Optimization of Process Parameters of Turning using Various Tool Geometry of Cemented Carbide inserts (CNMG) for hardened AISI420 Stainless Steel Material

Suresh S Chougule[1], Dr.G. R. Naik[2], Prof. R. S. Patil[3]
[1]*Reasearch scholar, Department of Production Engineering, KIT's college of engineering, Kolhapur, Maharashtra, India*
[2,3]*Professor, Department of Production Engineering, KIT's college of engineering, Kolhapur, Maharashtra, India*

***Abstract* - The objective of this paper is to obtain an optimum setting of turning parameters for to get an optimum value of surface roughness and MRR while machining AISI420 stainless steel using CNMG inserts. Turning process parameters included spindle speed, feed, depth of cut and insert nose radius. A total number of 9 experiments conducted with orthogonal array. Attempt has been made to optimize the process parameters using Taguchi method. Minitab statistical software used for the analysis of the experimental work. After experimentation and analysis, it shows that feed affects greatly on MRR followed by DOC. For to achieve maximum MRR all process parameters have to be at level 3. In case of surface roughness, feed is a major influencing parameter followed by insert nose radius. To get good surface finish spindle speed, DOC, insert nose radius to be at level 3 and feed has to be at level 1.**

***Index Terms* - Turning process, MRR, surface roughness, Taguchi method, S/N ratio, carbide inserts, Minitab software.**

I.INTRODUCTION

Machining is one of the manufacturing processes in which the dimensions, shape or surface properties of machined parts are changed by removing the excess material. The turning process is carried out on lathe machine and the automatic turning process is performed by Computer numerical control lathe machine. Turning processes are widely used in automotive, aerospace and aircraft industries. Today's industries want the manufacturing of low cost and high-quality products in short time. Surface roughness and MRR are two important parameters. Material removal rate is an important factor that greatly effects on production rate and cost. So, it is required to find out surface roughness and material removal rate before the machining is done. This will be helpful in the production which will contribute to the minimization of production time and cost of product of desired surface quality. Better surface finish and higher machining rate are desirable for better performance of any machining process. The influence of spindle speed, feed rate, depth of cut and insert nose radius on the material while machining, Significance of each factor and also the interaction of input parameters on output can be founded easily. Taguchi was employed because it is difficult to make the analysis of input parameters simultaneously. One factor on one time gives influence on one factor of output. The results obtained from the experimental study are used to annualized and evaluating the effects of various input parameters (spindle speed, federate, depth of cut and insert nose radius) on material removal rate and surface finish. In this paper the attempts have been made on to find out the effect of cutting parameters on MRR and surface roughness in turning of hardened AISI 420 stainless steel. AISI 420 is one of the most popular high chromium and high-carbon steel. The researchers have studied the effect of various parameters using different methods on various materials, but it was found that the experimental investigation needed to be carried out on AISI 420 stainless steel considering its wide applications in motor vehicles, pump elements.

Prem S. Sapariya et al [1] optimized the turning process parameters on aluminum alloy 6061 for surface roughness and MRR. A total number of 27 experiments were conducted with an orthogonal array. They take spindle speed, feed rate, depth of cut, insert nose radius and cutting conditions as an input parameters. After experimentation and validation, they concluded that MRR is influenced by tool nose radius and surface roughness is influenced by spindle speed. M. Kaladhar et al [2] determined the optimum process parameter during turning of AISI 304 austenitic stainless steel using Taguchi method. They observed that,1) Feed plays an important role in minimization of surface roughness and maximization of metal removal rate. 2) For metal removal rate, depth of cut is dominant parameter followed by the feed. Rahul Shukla et al [3] obtained an optimal setting of turning parameters which results in an optimal value of Surface Roughness and MRR while machining AISI 1018 steel alloy with Titanium coated Carbide Inserts. They found from the analysis that the parameters which affect the MRR and surface roughness in descending orders are as spindle speed, feed rate and depth of cut. J. Chandrasekhar et al. [4] used Taguchi method for optimization of cutting parameters for turning AISI 316 Stainless steel with diamond cutting tool. Did the experiment with four cutting parameters feed, speed, depth of cut and cutting fluids. Minitab statistical software is used for the analysis of experimental work which gives signal to noise ratio. The average of S/N ratio is calculated. The Minitab software given the equation of surface roughness for work piece material. Then surface roughness is calculated. S. Hasan et al. [5] analyzed the surface roughness produced by turning process on hard martensitic stainless steel using CBN cutting tool. The work piece tool material was hard AISI 440C martensitic stainless steel. At cutting speed of 225m/min with feed rate of 0.125mm/rev and 0.50mm depth of cut produces low surface roughness. The prediction of performance of martensitic stainless steel is very difficult because of its characteristics. It is very efficient to turn the hard-martensitic stainless steel at medium level cutting speed, high feed rate and high depth of cut. S. Mohan Kumar et al [6] used Taguchi method as an optimization technique in turning operation. EN 24 is used as workpiece for carrying out experiment to optimize Material Removal Rate which is influenced by three machining parameters namely spindle speed, feed rate and depth of cut. Different experiments are done by changing single parameter and keeping other two fixed so that optimized value of each parameter can be obtained. Dry turning operation on EN 24 graded steel is performed using HSS tool. The range of cutting parameters at three levels are speed (200, 350 and 500 rpm), feed rate (0.1, 0.15 and 0.2 mm/rev), depth of cut (1.0, 1.5 and 2.0 mm) respectively. Taguchi method is a method used for optimization of various machining parameters, which reduces total number of experiments. Taguchi orthogonal array is designed with three levels of process parameters and ANOVA is applied to know the effect of each parameter on MRR. For the given set of conditions, spindle speed influences more on Material Removal Rate followed by feed rate and depth of cut. Mohd. Mustaque Ahmed et. al. [7] focused on to improve the productivity with optimum tool life and good surface finish. During experimentation they used two different tools such as tungsten carbide and cemented carbide for machining of Aluminum as a workpiece material. Considered input parameters are speed, feed, depth of cut and output parameters are tool life and surface finish. Experiments are carried out using full factorial method. After experimentation and result analysis they concluded that maximum tool life is obtained at a speed of 800 rpm, feed of 0.15mm/rev and depth of cut of 0.3mm for both tools. For tungsten carbide tool good surface finish is obtained at a speed of 1000 rpm, feed of 0.15mm/rev and depth of cut of 0.5mm. Mohd. Shadab Siddique et. al. [8] did the research on machining of AISI 4140 alloy steel using coated carbide insert of TNMG. The relation between input and output is determined and thereafter analysis is done how the input affected output.

