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Assessment of Factor Influencing Surface Roughness and Tool Wear on the Machining of Austenitic Stainless Steel Grade 304

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Abstract

Stainless steel are iron based alloys containing a minimum of about 12% chromium, this forms a protective self-healing oxide film. The ability of the oxide layer to heal itself means that the steel is corrosion resistance. The austenitic stainless steel contains 16% of the chromium and 6% of the nickel and range through to the high alloy or super austenitic. Additional elements can be added such as molybdenum, titanium or copper, to modify or improve their properties, making them suitable for many critical applications involving high temperature as well as corrosion resistance. The present work focuses on finding the optimal machining parameters setting for machining of Stainless steel grade 304. To achieve better surface finish and tool wear under dry machining conditions using coated carbide tool. Tool wear and the surface roughness was analyzed for various cutting conditions. Taguchi based statistical approach is employed to investigate the relationship between various machining parameters and their response. By applying ANOVA and mathematical model, the response factors are modelled in terms of input machining parameters. The developed model describes the interaction i.e. either single/multiple parameters of various input parameters with respect to response factors. Statistical approach has been proven to be a very powerful tool for solving optimization problems in industrial manufacturing conditions.

Keywords: Stainless steel, Optimization, DOE, ANOVA, Machining parameters

I. INTRODUCTION

A large number of engineering components such as shafts, gears, bearings, clutches, cams, screw nuts etc., need reasonably high dimensional and form accuracy and good surface finish for serving their functional purposes. In many applications, the surface finish requirements restrict the range of cutting process parameters which can be used. The increased use of high speed machining, particularly with automated machine tools, has spurred the use and development of several free cutting steels. These steels machine, readily and form small chips when cut. These smaller chips reduce the length of contact between the chip and cutting tool thereby reducing the associated friction and heat and therefore, the power and tool wear. The formation of small chips also reduces the likelihood of chip entanglement in the machine and makes chip removal much easier. The material used here is low carbon steel, which is Free-cutting steel for bulk applications for joining elements in mechanical engineering and automotive components. Manganese sulphide exists as globules in the microstructure which aid machining. These act as discontinuities in the structure which serve as sites to form broken chips. Many of the researchers conducted experiment on turning steel with multiple objective using DOE and reported that the proposed method simultaneously minimize the response. One of the investigation stated that the influence of cutting speed, feed rate and depth of cut on surface roughness, material removal rate and cutting force during turning of AISI 304 steel. L27 orthogonal array design of experiments was adopted .The proposed hybrid approach in optimizing the process parameter during turning of EN-31 and reported that the optimal machining setting increases the production capacity. A large number of researchers investigated the influence of machining parameter on surface finish and tool life during micro turning of steel alloy. Some studied the machining characteristics of EN-31 steel using Tungsten carbide insert and reported that use of cooled lubricant increases the surface finish. Detailed reports proposed a hybrid technique for optimizing the machining condition and reported that the results of the proposed technique are in good agreement with the other standard technique. Some used teaching learning based algorithm for optimizing the machining process parameters of cutting speed, feed rate and number of passes and reported the effectiveness of the proposed algorithm in terms of lower production cost and number of passes. Many studied the machining characteristics of duplex stainless steel and optimized the turning process parameter using Taguchi method. Their results are found to be in good agreement with the actual values less than 8% deviation. Few research actions on taguchi based optimization of machining parameters on steel alloys were investigated and studied the optimization of cutting force and surface roughness through the optimal setting of performance level of cutting speed, feed rate and depth of cut in high-speed turning of using carbide tools insert has been discussed. The surface quality of the machined part not only depends on the machining condition but also the type of cutting insert used. The behaviour of the tool can be attributed to the type of coating used. Coatings increase the wear resistant properties of the tool and may also reduce cutting forces and temperatures. It was concluded from the work that multi-

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layer coated carbide tool performed better than monolayer coated carbide. In machining high temperature super alloys, the cutting fluid plays an important role. But the adverse effect of cutting fluids cannot be neglected. Cutting fluid waste must undergo proper treatment prior to its disposal. The authors concluded that the effect of depth of cut and feed in variation of feed force were affected more as compare to speed. Some research developed the linear regression model for cutting force and surface roughness in dry turning operation. The regression equation was developed by a single cutting parameter i.e. cutting speed were chosen for in-process surface roughness and cutting force prediction system. By using Analysis of variance (ANOVA) and prediction model a strong linear relationship among the dominant parameters (feed rate and cutting tool) and the response (cutting force and surface roughness) was found. It was studied for tool flank wear growth for optimal tool life estimation by utilizing the DOE technique.

