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Optimization of Cutting Parameters in Turning of En-19 by using Taguchi and Genetic Algorithm

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***Abstract*— This paper deals with the Taguchi technique and Genetic algorithm (GA) for predicting the responses of turning operation on CNC lathemachine for EN19steel. The number of experiments has been carried out using Taguchi's orthogonal array in the design ofexperiments (DOE). The cutting parameters are spindle speed, feed rate and depth of cut. The Analysis of Variance (ANOVA) and Signal-to-Noise ratio were used to study the performance characteristics in turning operation. The accurate mathematical model has been developed using genetic algorithm.The genetic algorithm is used to get the optimum cutting parameters by using the regression equations of different parameters. The research showed acceptable prediction results for the developed model.**

Keywords* — *Taguchi, GA, DOE, ANOVA.

I. INTRODUCTION

Turning is the process of removal of metal from the outer diameter of a rotating cylindrical work piece. Turning is used to reduce the diameter of the work piece, usually to a specified dimension, and to produce a smooth finish on the metal. The selection of EN-19 steel is widely used in production of gears, bolts, studs and a wide variety of applications where a good quality high tensile steel grade is suited. In the past, Aasheet Kumar (2014) investigated the effect of cutting speed, feed, axial and radial depth of cut on cutting force in machining of EN19 steel in turning process for achieving the optimum surface finish. Shashikant (2014) investigated the effect of pulse on time, pulse off time, discharge current and gap voltage in machining of EN19 steel in EDM process. They concluded that pulse off time, discharge current, gap voltage and the interaction terms were significant where as the pulse on time had almost negligible effect towards MRR. Ashish Kabra (2013) investigated the effect of process parameters in CNC turning on Surface roughness, feed and radial forces of EN19/AISI4140 (medium carbon steel) work material in dry environment conditions. The optimal and predicted results are also verified with the help of confirmation experiments using Taguchi's Orthogonal Array (OA) and Minitab-16 statistical software. Adnan Jameel (2013) used GA algorithm in different machining aspects in turning operation like surface roughness, production rate, tool life, production cost, machining time and cutting temperature. The survey showed that there are many papers in the field of turning parameters optimization using GA, but there is a lack in studies in the field of cutting temperature optimization in turning operation which is very important problem in machining operation. N.Zeelan Basha (2013) developed the response surface model to predict the surface roughness in turning operation of Aluminium 6061 using coated carbide tool. This technique used Box-Behnken of Response Surface Methodology (RSM) in design expert software 8.0 and genetic algorithm in matlab8.0. The objective is to predict the surface roughness of cutting parameters like Spindle speed, Feed rate and Depth of cut. Abdelouahhab Jabri (2013) developed a multi-optimization technique based on genetic algorithms to search optimal cuttings parameters such as cutting depth, feed rate and cutting speed of multi-pass turning processes. Two objective functions are simultaneously optimized under a set of practical of machining constraints, the first objective function is cutting cost and the second one is the used tool life time. The proposed model deals multi-pass turning processes where the cutting operations are divided into multi-pass rough machining and finish machining. Results obtained from Genetic Algorithms method are presented in Pareto frontier graphic; this technique helps us in decision making process.

II. MATERIALS AND METHODS

A. EN 19 STEEL

A high quality alloy steel specification usually supplied as a high tensile steel grade to EN19T or EN19U. This grade offers good ductility and shock resisting properties combined with resistance to wear. With these characteristics it is a popular high tensile engineering steel with a tensile of 850/1000 N/mm². At low temperatures EN19 has reasonably good impact properties. It is also suitable for a variety of elevated temperature applications. For maximum wear and abrasion resistance EN19 can be nitride to give a shallow depth wear resistant case. Flame or induction hardening can give a case hardness of 50 HRC or higher.

