Experimental Investigation of Factors Affecting Milling Operation

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***Abstract*- CNC milling is an ideal adaption of the conventional milling process which uses an end mill cutter for the machining operation. Plain milling is one of the essential machining operations and it is used for planning the top surface of component to achieve the high accuracy with good surface finish. In this work, plain milling operation is performed on CNC milling machine. The parallel shank end milling cutter having 14 mm diameter, M2 grade is used for the operation. Mild Steel containing 20% Carbon is used as work piece. The dimension of work piece is taken as 55×50×16 mm. Full factorial experimentation is carried out for conducting pilot experiments to study the effects of machining parameters such as spindle speed, feed and depth of cut on surface roughness and material removal rate in minimum machining time. After experimentation it is observed that the effect of surface roughness is increased when material removal rate is high. Both surface roughness and material removal rate is inversely proportional to each other.**

***Keywords*- Surface roughness, MRR, CNC Milling, Machining time.**

I. Introduction

As per the demand of today's end users in concern, it is essential to have a good quality product for its functional aspect. While manufacturing any component in industries, manufacturers concentrated on the quality and productivity of the product. To extend the productivity and quality of product, computer numerically machine tools have been used during the past decades. Surface roughness of milled component has massive influence on the quality of the finished product. Surface roughness had been found to be influenced in varying amounts by a number of controllable as well as uncontrollable factors. Controllable factors include spindle speed, feed depth of cut, work hardness, built-up edge, coolant used, cutting time etc. Uncontrollable factors such as tool geometry and material properties of both tool and work piece. Many time most of the machine operator using 'trial and error' method to set-up machining condition for milling machine. This method is not effective and efficient. So it is difficult to achieve the better surface finish. Therefore it is essential to have proper selection of machining and geometry parameters. It is well known that many machining and geometry parameter, tool and work piece material that affects machining operation. But major effect on machining operation due to controllable factors includes spindle speed, feed depth of cut. Advantageously these controllable factors can be easily changed during the process of machining operations without extra cost and time. The main objective of any machining industry will be-

- Reduction in total manufacturing time and machining cost without compromising product quality.
- Increase in metal removal rate and production rate.

All those objectives are commonly and substantially governed by total machining time. Hence it becomes necessary to determine the actual machining time to produce a component mainly for-

- Assessment of quality and productivity.
- Evaluation of machining cost, labour cost.
- Assessment of relative performance of machine tool, cutting tool.

The objective of this study is to set-up machining parameters in order to achieve the desired surface roughness. The objective is to predict surface roughness and material removal rate under different cutting conditions determined by spindle speed, feed, and depth of cut. Experimental results are expected to prove that the parameters of spindle speed, feed, and depth of cut could calculate surface roughness and material removal rate under different cutting parameters.

