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OPTIMIZATION OF MACHINING PARAMETERS IN CNC TURNING OF MARTENSITIC STAINLESS STEEL USING RSM AND GA

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ABSTRACT

Metal cutting process is one of the complex process which has numerous factors contributing towards the quality of the finished product. CNC turning is one among the metal cutting process in which quality of the finished product depends mainly upon the machining parameters such as feed, speed, depth of cut, type of coolant used, types of inserts used etc. Similarly the work piece material plays an important role in metal cutting process. Hard materials such as stainless steel grades, Nickel alloys , Titanium alloys are very difficult to machine due to their high hardness. While machining these hard materials, optimized machining parameters results in good surface finish, low tool wear, etc. This study involves in identifying the optimized parameters in CNC turning of martensitic stainless steel. The optimization technique used in this study are Response surface methodology, and Genetic algorithm. These optimization techniques are very helpful in identifying the optimized control factors with high level of accuracy.

Key words: **Turning, machining, response surface methodology, genetic algorithm.**

I.INTRODUCTION

Hard turning is a process, in which materials in the hardened state (50–70 HRC) are machined with the single point cutting tools. This has become possible with the availability of the new cutting tool materials. Since a large number of operations are required to produce the finished product, if some of the operations can be combined, or eliminated, or can be substituted by the new process, product cycle time can be reduced and productivity can be improved. The traditional method of machining the hardened materials includes rough turning, heat treatment, and then grinding process. Hard turning eliminates the series of operations required to produce the component and thereby reducing the cycle time and hence resulting in productivity improvement. The various advantages of hard tuning are the higher productivity, reduced set up times, surface finish closer to grinding and ability to machine the complex parts. Various work materials which can be machined by the hard turning process include high speed steels, die steels, bearing steels, alloy steels, case hardened steels, white cast iron and alloy cast iron. Rigid machine tools with adequate power, very hard and tough tool materials with appropriate tool geometry, tool holders with high stiffness and appropriate cutting conditions are some of the prerequisites for hard turning.

Surface roughness plays an important role as it influences the fatigue strength, wear rate, coefficient of friction, and corrosion resistance of the machined components. In actual practice, there are many factors which affect the surface roughness, i.e. tool variables, work piece variables and cutting conditions. Tool variables include tool material, nose radius, rake angle, cutting edge geometry, tool vibration, tool overhang, tool point angle, etc. Work piece variables include material, hardness and other mechanical properties. Cutting conditions include speed, feed and depth of cut. As the hard turning process involves large number of parameters, the process control becomes complex and it would be difficult to select the appropriate cutting conditions and tool geometry for achieving the required surface quality. Various researchers have developed the surface roughness predictive models for the conventional turning, but these models may not be useful for hard turning because hard turning differs from that of the conventional turning process. So, it would be necessary to study the effects of speed, feed, effective rake angle and nose radius on the surface roughness so as to develop the predictive models for hard turning. In hard turning process, the cutting inserts are always provided with the negative chamfer angle in order to increase the edge strength of the cutting tools. This negative chamfer angle acts as a negative rake angle to the insert. The total effective rake then becomes the sum of the negative rake angle provided by the chamfer angle of the inserts and the negative rake angle provided by the tool holder to the cutting inserts.

