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Optimization of Cutting Parameters On CNC Turning of AISI H13 Steel Using CNMG Tool

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ABSTRACT

Quality of the product is totally dependent upon the selection of optimum process parameters. One of the major challenging task is to optimize various process parameters like depth of cut, cutting speed and feed rate so that all the quality requirements can be achieved simultaneously. This paper analysis the effect of various cutting parameters like depth of cut, cutting speed and feed rate on surface roughness and tool wear of AISI H13 Steel during CNC turning under dry and wet conditions. Taguchi method with MINITAB software is used to reduce the number of experiments but to get best possible results. The results indicate that response variables i.e. surface roughness and tool wear are influenced mainly by depth of cut while the effect of feed rate and cutting speed is less. Also more optimum results are obtained in wet conditions of turning rather than dry conditions. Finally, the domain for most optimum process parameters to obtain minimum surface roughness and tool wear is proposed taking into consideration dry and wet conditions.

Keywords: Process parameters, Taguchi method, cutting speed, Feed rate, Depth of cut, Minitab

INTRODUCTION

The selection of optimum process parameters plays an important role to ensure quality of product. If more than one factor comes into consideration it is very difficult to select the optimal setting which can achieve all the optimum requirements on single time. Turning has been the object of technical research for several decades now. Hard turning is one of the most significant processes industries as well as researchers to replace traditional grinding operations. This paper investigates the values of various process parameters like cutting speed, depth of cut and feed rate to get the most optimum response variables: surface finish and tool wear during CNC turning of AISI H13 steel using CNMG tool under dry and wet conditions.

LITERATURE REVIEW

Gonzaga and Abrão [1] have focused on dry turning of annealed AISI H13 hot work die steel (230 HV) using coated carbide tools to identify the tool material and optimum cutting parameters which will provide longest tool life, maximum metal removal rate and best work piece surface finish. The obtained result shows that an increase in cutting speed results in higher tool wear rates and the tool wear increases with the feed rate. The UC6010 coated carbide tool performed better than the VRA coated carbide when analysing tool life, metal removal and surface finish using intermediate cutting conditions. Kumar and Sharma [2] have investigated the ways by which H13 steel can be machined easily and economically. For the same the parameter material removal rate is selected by him to be optimized by using selected combination of machining parameters by using Taguchi orthogonal array. Kumar and Singh [3] studied the performance TIN and TIALN coated carbide tools in machining of medium carbon steel alloy (AISI H13) under the dry turning condition and also analyse the influence of cutting parameters (cutting speed, feed rate, and depth of cut) on surface roughness which is as a response variable. For the study of response variable efficiently, he used Taguchi parameter design method. The obtained results suggest that Taguchi method in design of experiment technique can be very effectively used in the optimization of various process parameters in metal cutting processes. Das et al [4] made an attempt to analyse the performance of multilayer coated carbide inserts during dry turning of hardened AISI H13 steel (47 HRC). The effect of machining parameters on surface roughness (Ra) was investigated by applying Taguchi method. The experiments were planned based on Taguchi's L27 array design. Results showed that surface roughness (Ra) is mainly influenced by feed rate and speed of cutting, whereas depth of cut has negligible influence on surface roughness hence feed rate was found to be most significant parameter for the workpiece surface roughness (Ra) with a percentage contribution of 52.55%. Cutting speed was found to be the next important process parameter for Ra with contribution of 25.85%. Depth of cut was found a negligible influence in case of Ra. Ferreira et al [5] have developed an experimental setup for the analysis of the hard turning of AISI H13 steel with ceramic tools based on tool geometry. In his results, no clear relation was found between the flank wear and the surface roughness. Aouici et al [6] aims to investigate the turning conditions of hardened AISI H13 steel, the effects of cutting parameters on flank wear (VB) and surface roughness (Ra) using CBN tool. As per his experiment, flank wear is influenced by cutting time and also by cutting speed. Shihab et al [7] Investigated the effect of different cutting parameters like feed rate, depth of cut and speed of cutting in dry and wet hard turning processes. Three cutting parameters each at three levels were considered in the study. Response surface methodology (RSM) was used to determine optimum values of process parameters. The results indicated that cutting force components are influenced mainly by the depth of cut, while the effect of both feed rate and speed of cutting is small. Kumar and Paswan [8] have researched the multi-response optimization of turning process to investigate the tool wear and surface roughness. It deals with the optimization of three important process parameters chosen on the machining of AISI H13 by using design of experiments.

