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Effect of Different Cutting Tools and Cutting Parameters on MRR and Surface roughness in CNC Turning

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Abstract – In this present work, study has been made to optimize the cutting parameters of CNC turning operation to get better surface finish and MRR. The combined effects of the type of cutting tool and process parameters on performance characteristics are investigated employing Taguchi's, Orthogonal Array method and analysis of variance. The result shows the type of tool material, feed rate and spindle speed strongly influence surface roughness. But the material removal rate influenced by depth of cut and feed rate and type of tool material provided to the turning operation. The experimental data were further analyzed to predict the optimal range of type of tool material, depth of cut, feed rate, and spindle speed to get improved surface finish and material removal and to correlate between cutting parameters and performance characteristics by using multiple linear regression analysis. Taguchi Orthogonal Array L9 has been used as a DOE (Design of Experiment) method to program and analyses the experiments. It has been investigated the type of tool material is most significant factor that influence the output responses of surface roughness followed by feed rate and spindle speed. Carbide tool provides better surface finish and increase in feed rate and spindle speed gives more surface roughness. But MRR value is most significantly influenced by depth of cut followed by feed rate and tool material. Aluminum 6063 has been selected as workpiece material, HSS and Carbide tool is used as cutting tools.

Index Terms – Cutting parameters (Depth of cut, Feed rate and Spindle speed), Aluminum 6063 workpiece, HSS tool, Carbide tool, MRR, Surface roughness.

1. INTRODUCTION

The automation of machine implement industry witnessed a revolution in 1949, by the Development of CNC. Presently most conventional machine implement has been superseded by CNC machine implement where all forms of kinetics of the machine implements are programmed and controlled electronically rather than by the conventional denotes. The CNC machine comprises of the computer in which the program is fed for cutting of the metal of the job as per the requirements. All the cutting processes that are to be carried out and all the final dimensions are fed into the computer via the program. The computer thus knows what exactly is to be done and carries out all the cutting processes. Among the metal cutting methods, turning is one of the widely used manufacturing processes in industry in which a single point cutting implement abstracts unwanted material from the surface of a rotating cylindrical work piece. The cutting implement is victualed linearly in a direction parallel to the axis of rotation. In integration to implement and work piece material, type of tool material, depth of cut, feed rate and spindle speed are most consequential cutting parameters which highly affect the performance characteristics. To get optimum turning process parameter soft computing techniques are required. In present many optimization techniques are available but only few have been utilized for CNC turning process parameter. This paper brings to the forefront the work done in this area, the techniques used along with the results established. In the process of CNC machining, a tool penetrates into the work piece and removes the material in the form of chips, this causes for high friction and heat at the tool chip interface, due to this tool wear increases and cause for surface roughness. To reduce tool wear and improve surface finish different types of tool will use with optimised cutting parameter at coolant pressure of 10 bar. Carbide tool with low feed rate and spindle speed provide less surface roughness. But in case of MRR, Carbide tool with high depth of cut and feed rate cause for high material removal rate (MRR).

2. LITERATURE REVIEW

R.Patil *et al*. [1] This paper is based on the study of improving surface finish by using effect of high pressure coolant during CNC turning operation. He took water base Ashoka LD-700 as a coolant at pressure of 10 bar and 70 bar for turning EN8. He observed that as the pressure of coolant increases from 10 bar to 70 bar surface roughness decreases from 0.817 µm to 0.542 µm. here he observe that as coolant pressure increases the surface roughness of the work material EN8 steel decreases. B.Tulasiram Rao *et al.* [2] :- This paper deals with finding optimal control parameters to get the minimum Surface roughness. It considers the analysis of effect of the process parameters (cutting speed, feed rate and depth of cut) on cutting forces during turning operation. Surface finish obtained in machining process depends upon so many factors like work material, tool material, tool geometry, machining conditions, cutting fluids used and feed rate etc. In this experimental work it is planned to study the effect of process parameters on surface finish obtained in the machining process of materials like stainless steel and aluminum. This experiment arrived on a conclusion that the minimum surface roughness in stainless steel (1.38 µm) is obtained when the Spindle speed is (1200 rpm approx.), Depth of cut and Feed Rate are minimum (i.e 0.2 mm and 0.15 mm respectively). In case of aluminum the minimum surface (1.14 µm) is obtained when the spindle speed is (800 rpm approx), Depth of cut and Feed Rate are minimum (i.e 0.3 mm and 0.15 mm respectively). Drlička R. *et al*. [3] this paper deals with the study of machinability improvement using high-pressure cooling in turning.