II. Literature Survey

Many researchers have studied the effects of machining and geometry parameters using various optimization techniques. M. Nalbant et al (2006) studied the effects of cutting parameters on turning operations of AISI 1030 steel bars using TiN coated tools. This work presented that the insert radius and feed rate are the main dominant parameters for surface roughness [1]. Rajendra, Deepak D (2015) presented work for increasing material removal rate for turning Al6061. This work observed that the feed rate is most influential process parameters that influence MRR [2]. Sayak Mukherjee et al (2014) focused on the effect of SAE 1020 on material removal rate. The paper presented the optimum machining parameter during turning on CNC lathe [3]. Lohithaksha M Maiyara et al (2013) investigated the parameter optimization of end milling operation for Inconel 718 super alloy. This paper used Taguchi method and Grey Relational Analysis [4]. Julie Z Zhang et al (2007) studied Taguchi design application to optimize surface roughness in face milling operation. This work described the relationship between controllable parameter and response factor, find out the optimum machining parameters for surface roughness [5]. A Mansour, H Abdulla (2002) presented the development process of surface roughness in end milling EN32M [6]. N.V.Mahesh Babu Talupula, Nersu Radhika (2015) investigated the optimal machining parameters for Mild Steel using Particle Swarm Optimization technique. This work investigated the effect of machining parameters on surface roughness in minimum machining time [7]. Hrelja Marko et al (2013) studied the effects of machining parameters on cutting force and tool life using Particle Swarm Optimization technique [8]. Girish Kant, Kuldip Singh Sangwan (2015), presented the optimization model using two techniques one Artificial Neural Network and other is Genetic Algorithum [9]. Uros Zuper, Franc Cus (2016) presented system of ANFIS and TLBO is an effective approach for solving multi-objective cutting conditions optimization problem in milling. This work proved that the experimental result is very close to TLBO [10]. B.T.H.T Baharudin et al presented to find optimum machining parameter for HSS insert face cutting on material AL6061 using Taguchi method. This work shows that good surface finish can be generated with high spindle speed, low feed rate and using 00 rake angle [11]. Azlan Mohd Zaina et al (2010) studied the influence of machining and geometry parameter of milling operation on surface roughness. The parameters were optimized using Genetic Algorithm [12].

III. Materials and Methods

A. Experimental Set-Up

All the experimentation has been carried out in wet cutting conditions on a Hass-US five-axis, high-speed CNC milling machine having a maximum spindle speed of 12000 RPM, feed rate of 10 m/min and a 25-kW drive motor. The experimental trials have been carried out at Indo German Tool Aurangabad, M.S., India. CNC part programs for tool paths have been generated. The work piece material is mounted on the machine table to provide maximum rigidity.

(a) (b)

Figure 1. CNC Milling Machine (a) and (b)

B. Measurement of Responses

In this work stylus type Profilometer has been used to measure surface roughness of the machined work piece. All the measurement of surface roughness of work pieces have been done at Micronics Calibration Centre, Chikhalthana MIDC, Aurangabad. Micronics Lab is a National accredited board for testing of laboratory and calibration. The range of surface tester is 0-100 µm and least count is 0.1µm.