TABLE I. CHEMICAL COMPOSITION

Element	C	Si	Mn	Cr	Mo	S	P
Weight%	0.36-0.44	0.1-0.35	0.70-1	0.9-1.20	0.25-0.35	0.035	0.040 Max

Genetic algorithm, differing from conventional search techniques, start with an initial set of random solutions called population. Each individual member of the population is called chromosome, representing a solution to the problem at hand. A chromosome, is a string of symbols or genes, it is usually, but not necessarily, a binary bit string. The chromosomes evolve through successive iterations called generations. During each generation, the next chromosomes are evaluated using some measure of fitness.

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B. *Design of Experiments*

The design of experiments (DOE) technique has been implemented to conduct the experiments. It is a powerful work tool which allows us to model and analyse the influence of determined process variables over the specified variables, which are usually known as response variables. These response variables are unknown functions of the former design variables, which are also known as design factors. Within the design of experiments, there are various types that can be considered. One of the most widely known ones is the orthogonal array design. In this study, the surface roughness of EN19 material was investigated by considering the process parameters, cutting speed, cutting feed and depth of cut. Therefore, a DOE setup was considered cutting speed with two levels, cutting feed and depth of cut with four levels each and then 2×4×4=32 runs were required in the experiments for three independent variables.

III. EXPERIMENTAL DETAILS

The experiments were conducted in CNC lathe machine from Hardinge (Taiwan) company. CNC lathe machine with model number SV 150 with capacity of work piece diameter 150 mm and length 300 mm. The maximum spindle speed of the machine is 6000 rpm and with machining accuracy ±0.5 mm. The number of tools stored in the CNC lathe machine 12 tools. The machining parameters used and their levels chosen are presented in Table

TABLE II. TABLE: CONTROL FACTORS

Control Factors	Units	Level 1	Level 2	Level 3	Level 4
Depth of cut	Mm	0.25	0.5		
Speed	Rpm	700	800	900	1000
Feed	mm/rev	0.05	0.10	0.15	0.20

The surface roughness was measured by using Surtronic 3+ stylus type instrument manufactured by Taylor Hobson with the following specifications. Traverse Speed: 1mm/sec, Cut-off values 0.25 mm, 0.80 mm and 2.50 mm, Display LCD matrix, Battery Alcaline 600 measurements of 4 mm measurement length.

IV. RESULTS AND DISCUSSION

The experiments were as conducted as per L32 orthogonal arrays and material removal rate is calculated by using below formula.

$$MRR = \prod * D*N*f/60(mm^3/min)$$

TABLE III. TABLE: EXPERIMENTAL RESULTS

SL. NO	Depth of cut (mm)	Speed (rpm)	Feed (mm/ rev)	Surface roughness	MRR (mm3/min)
1	0.25	700	0.05	2.020	652.862
2	0.25	700	0.10	3.820	1278.23
3	0.25	700	0.15	3.014	1876.12
4	0.25	700	0.20	2.661	2446.51
5	0.25	800	0.05	2.383	683.30
6	0.25	800	0.10	2.212	1335.18
7	0.25	800	0.15	2.400	2238.38
8	0.25	800	0.20	2.000	2921.68
9	0.25	900	0.05	2.400	804.05
10	0.25	900	0.10	1.200	1572.76
11	0.25	900	0.15	0.600	2306.13
12	0.25	900	0.20	0.200	3004.15
13	0.25	1000	0.05	3.081	932.66
14	0.25	1000	0.10	2.704	1826.05
15	0.25	1000	0.15	1.050	2680.17
16	0.25	1000	0.20	1.473	3495.02
17	0.5	700	0.05	3.546	1291.98
18	0.5	700	0.10	2.325	2474.00
19	0.5	700	0.15	1.697	3546.07
20	0.5	700	0.20	1.904	4508.19
21	0.5	800	0.05	2.190	1225.22
22	0.5	800	0.10	0.747	2324.78
23	0.5	800	0.15	1.957	4429.65
24	0.5	800	0.20	2.014	5654.87
25	0.5	900	0.05	2.027	1519.74
26	0.5	900	0.10	1.291	2898.12
27	0.5	900	0.15	1.118	4135.12
28	0.5	900	0.20	1.493	5230.75
29	0.5	1000	0.05	3.575	1845.68
30	0.5	1000	0.10	1.843	3534.29
31	0.5	1000	0.15	1.463	5065.29
32	0.5	1000	0.20	1.653	6440.26

