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Experimental Study of Parameters of P-20 Steel on CNC milling machine using Taguchi's Orthogonal Array

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ABSTRACT:

Milling is the most common form of machining process used in the production of moulds/dies, due to the high tolerances and surface finishes by cutting away the unwanted material. The selection of Pre-hardened steel (P-20) is widely used in production of moulds/dies because of less wear resistance and are used for large components. Due to extensive use of highly automated machine tools in the industry, manufacturing requires reliable models and methods for the prediction of output performance of machining processes.

The major objective of the present study is experimental analysis of machining parameters in end milling for surface roughness by considering the input parameters such as cutting speed, feed rate, axial-depth of cut, radial depth of cut and nose radius using taguchi's orthogonal array.

Keywords: Milling process parameters, taguchi's orthogonal array

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INTRODUCTION:

Several factors will influence the final surface roughness in a CNC milling operation. The final surface roughness might be considered as the sum of two independent effects.

1. The ideal surface roughness is a result of the geometry of the tool & feed and
2. The natural surface roughness is a result of the irregularities in the cutting operation.

Factors such as spindle speed, feed rate, axial depth of cut & radial depth of cut, Nose radius that control the cutting operation can be set up in advance. However factors such as tool geometry, tool wear, chip loads and chip formations or the material properties of both tool and work piece are uncontrolled. Even in the occurrence of chatter or vibrations of the machine tool, defects in the structure of the work material, wear of tool or irregularities of the chip formation contribute to the surface damage in practice during machining. In order to obtain better surface roughness, the proper setting of cutting parameters is crucial before the process takes place. As a starting point for determining cutting parameters, technologists could use the hands on data tables that are furnished in data hand books. Lin suggested that are trial and error approach could be followed in order to obtain the optimal machining conditions for a particular operation. To achieve the desired surface finish one should develop techniques to model, prediction and optimizing the surface finish of a product before milling in order to evaluate the fitness of machining parameters such as Nose radius, spindle speed, feed rate, axial depth of cut and radial depth of cut for keeping the desired surface finish and increasing product quality.

A solemn attempt is made in this project work to study the effect of surface roughness in a machining of P20 mould steel on CNC end milling machine with coated carbide cutting tool.

LITERATURE SURVEY

A milling machine is a machine tool that removes metal as the work is fed against a rotating multi-point cutter. The cutter rotates at a high speed and because of the multiple cutting edges it removes metal at a very fast rate. The machine can hold one or more number of cutters at a time. This is why a milling machine finds wide application in production work. This is superior to other machines as regards accuracy and better surface finish, and is designed for machining a variety of tool room work.

The first milling machine came into existence in about 1770 and was of French origin. The milling cutter was first developed by Jacques de Vaucanson in the year 1782. The first successful plain milling machine was designed by, Eli Whitney in the year 1818. Joseph R Brown a member of brown and

Sharpe Company invented the first universal milling machine in the year 1861.

Machining Parameters

The machining process depends upon several parameters such as the work piece material, the cutting tool material, the rigidity of the machine, the rigidity of the work piece, cutting speed, feed, axial depth of cut, radial depth of cut, chatter, tool wear etc.Some of them that we have considered in this project work are described below:

Cutting Speed

The speed of milling cutter is its peripheral linear speed resulting from rotation. It is normally expressed in terms of surface speed in "m/min". The cutting speed can be derived as

$$N= (1000*V) / (\pi *d) \quad \text{-------------- (1)}$$

Where N = Cutter Speed in rpm,

V = Cutting speed in m/min,

d = Diameter of the tool holder or cutter in mm

Feed

The feed rate in milling machine is defined as the rate with which the work piece advances under the cutter. The Units are expressed in "mm/min" or "mm/rev" or "mm/tooth". The feed is expressed in a milling machine by the following three different methods.

Feed per tooth (s_z)

The feed per tooth is defined by the distance the work advances in the time between engagements by the two successive teeth. It is expressed in mm/tooth.

Feed per cutter revolution (s_{rev})

The feed per cutter revolution is the distance the work advances in the time when the cutter turns through one complete revolution. It is expressed in mm/revolution of the cutter.

