum 280 turning diameter, maximum 300 mm turning length, position accuracy (0,01mm) and repeatability (+ 0,05 or – 0,05) as per VDI DGQ - 344. Coated carbide (CGC4305) insert was used as a tool with the recommendation of sandvick coromant (tool manufacturer). AISI 410 stainless steel impeller component was used as a work piece material with an outer diameter of 95 mm.

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Experimental design and procedure

Design matrix was developed by the software Design expert Version.10 to perform the experiment. Fifteen sets of actual values were matrixes based on three factor central composite face centered (CCF) design and comprising of half fraction, six center points in which one replicated the factorial points and other with axial points. The Table 1 portrays the turning parameters selected for the experimental work. Figure 1 shows the machined impeller

Temperature rise (Tr) and surface roughness (Ra) are the responses analyzed on the impeller in the turning process. For experimental studies, the thermal radiations are measured with contacting devices to observe tool-work interface temperature. The chips of the workpiece and carbide insert jointly constructed to observe the cutting temperature (C_t). Temperature is measured using a K-type thermocouple digital thermometer with a maximum range of 2 000 °C with higher accuracy of 0, 1 °C. The maximum temperature noted during the machining process thrice to avoid environmental errors. The quality of the machining product is mainly depends on the Surface roughness (R_a). The surface roughness is measured at three different positions on the machined surface with surf tester SJ-210. Experimental values with measured responses are presented in Table 2

Table 1 **Turning parameters**

Parameters	Units	levels		
		-1	0	1
C_s	mm/ min	80	120	160
F_r	mm/rev	0,12	0,14	0,16
D_c	mm	0,5	1	1,5

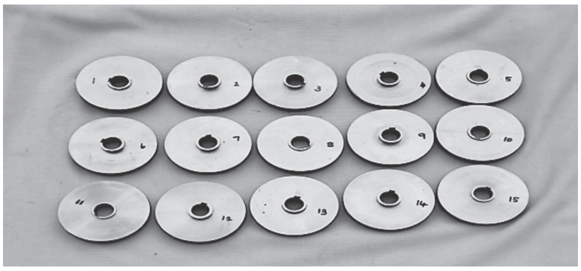

Figure 1 Machined impellers

Table 2 **Actual values and their responses**

C_s / m/min	F_r / mm/rev	D_c / mm	C_t / °C	R_a / µm
80	0,14	1	278	1,01
160	0,14	1	512	0,69
120	0,14	1	379	1,03
120	0,12	1	381	1
120	0,14	1	330	0,89
120	0,16	1	401	0,99
120	0,14	0,5	250	0,96
120	0,14	1,5	522	1,29
80	0,16	1,5	418	1,63
160	0,12	1,5	382	0,99
120	0,14	1	382	0,98
160	0,16	0,5	512	0,63
120	0,14	1	385	1,02
80	0,12	0,5	201	0,89
120	0,14	1	383	1,06

RESULTS AND DISCUSSION

Response surface methodology

The Model F-value of 46,68 and 21,71 corresponding to cutting temperature and surface roughness implies the developed model is adequate. The terms A, C, AB, AC, BC and A, C, A^2, C^2 have achieved significant in the case of T_c and R_a. The R^2 value (0,97) for C_t and R_a are in reasonable agreement with the adjusted R^2 value (0,95) and (0,93). The Figure 2 perturbation effects from the surface plots reveals that minimum cutting temperature attained for the range of cutting parameters like cutting speed (80 - 90) m/min, feed rate (0,12 - 0,13) mm/rev and depth of cut less than 0,7 mm. It is also observed from Figure 3 that surface roughness can be achieved minimum condition for the range of process parameters like cutting speed (145 - 160) m/min, feed rate (0,13-0,14) mm/rev and depth of cut less