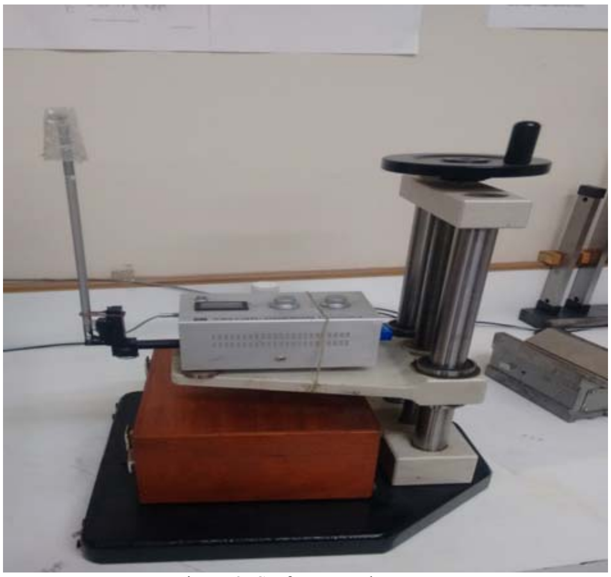


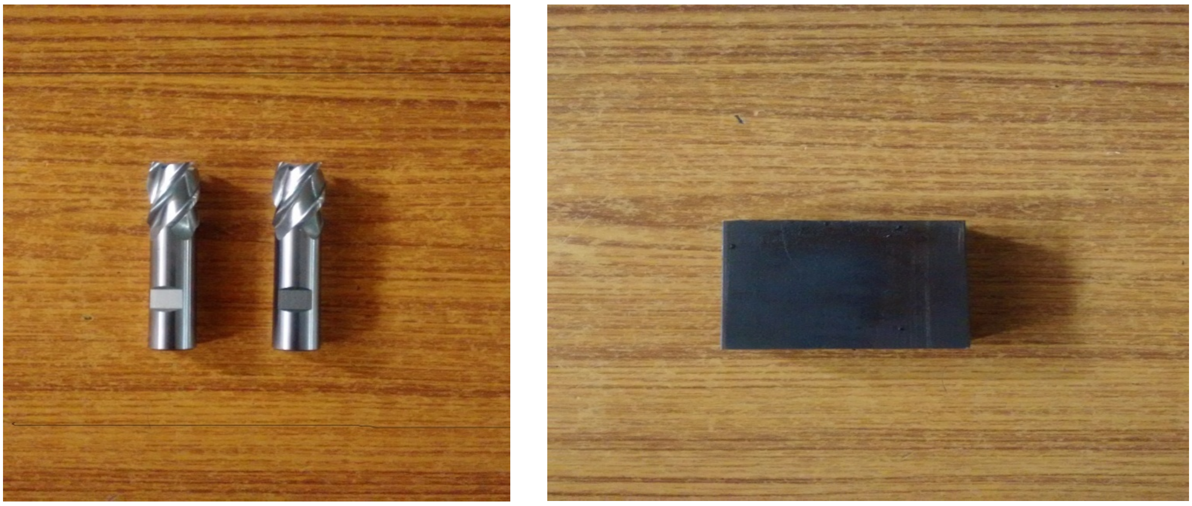
Figure 2. Surface Roughness Tester

C. High Speed Steel Tool

This High Speed Steel material is usually used in the manufacture of machine tool bits, power saw blades, drill bits and other cutter. These tools are available in many different tool geometries and material grades. Basically there are two types of High Speed Steel, i.e. molybdenum (M- series) and tungsten (T- series). 98 % of all High Speed Steel made of M- series steel. This particular grade M2 has decided for the experiment as it is most widely used in the industries. The High Speed Steel (14mm diameter, 4–flutes parallel shank end milling cutter) tool has been used for performing end milling operation produced by Sandvik. The hardness of the tool has been measured as 64-65 HRC. The testing of tool material has taken from S N Metallurgical Services Aurangabad, M.S., India and chemical composition of High Speed Steel has been observed as given in Table 1.

TABLE I. Chemical composition of High Speed Steel Tool (wt %)

Element	C	Mn	Cr	Ni	Mo	W	S	P	Si	Co	V
%	1.14	0.37	4.33	0.17	9.25	1.35	0.009	0.015	0.46	8.09	1.60



(a) (b)

Figure 3. (a) High Speed Steel Tool (b) AISI 1020 Mild Steel

D. 1020 AISI Mild Steel

The work piece material has been used AISI 1020 Mild Steel in the form of a 55mm (length), 50mm (width), 16mm (height) block. The testing of tool material has been done from S N Metallurgical Services Aurangabad, M.S., India and chemical composition of work piece material has been observed as given in Table-2. The mechanical properties of material have been observed during testing are listed in Table-3.

TABLE II. Chemical composition of 1020 AISI Mild Steel (wt %)

Element	C	Mn	Cr	Ni	Mo	S	P	Si
%	1.14	0.37	4.33	0.17	9.25	0.009	0.015	0.46

TABLE III. Mechanical Properties of 1020 AISI Mild Steel

Density (Kg/M^3)	Hardness (BHN)	Tensile strength (MPA)
7.850	115	750

E. Plan of experiments

TABLE IV. Experimental results of machining time and surface roughness for the given machining parameters

Sr. No.	Cutting Speed (RPM)	Feed (m/min)	Depth of cut (mm)	Machining time (Sec)		Surface roughness (microns)	MRR (Wf-Wi) /ρ*tm(mm3/sec)
				Theoretical	Experimental		
1.	600	200	0.2	23	20.52	1.4	8.363
2.	600	200	0.4	23	20.26	1.5	12.572
3.	600	200	0.6	23	19.93	1.4	18.443
4.	600	250	0.2	18	16.19	1.2	4.033
5.	600	250	0.4	18	16.23	1.4	14.649
6.	600	250	0.6	18	16.01	1.5	21.514
7.	600	300	0.2	15	13.44	1.5	12.229
8.	600	300	0.4	15	13.30	1.6	17.409