Feed per minute (s_m)

The feed per minute is defined by the distance the work advances in one minute. It is expressed in mm/min.

The feed per tooth, the feed per cutter revolution, and the feed per minute are related by the formula which is given below.

$$s_m = N^* s_{rev} = z^*N^*s_z \quad \text{------------------ (2)}$$

Where z = number of teeth in the cutter,

N = the cutter speed in rpm.

Abbas Fadhel Ibraheem et.al.[5] investigated the effect of cutting speed, feed, axial and radial depth of cut on cutting force in machining of modified AISI P20 tool steel in end milling process. They concluded that, higher the feed rates, larger the cutting forces. They also developed the genetic network model to predict the cutting forces.

Muammer Nalbant et.al.[6] used the multiple regression analysis and artificial neural network models for predicting the surface roughness in turning of AISI 1030 steel material. These techniques used full factorial design and analysis of variance (ANOVA). According to them, Surface roughness increases with increase of feed rate but decreases with increase of insert nose radius.

R.A. Ekanayake and P. Mathew[7], investigated the effect of cutting speed, feed and depth of cut on cutting forces with different inserts while milling AISI1020 steel. According to them, the tool offsets and run-outs affect significantly on the cutting forces when it comes to high speed milling, where small cut sections are employed. This can cause uneven wear of the tool tips due to uneven chip loads.

Lajis et al.[8] developed the response surface model to predict the tool life in end milling of hardened steel AISI D2. This technique used central composite design in the design of experiments and ANOVA. The objective was to obtain the contribution percentages o f the cutting parameters (cutting speed, feed and depth of cut) on the tool life.

Richard Dewes et al.[9] carried out the study on rapid machining of hardened AISI H13 and D2 moulds, dies and press tools. The primary objective was to assess the drilling and tapping of AISI D2 and H13 with carbide cutting tools, in terms of tool life, work piece quality, productivity and costs. The secondary aim was to assess the performance of a number of water-based dielectric fluids, intended primarily for EDM operations, against a standard soluble oil cutting fluid, in order to assess the feasibility of a duplex machining arrangement involving HSM and EDM on one machine tool.

Mohammad Reza Soleymani Yazdi and Saeed Zare Chavoshi[10], studied the effect of cutting parameters and cutting forces on rough and finish surface operation and material removal rate (MRR) of AL6061 in CNC face milling operation. The objective was to develop the multiple regression analysis and artificial neural network models for predicting the surface roughness and material removal rate. According to them, in rough operation, the feed rate and depth of cut are the most significant effect parameters on R_a and MRR and increases with the increase of the cutting forces.

Abou-El-Hossein et al.[11] predicted the cutting forces in an end milling operation of modified AISI P20 tool steel using the response surface methodology (RSM) and Minitab software.

Khalid Hafiz et al.[12] developed the response surface model to predict the tool life in end milling of hardened steel AISI H13 hardened tool steel. This technique used central composite design in the design of experiments and ANOVA. The objective was to obtain the contribution percentages o f the cutting parameters (cutting speed, feed and depth of cut) on the tool life.

Rahman et al.[13] (2001, 2002) compared the machinability of the P20 mould steel (357 HB) in dry and wet milling conditions. They considered a range of 75–125 m/min for the cutting speed and a feed ranging between 0.3 and 0.7 mm/tooth: they found the cutting forces in both processes to be similar, but with the flank wear acceleration higher in dry milling. Furthermore, they observed a better surface finish with wet milling.

Data collection:

The machining parameters used and their levels chosen are given in Table 4.3.

Table: Machining Parameters and Their Levels

Control parameters	Units	symbol	Levels				
			Level 1	Level 2	Level 3	Level 4	Level 5
Nose radius	mm	R	0.8	1.2	-	-	-
Cutting speed	m/min	V	75	80	85	90	95
Feed	mm/tooth	f	0.1	0.125	0.15	0.175	0.2
Axial depth of cut	mm	d	0.5	0.75	1	1.25	1.5
Radial depth of cut	mm	rd	0.3	0.4	0.5	0.6	0.7

Taguchi's orthogonal array of L_{50} (2^1*5^{11}) is most suitable for this experiment. Because, nose radius with two levels and cutting speed, cutting feed, axial depth of cut and radial depth of cut with five levels each and then 2×5×5×5×5=1250 runs were required in the experiments for five independent variables. But using Taguchi's orthogonal array the number of experiments reduced to 50 experiments from 1250 experiments. This needs 50 runs (experiments) and has 49 degrees of freedom's (DOFs). The L_{50} orthogonal array is presented in below table.