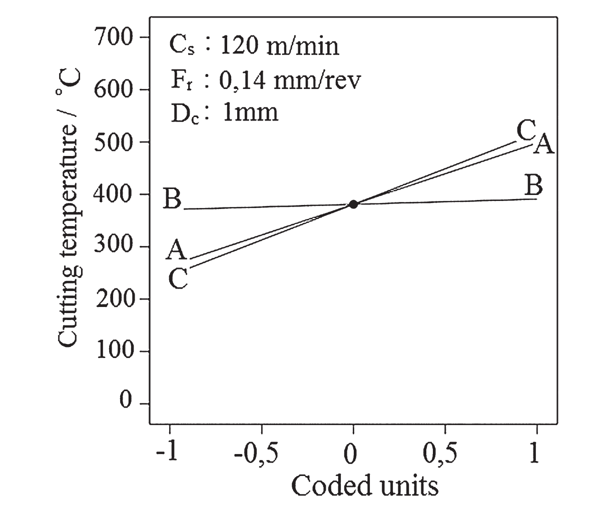

Figure 2 Direct effect of C_t

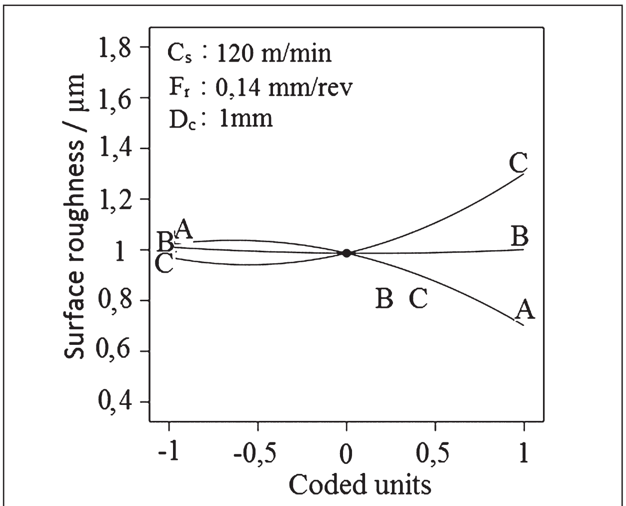

Figure 3 Direct effect of R_a

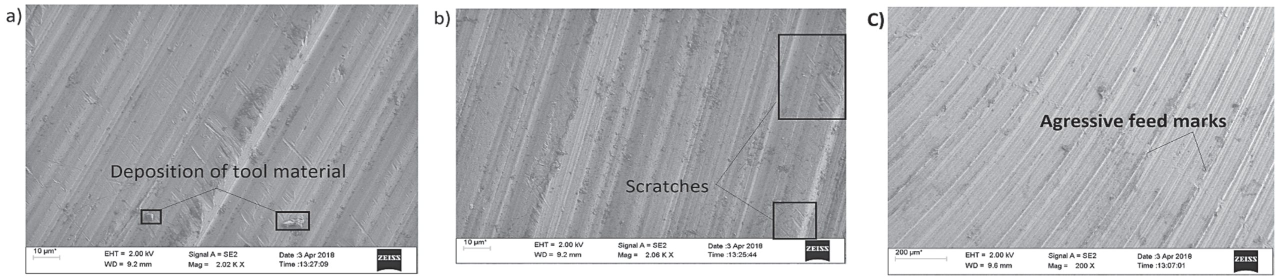

Figure 4 a-c Observed surface defects using SEM micrograph

than 0,6 mm. It is also noticed that reduction of cutting temperature improves tool life considerably.

Surface defect

SEM micrographs of different turning parameters are shown in Figure 4. From the Figure 4 a – c, SEM micrograph it is clear that the damage on the surface of AISI 410 impeller after the turning operation such as deposition of tool material, scratches and aggressive feed marks. Higher cutting temperatures (above 500 °C) are induced by the increase in cutting parameters (C_s: 160 m/min, F_r: 0,16 mm/rev and D_c: 1,5 mm. This leads to deposition of tool material on the machined surface causes to damages the surface finish. It has been observed from the Figure 4b, larger cutting speed (150 – 160) m/min and depth of cut (0,15 – 0,16) mm/rev produces unbalancing tool positions which causes to produce scratches on machined texture. Figure 4c portrays that higher feed rate (0,158 – 0,16) mm/rev causes to produce aggressive feed marks. This aggressive feed mark increases the surface roughness of the impeller component. Usually less surface roughness reduces the wear of the meshing components like impeller.

The above discussion clearly shows that accurate selection of turning parameter is required to achieve quality components.

Multi-performance optimization through desirability function approach

The objective of the present works deals in maximizing the overall desirability function for lower cutting temperature and minimizing the surface value for the optimal parameters. Table 3 portrays the twenty optimized parameter combination for the lower cutting temperature and surface roughness. The overall desirability for multi-performance characteristic is portrayed in ramp chart Figure 5.

From the interaction effects, the desirability value of 0,851 located on the left hand side are reduced and moves downward towards right. From the Figure 6 overlay plot, it has been found that corresponding to highest desirability 0,851 of turning parameters for multi-performance characteristics for optimal combination are C_s: 80 m/min, F_r: 0,12 mm/rev and D_c: 0,59. The optimized turning setting gives minimum cutting temperature 201°C and surface roughness 0,876 µm.