II.LITERATURE REVIEW

The performance of hard turning is measured in terms of surface finish, cutting forces, power consumed and tool wear. Surface finish influences functional properties of machined components. Surface finish, in hard turning, has been found to be influenced by a number of factors such as feed rate, cutting speed, work material characteristics, work hardness, cutting time, tool nose radius and tool geometry, stability of the machine tool and the work piece set-up, the use of cutting fluids, etc. König et al. [1] have reported that CBN and ceramic cutting tools are widely used in industries for the machining of the various hard materials. In many applications, the cutting of ferrous materials in their hardened condition can replace grinding to give significant savings in cost and increase in productivity. Cutting tool geometry plays a very important role in hard turning process. The rake angle and the nose radius of the turning inserts directly affect the cutting forces, power and surface finish. The edge strength of the cutting inserts depends upon edge preparation, i.e. by the honing radius, chamfer angles. Some investigations related to the effect of tool geometry have been reported by the researchers. Thiele and Melkote [2] have investigated the cutting edge geometry and the workpieces hardness on surface generation in the finish hard turning of AISI 52100 steel. CBN inserts, with various representative cutting edge preparations, were used as the cutting tool materials. This study shows that the effect of edge geometry on surface roughness and cutting forces is statistically significant. Specifically, large edge hones produce higher average surface roughness values than small edge hones. The effect of two factor interactions of the edge geometry and the work piece hardness on the surface roughness is also found to be important. Also large edge hones generate higher forces in the axial, radial and tangential directions than small edge hones. Dahlman et al. [3] have conducted the study on the influence of rake angle, cutting speed and cutting depth on residual stresses in hard turning. Results show that a greater negative rake angle gives higher compressive stresses as well as a deeper affected zone below surface. The compressive stresses increase with the increased feed rate. Zhou et al. [4] have investigated the effect of chamfer angle on the wear of PCBN cutting tool. Results show that chamfer angle has a great influence on the cutting force and tool life. All the three force components increase with an increase of the chamfer angle. The optimized chamfer angle, for the maximum tool life as suggested by this study, is 15°. In this study, cutting conditions were kept constant. Chou and Song [5] have investigated the effects of tool nose radius on finish hard turning with ceramic tools. In this study, surface finish, tool wear, cutting forces, and, particularly, white layers were evaluated at different machining conditions. Results show that large tool nose radii not only give finer surface finish, but also considerable tool wear compared to small nose radius tools. Specific cutting energy also increases slightly with tool nose radius. Large nose radius tools generate shallower white layers when cutting by worn tools. For new tools, small nose radius results in larger uncut chip thickness, and thus, induces deeper white layers. Endres and Kountanya [6] have reported the effects of corner radius and edge radius on tool flank wear. Results show the interaction of corner radius and edge radius and their effects on process performance, measured in terms of tool flank wear and forces. The general conclusion is that an advantage exists in using a larger corner radius when using a larger edge radius. Mital and Mehta rate and cutting speed on surface roughness and tool wear were experimentally

III.METHODOLOGY

A. Design of experiments

Design of experiments is a standard tool to conduct the experiment in an optimum way to investigate the effects of process parameters on the response or output parameter. The various steps involved in the design of experiments are identifying the important process parameter, finding the upper and lower limit of selected process parameter and developing the box benhen design matix. The design matrix for three factors involves three blocks in which each of two factors are varied through the four possible combinations of higher and lower limits. In each block a certain number of factors are put through all combinations for the three factorial design, while the other factors are kept at central values.

TABLE 1 MACHINING PARAMETER LEVELS

Parameters	Unit	Levels		
		-1	0	1
Speed	m/min	80	100	120
Feed	m/min	0.150	0.185	0.220
Depth of cut	mm	0.5	1.0	1.5

B. RESPONSE SURFACE METHODOLOGY

Response surface designs are employed in the empirical study of relationship between one or more measured response variables and a number of independent or controllable variables of a process. Response surface designs are employed to investigate and predict the following conditions of a process. RSM methodology is practical, economical and relatively easy for use. They are the effect on a particular response by a given set of input variables over some specified region of interest. The required values of variables to obtain desirable or acceptable levels of a response. The required values of variables to achieve a minimum or maximum response and the mature response surface near this minimal or maximal value. To describe the response surface method by second order polynomials, the factor in the experimental design should have atleast three levels. A three level factorial experiment in which all possible combinations of k factors at all the levels are used is called 3k full factorial design which is employed

C. ANOVA

Since there are a large number of variables controlling the process, some mathematical models are required to represent the process. However, these models are to be developed using only the significant parameters influencing the process rather than including all the parameters. In order to achieve this, statistical analysis of the experimental results will have to be processed using the analysis of variance (ANOVA). ANOVA is a computational technique that enables the estimation of the relative contributions of each of the control factors to the overall measured response. In the present work, only the significant parameters will be used to develop mathematical models using response surface methodology (RSM). These models would be of great use during the optimization of the process variables. RSM methodology is practical, economical and relatively easy for use.Regression equation obtained as follows:

$$SurfaceRoughness=1.51539-0.01518*A-1.30442*B-0.47976*C-0.00002A^2-6.80272B^2-0.02333C^2+0.07857*A*B+0.00575*A*C+2.142*B*C$$