Here process fluids are used primarily for their cooling and lubricating effect in machining. Many ways to improve their performance have been proposed; the analysis of some of them is provided in the paper. The effect of high pressure cooling has been investigated with regard to chip formation and tool life. Standard and for high pressure application particularly designed indexable cutting inserts were used with fluid pressure 1.5 and 7.5 MPa.

The pressure effect on tool life at different feed rates was observed as well. Not each cooling pressure value or machined material showed favorable chip formation. Tool life though has improved significantly while machining with a lower feed rate. He observed that high-pressure cooling is not working properly with pressure value 0.7 MPa when machining the material with a continuous chip (Ductile materials). When observing chip generation with different feed rates, we found useful using a lower feed rate in case of HPC geometry of indexable cutting insert.

Machining with feed per revolution 0.2 mm produced a well-formed chip in the whole range of cooling pressure used and tool wear occurred on the flank only. At higher feed rates per revolution 0.3 and 0.4 mm, the chip was elemental, but the feed stressed (loaded) the cutting edge much more, resulting in groove wear on the rake. Muhammmad Yasir *et al.* [4] This paper investigates the effect of cutting parameters on the surface topography of AISI 316L stainless steel with tungsten carbide tool by using response surface methodology (RSM). Feed rates ranges from 0.10 mm/rev to 0.14 mm/rev while the cutting speeds ranges from 80 m/min to 120 m/min were used. Scanning electron microscope (SEM) and Mitutoyo surface tester were used to study in detail the surface topography of AISI 316L stainless steel.

A mathematical relationship was built between cutting parameters and surface roughness. From the results it was found that feed rate was the main factor affecting the surface roughness while cutting speed have negligible effect on the surface roughness of the end-milled AISI 316L stainless steel samples. From analysis of variance it was found that the percentage contribution of feed rate was 10.38 % and cutting speed as 2.1 %. M.Alper İNCE *et al.*[5] This paper presents of the influence on surface roughness of Co28Cr6Mo medical alloy machined on a CNC lathe based on cutting parameters (rotational speed, feed rate, depth of cut and nose radius). In this paper he observed that the influences of cutting parameters have been presented in graphical form for understanding. To achieve the minimum surface roughness, the optimum values obtained for rpm, feed rate, depth of cut and nose radius were respectively, 318 rpm, 0.1 mm/rev, 0.7 mm and 0.8 mm. Maximum surface roughness has been revealed the values obtained for rpm, feed rate, depth of cut and nose radius were respectively, 318 rpm, 0.25 mm/rev, 0.9 mm and 0.4 mm. Surface roughness usually decreases with increase in nose radius. The minimum value of surface roughness obtained is 0.81 µm at n= 318 rpm, f= 0,1 mm/rev, a= 0,7 mm and r= 0.8 mm. Maximum value of surface roughness is 8.437 µm at n= 318 rpm, f= 0,25 mm/rev, a= 0,9 mm and r= 0.4 mm. Satish.G. *et al.*[6] The effect of surface roughness on pressure drop and heat transfer in circular tubes has been extensively studied in literature.

The pioneering work of Nikuradse established the sand grain roughness as a major parameter in defining the friction factor during laminar and turbulent flows. Recent studies have indicated a transition to turbulent flows at Reynolds number value much below 2300 during single phase flow in channels with small hydraulic diameters. In the present work, a detailed experimental study is undertaken to investigate the roughness effects in small diameter tubes. The roughness of the inside tube surface is changed by etching it with an acid solution. Two tubes of 1.032 mm and 0.62 mm inner diameter are treated with acid solution to provide three different roughness values for each tube. The Reynolds number range for the tests is 500-2600 for 1.067 mm tube and 900-3000 for 0.62 mm tube.