II. EXPERIMENTAL SETUP

Taguchi's Design of Experiments (DOE) is a statistical technique, used to study many factors simultaneously and most economically. By studying the effects of individual factors on the results, the best factor combination can be determined. When applied to a design, the technique helps to seek out the best design among the many alternatives. Taguchi's technique is a powerful tool in quality optimization. Taguchi's technique makes use of a special design of Orthogonal Array (OA) to examine the quality characteristics through a minimal number of experiments. When applied to a design, the technique helps to seek out the best design among the many alternatives. The experimental results based on the OA are then transformed into weighted grey relational grade to evaluate the performance characteristics. Taguchi's Design of Experiments is used to design the Orthogonal Array for the seven chosen input control parameters such as cutting speed, feed rate, depth of cut, material hardness, cutting tool insert shape (included angle), relief angle and nose radius. Each input parameter is varied through three levels and the chosen values. Based on the 3 parameters chosen, that are varied through 3 levels. For various combinations of input parameters and their level values, the inner L9 Orthogonal Array is formulated and the ISO insert designation for the corresponding cutting tool inserts. The inner array is the various combination of machining parameters, geometrical parameters and material hardness. Based on the L9 Orthogonal Array designed for 3 parameters varied through 3 levels, the experiments are conducted and the output quality characteristics are recorded.

A. Work Piece Material:

Austenitic Stainless steel grade 304 rods were utilized for the experimentation with the wet cutting environment. . The total length of the work piece is 70 mm and diameter is 25 mm, 20 mm is gripped in the chuck of the CNC machine and turning was performed on 50 mm. It is the most well-known type of steel and is used to manufacture automobile spare parts, for example, camshaft, heavy duty gear, pinion, gudgeon pins and shaft.

B. Selection of the Factors and their Levels:

The turning parameters and their levels of the experiments were identified based on trial of experiments. The feed rate and depth of cut levels have been selected in the view to avoid tool breakage and under the constraints of tool life. It has been observed during these trials of experiments that the built up edge starts building up with the increase in feed rate and depth of cut beyond the limits considered in the present study. The literature shows that with the increase in feed rate and depth of cut, tool life decreases. The three parameters, cutting speed, feed rate and depth of cut were chosen and input factor and their levels are indicated in Table 1.

Table - 1
Input factors and levels

Parameters	*Units*	*Symbols*	*Level1*	*Level2*	*Level3*
Speed	*(m/min)*	*S*	*80*	*160*	*240*
Feed	*(mm/rev)*	*F*	*0.1*	*0.15*	*0.2*

III. RESULTS & DISCUSSION

In this analysis, multiple objectives such as surface roughness and tool wear rate are to be estimated. The experimental values of surface roughness and tool wear rate are shown in table 2. Taguchi method uses SN ratio to interpret the experimental values and highest value of SN ratio is the optimum parameter combinations. Taguchi's utility concept has been employed for optimizing the multiple objectives. In this analysis surface roughness and tool wear rate are minimized. Hence smaller the better type characteristics for surface roughness and tool wear rate have been suggested.

Table – 2
The experimental values of Surface roughness and Tool wear

Sl.No	*S (m/min)*	*F(mm/rev)*	*D (mm)*	*Ra (µ)*	*Tool Wear(mm)*
1	*80*	*0.10*	*0.5*	*2.35*	*0.265*
2	*80*	*0.15*	*1*	*2.96*	*0.312*
3	*80*	*0.20*	*1.5*	*3.65*	*0.398*
4	*160*	*0.10*	*1*	*2.38*	*0.163*
5	*160*	*0.15*	*1.5*	*2.59*	*0.184*
6	*160*	*0.20*	*0.5*	*2.85*	*0.240*
7	*240*	*0.10*	*1.5*	*2.27*	*0.156*

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8	*240*	*0.15*	*0.5*	*2.48*	*0.221*
9	*240*	*0.20*	*1*	*2.36*	*0.310*

The objective of this study is to find the optimal machining parameters to demonstrate to the research domain. The results that conclude the optimal machining point is denoted in the schematic representation as shown in Figure 1.

