Optimizing Turning Process Parameters for EN24 Alloy Steel Using the Taguchi Approach

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Abstract: The present investigation aims to determine the optimum parameters during the turning of EN 24 alloy steel using tungsten coated carbide insert tool under dry cutting conditions. Feed rate, Speed, and depth of cut were selected as the machining parameters and all parameters were three levels each according to the design of experiments Taguchi's L9 orthogonal array (OA). Responses for the experimentation were considered as surface roughness. Effects of the each turning parameters and its levels over the responses was statistically analyzed with the help of response table and analysis of variance (ANOVA) technique. Experimental results represented that surface roughness influenced by Feed rate followed by Speed.

Keywords: *EN24 steel, Surface roughness, Taguchi method, Turning*

1. INTRODUCTION

EN24 is a high quality, high tensile, alloy steel and combines high tensile strength, shock. It is made up of a nickel–chromium-molybdenum and has high tensile strength, water resistance, and ductility. EN24 steel is for the most appropriate material for the manufacture of parts such as gears, bolts, heavy-duty axles, shafts and studs [1]. EN24 is proficient of maintain good impact values at low temperatures. Used at more significant temperatures, EN24 is an excellent material for the various applications because it is a high-strength steel alloy and generally delivered in a heat-treated state [2].

In view of the fact that Turning is the most important function in the majority of the manufacturing industry, Cutting zone temperature of machined components has superior influence on the end product quality [3]. Quality of the turned parts has been discovered to be influenced in varying amounts by a number of factors such as depth of cut, feed rate, unstable built up edge, work hardness, cutting speed, cutting time, cutting fluids etc [4].

Machinability is a very significant belonging for the metal removal process. Among a variety of material removal processes, the turning process is one of the most important and well-known material cutting practice for machining components that is acknowledged to be quick and flexible [5,6]. At the present time current industry are very much concerned about the quality of their products interns of excellence in all aspects. They are paying more concentration on manufacturing high-class quality products at least cost within particular period of time. Therefore, producing enhanced quality components and improving the productivity rate are amongst the major objective of the present production industry [7].

In latest times wide research is going on all the characteristics of the machining due to necessities of the industries, including monitoring cutting zone temperature, surface finish of the parts, tool wear and cutting force. Especially EN 24 alloy steel material used to manufacture machine parts consists of alloying elements like and molybdenum, nickel and chromium difficult to machine, since the cutting tool fails by high tool wear, if use uncoated carbide inserts to machine alloy steels. EN 24 alloy steel capable of retaining good impact values at low temperatures.

Effort has made to learn the outcome of different parameters feed rate, depth of cut and lubricant temperature while machining EN-31steel using tungsten carbide inserts. The authors have adopted L9 Orthogonal Array Taguchi's Experimental method to find out the optimal parameter combination and also the influencing parameter over the observed response surface roughness [8]. The authors expressed that Lubricant temperature is the major factor which affects the surface roughness of the machined work piece than other factors considered for the study. Intermediate depth of cut (0.4 mm), Low level feed rate (0.05 mm/rev) and Minimum lubricant temperature (10°C) are suggested to acquire better surface finish [9]. The authors have reported the influencing parameters on Material removal rate, Power consumption and Surface roughness of EN-19 steels in turning operation using taguchi method furthermore they have reported that four different machining parameters namely Spindle Speed (N), Feed (F), Depth of Cut (D) and Nose Radius (NR) [10]. The authors have suggested that a high cutting speed, low feed rate and medium depth of cut can produce a superior surface finish and taguchi technique is found to be most competent technique for the optimization of turning parameters for the output responses in steel turning with various grades [11].

The research focuses on using vibration signatures during the turning of EN9 and EN24 steel alloys to predict tool life through the application of an Artificial Neural Network (ANN) [12]. During initial meager experimentation, tool acceleration during turning was recorded, and the width of the flank wear at the end of each run was measured using Tool Makers Microscope. The recorded data is utilized to establish the neural network with the diffrent of operating parameters and corresponding tool vibration with measured tool flank wear.

By considering this point, in this current research are focused on optimization of turning operation to retain quality product without compromising of physical properties of alloy steel. Also turning is the primary function in the majority of the manufacturing industry, surface finish of turned components has greater influence on the quality of the product.

2. Materials and Methods

The specimen material for the current study is arranged from EN -24 steel alloys in the shape of 30 mm diameter cylindrical bars and 100 mm in length. The sample piece is machined and cut from lengthy bars by means of power saw and consequently preliminary turning operation is carried out to attain the required dimension. EN24 grade is a nickel chromium molybdenum combination -this offers high tensile steel strength, with good ductility and wear resistance characteristics. The different elements incurred in the material with its composition are listed in Table 1. The cutting tool used for the experimentation was throw away type tungsten carbide inserts. The tungsten carbide insert CNMG120408 of grade P20 was the insert used for these experiments.