The main objectives of the work [9] is to analyse the process parameters for surface roughness and tool wear. The observed results showed that surface roughness is directly proportional to feed rate and depth of cut while it is inversely proportional to spindle speed. Das et al [10] presented an approach for the measurement of surface roughness of the machined surface obtained by simple turning operation using computer numerically controlled (CNC) Lathe. The parameters used in the experiment were cutting speed, depth of cut, feed rate. The effect of the process parameters namely, cutting speed, depth of cut, feed rate, upon the response variables like surface roughness of the finished surface was analysed by using 3D profile meter. Experiments were carried out by keeping feed rate variable and cutting speed, depth of cut, as constant. The conclusion was drawn that the feed rate is a dominant parameter and the surface roughness is directly proportional to feed rate. The surface roughness increases gradually with increase in feed rate and after reaching certain value it also decreases and at some particular value of feed rate it reaches the maximum peak value. Goyal and Marwaha [11] presented a review article in which they gave reinforcement details of aluminium matrix composites and various techniques which are used to achieve composites with required characteristics and applications.

PROBLEM FORMULATION

The review of the literature suggests that not much research has been done on the coatings of tools used for machining purposes, especially carbide tools. Moreover, the range of cutting speed above 250rpm and depth of cut above 1.5mm is very rare to see in research areas. The above research was related more with optimization of process parameters like depth of cut, cutting speed and feed rate to small ranges. The cutting speed varies mostly from 100-250 rpm and depth of cut is rarely taken above 1.5mm. It has also been clear from the literature review that environment conditions of turning interface zone play an important role for tool wear and better surface finish of the work piece.

The need of the hour is to minimize the tool wear but simultaneously increasing the material removal rate hence in this research work, carbide tool with a coating of Titanium aluminium nitride- titanium nitride (CNMG 120408 ET TT5080) is used for the turning of AISI H13 steel. The range of cutting speed is taken to be 900 rpm-1300 rpm, depth of cut from 3.5mm to 4.5mm and feed rate from (0.15-0.2) mm/rev.

METHODOLOGY AND EXPERIMENTATION

As we have discussed above, in this project we are going to optimize the surface roughness and tool wear taking AISI H13 steel as workpiece and CNMG 120408 TT5080 as tool material. There are various types of optimization techniques like Taguchi Method, Response Surface Methodology etc. In this project we are taking Taguchi Method into consideration.

Taguchi Method

Each experimenter will have to plan and conduct various experiments to obtain enough data so that he can gather enough information of the science behind the observed phenomenon.

Dr. Taguchi of Nippon Telephones and Telegraph Company, Japan has developed a method based on 'ORTHOGONAL ARRAY' experiments which gives much less 'variance' for the experiment with 'optimum settings 'of process parameters. Thus the relation of Design of Experiments with optimization of process parameters to obtain most optimum results is achieved using Taguchi Method. 'Orthogonal Arrays' (OA) provide a set of well interrogated (minimum) experiments and Dr. Taguchi's (S/N) ratio i.e. Signal-to-Noise ratios, which are log functions of desired results, serve as main functions for optimization, help in analysis of optimum results.

Design of Experiments

If traditional method is followed, then to achieve a particular domain i.e. to obtain best possible values of process parameters to get required response variables, an infinite number of experiments would be required which is a lengthy process. The motive is to obtain best possible results but with minimum number of experiments. Hence design of experiments is an important aspect in determining the inputs given to do a particular experiment.

MINITAB SOFTWARE

The Taguchi method is applied using software known as Minitab. From the literature review about the behaviour of AISI H-13 steel and the CNMG 120408 TT5080 during hard turning operation, we have taken the two values of the process parameters as: -

Environment conditions- wet and dry
Depth of cut (mm) - 3.5 and 4.5
Cutting speed (RPM) - 900 and 1300
Feed rate (mm/min) - 0.15 and 0.20

The above values are then entered into the Minitab software and after the application of the Taguchi method the number of experiments gets reduced to 8. it involves the following steps-

Select the Appropriate Design

In this step we will define the level of designing (i.e. 2 in our case) and the total number of factors (like 4- environment, feed rate, speed of cutting and depth of the cut) as shown in Fig. 1

Defining the Type of Array

In this step we will define the type of array which is to be made like L8 array in our case which will correctly evaluate 2^4 types of problems as shown in Fig. 2

Defining the values and parameters

After defining all the above things, the final step involves, defining the numeric values of the respective parameters like cutting speed etc. as shown in Table-1. Once this step is done the software automatically rearranges all the parameters along with their specific values. This step completes the list of sequence of the operations which are ready to be performed in the shop floor.