They concluded that, the multilayer coated carbide inserts have performed well and provide an optimal operating condition for Material removal rate at a combination of speed of 2100 rpm, depth of 0.6 mm and feed of 0.3 mm/rev.

EXPERIMENTAL SET UP

For this study hardened AISI 420 stainless steel material is used to optimize the process parameter of MRR and surface roughness. The material diameter is 25mm and length of workpiece is 90mm which is shown in figure 1 and material chemical composition is given in Table 1. The workpiece is hardened up to 30HRC which is as shown in figure 2. The cemented carbide inserts with varying nose radius was used. To perform the experiments LL15T L3 CNC machine was used as shown in figure 3. To calculate the surface roughness Mitutoyo surface roughness tester SJ-210 is used which is as shown in figure 4 and for calculating the MRR weight scale is used.

Table 1 Chemical composition of AISI 420 stainless steel

Element	C	Si	Mn	S	P	Cr	Cu	Fe
Weight	0.185	0.34	0.85	0.028	0.038	12.34	0.15	86.04

Figure 1: Workpiece before hardening

Figure 2: Workpiece after hardening

Figure 3: CNC machine

Figure 4: Roughness tester

II.EXPERIMENTAL WORK

The experiment was carried out on LL15T L3 CNC lathe machine of Laxmi motor works ltd. installed at Blue line engineers, M.I.D.C. Gokul shirgaon, Kolhapur. In CNC machine, the turning process was completed on hardened AISI 420 stainless steel as workpiece using cemented carbide tipped tool with varying insert nose radius (0.4mm, 0.8mm and 1.2mm) as the cutting tool. The geometry of cutting tool is given in table 2. After machining we check the surface roughness (Ra) value of the workpiece with the help of the surface roughness tester. There are various process parameters of turning affecting the metal removal rate and surface roughness. On the basis of trial run investigations, the following process parameters have been selected. Their levels as selected given in table 3

Table 2: Tool geometry

Tool	Approach angle	Rake angle	Inclination angle	Insert nose radius (mm)
1	90°	6°	5°	0.4
2	90°	6°	5°	0.8
3	90°	6°	5°	1.2

Table 3: Process parameters with their levels

Parameters	Level 1	Level 2	Level 3
Spindle speed (rpm)	1800	1850	1900
Feed (mm/rev)	0.1	0.15	0.2
Depth of cut (mm)	1.0	1.2	1.4
Insert nose radius (mm)	0.4	0.8	1.2

III. RESULT AND DISCUSSION

After the experiment, data is collected. In this analysis, multiple objectives such as surface roughness, material removal rate are to be estimated. The experimental values of surface roughness and material removal rate are shown in table 4. Taguchi method uses SN ratio to interpret the experimental values and highest value of S/N ratio is the optimum parameter. In this analysis surface roughness is minimized and material removal rate to be maximized. Hence smaller the better type characteristics for surface roughness and larger the better type characteristics for material removal rate have been suggested. Minitab statistical software is used for the analysis of the experimental work. The Minitab software studies the experimental data and then provides the calculated results of S/N ratio. The average value of S/N ratios are calculated to find out the effects of different parameters and as well as their levels. The main plot effects for MRR is as shown in Figure 5 and the respective response table is given in table 5. They show that feed has greatly affected on MRR followed by depth of cut. The main effects plot for surface roughness is as shown in Figure 6 and the respective response table is given in table 6. They shows that feed affects strongly on SR followed by insert nose radius.