Table 1. Element Composition of EN24

Element	C	Mn	Si	S	P	Cr	Ni	Mo
Composition (%)	0.36-0.44	0.45-0.70	0.10-0.35	0.04	0.04	1.00-1.40	1.30-1.70	0.20-0.35

Table 2. Turning Parameters and its Levels

Levels	Speed (rpm)	Feed (mm/rev)	Depth of Cut (mm)
1	1000	0.1	0.5
2	1500	0.2	1
3	2000	0.3	1.5

Three turning parameters namely Spindle speed, Feed and Depth of cut with three different levels were selected to execute the experimentation according to design of experiment concept Taguchi L9 (OA). The table 2. illustrates the three different levels of each turning parameters considered for this study. Turning operations were conducted using CNC Machining centre (Make: Batliboi) using a tungsten carbide inserted tools having higher hardness characteristics under dry cutting conditions at elevated temperatures. The tests has been carried out according to Taguchi technique L9 (OA) given in table 3. with the aim of optimize the process parameters during turning of EN24 to obtain the superior quality of turned parts with reduced Cutting temperature. Surface roughness for the turned parts was measured with the use of HANDYSURFE-35B surface roughness tester shown in Fig. 1

3. RESULT AND DISCUSSION

The experiments have been conducted based L9 Orthogonal array and the observed values of surface roughness for different combination of spindle speed(rpm), feed(mm/rev), and depth of cut(mm) are shown in the Table 3. Surface roughness was calculated different locations of each turned specimens shown in Fig.3 with the help of surface roughness tester and average of three values are shown in Table 3.For the current analysis, the turning parameters have to be optimized for minimum surface roughness. Therefore, "the-smaller-the-better" concept is chosen for this study.

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Fig. 1 HANDYSURFE-35B surface roughness tester

Table 3. Taguchi technique L9 (OA)

Levels	Speed (rpm)	Feed (mm/rev)	Depth of Cut (mm)	Surface roughness (µm)
1	1000	0.1	0.5	2.52
2	1000	0.2	1	3.06
3	1000	0.3	1.5	3.98
4	1500	0.1	1	1.68
5	1500	0.2	1.5	2.51
6	1500	0.3	0.5	3.6
7	2000	0.1	1.5	1.46
8	2000	0.2	0.5	2.82
9	2000	0.3	1	3.13

Main effect Plot

For analysis, a statistical software-Minitab 16 was used for getting the results like interaction graphs with the corresponding responses. These responses are then used in choosing the influenced machining parameters. It has been observed from main effect plot Figure.2 that whenever spindle speed increased, corresponding surface roughness value of the turned surface is decreased. Increased in speed improves the surface finish and other hand surface roughness increases whenever feed increases. Figure.2 shows the main effects plot which has the effect of spindle speed, feed rate, depth of cut on surface roughness. It was observed from the result, feed is the influencing factor on surface roughness among other machining parameters considered.

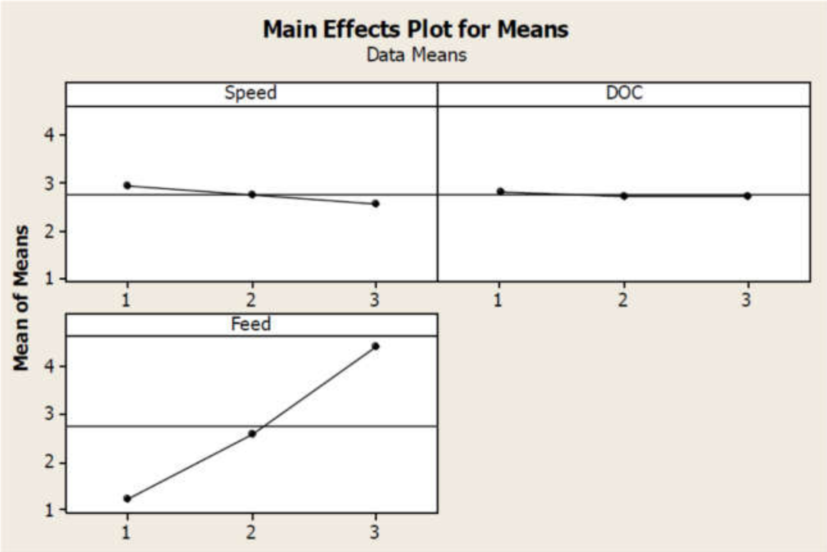

Figure.2 Main effect Plot

Ranking of parameters which indicates the effect of factor on to the response variable is tabulated in response table 4 which reveals that feed is the most influencing factor on surface roughness followed by cutting speed and depth of cut.

Table 4. Response Table for Means

RESPONSE TABLE FOR MEANS

Levels	Speed (A) (rpm)	Feed (B) (mm/min)	Depth of cut (mm)
1	3.44	2.133	3.233
2	2.48	3.047	2.867
3	2.72	3.82	2.9
Delta	0.72	1.687	0.367
Rank	2	1	3

Table 5. ANOVA Table for Surface Roughness

ANOVA TABLE FOR SURFACE ROUGHNESS

Source	Dof	Seq SS	Adj SS	F	P	Pc
Speed (A)	2	0.89280	0.89280	45.86	0.021	16.424
Feed (B)	2	4.27707	4.27707	219.71	0.005	78.68
Depth of cut (C)	2	0.24667	0.24667	12.67	0.073	4.538
Error	2	0.01947	0.01947	0.00973		0.358
Total	8	5.43600				100

Analysis of variance can be used to study the influence of the machining parameters on surface roughness. In the performed ANOVA Analysis (Table 5), there is a P-value for each of the independent parameter which can be used to test the significance and interactions among the parameters. The P-value which is less than 0.05 indicates the higher level of significance. The percentage contribution of each variable is shown in the last column of table 5. It has been found that feed has the highest contribution followed by cutting speed and depth of cut.

4. Conclusion

In this research work, the turning operation was done on EN24 material using tungsten carbide inserts. The surface roughness was calculated using surface roughness tester. The effect of process parameters in terms of surface roughness of machining was investigated. The results explains that the increase of cutting speed decreases the surface roughness in machining of EN24.The gradual increase of feed rate and depth of cut increases the surface roughness in machining of EN24 by tungsten carbide inserts.

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