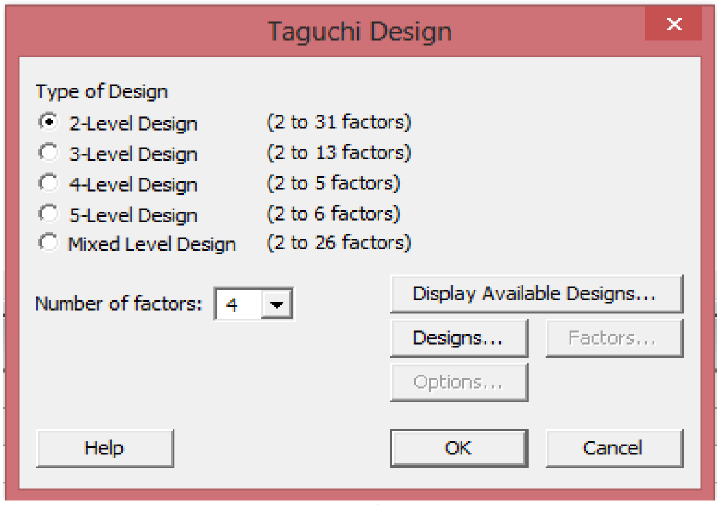

Fig. 1 Selection of Design Level

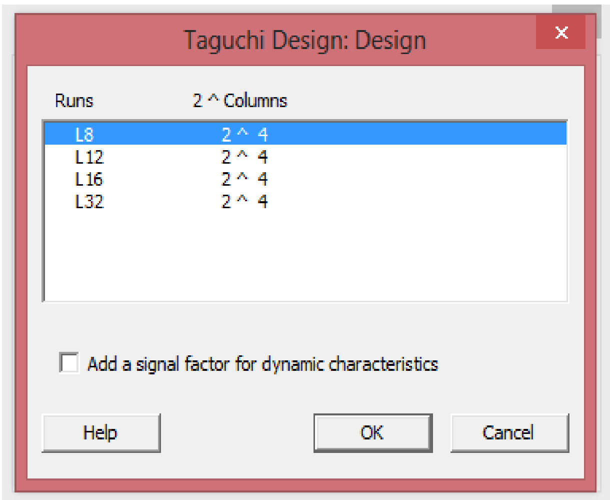

Fig. 2 Type of Array

Table – 1 To define numerical values of Cutting Parameters

	C1-T	C2	C3	C4
1.	Environment	Feed rate	Cutting Speed	Depth of Cut
2.	Wet	.15	900	4.5
3.	Wet	.15	1300	3.5
4.	Wet	.20	900	3.5
5.	Wet	.20	1300	4.5
6.	Dry	.15	900	3.5
7.	Dry	.15	1300	4.5
8.	Dry	.20	900	4.5
9.	Dry	.20	1300	3.5

MACHINING OF WORKPIECE

The machining of AISI H13 steel is done with CNMG 120408 TT5080 as tool material on the basis of the conditions given by the Minitab software. The hard turning operation of the workpiece is done in CNC lathe machine under dry and wet conditions along with the calculated value of the process parameters. The first four experiments are performed when the coolant is on i.e. under the wet conditions and the next four experiments are performed when the coolant is off i.e. under the dry conditions. After each of the experiment, the edge of the cutting tool is changed so that the tools wear can be measured. The eight work pieces, after the experimentation is taken for the measurement of the surface roughness.

Surface Roughness

Surface roughness often named as roughness, is a component of surface texture. It is measured by the deviations in the direction of normal vector of an original surface from its perfect form. If these deviations are large, then the surface is rough; if they are small, the surface is smooth. Amplitude and frequency are two important factors to ensure the fitness of as surface.

Tool Wear

Tool wear is basically the continuous failure of cutting tool due to its regular use. There are various types of tool wear like flank wear. Flank wear is a type of wear in which part of the tool which is in contact with the surface to be finished gets eroded. Crater wear is a type of wear in which rake surface of the tool is eroded due to its contact with the chips. Another type of tool war is built-up-edge in which the material being machined sticks to the cutting edge.