Reddy and Rao [7] They developed an empirical surface roughness model for end milling of medium carbon steel, whose parameters were optimized using GA also Reddy and Rao used genetic algorithm to optimize tool geometry, viz., radial rake angle and nose radius and cutting conditions, viz., cutting speed and feed rate to obtain desired surface quality in dry end milling process. Sujit Kumar Jha and Pramod K Shahabadkar [8] The objective of this research was to utilize Taguchi methods to optimize the material removal rate for machining operation and the effects of CNC machining processes on aluminum samples. There are three important cutting parameters namely, cutting speed, feed rates and depth of cut, which had been considered during the machining of Aluminum alloy.

This research examines the effects of process parameters on Material Removal Rate (MRR) during machining on CNC. An Orthogonal array had been selected and constructed to find the optimal levels and to analyze the effect of the turning parameters. The signal-to-noise (S/N) ratio had been calculated to construct the analysis of variance (ANOVA) table to study the performance characteristics in dry turning operations. ANOVA has shown that depth of cut has significant role in producing higher MRR. The optimal results have been verified through conformation experiments with minimum number of trials as compared with full factorial design. The best cutting parameters for material removal rate has been found as cutting speed 1000 RPM, feed 0.20 mm/rev and depth of cut 1.5 mm on the basis of ANOVA analysis. Sundaramoorthy, R. and Dr. Ravindran [9] This paper discuss of the literature review of aluminum alloys on CNC. Now a day's CNC milling is the most important milling operation, widely used in most of the manufacturing industries due to its capability of producing complex geometric surfaces with reasonable accuracy and surface finish along with flexibility and versatility. Aluminum alloys are used in engineering design chiefly for their light weight, high strength-to-weight ratio, corrosion resistance, and relatively low cost. They are also utilized for their high electrical and thermal conductivities, ease of fabrication, and ready availability. This paper highlights the major open points and gives the different machining parameters of the aluminum alloy in CNC milling operations. Aswathy V G, Rajeev N and Vijayan K [10] The main objective of this work is to investigate the effects of machining parameters, especially tool nose radius, on surface Finish, Material Removal Rate (MRR) and Roundness error during the wet turning of Ti-6Al-4V. The Selection of Ti-6Al-4V is due to the reason that it offers a unique combination of high strength, light weight and corrosion resistance which have made it an important material in aerospace applications. Despite its advantages the machinability of Ti-6Al-4V possesses many challenges such as its low thermal conductivity and work hardening effect reduces the tool life and quality of the product.

This paper presents research work of various cutting parameters affecting the surface roughness, Material Removal Rate and Roundness error in wet turning of Ti-6Al-4V alloy using CVD coated carbide tools .The findings of this study indicate that For maximum surface finish the optimal parametric combination is cutting velocity is 70 m/min, feed =0.010mm/rev, Depth of cut =0.02 and Nose radius =0.5. For maximum Material Removal Rate the optimal parametric combination is cutting velocity is 70 m/min., feed =0.030mm/rev, Depth of cut =0.05 and Nose radius =0.1. For minimum Roundness error the optimal parametric combination is cutting velocity is 70 m/min., feed =0.010mm/rev, Depth of cut =0.02 and Nose radius =0.5.

3. EXPERIMENTAL SETUP

The turning experiments were carried out with coolant at 10 bar pressure, cutting conditions on SIEMENS CNC Machine as shown in Fig. 5, which have a maximum spindle speed of 1000-2000 rpm and a maximum spindle power of 2.2 kW. Ranges of cutting parameters were selected as given in the tool manufacturer's catalogue. In this study, three factors were studied and their low– middle–high levels with two different tool materials are given in Table 1-6.

However in all experiments depth of cut (0.3-0.5 mm), cutting speed (1000-2000 RPM), and feed rate (50-150 mm/min) were taken as fixed values. Each tool was used for once and turned surface length was in 50 mm. The SIEMENS CNC machine is available at Sharda University CNC lab. The input parameters like type of tool material, depth of cut, feed rate and spindle speed are varied during the experiment. And these parameters are selected to study their significance influence to Surface roughness and MRR. The pressure of the coolant is taken as 10 bar and machining time period of each trial is noted from CNC machine. The diameter of the Aluminum 6063 bar is 30 mm.

