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Effect of Lubrication Condition on Surface Roughness in End Milling Operation by using AISI P20

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Abstract This paper presents an investigation into Full Quantity Lubrication Condition (FQLC) and Minimum Quantity Lubrication Condition (MQLC) in End milling process. AISI P20 steel material and carbide cutting tool are used to conduct the experiment and determine the effect of conditions on the material. The three input End milling process parameters are selected as spindle speed, depth of cut and feed rate with an output response as surface roughness. The levels of each parameters are selected as follows: spindle speed: 1200, 2000, 2500, 3000rpm, Depth of cut: 0.2, 0.4, and 0.6, 0.8 mm, feed rate: 1000. 1500, 2000, 2500 mm/min. The surface roughness values evaluated with the help of Mitutoyo surface tester. The taguchi design method used to design the experimental setup and result evaluated with the help of ANOVA and Grey Relational Analysis method. The Cutting fluid use is a type of coolant and lubricant designed specifically for metal working processes, such as machining. It has great impact on the surface roughness in the process of high machining. It is responsible for mainly to reduce heat which is generated during machining process and also to obtain high surface finish. During machining process, chip formation takes place and if the chip remains in the machining path it will increase the surface roughness because of the friction between the chips, tool and material and also damage the tool tip. To avoid such kind of problem in high machining process, cutting fluid with maximum pressure is used. From above it was found that the greater surface finish was obtained in FQLC condition than MQLC which result into reduction in surface roughness of AISI P20 steel material.

Index Terms— Milling machine, Lubrication condition, Surface roughness, Taguchi method, ANOVA and Regression Analysis..

1 Introduction

Milling is the process of removing metal in the form of chips against the action of end mill cutter. The cutter rotates clockwise or anti clockwise according to the motion respected material removal takes place due to which the high friction is take place between machine tool cutter tip and material i.e. P20 steel. The high heat is also generated due to friction which requires the cooling lubrication while machining.

Surface roughness is commonly encountered while machining process, the surface roughness may be defined as it is a small irregularities which generally causes the high roughness on metal surface while machining process, this is done due the improper combination of machining parameters on the respected material is used.

The quality of surface roughness plays a very important role on the material performance. It also affects the material life and decreases the efficiency of material under different condition consideration and it also increases the fatigue strength, corrosion resistance and creep life.

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2 Literature Review

H.S Harne et al (January 2015), applied orthogonal array, Signal to Noise ratio and Analysis of variance to analyze effect of experiments. The input parameters are cutting speed, feed rate and depth of cut selected with output as a surface roughness response. In that mathematical model generated by regression analysis. The result concluded that, the cutting speed and feed rate has great influences on the surface roughness. Hence feed rate is the dominant factor of the surface roughness and depth of cut has less effects on surface roughness. Hence lower the roughness value leads to higher cutting speed and low feed rate. The optimum parameters observed at optimum level are 3200rpm spindle speed, 250mm/min feed rate and 0.04mm depth of cut.[7] **Bala Raju. J et al** (MARCH, 2015), Applied taguchi technique for identify optimum surface roughness in CNC end milling process on Aluminium and mild steel material. The setup of end milling parameters done by taguchi design of experiment and Signal to Noise ratio, Analysis of variance(ANOVA) are employed to find optimum level of different parameters of end milling process. The end milling input process parameters are cutting speed, Feed rate and depth of cut selected with output surface roughness as response. The result shows taguchi parameters design successfully verified the optimum cutting parameters of Aluminium as 1400rpm of spindle speed, 50mm/min of feed rate and 0.75mm of depth of cut gives Ra= 0.29 microns of surface finish And for Mild steel the optimum levels of process parameters are 1400rpm of spindle speed, 50mm/min of feed rate and 0.75 mm depth of cut gives Ra= 1.19 microns of surface finish in Vertical CNC milling machine. [8] **R.N Nimase et al** (JUNE 2015),Used taguchi design of experiment and L8 orthogonal array method for optimizing the cutting parameters Signal to Noise ratio and analysis of variance used to obtain influencing parameters to the surface roughness. The input parameters are spindle speed, feed rate and depth of cut and surface roughness as output response are selected. Result concluded that from Signal to Noise ratio graph, the optimal setting of machining parameters for low surface roughness achieved at 2500rpm of spindle speed, 240mm/min of feed rate and 2.0mm depth of cut. It is observed that the feed rate has more affected on the surface roughness about 46.36%, secondly was spindle speed of about 34.78% and depth of cut has less affected to the surface roughness. [9] **Amal T .S et al** (August 2015), Used taguchi method for analysing the effect of surface roughness with L9 orthogonal array. And they had selected four input factors like speed of cut, depth of cut and feed rate and three levels .For analysis they had used MINITAB software. After all the experiment and analysis it was found that feed rate is the most influencing parameter to surface roughness and cutting force followed by other parameters. The smaller nose radius produces less cutting forces. [10] **Mohamad Syahmil Shahrom et al** (2013), the author determined the effect of lubrication condition in surface finishing process and three other factors cutting speed, feed rate, depth of cut influencing the surface roughness value the experiment conducted by using taguchi design approach from analyzed result value predicted that by minimum quantity of lubrication produces the better surface finish comparing to the full lubrication process and result shows significantly reduced cost and environmental pollution also[11].