Fig. 3 Work piece used

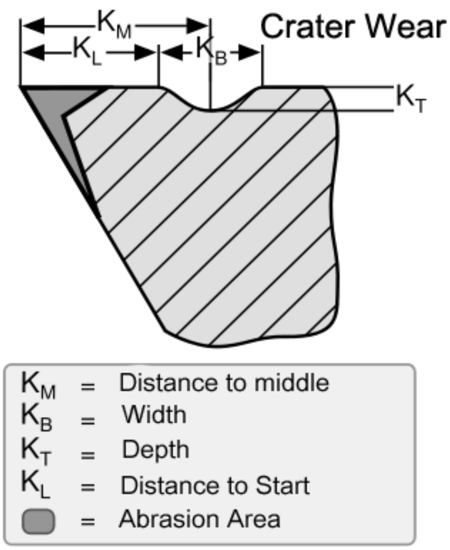

Fig. 4 Tool Wear

RESULTS

Fig. 5 Graph showing surface roughness under dry and wet conditions, with different feed rates in mm/rev, different cutting speeds in rpm and with change in depth of cut in mm. Smaller the value of surface roughness better will be the surface finish. As we can see, after performing the experiments and plotting the graphs according to the results obtained, the value of surface roughness is minimum when the feed rate is 0.15 mm/rev, depth of cut is 4.5 mm, the workpiece rotates at 900 rpm in dry conditions. According to results and the graph plotted, the optimum value of tool wear is obtained in wet conditions, when the workpiece rotates at 900 rpm, with feed rate of 0.15 mm/rev and 3.5 mm being the depth of cut. Fig. 6 shows tool wear under dry and wet conditions, with different feed rates in mm/rev, different cutting speeds in rpm and with change in depth of cut in mm.

Table - 2 Values of Tool wear and surface roughness under different feed rate, cutting speed and depth of cut under dry and wet conditions

	C1-T	C2	C3	C4	C5	C6
	Environment	Feed rate	Cutting Speed	Depth of Cut	Tool wear	Surface Roughness
1.	Wet	.15	900	4.5	19	.64
2.	Wet	.15	1300	3.5	16	.96
3.	Wet	.20	900	3.5	13	1.30
4.	Wet	.20	1300	4.5	36	1.51
5.	Dry	.15	900	3.5	18	.85
6.	Dry	.15	1300	4.5	30	.84
7.	Dry	.20	900	4.5	42	1.06
8.	Dry	.20	1300	3.5	32	1.14

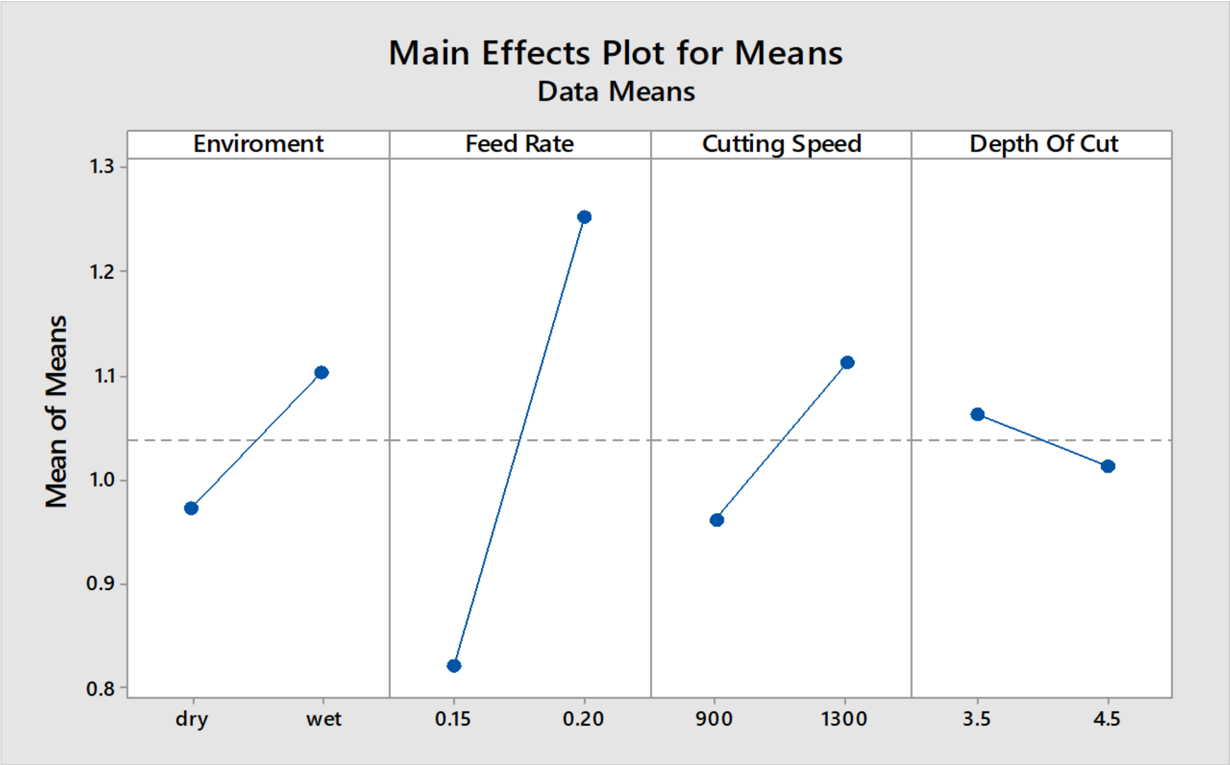

Fig. 5 Surface roughness under dry and wet conditions, with different feed rates in mm/rev, different cutting speeds in rpm and with change in depth of cut in mm