Figure 1.SIEMENS CNC Machine

Aluminum 6063 is selected as a workpiece. The chemical composition of different tools has been shown in the table 1 and 2. Aluminum bar of 30 mm diameter has been used as workpiece. Coolant is used at a pressure of 10 bar. MRR is calculated by measuring the loss of weight of the workpiece before and after the machining,

$$MRR=\frac{(Wi-Wf)}{\rho \times t} x\ 1000\ mm^3/min \quad \text{equation (i)}$$

Where,

Wi= Initial weight of work piece material (gms)

Wf= Final weight of work piece material (gms)

t= Time period of trails in minutes

ρ= Density of work piece in gms/cc

Table 1.Chemical composition of HSS Tool

Tool	W	Cr	V	C	Fe
HSS	18 %	4 %	1 %	2 %	75 %

Table 2.Chemical composition of Carbide Tool

Tool	W	Cr	V	C	Co	Fe
Carbide	13 %	4.75 %	6 %	2.15 %	10 %	64.1 %

Figure 2.HSS Tool

Figure 3.Carbide Tool

The input parameters, which will be kept constant during the experimentation, are given in table 3.

Table 3. Constant Parameters

S/NO	Parameter	Value set as
1	Coolant Pressure	10 bar
2	Direction of rotation of work	Clockwise

4. METHODOLOGY

The effect of various input parameters i.e. type of cutting tool material, depth of cut, feed rate and spindle speed to output responses Surface roughness and MRR were investigated.

The statistical software MINITAB are using for DOE (Design of Experiment). Under DOE we are using Taguchi design to create mixed level with four factors. Orthogonal Array L9 will be used to accommodation of combination of mixed level factors that is used to conduct of experiments to measure two values surface roughness and MRR.

We have taken three trials for each experiment. After the conduct of the 18 trials, the mean values for Surface roughness and MRR are recorded. For the analysis of the results, Analysis of Variance (ANNOVA) was performed.By applying Analysis of Variance (ANNOVA) using Minitab software, significant parameters (Surface roughness) and (MRR) are determined.

5. RESULTS AND DISCUSSIONS

MRR result is analyzed by using (ANNOVA) Analysis of Variance. The results shows that type of tool material, depth of cut and feed rate contributed significantly to change in MMR. Depth of cut has the highest rank significantly highest contribution to MMR followed by feed rate tool material and spindle speed.

Table 4.Measured Value of Mean S/N Ratio for MRR

S/NO	Tool	Depth of Cut (mm)	Feed rate (mm/min)	Spindle speed (rpm)	Mean MRR(mm3/min)	S/N Ratio
1	HSS	0.3	50	1000	5.456	14.737
2	HSS	0.3	100	1500	10.214	20.183
3	HSS	0.3	150	2000	18.054	25.131
4	HSS	0.4	50	1000	8.855	18.943
5	HSS	0.4	100	1500	17.951	25.081
6	HSS	0.4	150	2000	28.521	29.103
7	HSS	0.5	50	1500	13.059	22.318
8	HSS	0.5	100	2000	27.568	28.808
9	HSS	0.5	150	1000	34.263	30.696
10	Carbide	0.3	50	2000	10.125	20.107
11	Carbide	0.3	100	1000	15.095	23.576
12	Carbide	0.3	150	1500	23.541	27.436
13	Carbide	0.4	50	1500	18.521	25.353
14	Carbide	0.4	100	2000	37.802	31.550
15	Carbide	0.4	150	1000	46.958	33.434
16	Carbide	0.5	50	2000	32.125	30.136
17	Carbide	0.5	100	1000	50.124	34.000
18	Carbide	0.5	150	1500	75.032	37.504

Table 5.Response table for mean MRR

Level	Tool	Depth of cut (mm)	Feed rate (mm/min)	Spindle speed (rpm)
1	18.22	13.75	14.69	26.79
2	34.37	26.43	26.49	26.39
3		38.70	37.73	25.70
Delta	16.15	24.95	23.04	1.09
Rank	3	1	2	4

Each factor of the main effect plots of MMR are shown in figure 6. From the figure it can be seen that increase in depth of cut and feed rate increases the value of MMR. It is also observed that by using Carbide tool MRR value increases and spindle speed has no significant effect on MRR.

