Optimization of Cutting Parameters in Turning Operation of Hardened Steels based on Taguchi Method - A Review

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Abstract---This paper has presented a brief review of the application of Taguchi technique for optimization of turning operation in machining of hardened steels. Cutting parameter i.e cutting speed, feed rate and depth of cut are optimized using Taguchi method. The effect of cutting parameter on surface roughness, tool wear and cutting force are analyzed. From the study it was found that for surface roughness and cutting force feed rate is the most significant factor and for tool wear cutting speed is the most significant factor. Also found that Taguchi method provide simple, systematic and efficient methodology for optimization of the turning operation.

I. INTRODUCTION

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 common method for cutting and especially for the finishing machined parts.

Turning is the 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. It can be defined as the machining of an external surface with the work piece rotating, with a single-point cutting tool and with the cutting tool feeding parallel to the axis of the work piece and at a distance that will remove the outer surface of the work.

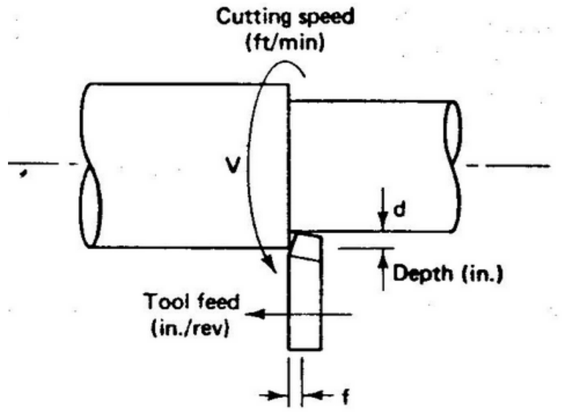

Fig 1: Cutting conditions for a turning operation

A. Cutting parameter In Turning

1) Speed:

It is the product of the rotating speed times the circumference of the work piece before the cut is started. It is expressed in meter per minute and it refers only to the work piece. Every different diameter on a work piece will have a different cutting speed, even though the rotating speed remains the same.

2) Feed:

it is the rate at which the tool advances along its cutting path. the feed rate is is expressed in mm per revolution

3) Depth of Cut:

It is the thickness of the layer being removed in a single pass from the work piece or the distance from the uncut surface of the work to the cut surface it is expressed in mm. It is important to note, though, that the diameter of the work piece is reduced by two times the depth of cut because this layer is being removed from both sides of the work.

Hardened steel is a type of carbon steel used for making tools and heavy machine parts. This material consists of steel that has been specially treated to improve its hardness and strength. Compared to standard steel, the hardened type offers greater wear resistance and durability, making it well-suited to heavy-duty applications

II. LITERATURE REVIEW

Ilhan Asilturk et al.[1] have studied the effects of the cutting parameters on surface roughness in hard turning of AISI 4140.For machining PVD TiAlN and CVD TiCN/Al2O3-coated carbide inserts are used under Dry condition. Experiments have been conducted using the L9 orthogonal array of Taguchi method on a CNC turning machine for three different levels of cutting speed, feed rate and depth of cut.Nine experiments were conducted to find effect of cutting parameter on surface roughness and flank wear. the analysis of variance(ANOVA) are applied to investigate effects of cutting speed, feed rate and depth of cut on surface roughness Ra and Rz.

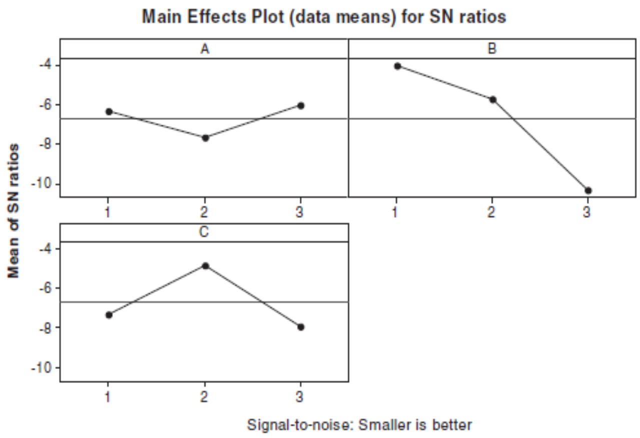

Fig 2: Mean effect plot for SN ratios of Ra

The optimum cutting condition for surface roughness is high cutting speed 150m/mm, low feed rate 0.18mm/rev and low depth of cut 0.2mm. According to the ANOVA analysis, the feed rate has an effect on Ra and Rz at a reliability level of 95%. so from this it was found that the feed rate has the most significant effect on Ra and Rz. Also the effects of two factor interactions of the feed rate-cutting speed and depth of cut-cutting speed appear to be important.