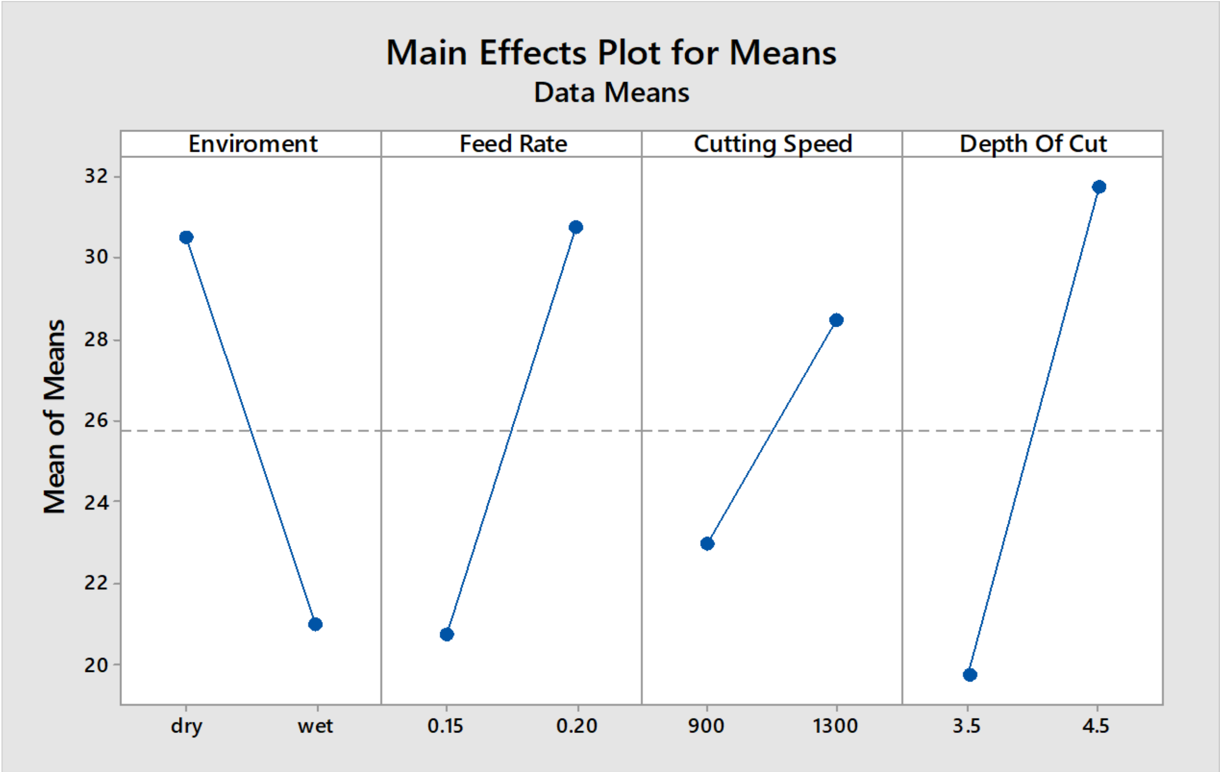

Fig. 6 Graph showing tool wear under dry and wet conditions, with different feed rates in mm/rev, different cutting speeds in rpm and with change in depth of cut in mm

Hence, the optimized value of parameters for good surface finish is:
Feed rate = 0.15 mm/rev Cutting speed = 900 rpm Depth of cut = 4.5 mm

And for minimum tool wear, the optimized value of parameters is:
Feed rate = 0.2 mm/rev Cutting speed = 900 rpm Depth of cut = 3.5

CONCLUSION

On the basis of the above research carried out, it cannot be denied that different researchers are carrying out different experiments on variety of materials to achieve best possible outputs which can be implemented in practical aspects. This paper gives a domain of the values of three process parameters: depth of cut; feed rate; cutting speed to optimize two response variables: tool wear and surface of a particular material: AISI H13 STEEL using Taguchi technique under dry and wet conditions. The main objective of the research is to get best possible results with minimum number of experiments in particular duration of time.

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