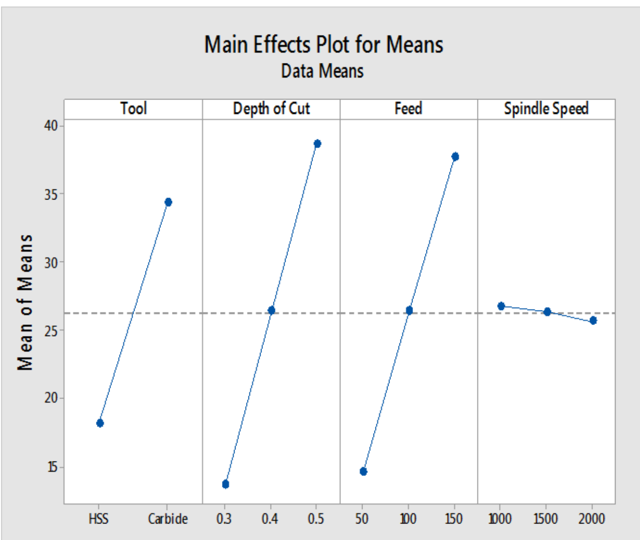

Figure 4.The main effect plots of MRR

Table 6.Response table for Signal to Noise Ratio (MRR)

Level	Tool Material	Depth of Cut (mm)	Feed rate (mm/min)	Spindle speed (rpm)
1	23.89	21.86	21.93	25.90
2	29.23	27.24	27.20	26.31
3		30.58	30.55	27.47
Delta	5.34	8.72	8.62	1.57
Rank	3	1	2	4

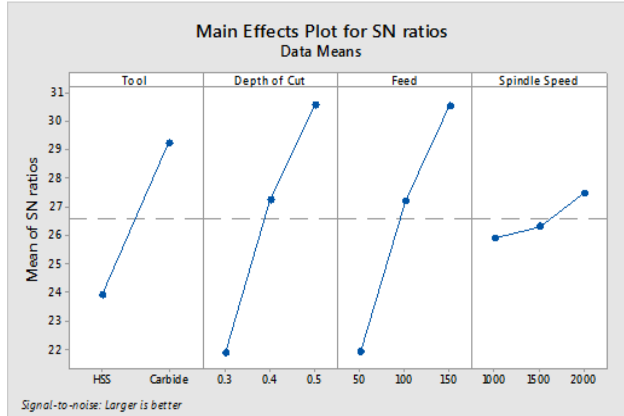

Figure 5.The main effect Plot of S/N Ratio for MRR

Table 7.Analysis of Variance for Mean, using for F-test (MRR)

Source	**DOF**	**Seq SS**	**V**	**F**	**P**	**SS'**	**% contribution**
Tool	1	1174.22	1174.22	16.01	0.003	1023.4	19.06
Depth of Cut	2	1867.22	933.67	12.73	0.002	1716.4	31.94
Feed	2	1592.50	796.67	10.86	0.003	1441.68	26.84
Spindle Speed	2	3.66	1.83	0.02	0.975	-147.16	2.73
Residual Error	10	733.50	73.35			582.68	10.85
Total	17	5371.21	2979.67	39.62	0.983	4181.48	
e pooled	12	737.27	75.41	0.02	0.975	435.52	

Table 8.Value of Mean and S/N Ratio for Surface Roughness

S/NO	Tool	Depth of Cut (mm)	Feed rate (mm/min)	Spindle speed (rpm)	Mean SR(μm)	S/N Ratio
1	HSS	0.3	50	1000	1.525	-3.66540

2	HSS	0.3	100	1500	1.825	-5.22526
3	HSS	0.3	150	2000	2.114	-6.50210
4	HSS	0.4	50	1000	1.210	-1.65571
5	HSS	0.4	100	1500	1.792	-5.06676
6	HSS	0.4	150	2000	2.181	-6.77311
7	HSS	0.5	50	1500	1.255	-1.97287
8	HSS	0.5	100	2000	1.524	-3.65975
9	HSS	0.5	150	1000	1.952	-5.80960
10	Carbide	0.3	50	2000	0.481	6.35710
11	Carbide	0.3	100	1000	0.495	6.10790
12	Carbide	0.3	150	1500	0.572	4.85208
13	Carbide	0.4	50	1500	0.521	5.66325
14	Carbide	0.4	100	2000	0.539	5.36822
15	Carbide	0.4	150	1000	0.581	4.71648
16	Carbide	0.5	50	2000	0.505	5.93417
17	Carbide	0.5	100	1000	0.568	4.91303
18	Carbide	0.5	150	1500	0.681	3.33706

