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EFFECT OF PROCESS PARAMETERS ON HARD TURNING OF EN19 STEEL AND OPTIMIZATION USING GENETIC ALGORITHM

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Abstract
The present 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, Feed, and Depth of cut and coolant flow rate. Surface roughness, tool-work piece interface temperature, is selected as responses. Design of experiment is prepared using Box-Behnken designs in Response surface methodology. 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 Genetic algorithm in the focus of attaining minimum surface roughness, minimum work piece temperature.
Keywords — EN 19, Hard turning, Response surface methodology, Genetic algorithm

Introduction

Machining operations have been the center of attraction of the manufacturing industry since the revolution of industries. Increasing the productivity and the quality of the machined parts are the main challenges of metal-based industry; there has been increased interest in monitoring all aspects of the machining process.[4] In modern industry the goal is to manufacture low cost, high quality products in short time. Automated and flexible manufacturing systems are employed for that purpose along with computerized numerical control (CNC) machines that are capable of achieving high accuracy and very low processing time. Turning is the most widely used among all the cutting processes. The increasing importance of turning operations is gaining new dimensions in the present industrial age, in which the growing competition calls for all the efforts to be directed towards the economical manufacture of machined parts and surface finish is one of the most critical quality measures in mechanical products.[2]

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.[3] Optimum machining parameters can be done by considering a single objective function like desired surface finish, maximum material removal rate or maximum tool life etc. Optimum machining parameters achieved for an objective function may not be suited for another objective function. Efficient machining parameters can be achieved by considering Multi Objective Optimization [1] .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. The objective of this experimental investigation 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 during hard turning of EN-19 steel with HRC 50 and to find out the Optimum Parameter Combination for better Surface Finish and Minimum Tool & Work interface Temperature for hard turning of EN-19 steel with HRC 50. Response Surface Methodology is 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 .[5]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.[5] 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

$$y = \beta_0 + \sum_{i=1}^{k} \beta i x i + \sum_{j=1}^{k} \beta i i x i^2 + \sum_i \sum_j \beta i j\, x i\, x j \pm \varepsilon \qquad (1)$$

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.[7]

Experimental details

The work material selected for the study is EN19 steel. EN19 is a high quality, high tensile steel which 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.

TABLE 3.1 Chemical composition of EN19

Constituent	C	Si	Mn	Cr	P & S	Mo
% composition	0.35 to 0.45	0.10 to 0.35	0.50 to 0.80	0.90 to 1	0.05 max	0.20 to 0.40

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 3.1 & 3.2 shows the chemical composition and selected parameters and their level for the experiment respectively

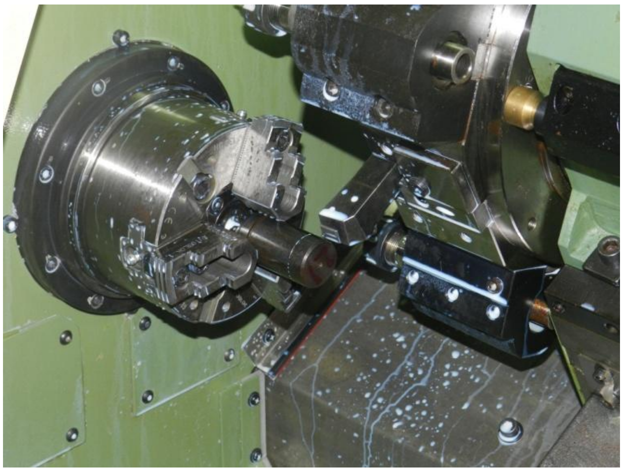

Figure 3.1 Turing

Figure 3.2 Surface Roughness Measurements

Figure 3.3 Temperature Measurement

The hard turning of EN 19 steel is done on a CNC lathe. Surface roghness can be generally described as the geometrical feature of the surafce.The surface roughness measuremnt is carried out by using a stylus type roghness tester. 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.The temperature measurement is carriedout using infrared type temeprature measuring instrument.