L B Abhang et al.[2] Presented an experimental work on turning EN-31 steel with tungsten carbide insert. In the cutting parameter design three levels and three factors are considered. The factors are feed, depth of cut and lubricant temperature. Cutting speed was kept constant throughout the experiments. The effect of parameters on surface roughness was find out.L9 Orthgonal array was used for experiment. It was found that lubricant temperature and feed rate are the main parameters that influence surface roughness. The optimum parameter for surface roughness are lower feed rate 0.05,medium depth of cut 0.4 and low lubricant temperature 10^0 C. It was observed that Taguchi method provide simple, systematic and efficient methodology for optimization of the machining process.

Indrajit Mukherjeet et al.[3] Presented a brief review on different optimization techniques used for optimization of metal cutting processes the application potential of several modeling and optimization techniques in metal cutting processes, classified under several criteria and a generic framework for parameter optimization in metal cutting processes is suggested for the benefits of selection of an appropriate approach. The generic framework for process parameter optimization in metal cutting operation attempts to provide a single, unified, and systematic approach to determine optimal or near-optimal cutting conditions in various kinds of metal cutting process optimization problems, It incorporates the use of one or more of the existing modeling and optimization techniques, making the framework a unified and effective means. They found that Taguchi method is appreciated for its distribution-free and orthogonal array design and it provides a considerable reduction of time and resource needed to determine important factors affecting operations with simultaneous improvement of quality and cost of manufacturing.

Ali Riza Motorcu.[4] presented a study on AISI 8660 Hardened Alloy Steel. Machining tests were carried out with PVD coated ceramic cutting tools under different conditions. L16 Orthogonal array of Taguchi method was used for experiment. The analysis of variance is to investigate the design parameters and to indicate which parameters significantly affect the quality characteristic. This analysis helps to find out the relative contribution of machining parameter in controlling the response of turning operation.

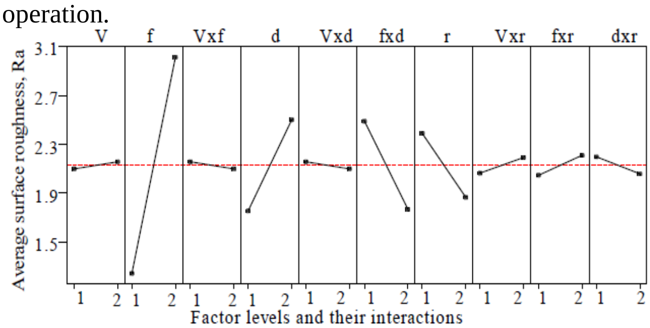

Fig 3: Average surface roughness value in the machining alloy steel

The obtained results indicate that the feed rate was found to be the dominant factor among controllable factors on the surface roughness, followed by depth of cut and tool's nose radius**.** the interaction of feed rate/depth of cut was found to be significant on the surface finish due to surface hardening of steel. The surface roughness increased with increasing feed rate, depth of cut and decreased with increasing the tool's nose radius. the second order regression model also shows that the predicted values were very close to the experimental one for surface roughness.

D. Philip Selvaraj et al.[5] have investigated the effects of cutting speed and feed rate on surface roughness, cutting force and tool wear of two different grades of nitrogen alloyed duplex stainless steel in dry turning. Taguchi method was used for optimization. The turning operations were carried out with TiC and TiCN coated carbide cutting tool inserts. The experiments are planned using Taguchi orthogonal array. The machining tests were conducted according to a 3-level and 2-factor L9 orthogonal array.The cutting parameters are optimized using signal to noise ratio and the analysis of variance.

