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MULTI OBJECTIVE GENETIC ALGORITHM BASED OPTIMIZATION OF PROCESS PARAMETERS FOR HARD PART TURNING

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ABSTRACT

The paper outlines an experimental study to explain the effect of various process parameters on hard turning of EN19, is a high quality alloy steel which is heat treated to 50HRC. Four parameters were chosen as process variables: Speed, Feedrate, and Depth of cut and coolant flow rate. Surface roughness, tool-work piece interface temperature, and Material removal rate are selected as responses. Design of experiment is prepared using Box-Behnken designs in Response surface methodology and 28 experiments were performed on a CNC lathe. Minitab-17, a software environment for statistical computing and graphics is applied successfully for analyzing the effect of different process parameters. An attempt is be made to optimize the cutting parameters using Multi Objective Genetic Algorithm in the focus of attaining minimum surface roughness, minimum work piece temperature and maximum material removal rate.Confirmation experiments were performed in order evaluate the effectiveness of the generated result

KEYWORDS: Genetic Algorithm, Hard Part Turning, Response Surface Methodology

INTRODUCTION

The main challenge of the manufactures is to increase the production rate and to decrease the production cost without affecting the quality, for which selection of machining parameters place an important role. Manufacturers now design these components for HPT rather than grinding. As a single-point contact method, HPT can easily accomplish complex contours without need for the costly form wheels that multi-point contact grinding requires. Similarly, HPT permits machining of multiple operations with just one set-up. The result is excellent positional accuracy, reduced part handling and less risk of part damage. All in all, HPT reduces machine tool costs and gives better production control, quicker throughput and higher quality. Optimization is the act of obtaining the best result under given circumstances. It can be defined as the process of finding the conditions that give the maximum or minimum value of a function. Optimum machining parameters can be done by considering a single objective function like desired surface finish, maximum material removal rate, minimum tool-work piece interface temperature, minimum cutting force, minimum tool wear, maximum tool life, and minimum power consumption during machining. Evolutionary algorithms like genetic algorithm, ant colony optimization and swarm particle optimization are used to solve multi objective optimization.[1]. The MOGA is a population based search procedure which has been shown to solve linear and nonlinear problems by exploiting promising areas through mutation, crossover and selection operations applied to individuals in the population. [2]. A large number of analytical and experimental studies have been conducted on surface roughness in turning operations

[3].The work piece was considered to be smooth enough when the two surfaces were felt to have the same roughness [4]. The importance of temperature prediction for the machining processes has been well recognized in the machining research community primarily due to its effects on tool wear and its constraints on the productivity. It is well observed that particularly the rate of wear is greatly dependent on the tool–chip interface temperature [5]. The material removal rate (MRR) in turning operations is the volume of material/metal that is removed per unit time in mm^3/min. For each revolution of the work piece, a ring shaped layer of material is removed. In this work the MRR during hard turning of EN19 steel is considered. Machining of hard part components is very difficult. The HPT refers to the turning of work pieces having hardness value greater than 45 HRC. In HPT the MRR has very much importance because it determines the machining time required to finish the heat treated specimen. The objective of this research is to study the effects of machining parameters such as Speed, Feed, Depth of Cut and Coolant flow rate on Surface Finish, Tool - Work interface Temperature and Material Removal Rate during hard turning of EN-19 steel with HRC 50 and to find out the Optimum Parameter Combination for better Surface Finish ,minimum Tool & Work interface Temperature and Material Removal Rate for hard turning of EN-19 steel with HRC 50. Response Surface Methodology and Multi Objective Genetic Algorithm are used to accomplish the objective.

RESPONSE SURFACE METHODOLOGY

Response Surface Methodology is a specialized DOE technique that may be used to detail and optimize transfer functions of different problems .[6] The method can be used in the optimization phase of the problem . Response Surface Methodology (RSM) is a combination of statistical and optimization methods that can be used to model and optimize designs. RSM works by applying different designed experiments to obtain a polynomial model of the process keeping the independent variable as the system output which is minimized the various forms of regression analysis concentrate on using existing data to predict future results. It is used to examine the relationship among several factors and the results.[7] Regression is applied to create models to predict the results when combinations of factors interact under various conditions. It is one of the most widely used statistical tools because it provides a simple method of establishing a functional relationship among variables. In most of the RSM problems, the form of relationship between the response and the independent variable is unknown. Thus the first step in RSM is to find a suitable approximation for the true functional relationship between 'y' and the set of independent variables employed. Usually a second-order model is utilized in response surface methodology. The Box-Behnken design is a response surface methodology (RSM) design that requires only three levels to run an experiment. It is a special 3-level design because it does not contain any points at the vertices of the experiment region.in this investigation the Box-Behnken design is selected to prepare the trial table to conduct the experiment.it involves 28 set of experiment with combination of three levels of all the parameters considered.[8]