9.	600	300	0.6	15	13.13	1.7	29.044
10.	700	200	0.2	23	19.09	1.3	7.089
11.	700	200	0.4	23	19.75	1.5	13.071
12.	700	200	0.6	23	19.6	1.7	17.003
13.	700	250	0.2	18	15.38	1.3	8.634
14.	700	250	0.4	18	15.40	1.6	15.074
15.	700	250	0.6	18	15.65	1.7	23.566
16.	700	300	0.2	15	13.21	1.5	9.596
17.	700	300	0.4	15	13.14	1.7	20.297
18.	700	300	0.6	15	13.15	1.7	28.1104
19.	800	200	0.2	23	19.05	1.3	5.427
20.	800	200	0.4	23	19.14	1.6	13.015
21.	800	200	0.6	23	19.32	1.6	18.609
22.	800	250	0.2	18	15.56	1.4	8.421
23.	800	250	0.4	18	15.68	1.6	15.074
24.	800	250	0.6	18	15.73	1.6	23.566
25.	800	300	0.2	15	13.03	1.5	10.53
26.	800	300	0.4	15	13.65	1.7	17.664
27.	800	300	0.6	15	13.03	1.8	29.214
28.	900	200	0.2	23	19.35	1.4	5.649
29.	900	200	0.4	23	19.59	1.6	11.631
30.	900	200	0.6	23	19.48	1.7	17.945
31.	900	250	0.2	18	15.56	1.3	8.138
32.	900	250	0.4	18	15.63	1.6	14.861
33.	900	250	0.6	18	15.71	1.7	23.425
34.	900	300	0.2	15	13.33	1.5	11.464
35.	900	300	0.4	15	13.76	1.7	21.316
36.	900	300	0.6	15	13.23	1.8	25.222

During experimentation the parameters such as spindle speed, feed and depth of cut have been considered as input parameter whereas surface roughness and material removal rate as output parameter. The feasible range of machining parameters has been taken from machine limitation and machine tool handbook. Full factorial experimentation has been carried out for conducting pilot experiments to study the effects of machining parameters on surface roughness and material removal rate in minimum machining time. By changing the spindle speed in four levels, feed in three levels and depth of cut in three levels the experimentation has been carried out. Full factorial experimentation is the design of experiment adopted for conducting experiments. During conduction of experiments total 36 numbers of trials has been conducted. During conduction of experiments the weight of work piece has been measured before and after machining using weight balanced machine for calculation of material removal rate. The surface roughness tester has been used to measure surface roughness. The above table shows machining time, surface roughness and material removal rate measured for different combination of spindle speed, feed and depth of cut.

IV. Result and Discussion

Pilot experiments have been carried out to study the effect of machining parameters on the surface roughness, material removal rate in minimum machining time. Based on full factorial experimentation, total 36 numbers of trials have been conducted on CNC milling machine. From the experiments conducted, it is observed that the surface roughness decreases when there is an increase in spindle speed and surface roughness decreases with a decrease in feed and depth of cut. Similarly it is also observed that the material removal rate increases with increase in spindle speed, feed and depth of cut. Figure 4 and 5 shows the effect of machining parameters on surface roughness and material removal rate.