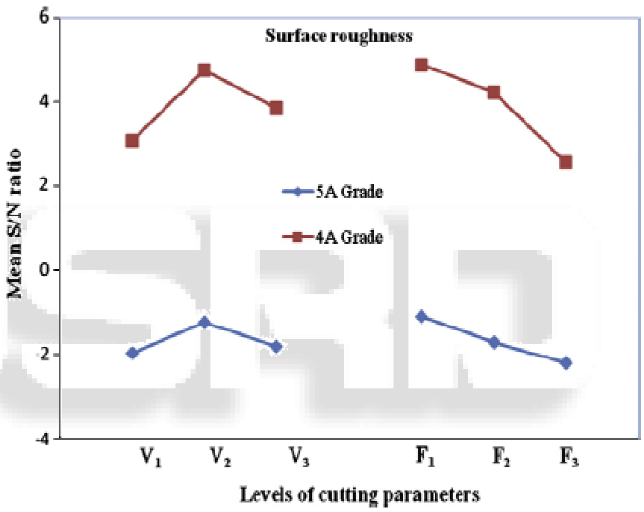

Fig 4: S/N graph for surface roughness -5A and 4A grade DSS

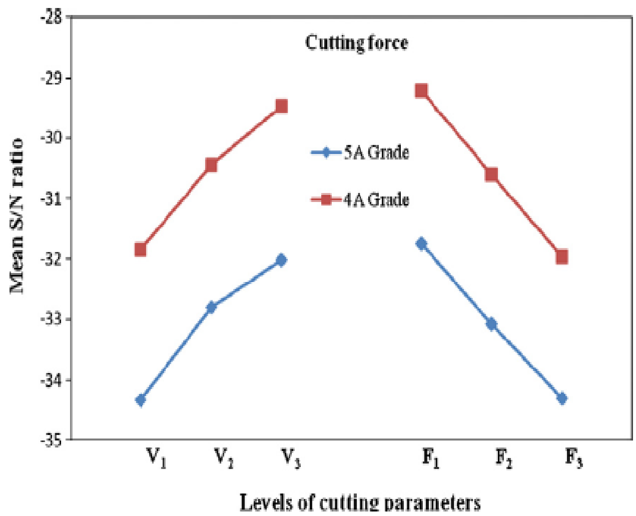

Fig 5: S/N graph for cutting force -5A and 4A grade DSS

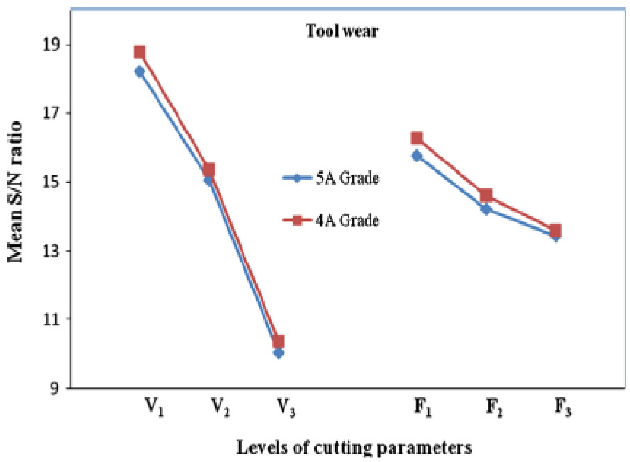

Fig 6: S/N graph for tool wear -5A and 4A grade DSS

The results shows that the feed rate is the more significant parameter influencing the surface roughness and cutting force. The cutting speed was identified as the more significant parameter influencing the tool wear. Tool wear was analyzed using scanning electron microscope image. For confirmation the results at optimum cutting condition are predicted using estimated signal to noise ratio equation. The predicted results are found to be closer to experimental results within8% deviations

Navandeep Singh Tung et al.[6] have worked on AISI D2 Steel to optimized cutting parameter and find the effect of cutting parameter on surface roughness and flank wear. Taguchi method was used for optimization. The L9 Orthogonal Array has been selected for experiments. It was found that the cutting speed to be the most contributing factor influencing Flank wear and the feed rate is the most contributing factor influencing Surface roughness. The optimized machining conditions for minimizing tool wear is cutting speed 130 m/min., feed 0.10 mm/rev., depth of cut 0.40 mm with an estimated flank wear 96µm. The optimized machining conditions for minimizing surface roughness is cutting speed 155 m/min., feed 0.10 mm/rev., depth of cut 0.25 mm with an estimated surface roughness of 0.57 µm.