TABLE IV. RESPONSE TABLE FOR MATERIAL REMOVAL RATE

Level	Depth of cut		Speed		Feed	
	S/N ratios	*Means*	*S/N ratios*	*means*	*S/N ratios*	*means*
1	64.38	1878	65.73	2259	60.43	1119
2	69.84	3508	66.57	2602	66.15	2155
3			67.30	2684	69.83	3285
4			68.83	3227	72.02	4203
Delta	5.46	1629	3.10	968	11.59	3093
Rank	2	2	3	3	1	1

TABLE V. ANALYSIS OF VARIANCE FOR MATERIAL REMOVAL RATE

Source	DOF	Sum of squares	Mean of squares	F	P	% of total
Depth of cut	1	2.12410E+07	2.12410E+07	29.980	0.002	38.96
Speed	6	4.25101E+06	7.08502.0937	0.352	0.901	0.001
Feed	24	4.82531E+07	2.01055E+06			61.04
Total	31	7.37452E+07				

The regression equation of material removal rate is

MRR (mm3/min) = - 4892 + 6518 doc + 2.99 speed + 20818 feed.

TABLE VI. RESPONSE TABLE FOR SURFACE ROUGHNESS

Level	Depth of cut		Speed		Feed	
	S/N ratios	*means*	*S/N ratios*	*means*	*S/N ratios*	*means*
1	-4.8043	2.076	-8.0428	2.623	-8.2542	2.653
2	-5.1011	1.928	-5.5314	1.988	-5.1356	2.018
3			-0.4471	1.291	-3.4886	1.663
4			-5.7894	2.107	-2.9324	1.676
Delta	0.2968	0.148	7.5956	1.332	5.3219	0.990
Rank	3	3	1	1	2	2

TABLE VII. ANALYSIS OF VARIANCE FOR SURFACE ROUGHNESS

Source	DOF	Sum of squares	Mean of squares	F	P	% of total
Depth of cut	1	0.1745	0.1745	0.124	0.736	0.001
Speed	6	8.4120	1.4020	2.398	0.059	25.89
Feed	24	14.0341	0.5848			74.11
Total	31	22.6206				

The regression equations for surface roughness is

= 4.96 - 0.59 doc - 0.00225 speed - 6.57 feed.

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A. Optimization using genetic algorithm:

The script function is generated for the above equations and with the help of optimtool solver in MATLAB software optimization can be done. To attain desirable surface roughness the optimum parameters are depth of cut 0.498mm, speed 969.264rpm and feed 0.2 mm/rev. To attain desirable surface roughness the optimum parameters are depth of cut 0.5mm, speed 910.477rpm and feed 0.2 mm/rev.

The multi objective functions are converted into single objective function by using operation research techniques like

Objective Function = Max(x) – Min(y) Where Max(x) = Max(MRR), Min(y) = Min(Ra)

*OBJECTIVE FUNCTION = [-4892 + (6518*Doc) + (2.99*Speed) + (20818*Feed)] – [4.96-(0.59*Doc) - (0.002255*Speed) - (6.57*Feed)]*

By combining both surface roughness and material removal rate, the optimum process parameters obtained are Depth of Cut 0.25mm, Speed 712.161rpm and Feed 0.05mm/rev.

V. CONCLUSION

Using Taguchi's orthogonal array design in the design of experiments, the machining parameters which are influencing the surface roughness, material removal rate in turning operation of EN 19 steel has been modeled using genetic algorithm. Based on experimental and GA results, the optimum process parameters obtained for surface roughness and material removal rate are Depth of Cut 0.25mm, Speed 712.161rpm and Feed 0.05mm/rev.

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