Table 4: Experimental results

Sr. No.	Spindle speed (rpm)	Feed mm / rev	Depth of cut (mm)	Insert nose radius (mm)	MRR (cm^3/min)	S/N ratio (dB)	SR (µm)	S/N ratio (dB)
1	1800	0.1	1.0	0.4	1.20586	1.625916	1.30	-2.27887
2	1800	0.15	1.2	0.8	4.38789	12.84511	1.14	-1.1381
3	1800	0.2	1.4	1.2	7.10594	17.03243	1.23	-1.7981
4	1850	0.1	1.2	1.2	3.41997	10.68045	0.57	4.882503
5	1850	0.15	1.4	0.4	6.45995	16.20458	1.36	-2.67078
6	1850	0.2	1.0	0.8	4.30663	12.68276	1.82	-5.20143
7	1900	0.1	1.4	0.8	3.10078	9.829406	0.70	3.098039
8	1900	0.15	1.0	1.2	4.84496	13.70581	0.75	2.498775
9	1900	0.2	1.2	0.4	6.45995	16.20458	2.10	-6.44439

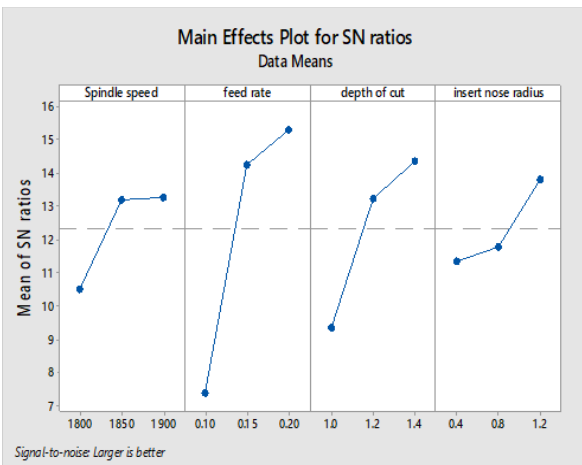

Figure 5: Main effects plot for S/N ratio (MRR)

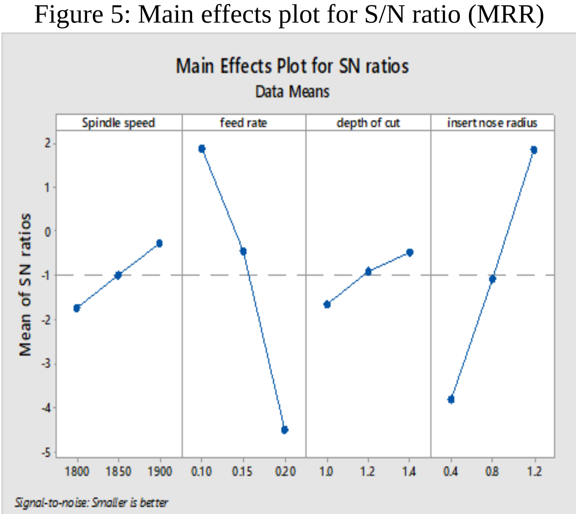

Figure 6: Main effects plot for S/N ratio (SR)

Table 5: Response table for signal to noise ratio (larger is better)

Level	Spindle speed (rpm)	Feed (mm/rev)	DOC (mm)	Insert nose radius (mm)
1	10.501	7.379	9.338	11.345
2	13.189	14.252	13.243	11.786
3	13.247	15.307	14.355	13.806
Delta	2.745	7.928	5.017	2.461
Rank	3	1	2	4

Table 6: Response table for signal to noise ratio (Smaller is better)

Level	Spindle speed (rpm)	Feed (mm/rev)	DOC (mm)	Insert nose radius (mm)
1	-1.7384	1.9006	-1.6605	-3.7980
2	-0.9966	-0.4367	-0.9000	-1.0805
3	-0.2825	-4.4843	-0.4559	1.8611
Delta	1.4558	6.3819	1.2036	5.6591
Rank	3	1	4	2

IV.CONCLUSION

Turning tests were performed on hardened AISI 420 stainless steel work piece using cemented carbide inserts with varying nose radius (0.4, 0.8, 1.2 mm). The influences of cutting speed, feed rate, depth of cut and insert nose radius were investigated on the machined surface roughness and Material Removal

Rate (MRR). Based on the results obtained and analysis the following conclusions have been drawn:

- The analysis of the experimental observations highlights that MRR in CNC turning process is greatly influenced by feed followed by depth of cut.
- It is observed that the feed is most significantly influences the Ra followed by the insert nose radius.
- The investigated optimal process parameters for MRR are spindle speed (1800 rpm), feed rate (0.2 mm/rev.), depth of cut (1.4 mm) and insert nose radius (1.2 mm).
- The investigated optimal process parameters for surface roughness are spindle speed (1850 rpm), feed rate (0.1mm/rev.), depth of cut (1.2 mm) and insert nose radius (1.2 mm).

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