2.1 Methodology

FQLC and MQLC have been used in this experiment. Based on observation, the **FQLC** uses the more lubrication with pressure in the process while the **MQLC** uses the small amount of lubrication while machining by just closing the half portion of valve.

FQLC:

In this process condition the fully opened valve is used to provide high pressure with more quantity of lubricants in the machining process area, where the friction between tool and work piece generated. Due to the high pressure of fluid on the machining area which causes to take away metal chips, formed from the machining process. Which provides better surface finish as compare to the MQLC process?

MQLC:

In this condition of machining process the half or little more closed valve is operated to provide the minimum quantity of lubricants into the machining area while working. It causes the less removal of metal chips from the machining zone while working and it again machined between working surface and the end mill cutter tool which provides more roughness to the metal surface than FQLC.

The taguchi design method is employed to design experimental setup. The L16 Orthogonal array is used to design the experiments and the levels are also decided according to the past literature reviews. For analyzing the parameters the ANOVA (Analysis of variance) is used to find the optimum affecting input process parameter. The final result is compared with the help of Grey Relational analysis, from which the Regression equation found. The practical experiment result is compared with the predicted value of surface roughness in both cases.

The final result is concluded with help of S/N ratio and regression analysis, which stated that, in both FQLC and MQLC cases the spindle speed is the most affecting input process parameter found. But the FQLC case provides more surface finish as compare to the MQLC condition.

The selected levels of process parameters are as follows

Factors	Parameters	Levels			
		L1	L2	L3	L4
A	Spindle speed	1200	2000	2500	3000
B	Depth of cut	0.2	0.4	0.6	0.8
C	Feed rate	1000	1500	2000	2500

After the selecting process parameters levels, the orthogonal L16 is set up properly for the experiment. The experiment is run in MINITAB 17 and analyzed.

L16 orthogonal experiment levels for FQLC and MQLC.

Expt. No	Spindle speed (rpm)	Depth of cut (mm)	Feed rate (mm/min)
1.	1200	0.2	1000
2.	1200	0.4	1500
3.	1200	0.6	2000
4.	1200	0.8	2500
5.	2000	0.2	1500
6.	2000	0.4	1000
7.	2000	0.6	2500
8.	2000	0.8	2000
9.	2500	0.2	2000
10.	2500	0.4	2500
11.	2500	0.6	1000
12.	2500	0.8	1500
13.	3000	0.2	2500
14.	3000	0.4	2000
15.	3000	0.6	1500
16.	3000	0.8	1000

After the experimental design the experiment is performed on the CNC End milling machine and the mean values of surface roughness is tested with the help of surface roughness tester, after that the full experiment is analysed in **MINITAB17** software and result concluded with the help of **ANOVA** and Regression analysis.