Table 9.Response table for mean SR

Level	**Tool**	**Depth of Cut (mm)**	**Feed (mm/min)**	**Spindle Speed (rpm)**
1	1.7087	1.1687	0.9162	1.0552
2	0.5492	1.1373	1.1238	1.1077
3		1.0808	1.3468	1.2240
Delta	1.1594	0.0878	0.4307	0.1688
Rank	1	4	2	3

Each factor of the main effect plots of SR are shown in figure 8. From the figure it can be seen that increase in feed rate and spindle speed increases the value of SR. It is also observed that by using Carbide tool SR value increases most significantly.

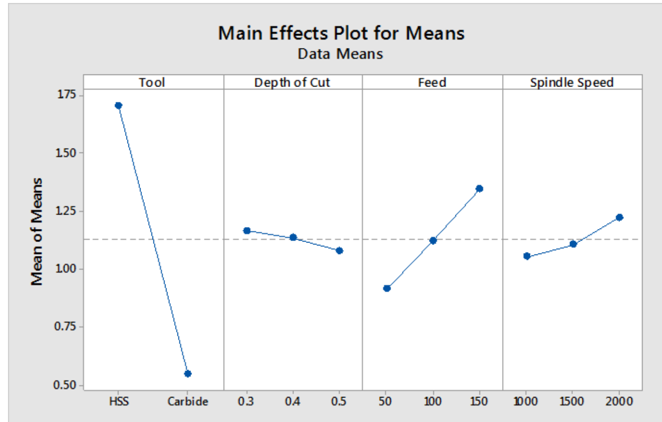

Figure 6.The main effect plots of SR

Table 10.Response table for Signal to Noise Ratio (S/N)

Level	**Tool**	**Depth of Cut**	**Feed**	**Spindle Speed**
1	-4.4812	0.3207	1.7768	0.7678
2	5.2499	0.3754	0.4062	0.2646
3		0.4570	-1.0229	0.1208
Delta	9.7311	0.1363	2.8066	0.6470
Rank	1	4	2	3

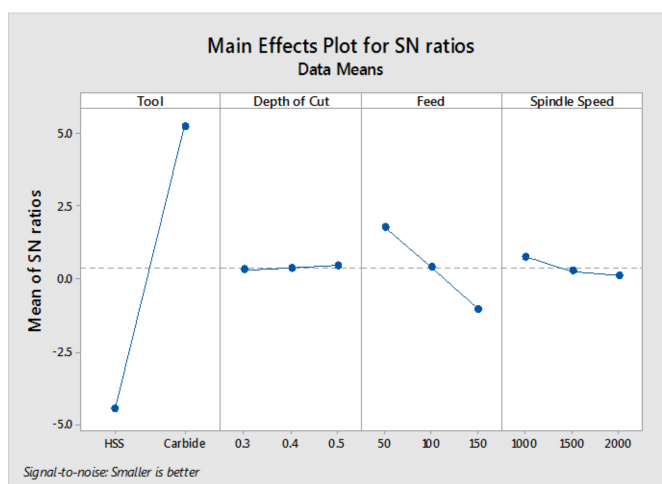

Figure 7.The main effect Plot of S/N Ratio for MRR

Table 12. ANOVA for Surface Roughness

Source	**DOF**	**Seq SS**	**V**	**F**	**P**	**SS'**	**% contribution**
Tool	1	6.04940	6.04940	173.30	0.000	5.93604	83.97
Depth of Cut	2	0.02378	0.01189	0.34	0.719	-0.08958	1.26
Feed	2	0.55666	0.27833	7.97	0.009	0.4433	6.27
Spindle Speed	2	0.08959	0.04479	1.28	0.319	-0.02377	0.33
Residual Error	10	0.34907	0.03491			0.23571	3.33
Total	17	7.06850	6.38441	182.89	1.047	6.95514	
E pooled	12	0.46244	0.05668	1.62	1.038	0.5758	

The response parameter of mean and S/N ration of SR is shown in table 9. The F-value and contribution % (P) of each factor obtained from ANOVA method are shown in table 10 and 12. The significance factor that contributed most is arranged in their ranking manners based on P value. Tool material place the highest rank followed by feed rate and spindle speed respectively.