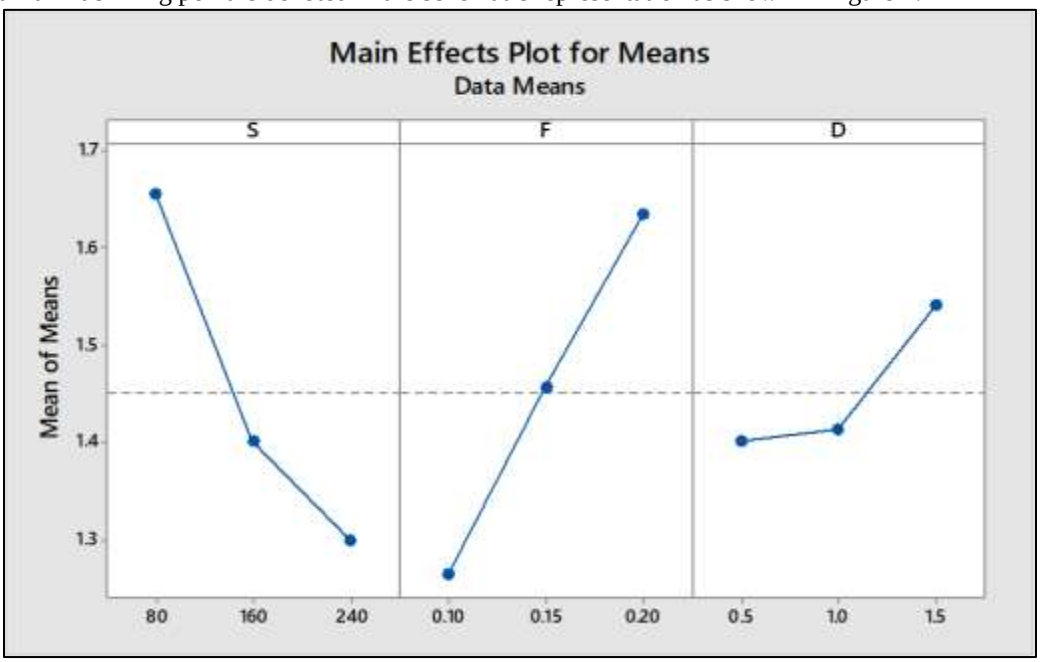

Fig. 1: Main effect plot for optimal condition

The Results depicts that, at speed 240 rpm, feed 0.10 mm/rev and depth of cut at 0.5 the optimality condition is found. Furthermore the research can get in to other direction by changing the parameter and levels.

A. ANOVA Analysis

Analysis of variance is a statistical method used to test differences between two or more means. It may seem odd that the technique is called analysis of variance rather than analysis of means. ANOVA is a collection of statistical models used to analyse the difference among the groups. In this section the percentage contribution of every individual parameters are categorized, among which the speed is the major influencing factor. The results tabulated in Table 3.

Table – 3
ANOVA Results

Source	*DOF*	*Adj SS*	*Adj MS*	*F*	*P*	*% Contribution*
S	*2*	*0.027054*	*0.013527*	*140.38*	*0.04*	*61.36*
F	*2*	*0.022616*	*0.011308*	*95.54*	*0.20*	*37.22*
D	*2*	*0.006482*	*0.003248*	*2.68*	*0.375*	*1.021*
Error	*2*	*0.009567*	*0.004782*			
Total	*8*	*0.051275*				*99.6%*

IV. CONCLUSION

In this work, CNC turning of Stainless steel Grade 304 alloy was studied by doing experiments, and the experimental data were statistically analysed to identify the significant factors influencing the surface roughness and tool wear rate responses of the process. Within the range of selected process parameters, following conclusions were drawn.

1) L9 orthogonal array design of experiment was used to study the influence of machining parameters on tool wear rate and surface roughness values during wet turning of Austenitic Stainless steel Grade 304.
2) The optimal machining condition was identified using the main effect plot, which shows that at speed 240 rpm, feed 0.10 mm/rev and depth of cut at 0.5 the optimality condition is found.
3) The ANOVA analysis depicts that the percentage contribution of every individual parameters are categorized, among which the speed is the major influencing factor, next to that feed and depth of cut.

Furthermore the research can extents with more number of trial runs and the change of parameter and their levels are need to be investigated.

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