In addition to the S/N ratio (smaller is better), the ANOVA method also employed to provide result with 95% confidence level. In this way, the optimal levels of process parameters can be estimated.

In multiple regression analysis, a R-sq, is the correlation coefficient and should fall between 0.8 to 0.1.

3 RESULT AND DISCUSSION

The result is expressed in below table both for FQLC and MQLC. The experiment readings for both cases analysed in MINITAB17 for mean surface roughness and S/N ratio analysis

Sr	FQLC	S/N ratio	MQLC	S/N ratio

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No.	R_a value		R_a value	
1	5. 82300	-14.5117	6.28667	-15.9684
2	4.28967	-12.6533	5.82966667	-15.3129
3	3.87467	-11.7788	4.21966667	-12.5056
4	3.31367	-10.4547	3.49	-10.8565
5	3.08433	-9.8417	2.79333333	-8.9225
6	2.71900	-8.7207	2.62666667	-8.3881
7	2.91000	-9.3882	2.49333333	-7.9356
8	2.89333	-9.3489	2.27033333	-7.1218
9	2.50567	-8.0458	1.88	-5.4832
10	2.20333	-6.8749	2.25533333	-7.0642
11	2.09233	-6.4165	3.30133333	-10.3738
12	2.15667	-6.6832	2.80133333	-8.9473
13	1.91900	-5.7139	1.75633333	-4.8921
14	2.23667	-7.0799	1.887	-5.5154
15	0.93833	0.5136	1.87633333	-5.4662
16	0.86067	1.2983	1.67066667	-4.4578

3.1 Analysis of Variance (ANOA)

In this study the ANOVA analysis, it analyse the most influencing input process parameter on the output response as a surface roughness with 95% confidence level from MINITAB software. It shows that the spindle speed in both the cases FQLC and MQLC affected greatly to the surface roughness.

3.2 Analysis of Variance for FQLC (S/N ratio):

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Spindle speed	3	197.267	197.267	65.756	15.52	0.003
Depth of cut	3	29.524	29.524	9.841	2.32	0.175
Feed rate	3	9.761	9.761	3.254	0.77	0.552
Residual Error	6	25.423	25.423	4.237		
Total	15	261.975				

DF - degrees of freedom, SS - sum of squares, MS - mean squares(Variance), F-ratio of variance of a source to variance of error, P < 0.05 - determines significance of a factor at 95% confidence level

The table shows the spindle speed is the most affecting parameter to the surface roughness.

3.3. Analysis of Variance for MQLC (S/N ratio):

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Spindle speed	3	154.401	154.401	51.467	24.80	0.001
Depth of cut	3	4.069	4.069	1.356	0.65	0.609
Feed rate	3	16.977	16.977	5.659	2.73	0.137
Residual Error	6	12.450	12.450	2.075		
Total	15	187.896				

DF - degrees of freedom, SS - sum of squares, MS - mean squares(Variance), F-ratio of variance of a source to variance of error, P < 0.05 - determines significance of a factor at 95% confidence level

The table shows the spindle speed is the most affecting parameter to the surface roughness.

4 Optimal Level R_A Value

The Analysis of variance provided the optimal level for each level, The **MINITAB** software is used to analyze the parameters. The below table shows the rank of each level by analyzing each process level in **ANOVA** method to show which factor is affecting most to the surface roughness.

4.1. Response Table for FQLC: (S/N ratio smaller is better)

Level	Spindle speed	Depth of cut	Feed rate
1	-12.333	-9.484	-7.077
2	-9.244	-8.798	-7.139
3	-6.982	-6.726	-8.991
4	-2.699	-6.252	-8.052
Delta	9.366	3.232	1.913
Rank	1	2	3

Response table for FQLC shows that also spindle speed has 1st rank and followed by depth of cut and feed rate respectively.

