An Investigation and Prediction of Flatness and Surface Roughness during Face Milling Operation on HCHCR Material

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Abstract – Materials are manufactured from casting, forging and extrusion processes have higher typical dimension tolerances due to its producing ability. So machining processes were introduced for close tolerance assembly and improve the product working efficiencies. Milling operation is playing vital role on making the components with high accuracy and higher productivity. Subsequently, face milling operation is utilized for planning the surface of work material with improved surface texture. It is one of the important milling processes to achieve high flatness and low roughness. The work enlights the parameters influence on Material Removal Rate (MRR) and Surface Roughness (SR) in HCHCR as a work piece material. . The present work was focused on the influence of cutting speed, feed rate and depth of cut on the HCHCR during face milling. Taguchi design method were employed to investigate the machining characteristics of HCHCR. In this experimental study optimal control factor lies in same parameter during investigation of HCHCR steel under wet conditions. The optimal factor for Surface Roughness, Machining time, MRR and Flatness error were Speed – 1000 R.P.M, Feed – 1400mm/min and DOC –0.75 mm. . The optimal factor for Surface Roughness, Machining time, MRR and Flatness error were Speed – 1000 R.P.M, Feed – 1400mm/min and DOC –0.75 mm. The Percentage of contribution roughness and Machining time &MRR were maximum influenced with speed and flatness error only influenced with feed.

Index Terms – HCHCR, Tolerances, MRR, SR, Materials.

1. INTRODUCTION

Milling is the process of removing metal by feeding the work past a rotating multipoint cutter. In milling operation the rate of metal removal is rapid as the cutter rotates at a high speed and has many cutting edges. Thus the jobs are machined at a faster rate than with single point tools and the surface finish is also better due to multipoint cutting edges.

The action of the milling cutter is vastly different from that of a drill or lathe tool. In milling operation the cutting edge of the cutter is kept continuously in contact with the material being cut. The cuts picks gradually. The cycle of operation to remove the chip produced by each tooth is first a sliding action at the beginning, the cutter comes in contact with the metal and then crushing action takes place just after it leading finally to the cutting actions. The versatility and accuracy of the milling process causes it to be widely used in modern manufacturing.

1.1 Surface Roughness

Whatever may be the manufacturing process, an absolutely smooth and flat surface cannot be obtained. The machine elements or parts retain the surface irregularities left after manufacturing The surface of a part is exterior or boundary and the surface irregularities consists of numerous small wedges and valleys that deviate from a hypothetical nominal surface. These irregularities are responsible to a greater extent for the appearance of a surface and its suitability for an intended application of the component. These irregularities are usually understood in terms of surface roughness. Surface roughness play a major role in many areas and is a factor of greater importance in the evaluation of machining A section of standard length is sampled from the mean line on the roughness chart. The mean line is laid on a Cartesian Coordinate system wherein the mean line runs in the direction of the X-axis and the magnification in Y-axis. The value expressed in micrometer.

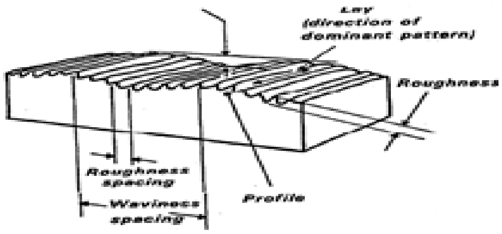

Fig 1.1 : Surface Roughness

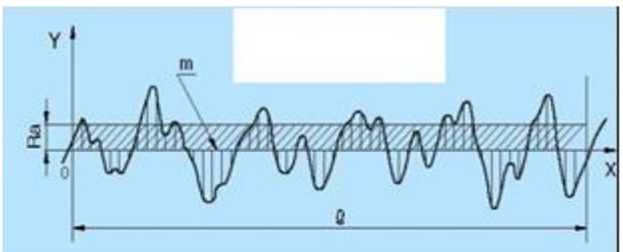

Fig :1.2 : Roughness Chart

1.2 Flatness Measuring System Through CMM

The typical 3 "bridge" CMM is composed of three axes, an X, Y and Z. These axes are orthogonal to each other in a typical three-dimensional coordinate system. Each axis has a scale system that indicates the location of that axis. The machine will read the input from the touch probe, as directed by the operator or programmer. The machine then uses the X, Y, Z coordinates of each of these points to determine size and position with micrometer precision typically. A coordinate measuring machine (CMM) is also a device used in manufacturing and assembly processes to test a part or assembly against the design intent. By precisely recording the X, Y, and Z coordinates of the target, points are generated which can then be analyzed via regression algorithms for the construction of features. These points are collected by using a probe that is positioned manually by an operator or automatically via Direct Computer Control (DCC). DCC CMMs can be programmed to repeatedly measure identical parts, thus a CMM is a specialized form of industrial robot.