Where A- speed, B-Feed, C-Depth of cut

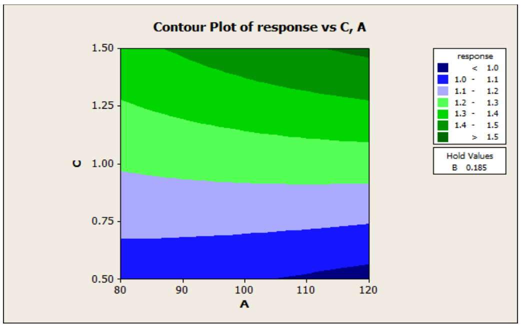

Fig.1 contour plot for speed vs feed

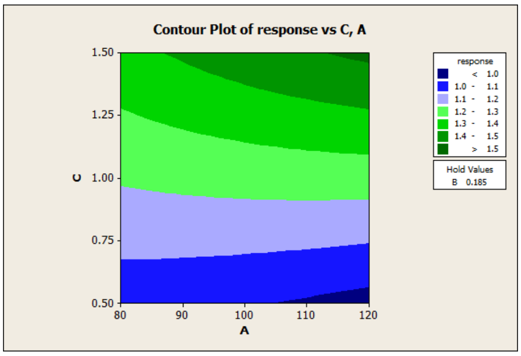

Fig. 2 contour plot for speed vs depth of cut

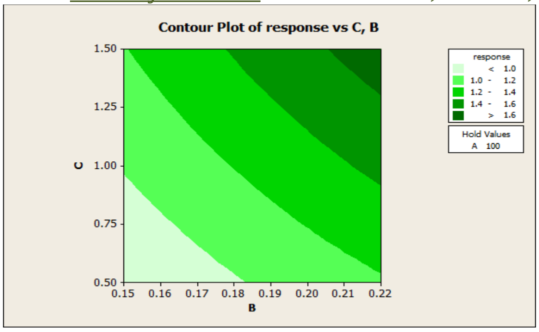

Fig.3 contour plot for feed vs depth of cut

D.GENETIC ALGORITHM

Genetic algorithm is a heuristic search technique used in computing to find exact or approximate solutions to optimization and search problems. They are categorised as global search heuristics and are particular class of evolutionary algorithms that use techniques inspired by evolutionary biology such as inheritance, mutuation, selection and cross over. The key issues such as chromosome encoding, selection process and evalution methodology. In addition a local search mechanism is proposed for selecting the initial population to improve the performance of GA. Genetic algorithm in general is a purpose search algorithm suitable for optimization problems due to its processing approach and due to its structure and it is able to return a set of optimal solutions. MATLAB is a high performance language for technical computing which is used to optimize the objective function of different materials in genetic algorithm.

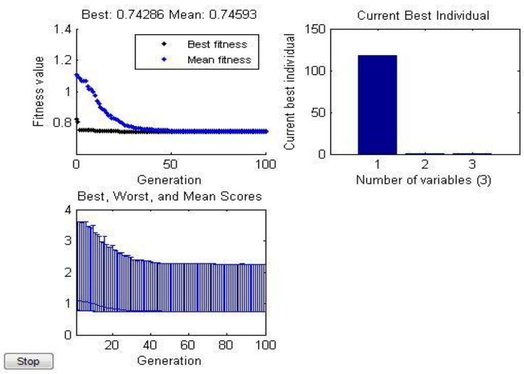

Fig 4 Genetic algorithm results

IV. ANALYSIS AND DISCUSSION

The surface quality of the machined parts is the value of surface roughness or the waviness are mainly decided by the three factors speed, feed and depth of cut beyond the levels influenced by the other factors. The surface roughness is mainly a result of three controllable factors and hence it is easier to attain the physical dimensions. A detailed study could give the effect of speed, feed, depth of cut, nose radius and other factors on the surface roughness. These studies and effects of factors on surface roughness have been evaluated and models are developed to address the requirements of the end operator, who decides the input parameters based on the specified requirements. The goal of this study is to obtain a mathematical model that relates the surface roughness to three machining parameters in turning operation, precisely to the speed, feed and depth of cut. Therefore two approaches have been used such as response surface methodology (RSM) and analysis of variance (ANOVA). Genetic algorithm approach can be used for the fine tuning of the results obtained to get the optimized solution.

VII. CONCLUSION

This paper provides a detailed study on the surface roughness of the martensitic stainless steel (SS40). The detailed study and the optimization procedure has been made to study the effect of speed, feed and depth of cut while machining which would help in real practice. The machining parameter ranges were analyzed and then the experimentation was carried out according to the optimization approaches. The results obtained from RSM are R-Sq obtained was 99.9% which indicates that selected parameters (speed, feed, depth of cut)significantly affect the response (surface roughness). The Best ranges obtained by using the genetic algorithm approach are Cutting velocity (speed) -119.93 m/min, Feed-0.15 m/min and Depth of cut -0.5mm. Hence the Optimal surface roughness from GA is 0.74 microns.

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