4.2. Response Table for MQLC: (S/N ratio smaller is better)

Level	Spindle speed	Depth of cut	Feed rate
1	-13.661	-8.817	-9.797
2	-8.092	-9.070	-9.662
3	-7.967	-9.070	-7.656
4	-5.083	-7.846	-7.68
Delta	8.578	1.224	2.141
Rank	1	3	2

Response table for FQLC shows that also spindle speed has 1st rank and followed by feed rate and depth of cut respectively.

5 Experimetal Result and Analysis

5.1. FQLC: Optimization of Parameters by GRA (Grey Relational Analysis) (Full Quantity Lubrication)

Steps in GRA:

Normalization > Deviation sequence > Grey relational coefficient > Grey relational grade.,Data Pre-Processing:

In GRA, data pre-processing is needed since the range and unit in one data sequence may differ from the others. Data Pre-processing is required when the sequence scatter range is too large, or when the directions of the target in the sequences are different. It is a process of transferring the original sequence to a comparable sequence. For this reason, the experimental results are normalized in the range between zero and one. Depending on the characteristics of data sequence, various methods of data pre-processing are available for the GRA. The procedure is given below.

$$Xi^*(ki) = \max xi(k) - xi(k) / \max xi(k) - \min xi(k)$$

Where, xi*(ki) & xi (k) are the sequence after the data preprocessing and comparability sequence respectively, k=1 for surface roughness; i=1, 2, 3…, 16 for experiment numbers 1 to 16.

5.2 Signal-to-Noise Ratio & Normalized S/N Ratio for FQLC:

Experiment No.	Surface Roughness	S/N Ratio	Normalized S/N Ratio
1.	5.316	-14.5117	1
2.	4.28966667	-12.6485	0.8821
3.	3.87466667	-11.7647	0.8263
4.	3.31366667	-10.4062	0.7404
5.	3.08433333	-9.7832	0.7010
6.	2.72566667	-8.7095	0.6331
7.	2.91	-9.2779	0.6690
8.	2.89333333	-9.2280	0.6659
9.	2.39233333	-7.5764	0.5614
10.	2.20333333	-6.8616	0.5163
11.	2.09233333	-6.4126	0.4878
12.	2.15666667	-6.6757	0.5045
13.	1.919	-5.6615	0.4404
14.	2.23666667	-6.9920	0.5245
15.	0.93833333	0.5529	0.0474
16.	0.86066667	1.3033	0

Now, Δoi (k) is the deviation sequence of the reference sequence x0* (k) and the comparability sequence xi*(k), i.e.

$$\Delta 0i\ (k) = |(k) - xi(k)|$$

5.3 Computing the Grey Relational Coefficient and the Grey Relational Grade:

After data pre-processing is done, a grey relational coefficient can be calculated with the preprocessed sequence. It defines the relation between the ideal and actual normalized experimental results. The grey relational coefficient is defined as follows:

$$\xi i(k) = \Delta min + \xi \Delta max / \Delta oi(k) + \xi \Delta max$$

5.4 Grey Relational Coefficient and the Grey Relational Grade:

Experiment No.	Normalized S/N Ratio	Deviation Sequence	Grey Relational Coefficient
1.	1	0	1
2.	0.8821	0.1179	0.8092
3.	0.8263	0.1737	0.7422
4.	0.7404	0.2596	0.6582
5.	0.7010	0.2990	0.6257
6.	0.6331	0.3669	0.5768
7.	0.6690	0.3310	0.6017
8.	0.6659	0.3341	0.5994
9.	0.5614	0.4386	0.5327
10.	0.5163	0.4837	0.5083
11.	0.4878	0.5122	0.4939
12.	0.5045	0.4955	0.5023
13.	0.4404	0.5596	0.4719
14.	0.5245	0.4755	0.5126
15.	0.0474	0.9526	0.3442
16.	0	1	0.3333