2. MATERIALS AND METHOD

The principal properties required of a modern cutting tool material for a high production rate and high precision machining include good wear resistance, toughness, chemical stability under high temperature and large sliding forces and sufficiently high flow strength. It is not possible to achieve all these properties, some of which are mutually exclusive, in a single material. Techniques have been developed to exploit the beneficial properties of a number of materials in a single application. One effective technique is the coating of thin layers of one or more highly wear resistant materials such as TiC, TIN, Ti (N, C), Al2O3 and Ti (N, C, O) on tough and strong substrates. Coating of cutting tool has to have some characteristics of which some are shown below.

2.1 Hardness: A high surface hardness of the coating is one of the best ways to increase tool life. Generally speaking, the harder the material or surface, the longer the tool will last.

2.2 Wear Resistance: This is the ability of the coating to protect against abrasion. Although a material may not be hard, elements and processes added during production may aid in the breakdown of cutting edges.

2.3 Surface Lubricity: A high coefficient of friction causes increased heat, leading to a shorter coating life or coating failure. However, a lower coefficient of friction can greatly increase tool life.

2.4 Oxidation Temperature: This is the point at which the treatment starts to break down. A higher oxidation temperature rating improves success in high heat applications.

2.5 Work Material Details

Work material –HCHCR steel
Work material size–100X 100 mm
Square plate 6 mm thickness

2.6 Chemical Properties

C	Mn	Si	S	P	Cr
0.90	0.30	0.10	0.40	0.40	1.00
1.20	0.75	0.35	-	-	1.60

Table 4.1 Chemical properties

S.No	Properties	Value
1.	Ultimate Tensile Strength (Mpa)	224.07
2.	Yield Stress (Mpa)	2033.95
3.	Elongation (%)	5
4	Density (Kg/m^3)	7833.413
5	Hardness (HRC)	62

Table 4.2 Physical properties

3. METHODOLOGY

3.1 Taguchi's Approach.

Taguchi's Approach to Parameter Design Taguchi's approach to parameter design provides the design engineer with a systematic and efficient method for determining near optimum design parameters for performance and cost. The objective is to select the best combination of control parameters so that the product or process is most robust with respect to noise factors.

A brief overview of Taguchi's approach for parameter design.

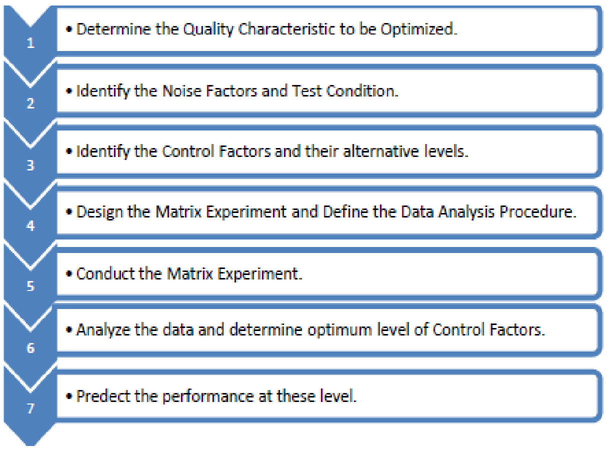

Fig 3.1: Taguchi's Approach

3.2 ANOVA (ANALYSIS OF VARIANCE)

Analysis of Variance (ANOVA) is a hypothesis-testing method used to analysis the equality of two or more population (or treatment) mean by examining the variances of samples which are taken. ANOVA permits to determine whether the differences between the samples are only due to random error or if there are systematic treatment effects which make the mean in one group to differ from the mean in another. Mainly ANOVA is used to compare the parity of three or more means, but when the means from two samples are compared using ANOVA it is similar to using a t-test to compare the means of independent samples. ANOVA is comparing the variance (or variation) between the data samples to variation within each particular sample. Whenever the between variation is much larger than the within variation, the means of different samples will not be equal. If samples will not be equivalent. If the between and within variations are approximately the equal size, then there will be no significant difference among sample means.

4. CNC MILLING OVER VIEW & INPUT PARAMETER

Fig 4.1: Vertical Milling Method

4.1 Vertical Milling Machine

Computer Numerical Control (CNC) Milling is the most common form of CNC. CNC mills can perform the functions of drilling and often turning. CNC Mills are classified according to the number of axes that they possess. Axes are labeled as x and y for horizontal movement, and z for vertical movement, as shown in this view of a manual mill table. A standard manual light-duty mill (such as a Bridgeport™) is typically assumed to have four axes:

1 Table x.
2 Table y.
3 Table z.
4 Milling Head z.

The number of axes of a milling machine is a common subject of casual "shop talk" and is often interpreted in varying ways. We present here what we have seen typically presented by manufacturers. A five-axis CNC milling machine has an extra axis in the form of a horizontal pivot for the milling head, as shown below. This allows extra flexibility for machining with the end mill at an angle with respect to the table. A six-axis CNC milling machine would have another horizontal pivot for the milling head, this time perpendicular to the fifth axis. CNC milling machines are traditionally programmed using a set of commands known as G-codes. G-codes represent specific CNC functions in alphanumeric format.