R. Suresh et al.[7] have worked on AISI 4340 steel for hard turning. The effect of cutting parameters such as cutting speed, feed rate and depth of cut on force, power, specific cutting force, tool wear and surface roughness was analyzed. Three factors and three levels are used in the experiment. L27 orthogonal array was used for experiment. The performance of multilayer hard coatings (TiC/TiCN/Al2O3) on cemented carbide substrate using chemical vapor deposition for machining was evaluated. An attempt has been made to analyze the effects of process parameters on machinability using Taguchi technique. Response surface plots are generated for the study of interaction effects of cutting conditions on machinability factors. The correlations were established by multiple linear regression models. The linear regression models were validated using confirmation tests. The analysis of the result revealed that, the optimal combination of low feed rate and low depth of cut with high cutting speed is beneficial for reducing machining force. Higher values of feed rates are necessary to minimize the specific cutting force. Abrasion was the principle wear mechanism observed at all the cutting conditions. The machining power and cutting tool wear increases almost linearly with increase in cutting speed and feed rate. The combination of low feed rate and high cutting speed is necessary for minimizing the surface roughness.

Ersan Aslan [8] have worked on AISI 4140 steel. The effects of three cutting parameters, namely cutting speed, feed rate and depth of cut on two performance measures. Surface roughness (Ra) and flank wear (VB) was found. Optimization was done with the help of Taguchi method. L27 orthogonal array was used for Performing experiment and the analysis of variance (ANOVA) was used for finding significant factors to the performance also the relationship between the parameters and the performance measures were determined using multiple linear regression.

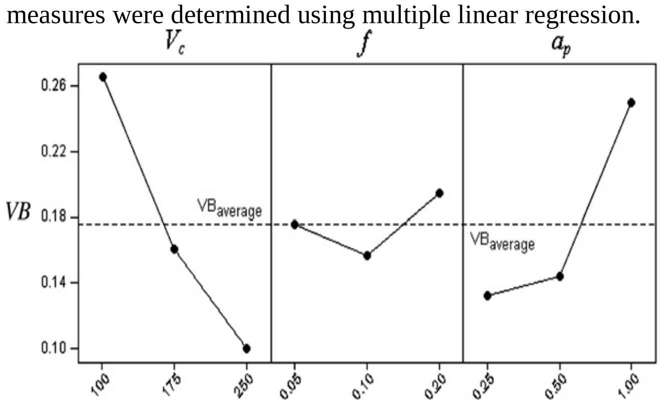

Fig. 7: Main factor plots: averages for VB.

The cutting speed is the only statistically significant factor influencing the tool wear. In order to minimize the tool wear, the highest level of the cutting speed 250 m/min, and the low levels of depth of cut, 0.25 should be preferred

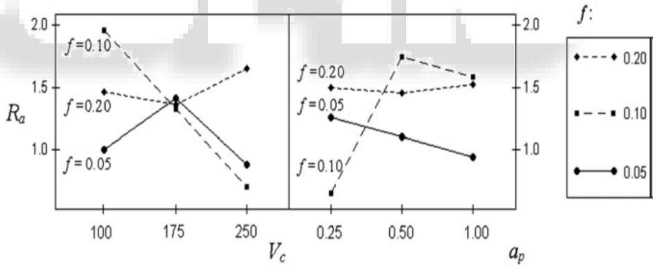

Fig. 9: Interaction plots: averages for Ra.

From interactions plot it was found that cutting speed-feed rate and feed rate- depth of cut have significant influence on the surface roughness. To minimize the surface roughness the optimum value is highest level of cutting speed 250 m/min, the lowest level of depth of cut 0.25 mm, and the medium level of feed rate,0.10 mm/rev should be preferred. The results of the study encourage the use of Taguchi parameter design for obtaining optimal cutting parameters for ceramic tools.

Ahmad Hamdan et al.[9] have investigated the effect of machining parameters in high speed machining of stainless steel using coated carbide tool to achieve minimum cutting forces and better surface roughness. The standardized orthogonal array L9 was used in this experiment and the results were analyzed using analysis of variance to identify the most significant parameters affecting the cutting force and surface roughness. The feed rate is found to be more significant followed by the cutting speed and the depth of cut while, the lubrication mode was found to be statistically insignificant.