5.5 The calculated grey relational grade and its order in the optimization process:

Experiment No.	Cutting speed (rpm)	Depth of cut (mm)	Feed Rate (mm/min)	Ra (µm)	Grade
1.	1200	0.2	1000	1	1
2.	1200	0.4	1500	0.8091	0.8091
3.	1200	0.6	2000	0.7422	0.7422
4.	1200	0.8	2500	0.6582	0.6582
5.	2000	0.2	1500	0.6257	0.6257
6.	2000	0.4	1000	0.5768	0.5768
7.	2000	0.6	2500	0.6017	0.6017
8.	2000	0.8	2000	0.5994	0.5994
9.	2500	0.2	2000	0.5327	0.5327
10.	2500	0.4	2500	0.5083	0.5083
11.	2500	0.6	1000	0.4939	0.4939
12.	2500	0.8	1500	0.5023	0.5023
13.	3000	0.2	2500	0.4719	0.4719
14.	3000	0.4	2000	0.5126	0.5126
15.	3000	0.6	1500	0.3442	0.3442
16.	3000	0.8	1000	0.3333	0.3333

After acquiring the grey relational coefficient, the grey relational grade (GRA) is computed by averaging the grey relational coefficient similar to each performance characteristic. The overall evaluation of the performance characteristics is based on the grey relational grade, that is
Where i the grey relational grade for the ith experiment and n is the number of performance characteristics. Above table shows the grey relational grade for each experiment using L16 OA. The larger grey relational grade represents that the corresponding experimental result is closer to the ideally normalized value.

5.6 Response table for the grey relational grade:

S	M P	Grey relational grade				Main effect (max-min)	Rank
		L 1	L 2	L 3	L 4		
A	C S	0.80*	0.60	0.50	0.41	0.39	1
B	D C	0.65*	0.60	0.54	0.52	0.13	2
C	F R	0.60*	0.57	0.59	0.56	0.04	3

Where S- Symble, M P- Machine Parameter

. The higher the grey relational grade, the better is the performance characteristics. However, the relative importance among the machining parameters for the performance characteristics still needs to be known, so that the optimal combinations of the machining parameter levels can be determine more accurately. Table 4.1 the optimal parameter combination was determined as A1 (Cutting speed) - B1 (Depth of cut) - C1 (Feed rate).

5.7 MQLC: Optimization of Parameters by GRA (Grey Relational Analysis) (Minimum Quantity Lubrication):

steps in GRA:Normalization > Deviation sequence > Grey relational coefficient > Grey relational grade.

Data Pre-Processing

In GRA, data pre-processing is needed since the range and unit in one data sequence may differ from the others. Data Pre-processing is required when the sequence scatter range is too large, or when the directions of the target in the sequences are different. It is a process of transferring the original sequence to a comparable sequence. For this reason, the experimental results are normalized in the range between zero and one. Depending on the characteristics of data sequence, various methods of data pre-processing are available for the GRA. The procedure is given below

$$xi^*(ki) = \max xi(k) - xi(k) / \max xi(k) - \min xi(k)$$

Where, xi*(ki) & xi (k) are the sequence after the data pre-processing and comparability sequence respectively, k=1 for surface roughness; i=1, 2, 3…, 16 for experiment numbers 1 to 16.

5.8 Signal-to-Noise Ratio & Normalized S/N Ratio for MQLC:

Experiment No.	Surface Roughness	S/N Ratio	Normalized S/N Ratio
1.	6.28667	-15.9684	1
2.	5.82966667	-15.3129	0.94
3.	4.21966667	-12.5056	0.699
4.	3.49	-10.8565	0.5558
5.	2.79333333	-8.9225	0.3878
6.	2.62666667	-8.3881	0.3414
7.	2.49333333	-7.9356	0.3021
8.	2.27033333	-7.1218	0.2314
9.	1.88	-5.4832	0.0890
10.	2.25533333	-7.0642	0.2264
11.	3.30133333	-10.3738	0.5139
12.	2.80133333	-8.9473	0.3900
13.	1.75633333	-4.8921	0.0377
14.	1.887	-5.5154	0.0918
15.	1.87633333	-5.4662	0.0876
16.	1.67066667	-4.4578	0