EXPERIMENTAL DETAILS

EN19 is usually available as untreated but it can be heat treated to required hardness for different applications. EN19 in its heat treated forms possesses good homogenous metallurgical structures, giving consistent machining properties. It can be surface-hardened typically to 45-55 HRC by induction processes, producing components with enhanced wear resistance.EN19 is suitable for the manufacture of parts such as general-purpose axles and shafts, gears, bolts and studs, I C engine camshafts. Table 3.1 & 3.2 shows the chemical composition and selected parameters and their level for the experiment respectively. The cutting tools used are uncoated carbide inserts of grade H13A made by SANDVIK Coromant. Uncoated grades are selected due to the fact that the EN19 alloy has got high chemical reactivity in its heat treated condition. The hard turning of EN 19 steel is done on a CNC lathe. Surface roughness can be generally described as the geometrical feature of the surface. The surface roughness measurement is carried out by using a stylus type roughness tester. The temperature measurement is carried out using infrared type temperature measuring instrument. The diameter of the work piece before and after the machining and the machining time also noted for calculating MRR. 28 experiments were performed as per the box- behnken design on a CNC lathe to study the effect of process parameters over the response.

Table 3.1: Chemical Composition of EN19 [10]

Component	Percentage
Carbon	**0.**0.35-0.45 %
Silicon	0.10-0.35 %
Manganese	0.50-0.80 %
Chromium	0.90-1 %
Sulphur	0.050 Max

Table 3.2: Parameters and Their Level Selected

	-1	0	1
Speed (m/min)	20	30	40
Feed (mm/min)	0.1	0.15	0.2
Depth of cut (mm)	0.4	0.6	0.8
Coolant flow rate	0	0.5	1

Table 3.3: Data Collection

Trial	Temperature °C	Ra µm	MRR Mm^3/Sec
1	33.8	1.36	40.004
2	35	2.2	43.52
3	34.8	1.29	23.89
4	33.8	1.911	54.29
5	32.7	0.911	35.32
6	35.2	0.901	44.17
7	32.2	0.65	30
8	32.6	2.41	29.49
9	32.8	1.201	54.6
10	32.3	0.921	33.7
11	31.5	1.31	33.01
12	32.8	0.931	24.08
13	30.7	0.911	23.75
14	31.7	0.891	15.39
15	32.5	0.801	15.45
16	35.6	1.311	24.08
17	31.5	0.801	44.92
18	31.5	1.701	30.29
19	31.8	0.641	28.29
20	35.5	1.211	31.64
21	31.9	0.801	35
22	32	0.681	22.84
23	32.8	1.031	32.92
24	31.4	1.008	59.3

25	30.7	0.871	22.96
26	30.9	1.711	42.45
27	34.5	1.611	44
28	30.5	0.85	23.71

RESULTS AND DISCUSSIONS

From the analysis of the results using MINITAB-17 it is found that as the feed rate varies from 0.1 to 0.2 mm/min, it is found that the Ra value is increased that is the surface finish is decreased and when the cutting speed varies from 20 to 40 m/min, it is found that the Ra value is decreased that is the surface finish is increased. As the depth of cut varies from 0.4 to 0.8 mm, it is found that the Ra value is increased that is the surface finish is decreased and when the coolant flow rate varies from 0 to 1 liters/min, it is found that the Ra value is decreased that is the surface finish is increased. Figure 4.1 shows the main effect plot for surface roughness.

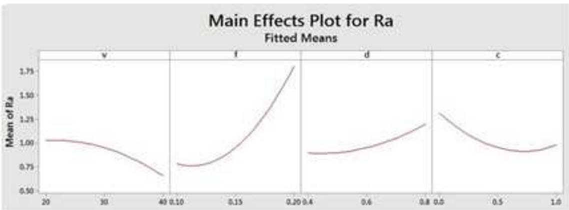


Figure 4.1: Main Effect Plots for Ra

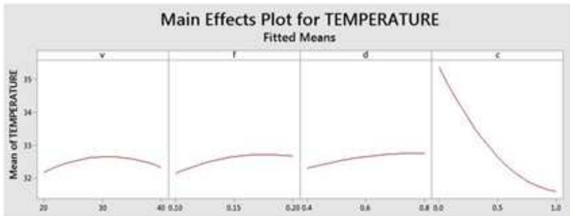


Figure 4.2: Main Effect Plots for Temperature

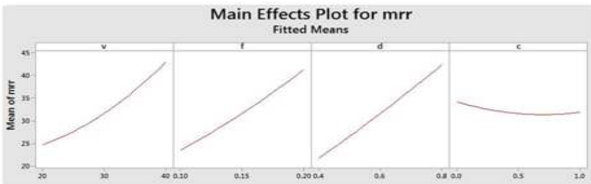


Figure 4.3: Main Effect Plots for MRR

From the main effect plot shown in the figure 4.2 we can say that when the cutting speed varies from 20 to 40 m/min, it is found that the temperature is increased first then decreased and as the feed rate varies from 0.1 to 0.2 mm/min, it is found that the temperature is increased. As the depth of cut varies from 0.4 to 0.8 mm, it is found that temperature is increased since load on tool is increased ad feed and depth of cut proceeds. When the coolant flow rate is varied from 0 to 1 liters/minute, it is found that the temperature is decreased.