L50(2^1*5^11)					
S. NO	**Nose Radius**	**Cutting Speed**	**Cutting Feed**	**Axial depth of cut**	**Radial depth of cut**
1	1	1	1	1	1
2	1	1	2	2	2
3	1	1	3	3	3
4	1	1	4	4	4
5	1	1	5	5	5
6	1	2	1	2	3
7	1	2	2	3	4
8	1	2	3	4	5
9	1	2	4	5	1
10	1	2	5	1	2
11	1	3	1	3	5
12	1	3	2	4	1
13	1	3	3	5	2

14	1	3	4	1	3
15	1	3	5	2	4
16	1	4	1	4	2
17	1	4	2	5	3
18	1	4	3	1	4
19	1	4	4	2	5
20	1	4	5	3	1
21	1	5	1	5	4
22	1	5	2	1	5
23	1	5	3	2	1
24	1	5	4	3	2
25	1	5	5	4	3
26	2	1	1	1	4
27	2	1	2	2	5
28	2	1	3	3	1
29	2	1	4	4	2
30	2	1	5	5	3
31	2	2	1	2	1
32	2	2	2	3	2
33	2	2	3	4	3
34	2	2	4	5	4
35	2	2	5	1	5
36	2	3	1	3	3
37	2	3	2	4	4
38	2	3	3	5	5
39	2	3	4	1	1
40	2	3	5	2	2
41	2	4	1	4	5
42	2	4	2	5	1
43	2	4	3	1	2
44	2	4	4	2	3
45	2	4	5	3	4
46	2	5	1	5	2
47	2	5	2	1	3
48	2	5	3	2	4
49	2	5	4	3	5
50	2	5	5	4	1

Table: L50 (2^1*$5^{11)}$ orthogonal array.

In the above Table, 1, 2, 3, 4and 5 in columns represents the levels of factors corresponding to the particular variable presented in the column. For the above coded values of machining parameters, actual setting values are presented in below table.

S.No	Nose Radius (mm)	Cutting Speed (mm/min)	Feed (mm/tooth)	Axial depth of cut (mm)	Radial depth of cut (mm)
1	0.8	75	0.1	0.5	0.3
2	0.8	75	0.125	0.75	0.4
3	0.8	75	0.15	1	0.5
4	0.8	75	0.175	1.25	0.6
5	0.8	75	0.2	1.5	0.7
6	0.8	80	0.1	0.75	0.5
7	0.8	80	0.125	1	0.6
8	0.8	80	0.15	1.25	0.7
9	0.8	80	0.175	1.5	0.3
10	0.8	80	0.2	0.5	0.4
11	0.8	85	0.1	1	0.7
12	0.8	85	0.125	1.25	0.3
13	0.8	85	0.15	1.5	0.4
14	0.8	85	0.175	0.5	0.5
15	0.8	85	0.2	0.75	0.6
16	0.8	90	0.1	1.25	0.4
17	0.8	90	0.125	1.5	0.5
18	0.8	90	0.15	0.5	0.6
19	0.8	90	0.175	0.75	0.7
20	0.8	90	0.2	1	0.3
21	0.8	95	0.1	1.5	0.6
22	0.8	95	0.125	0.5	0.7
23	0.8	95	0.15	0.75	0.3
24	0.8	95	0.175	1	0.4
25	0.8	95	0.2	1.25	0.5
26	1.2	75	0.1	0.5	0.6
27	1.2	75	0.125	0.75	0.7
28	1.2	75	0.15	1	0.3
29	1.2	75	0.175	1.25	0.4
30	1.2	75	0.2	1.5	0.5
31	1.2	80	0.1	0.75	0.3
32	1.2	80	0.125	1	0.4
33	1.2	80	0.15	1.25	0.5
34	1.2	80	0.175	1.5	0.6
35	1.2	80	0.2	0.5	0.7
36	1.2	85	0.1	1	0.5
37	1.2	85	0.125	1.25	0.6
38	1.2	85	0.15	1.5	0.7
39	1.2	85	0.175	0.5	0.3
40	1.2	85	0.2	0.75	0.4
41	1.2	90	0.1	1.25	0.7
42	1.2	90	0.125	1.5	0.3
43	1.2	90	0.15	0.5	0.4
44	1.2	90	0.175	0.75	0.5
45	1.2	90	0.2	1	0.6
46	1.2	95	0.1	1.5	0.4
47	1.2	95	0.125	0.5	0.5
48	1.2	95	0.15	0.75	0.6
49	1.2	95	0.175	1	0.7
50	1.2	95	0.2	1.25	0.3