Now, Δoi (k) is the deviation sequence of the reference sequence x0* (k) and the comparability sequence xi*(k), i.e.

$$\Delta 0i\ (k) = |(k) - xi(k)|$$

5.9 Computing the Grey Relational Coefficient and the Grey Relational Grade:

After data pre-processing is done, a grey relational coefficient can be calculated with the preprocessed sequence. It defines the relation between the ideal and actual normalized experimental results. The grey relational coefficient is defined as follows:

$$\xi i(k) = \Delta min + \xi \Delta max / \Delta oi(k) + \xi \Delta max$$

5.10 Grey Relational Coefficient and the Grey Relational Grade:

Experiment No.	Normalized S/N Ratio	Deviation Sequence	Grey Relational Coefficient
1.	1	0	1
2.	0.94	0.06	0.892857
3.	0.699	0.301	0.624219
4.	0.5558	0.4442	0.529548
5.	0.3878	0.6122	0.449559
6.	0.3414	0.6586	0.431555
7.	0.3021	0.6979	0.417397
8.	0.2314	0.7686	0.394135
9.	0.0890	0.9110	0.354358
10.	0.2264	0.7736	0.392587
11.	0.5139	0.4861	0.507047
12.	0.3900	0.6100	0.450450
13.	0.0377	0.9623	0.341927
14.	0.0918	0.9082	0.355063
15.	0.0876	0.9124	0.354007
16.	0	1	0.333333

5.11 The calculated grey relational grade and its order in the optimization process

Experiment No.	Cutting speed (rpm)	Depth of cut (mm)	Feed Rate (mm/min)	Ra (μm)	Grade
1.	1200	0.2	1000	1	1
2.	1200	0.4	1500	0.892857	0.892857
3.	1200	0.6	2000	0.624219	0.624219
4.	1200	0.8	2500	0.529548	0.529548
5.	2000	0.2	1500	0.449559	0.449559
6.	2000	0.4	1000	0.431555	0.431555
7.	2000	0.6	2500	0.417397	0.417397
8.	2000	0.8	2000	0.394135	0.394135
9.	2500	0.2	2000	0.354358	0.354358
10.	2500	0.4	2500	0.392587	0.392587
11.	2500	0.6	1000	0.507047	0.507047
12.	2500	0.8	1500	0.450450	0.450450
13.	3000	0.2	2500	0.341927	0.341927
14.	3000	0.4	2000	0.355063	0.355063
15.	3000	0.6	1500	0.354007	0.354007
16.	3000	0.8	1000	0.333333	0.333333

After acquiring the grey relational coefficient, the grey relational grade (GRA) is computed by averaging the grey relational coefficient similar to each performance characteristic. The overall evaluation of the performance characteristics is based on the grey relational grade, that is

Where i the grey relational grade for the ith experiment and n is the number of performance characteristics. Above table shows the grey relational grade for each experiment using L16 OA. The larger grey relational grade represents that the corresponding experimental result is closer to the ideally normalized value.

5.12 Response table for the grey relational grade

S	M P	Grey relational grade				Main effect (max-min)	Rank
		L 1	L 2	L 3	L 4		
A	C S	0.76*	0.42	0.42	0.34	0.4155	1
B	D C	0.53*	0.51	0.47	0.42	0..1121	3
C	F R	0.57*	0.53	0.43	0.42	0.1521	2

The higher the grey relational grade, the better is the performance characteristics. However, the relative importance among the machining parameters for the performance characteristics still needs to be known, so that the optimal combinations of the machining parameter levels can be determine more accurately. Table 4.1 the optimal parameter combination was determined as A1 (Cutting speed) - B1 (Depth of cut) - C1 (Feed rate).