TABLE 3.3 Box-Behnken design for the present work

Trial	Speed	Feed	D O C	Coolant Flow Rate
1	30	0.15	0.8	1
2	30	0.20	0.6	0
3	30	0.10	0.6	0
4	30	0.20	0.8	0.5
5	30	0.15	0.6	0.5
6	40	0.15	0.6	0
7	40	0.15	0.4	0.5
8	20	0.20	0.6	0.5
9	40	0.20	0.6	0.5
10	30	0.15	0.6	0.5
11	20	0.15	0.8	0.5
12	30	0.15	0.6	0.5
13	20	0.15	0.6	1
14	20	0.15	0.4	0.5
15	30	0.10	0.4	0.5
16	30	0.15	0.4	0
17	40	0.15	0.6	1
18	30	0.20	0.4	0.5
19	40	0.10	0.6	0.5
20	20	0.15	0.6	0
21	30	0.10	0.8	0.5
22	20	0.10	0.6	0.5
23	30	0.15	0.6	0.5
24	40	0.15	0.8	0.5
25	30	0.15	0.4	1
26	30	0.20	0.6	1
27	30	0.15	0.8	0
28	30	0.10	0.6	1

Results and analysis

The experiments were conducted to study the effect of process parameters over the output response characteristics with the process parameters as given in table 3.3.The experimental result for surface roughness and tool-work piece interface temperature is shown in table 4.1

TABLE 4.1 Experimental results

Trial	**Temperature**	**Ra**
	°c	**µm**
1	33.8	1.36
2	35	2.2
3	34.8	1.29
4	33.8	1.911
5	32.7	0.911
6	35.2	0.901
7	32.2	0.65
8	32.6	2.41
9	32.8	1.201
10	32.3	0.921
11	31.5	1.31
12	32.8	0.931
13	30.7	0.911
14	31.7	0.891
15	32.5	0.801
16	35.6	1.311
17	31.5	0.801
18	31.5	1.701
19	31.8	0.641
20	35.5	1.211
21	31.9	0.801
22	32	0.681
23	32.8	1.031
24	31.4	1.008
25	30.7	0.871
26	30.9	1.711
27	34.5	1.611
28	30.5	0.85

From the analysis of the results using MINITAB-17 it 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.

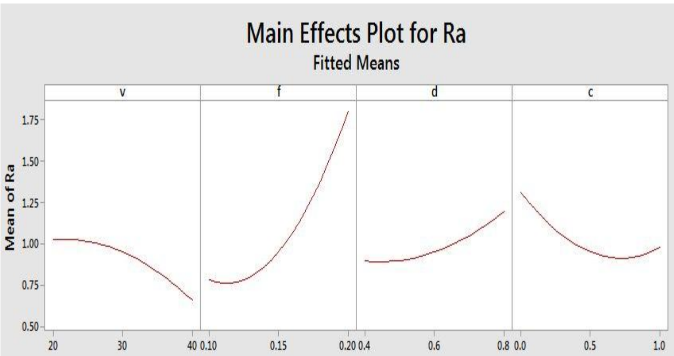

Figure 4.1 Main effect plots for Ra

As the feed rate varies from 0.1 to 0.2 mm/min, it is found that the temperature is increased and when the cutting speed varies from 20 to 40 m/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 and when the coolant flow rate varies from 0 to 1 liters/min, it is found that the temperature is decreased. Figure 4.2 shows the effect plots for temperature.

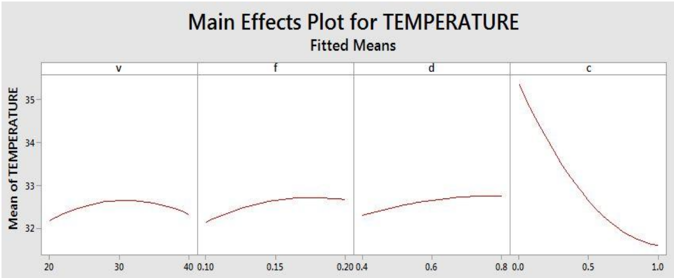

Figure 4.2 Main effect Plot for temperature

A second order Response surface equations has been fitted using Minitab-17 for all the response variables Ra and temperature.

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 (2)

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 (3)

Equation (2) and (3) shows the best fitted models for surface roughness and temperature.