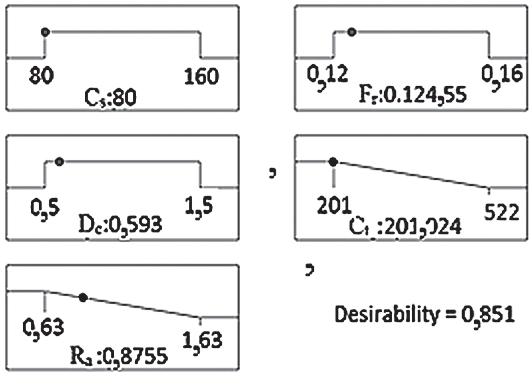

Figure 5 Ramp of desirability values

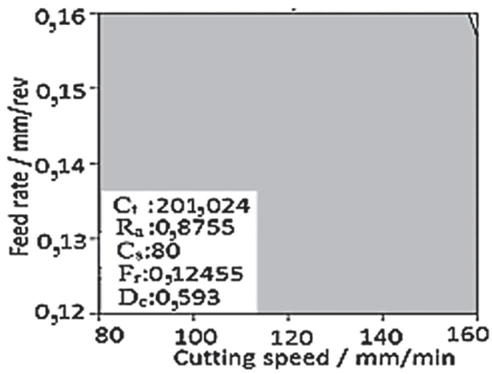

Figure 6 Overlay plot

Table 3 **Optimized results using desirability function**

C_s / m/ min	F_r / mm/rev	D_c / mm	C_t / °C	R_a / µm	D_f
80,00	0,12	0,59	201,00	0,876	0,851
80,00	0,12	0,59	201,00	0,876	0,851
80,00	0,12	0,60	201,00	0,876	0,851
80,00	0,13	0,60	201,00	0,876	0,851
80,00	0,12	0,58	200,89	0,876	0,851
80,00	0,13	0,61	201,00	0,876	0,851
80,00	0,12	0,58	200,92	0,876	0,851
80,00	0,12	0,58	200,21	0,876	0,851
80,00	0,12	0,58	201,00	0,876	0,851
80,01	0,13	0,61	201,00	0,876	0,851
80,00	0,13	0,62	200,99	0,876	0,851
80,00	0,13	0,59	195,14	0,876	0,851
80,00	0,13	0,63	200,71	0,877	0,850
80,00	0,13	0,59	192,78	0,877	0,850
80,00	0,13	0,63	198,79	0,878	0,850
80,00	0,12	0,54	200,99	0,879	0,849
80,52	0,13	0,60	201,00	0,879	0,849
80,00	0,13	0,65	201,00	0,879	0,849
80,00	0,13	0,58	177,04	0,880	0,849
80,00	0,13	0,58	165,95	0,882	0,847

CONCLUSION

An observation made from this investigation draws the following conclusion.

- Higher cutting temperatures (above 500 °C) are induced by the increase in cutting parameters (C_s: 160 m/min, F_r: 0,16 mm/rev and D_c: 1,5 mm. This leads to deposition of tool material on the machined surface causes to damages the surface finish.
- By adopting selections of lower feed rate values, the aggressive feed marks can be reduced
- The perturbation effects from the surface plots reveals that minimum cutting temperature attained for the range of cutting parameters like cutting speed (80 - 90) m/min, feed rate (0,12 - 0,13) mm/rev and depth of cut less than 0,7 mm.
- It is also observed from perturbation plot that surface roughness can be achieved minimum condition for the range of process parameters like cutting speed (145 - 160) m/min, feed rate (0,13-0,14) mm/rev and depth of cut less than 0,6 mm·mm/rev and depth of cut less than 1 mm.
- A parameter combination of twenty optimized solutions is obtained based with multi-objective optimization by desirability approach. Corresponding to highest desirability 0,851 of turning parameters for multi-performance characteristics for optimal combination are C_s: 80 m/min, F_r: 0,12 mm/rev and D_c: 0,59. the optimized turning settings gives minimum cutting temperature 201°C and surface roughness 0,876 µm.

REFERENCES

[1] W. B. Rashid, S. Goel, J. P. Davim,N.Shrikrish--na. Parametric design optimization of hard turning of AISI 4340 steel (69 HRC). Int J Adv Manuf Technol 82(2016), 451–462.

[2] N. Sugita, K. Ishii, T. Furusho, K. Harada, M. Mitsuishi. Cutting temperature measurement by a micro-sensor array integrated on the rake face of a cutting tool. CIRP Annals - Manufacturing Technology 64(2015), 77-80.

[3] N. Zeelanbasha, V. Senthil, B. S. Sylvester. An experimental investigation into the impact of vibration on the surface roughness and its defects of Al6061-T6. Metaulurgija 57(2018) 1-2, 121-124.

[4] J. A. Palacios. Combination of simulated annealing and pseudo spectral methods for the optimum removal rate in turning operations of nickel-based alloys.Advances in Engineering Software 115(2018), 391-397.

[5] Mia, Mozammel. Prediction and optimization of surface roughness in minimum quantity coolant lubrication applied turning of high hardness steel. Measurement, 118 (2018), 43-51.

[6] Y. Feng, L. Zheng, M. Wang, B. Wang, J. Hou, T. Yuan. Research on cutting temperature of work-piece in milling process based on WPSO. Int J Adv Manuf Technol, 128 (2015), 416-424.

[7] Ghosh, P. Sarathi. Empirical Modelling and Optimization of Temperature and Machine Vibration in CNC Hard Turning. Materials Today: Proceedings 5 (2018) 5, 12394-12402.

[8] Selaimia, Abde. Modeling and optimization in dry face milling of X2CrNi18-9 austenitic stainless steel using RMS and desirability approach. MeasurementN 107 (2017), 53-67.

[9] G. Srinivasarao, D. Suneel. Parametric Optimization of WEDM on α-β Titanium Alloy using Desirability Approach. Materials Today: Proceedings 5 (2018) 2, 7937-7946.

[10] Kumar, Vikas, H. Singh. Machining optimization in rotary ultrasonic drilling of BK-7 through response surface methodology using desirability approach. Journal of the Brazilian Society of Mechanical Sciences and Engineering 40 (2018) 2, 83-95.

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