6. CALCULATION FOR RA VALUE:

6.1 Regression analysis for FQLC:

Ra (predicted) = 7.229 - 0.001567xA1 - 1.745xB1 - 0.000120xC1

(Predicted value of surface roughness) = 7.229 – 0.001567 x 0.8021 – 1.745 x 0.6576 - 0.000120 x 0.6010= 6.0801**μm**

Where, A1 spindle speed, B1 depth of cut, C1 feed rate

Confirmation results:

Unit	Predicted	Experimental	Error
Ra mean(μm)	6.0801	5.82300	0.2571

The above table shows that the error difference between FQLC and predicted regression surface roughness value is below 5% i.e. experiment with 95% confidence level.

6.2. Regression analysis for MQLC:

$\mathbf{R_a}$ (predicted) = 6.760 - 0.946 A1 - 0.204 B1 - 0.368 C1

(Predicted value of surface roughness)

= 6.760 - 0.946x0.7616 - 0.204x0.5364 - 0.368x0.5724

= 5.7194**μm**

Where, A1 spindle speed, B1 depth of cut, C1 feed rate.

6.3 Confirmation results:

Unit	Predicted	Experimental	Error
Ra mean(μm)	5.7194	6.28667	0.5672

The above table shows that the error difference between MQLC and predicted regression surface roughness value is below 5% i.e. experiment with 95% confidence level.

7. CONCLUSION:

According to the experimental result, it shows that lubrication has a most significant effect on the surface roughness of P20 steel material followed by the carbide cutting End mill tool. The effect of different lubrication condition, including FQLC and MQLC on the surface roughness, Ra values analysed in the study. The conclusion is made and it shows that FQLC condition has greater effects on the surface roughness as compare to the MQLC condition on the P20 steel material in CNC End milling process.

The result calculated from regression analysis for FQLC, it shows error between predicted value and experimental values is about 4.2% and in MQLC case the error between predicted value and experimental value is about 4.87%, therefore it is clearly shows FQLC condition gives better surface finish as compare to MQLC case.

REFERENCES

[1] Dale H.Besrerfield, Total quality management, Pearson Education (Singapore) Pvt Ltd, Delhi India 2004.

[2] Douglas Montgomery, Design and analysis of experiment, Wiley India PVT.LTD, Delhi 2006.

[3] Jijo anatomy, Design of Experiment, Elsevier Science & Technology Books, October 2003.

[4] B.S. Raghuwanshi, Work shop technology vol. II (machine tools), Dhanpat Rai & co. LTD , Delhi India 2001.

[5] S.K.Hajra choudhary, Elements of Work shop technology Vol II,(machine tools),Media promoters and publishers PVT LTD, Mumbai 2008

[6] C.R. Kothari, Research Methodology methods and techniques, New Age International Publishers, New Delhi India 2004.

[7] M.S. Harne, Ravikumar L. Shirsat, "Optimization of End Milling Parameters on Surface Roughness of Die Steel HCHCr by Taguchi Method", International Journal of Science and Research (IJSR) ,Volume 4 Issue 1, pp. 2699-2702, January 2015.

[8] Bala Raju.J, AnupKumar.J, DayalSaran.P, Dr.C.S.Krishna Prasad Rao, "Application of Taguchi Technique for Identifying Optimum Surface Roughness in CNC end Milling Process", International Journal of Engineering Trends and Technology (IJETT)– Volume 21 , pp. 103-110, March 2015.

[9] R.N.Nimase, Dr. P. M. Khodke, "Effect of Machining Parameters on Surface Roughness of Al-7075 Alloy in End Milling "International Research Journal of Engineering and Technology (IRJET) , Volume: 02 Issue: 03, pp. 1505-1508, June-2015.

[10] Amal T.S, Vidya V& Abraham K Varughese, "Machining Parameters Optimization In End Milling Of Ti6Al4V Using Taguchi Method", International Journal of Research in Engineering & Technology ,Vol. 3, Issue 8, pp. 31-40, Aug 2015.

[11] Mohamad SyahmiShahrom ,Nafrizuan Mat Yahya and Ahmad ad RazlanYusoff, "Taguchi Method Approach on Effect of Lubrication Condition on Surface Roughness in Milling Operation", Procedia Engineering 53, pp. 594-599, 2013.