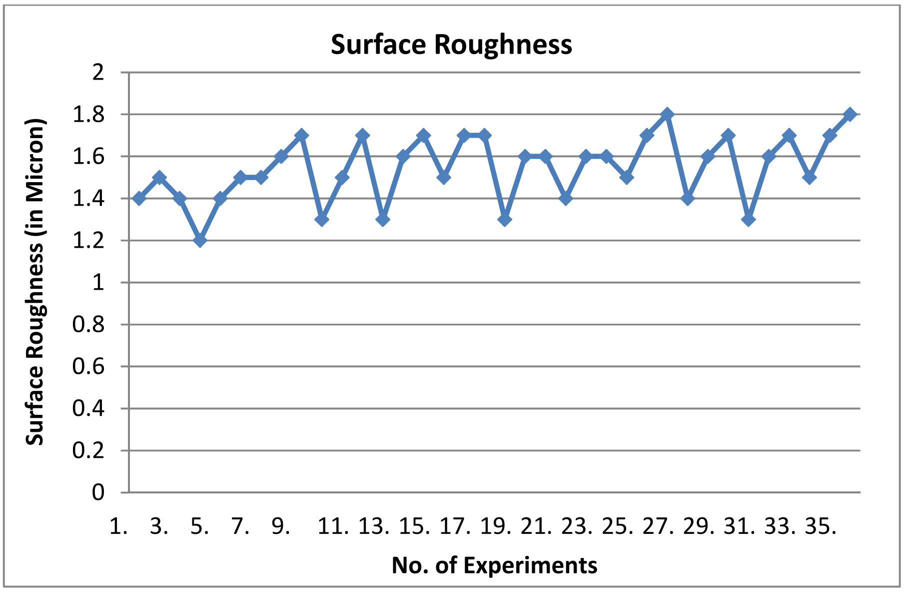


Figure 4. Graph for surface roughness versus number of experiments

From figure 5, it is observed that in surface roughness the feed is most dominant factor than spindle speed and depth of cut. Also from figure 6 in material removal rate the depth of cut is most dominant factor than spindle speed and feed.

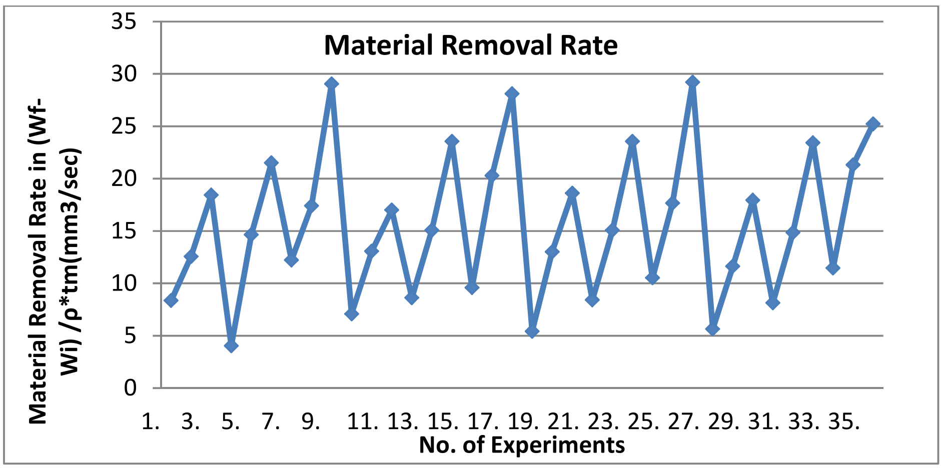


Figure 5. Graph for material removal rate versus number of experiments

V. CONCLUSION

In this presented work the machining parameters and machining operations of CNC milling are studied. From experimentation it is observed that minimum surface roughness is found to be 1.2 microns at 600 RPM (spindle speed), 250 m/min (feed), 0.2 mm (depth of cut). Also maximum material removal rate is found to be 29.214 mm3/sec., at 800 RPM (spindle speed), 300 m/min (feed), 0.6 mm (depth of cut). It is also found that the minimum time 13.03 second required for maximum material removal rate. After conduction of trials it is observed that when surface roughness increases at the same material removal rate also increases. It means that both surface roughness and material removal rate is inversely proportional to each other.

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