Tool material places the highest rank and feed rate, spindle speed and depth of cut respectively for mean Surface roughness. The most significant factor that contributed is tool material with 83.97% and the second is feed rate with 6.27%.

6. CONCLUSION

In this study the effect of cutting parameters on MRR and Surface roughness with HSS and Carbide tool in CNC turning machine on Aluminum 6063 workpiece at 10 bar pressure has been investigated. MRR and Surface roughness was analyzed for effects of different input parameters. The following conclusion has been found out from the experiment and results

1. Higher depth of cut and higher feed rate with Carbide tool influence most significantly in case of MRR. It has been seen from the results that when depth of cut and feed rate by using Carbide tool increases Material Removal Rate of work piece is increase by 31.95%, 26.84% and 19.05% respectively.

2. But in case of Surface roughness higher feed rate with Carbide tool is most significant factor. It has been seen from the results that when feed rate by using Carbide tool increases Surface roughness of work piece is decreases by 6.27% and 83.97% respectively.

3. The maximum MRR value 75.032 mm^3/min is obtained at depth of cut 0.5 mm, feed rate 150 mm/min and spindle speed 1500 rpm by using carbide tool also the minimum surface roughness 0.481 µm is obtained at depth of cut 0.3 mm, feed rate 50 mm/min and spindle speed 2000 rpm by using carbide tool.

REFERENCES

[1] R. A. Patil and V. D. Shinde (2008). **"**Performance of high pressure coolant on tool wears" International Journal of Research in Engineering and Technology eISSN: 2319-1163 | pISSN: 2321-7308

[2] B. Tulasiram Rao (2013). "Experimental study on the effect of cutting parameters on Surface finish obtained in CNC turning operation". International Journal of Innovative Research in Science, Engineering and Technology (An ISO 3297: 2007 Certified Organization) Vol. 2, Issue 9, September 2013

[3] Drlička R., Kročko V., 2014. Machinability improvement using high-pressure cooling in turning. Res. Agr. Eng., *60* (Special Issue): S70–S76.

[4] Muhammmad Yasir (2016). "Effect of cutting speed and feed rate on Surface roughness of AISI 316L SS using end-milling" ARPN Journal of Engineering and Applied Sciences ISSN 1819-6608.

[5] Mehmet Alper İNCE (2015) "Effects of Cutting Tool Parameters on Surface Roughness" International Refereed Journal of Engineering and Science (IRJES) ISSN (Online) 2319-183X, (Print) 2319-1821 Volume 4, Issue 8 (August 2015), PP.15-22

[6] Satish. G Kandlikar, Shailesh Joshi and Shurong Tian (2003). "Effect of surface roughness on heat transfer and fluid flow characteristics at low Reynolds No. in small diameter tube" Heat Transfer Engineering, 24(3):4-16, 2003 Copyright © 2003 Taylor & Francis 0145-7632/03

[7] Reddy and Rao (2005) "Optimisation of turning parameters of Inconel 718 alloy using RSM" *Int. J. Manufacturing Technology and Management, Vol. 25, Nos. 1/2/3,* (2012), pp.113–134.

[8] Sujit Kumar Jha and Pramod K Shahabadkar (2015) "EXPERIMENTAL INVESTIGATION OF CNC TURNING OF ALUMINUM USING TAGUCHI METHOD" International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 02 Issue: 03 June-2015 www.irjet.net p-ISSN: 2395-0072

[9] Sundaramoorthy R and Dr. Ravindram R (2016) "A LITERATURE STUDY ON DIFFERENT TYPES OF ALUMINUM ALLOYS WITH CNC MILLING MACHINE" Asian Journal of Science and Technology Vol.07, Issue, 02, pp.2433-2436 February, 2016

[10] Aswathy V G, Rajeevv N and Vijayan K (2015) 'Effect of machining parameters on surface roughness, material removal rate and roundness error during the wet turning of Ti-6Al-4V alloy' Int. Journal of Applied Sciences and Engineering Research, Vol. 4, Issue 1, 2015.