Table: Actual Setting Values for the Coded Values

The surface roughness was measured by using Surtronic 3^+ stylus type instrument manufactured by Taylor Hobson is shown in Fig.4.5. The specification of the Surtronic 3+ machine is presented in Table -4.6

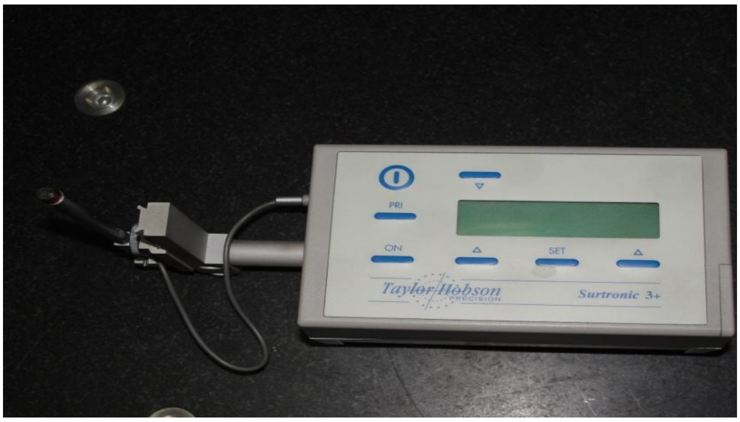

Fig. Taylor Hobson Surtronic 3+ machine

Results:

The experimental results are presented in below Table.

S.NO	R_a (µm)	MRR (cm^3/min)	S.NO	R_a (µm)	MRR (cm^3/min)
1	0.94	23.39	26	0.98	46
2	1.16	58.73	27	1.2	97.4
3	1.12	116.6	28	1.68	69.06
4	0.86	197.8	29	1.06	136.3
5	0.66	298.8	30	0.52	230.8
6	0.82	63.13	31	1.14	37.07
7	1.44	121.7	32	2.48	83.54
8	0.7	206.6	33	1.74	154.9
9	0.92	127.7	34	1.48	253.4
10	1.28	66.4	35	1.72	109.2
11	1.08	117.9	36	0.52	88.5
12	1.3	81.54	37	0.92	161.3
13	1.48	158.4	38	0.76	257.7
14	1.44	76.1	39	0.64	45.33
15	1.54	152.1	40	0.96	105.3
16	0.56	94.13	41	0.8	156.3
17	0.46	174	42	0.5	103.8
18	0.42	81.3	43	1.54	56.18
19	0.58	161.3	44	1.27	120.6
20	0.5	109.1	45	1.32	214.1
21	0.46	173.4	46	0.87	119.3
22	1.1	81.97	47	1.1	61.35
23	0.86	65.33	48	0.78	128.6
24	0.48	137.6	49	1.14	227.3
25	0.74	241.4	50	0.87	143.7

Table: Experimental results for R_a and MRR.

CONCLUSION:

The machining parameters which are influencing the surface roughness in the end milling of P20 mould steel has been analysed using the experimental results. Based on experimental results relatively small number of experimental runs could be possible using Taguchi's orthogonal array and hence reduces the cost of experimentation. For achieving good surface finish of P20 mould steel low feed rates higher cutting speeds and smaller depth of cuts are preferred.

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