From the main effect plot shown in the figure 4.3 we can say that as the feed rate varies from 0.1 to 0.2 mm/min, it is found that the MRR is increased and also when the cutting speed varies from 20 to 40 m/min, it is found that the MRR is increased. When the depth of cut varies from 0.4 to 0.8 mm, it is found that the MRR is increased. When the coolant flow rate varies from 0 to 1 liters/min, it is found that the MRR is found to be almost constant.

A second order Response surface qadratic model were fitted using Minitab-17 for all the response variables Ra and temperature and MRR.

$$Ra = 0.81 - 16.1 f + 0.1330 v - 2.88 d - 1.625 c + 136.3 f*f - 0.001070 v*v + 2.36 d*d + 0.778 c*c - 0.585 f*v + 5.25 f*d - 0.49 f*c - 0.0076 v*d + 0.0100 v*c + 0.472 d*c \quad (1)$$

$$T = 37.02 - 15.8 f + 0.233 v - 9.1 d - 15.32 c - 98 f*f - 0.00396 v*v - 3.02 d*d + 3.32 c*c + 0.200 f*v + 72.5 f*d$$

$$+ 2.0\, f*c - 0.075\, v*d + 0.0550\, v*c + 10.50\, d*c \qquad (2)$$

$$MRR = 68.1 - 3.11\, v - 266\, f - 26.2\, d - 15.0\, c + 0.0217\, v*v + 306\, f*f + 10.2\, d*d + 5.46\, c*c + 9.61\, v*f + 1.750\, v*d + 0.432\, v*c + 111\, f*d - 9.1\, f*c - 7.2\, d*c \qquad (3)$$

Equation (1) , (2) and (3) shows the best fittedregression models for surface roughness , temperature and MRR. The adequacy of the regression model is evaluated using ANOVA and the percentage contribution of each parameter on each response also found out. Feed rate has largely contributed to Ra by 52.50%,Coolant flow rate has largely contribute to temperature by 66.57 %,Coolant flow rate has largely contributed to power consumption by 55.59 %, Depth of cut has largely contributed to MRR by 36.12 %,

OPTIMIZATION USING MULTI OBJECTIVE GENETIC ALGORITHM

Genetic algorithm optimization technique is proposed to determine the optimal level for each parameter and the developed regression models are used as the fitness function in genetic algorithm (GA) optimization technique. The MOGA tool is run by changing population size, reproduction cross over fraction, migration fraction to minimize the fitness/objective function. In case of larger-the-best type (MRR) of responses a unity negative factor is multiplied to fitness function to make them minimize type. In the present study, the objectives are minimization of Ra, maximization of MRR, minimization of temperature.Crossover is a mechanism, which creates new individuals by combining parts from two individuals. Mutation is a mechanism, which creates new individual by making changes in a single individual. The GA code was developed using MATLAB14. The input machining parameter levels were fed to the GA program.

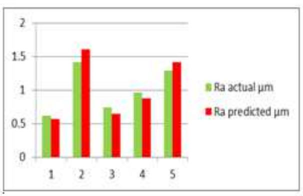
The objective functions are given below.

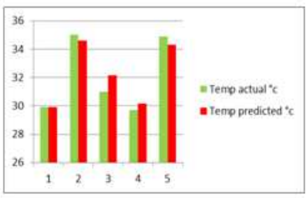
Objective 1 = Surface Roughness (Ra)

Objective 2 = - (MRR)

Objective 3 = Temperature

50 non-dominated solutions are obtained at the end of 223 generation and from that 5 combinations were randomly selected and conducted the confirmation experiment to evaluate the effectivenss of the generated results and is is found that the generated results are with in the acceptable limits. The average percentage of error for the surface finish is found to be 10.58 %.Figure 5.1 shows bar graph of actual Ra vs. Predicted. The average percentage of error for the temperature is found to be 1.60 %.Figure 5.2 shows bar graph of actual temperature vs. Predicted. The average percentage of error for the MRR found to be 5.62 %.Figure 8.3 shows bar graph of actual MRR vs. Predicted.





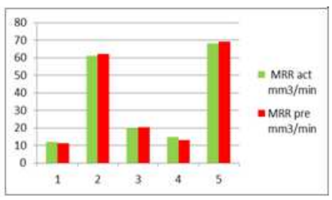


Figure 5 1: Actual Ra Vs. Predicted. Figure 5.2: Actual Temp Vs. Predicted. Figure 5.3: Actual MRR Vs. Predicted

CONCLUSIONS

Feed rate has largely contributed to Ra by 52.50%, speed by 6.97% and coolant flow rate by 5.81% and depth of cut by 4.49 %. Coolant flow rate has largely contribute to temperature by 66.57 %, feed rate by 1.26%, depth of cut by 0.95% and cutting speed by 0.106 %.Depth of cut has largely contributed to MRR by 36.12 %, cutting speed by 27.21%, feed rate by 26.47% and coolant flow rate by 0.42%.Confirmation test were carried out to evaluate the effectiveness of the proposed MOGA optimization results and the percentage of error is calculated and is within the acceptable limit.

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