I. Optimization Using Multi Objective Genetic Algorithm

Genetic algorithms are search procedures that emulate the process of evolution in nature [7].The algorithm start with an initial population generated randomly by a seeding procedure. The quality of each solution of the population is evaluated using the fitness function. [6] The crossover process consists of taking two strings or parents from the population and performing a random exchange of portions between them to form a new solution. Mutation involves changes in individual *values of variables in a solution. In the present study a*n initial set of 50 populations are chosen randomly *and* Cross over probability is set to 0.8 and mutation interval as 20.*The* Pareto fraction is set to 0.35 *and* 18 efficient solutions are obtained at the end of 267 generation.

TABLE 5.1 Pareto Front solutions

No.	Ra	T	S	F	DOC	Flow rate
1	0.464	30.4	20	0.10	0.44	0.810
2	1.95	28.6	20	0.19	0.40	0.998
3	1.49	28.9	20	0.18	0.40	0.996
4	0.79	29.4	20	0.14	0.40	0.987
5	1.29	29.1	20	0.17	0.40	0.984
6	0.82	29.4	20	0.14	0.40	0.988
7	0.61	29.5	20	0.12	0.40	0.985
8	1.3	29.1	20	0.17	0.40	0.988
9	0.46	30.4	20	0.10	0.44	0.810
10	1.17	29.1	20	0.16	0.40	0.996
11	1.08	29.5	20	0.16	0.40	0.992
12	1.41	29.0	20	0.17	0.40	0.995
13	0.56	29.8	20	0.12	0.41	0.945
14	0.48	30.1	20	0.10	0.43	0.889

15	1.78	28.7	20	0.19	0.40	0.997
16	1.95	28.6	20	0.19	0.40	0.998
17	1.64	28.8	20	0.18	0.40	0.997
18	0.703	29.5	20	0.13	0.401	0.988

Table 5.1 shows the Pareto front solution generated by Genetic algorithm and 7th pareto-front solution is suggested for hard turning of EN19 steel with HRC 50 for cam shaft applications. The figure 5.1 shows the Pareto-Front plot of the generated solution.

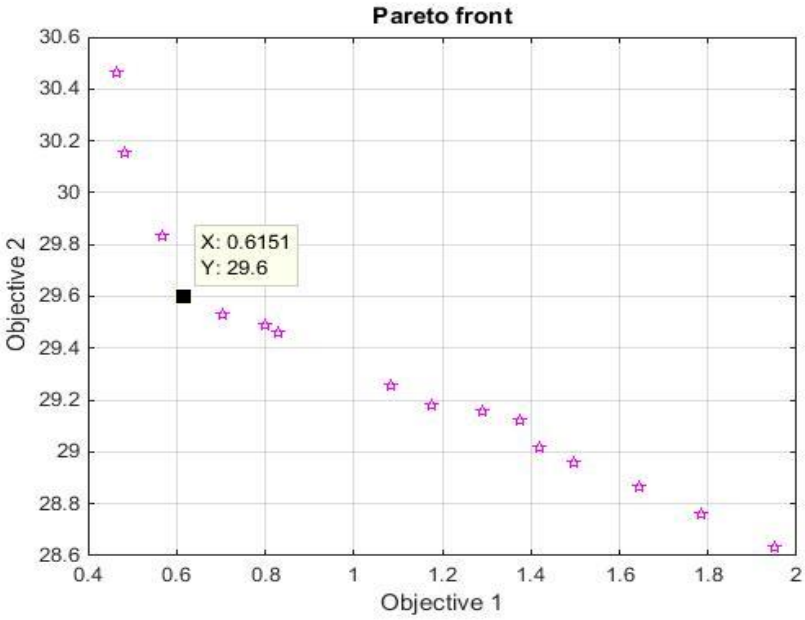

Figure 5.1 Pareto Front plot

VI.Conclusions

It is found that surface finish is directly proportional to Cutting speed and coolant flow rate and inversely proportional to federate and depth of cut. Tool-work piece interface temperature is directly proportional to Cutting speed, feed, Depth of cut and inversely proportional to coolant flow rate. The Machining process is optimized for better surface finish and minimum tool-work piece temperature using Multi-objective Genetic algorithm and is 0.61µm and 29.6°c respectively.

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