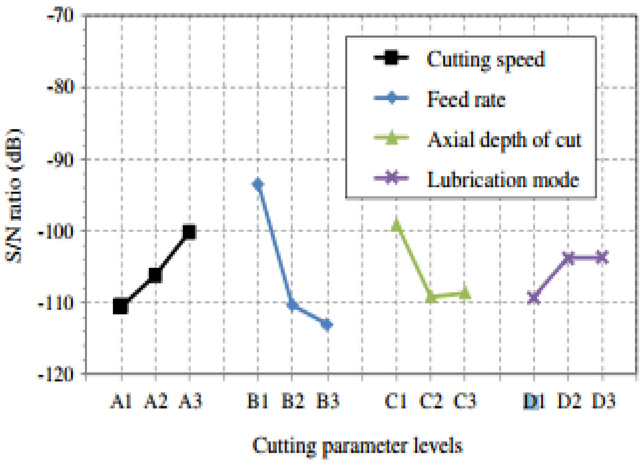

Fig 8: S/N ratio response graph of resultant cutting force

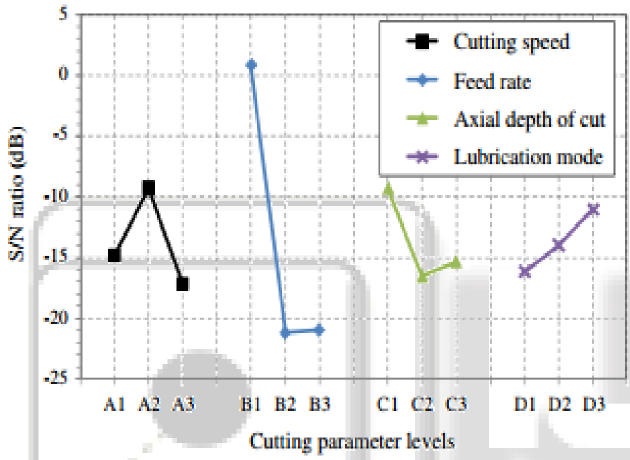

Fig 9: S/N ratio response graph of surface roughness

The optimum cutting parameters found for cutting force are high cutting speed 400, low feed rate 0.05, low depth of cut 0.5 and MQL lubrication mode. And for surface roughness medium cutting speed, low feed rate. Low depth of cut and MQL lubrication mode. Conformation tests with the optimal levels of all the parameters were carried out to investigate the improvement of the optimization. This was accomplished with a relatively small number of experimental runs, suggesting that Taguchi optimization method is an efficient and effective method for optimizing surface roughness in high-speed machining of stainless steel using coated carbide tool.

III. CONCLUSION

This paper has presented a brief review of the application of Taguchi technique for optimization of turning operation in machining of hardened steels.

From above study it was found that for surface roughness feed is the most significant factor. Low feed rate give good surface roughness for hardened steel. For tool wear cutting speed is the most significant factor. Tool wear increase at high cutting speed. For cutting force feed rate is the most significant factor. High feed rate is preferred for low cutting force for turning hardened steels. The major observations gleaned from the literature are the Taguchi method and ANOVA have proved to be efficient tools for controlling the effect of cutting parameter on surface roughness, tool wear and cutting force. The advantages of Taguchi method is simplifying the experimentation was effectively utilized in this investigation for design . The Taguchi method provide simple, systematic and efficient methodology for optimization of the turning operation.

REFERENCES

[1] Ilhan Asilturk , Harun Akkus."Determining the effect of cutting parameters on surface roughness in hard turning using the Taguchi method" Measurement 44 (2011) 1697–1704 2011 Elsevier.

[2] L B Abhang and M Hameedullah. "Optimization of maching parameter in steel turning operation by taguchi method " Procedia Engineering 38 (2012) 40 – 48 2012 Elsevier.

[3] Indrajit Mukherjee, Pradip Kumar Ray. "A review of optimization techniques in metal cutting processes " Computers & Industrial Engineering 50 (2006) 15–34 2006 Elsevier.

[4] Ali Riza Motorcu, "The optimization of machining parameters using the taguchi method for surface roughness of AISI 8660 hardened alloy steel " Journal of Mechanical Engineering 56(2010)6, 391-401

[5] D. Philip Selvaraj , P. Chandramohan , M. Mohanraj, "Optimization of surface roughness, cutting force and tool wear of nitrogen alloyed duplex stainless steel in a dry turning process using Taguchi method" Measurement 49 (2014) 205–215 2013 Elsevier Ltd.

[6] Navandeep Singh Tung, Sukhjinder Singh "Selection of the orthogonal array in turning

[7] of AISI D2 steel" International Journal Of Innovative Research & Development June, *2013* Vol 2 Issue 6

[8] R. Suresh, S. Basavarajappa, G. L. Samuel, "Some studies on hard turning of AISI 4340 steel using multilayer coated carbide tool" Measurement 45 (2012) 1872–1884 2012 Elsevier Ltd

[9] Ahmad Hamdan & Ahmed A. D. Sarhan & Mohd Hamdi, "An optimization method of the machining parameters in high-speed machining of stainless steel using coated carbide tool for best surface finish" Springer 2011