4.2 Experimental Setup

The experiments were conducted based on L 9 orthogonal array with respect to full factorial design. The three factors and each three levels with two replicates were considered based on machine tool pecifications and tool manufacturer recommendations.

4.3 Machine Specification

The experiments were conducted on AKSARA VF 30 CNC machining center.

Travel x-axis y axis z axis	 800 mm 350 mm 480 mm
Table dimension Length Width	 1000 mm 350 mm
Spindle speed Max. motor rating	0 – 2000 rpm 5 Kw
Feed rates max. rapids Max .cutting	10 m/min 5 m/min
Tool Type Max. tool diameter Max. tool weight	 BT40 150 mm 10 kg
Accuracy Positioning Repeatability	 +/- 0.0051 mm +/-0.0025 mm
General Power	 10 kW

Table 4.1 specification of milling machine

5. MACHINING PARAMETER

5.1 Taguchi Approach

Basically, experimental design methods were developed original fisher. However experimental design methods are too complex and not easy to use. Furthermore, a large number of experiments have to be carried out when the number of the process parameters increases, to solve this problem, the Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with a small number of experiments only. The experimental results are then transformed into a signal – to – noise (S/N) ratio [1][2] to measure the quality characteristics deviating from the desired values. Usually, there are three categories of quality characteristics in the analysis of the S/N ratio, i.e., the – lower – better, the – higher – better, and the – nominal – better. The S/N ratio for each level of process parameter is compared based on the S/N analysis. Regardless of the category of the quality characteristic, a greater S/N ratio corresponds to better quality characteristics. Therefore, the optimal level of the process parameters is the level with the greatest S/N ratio Furthermore, a statistically significant with the S/N and ANOVA[3] analyses, the optimal combination of the process parameters can be predicted. Finally, a confirmation experiment is conducted to verify the optimal process parameters obtained from the parameter design.There are 3 Signal-to-Noise ratios [5][6] of common interest for optimization of Static Problems. The formulae for signal to noise ratio are designed so that an experimenter can always select the largest factor level setting to optimize the quality characteristic of an experiment.

5.2 Design of Experiment.

Level	Process Parameter		
	Speed	Feed	DOC
1	1000	1200	0.25
2	1500	1400	0.50
3.	2000	1600	0.75

Table:5.1 Process parameters and their levels

5.3 MINITAB-17 Software

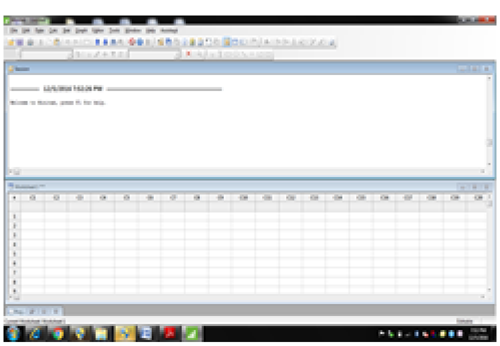

Fig5.1 Image of MINITAB-17

By using Minitab-17 software have optimized the edm process parameters

5.4 An Orthogonal Array L9 Formation

Trial No.	Designation	Speed	Feed	DOC
1	A1B1C1	1000	1200	0.25
2	A1B2C2	1000	1400	0.50
3	A1B3C3	1000	1600	0.75
4	A2B1C2	1500	1200	0.50
5	A2B2C3	1500	1400	0.75
6	A2B3C1	1500	1600	0.25
7	A3B1C3	2000	1200	0.75
8	A3B2C1	2000	1400	0.25
9	A3B3C2	2000	1600	0.50

Table:5.2 L9 Array Formation

5.5 Experimental Data

Trial	Designation	Speed	Feed	DOC	Machining Time	SNRA1
1	$A_1B_1C_1$	1000	1200	0.25	4.32	-12.7097
2	$A_1B_2C_2$	1000	1400	0.50	4.25	-12.5678
3	$A_1B_3C_3$	1000	1600	0.75	4.17	-12.4027
4	$A_2B_1C_2$	1500	1200	0.50	4.21	-12.4856
5	$A_2B_2C_3$	1500	1400	0.75	4.19	-12.4443
6	$A_2B_3C_1$	1500	1600	0.25	4.16	-12.3819
7	$A_3B_1C_3$	2000	1200	0.75	4.19	-12.4443
8	$A_3B_2C_1$	2000	1400	0.25	4.15	-12.3610
9	$A_3B_3C_2$	2000	1600	0.50	4.05	-12.1491

Table:5.4 S-N Ration value for Machining Timing

5.6 Taguchi Analysis: MT versus SPEED, FEED, DOC

Response Table for Signal to Noise Ratios Smaller is better

Level	Speed	Feed	DOC
1	-12.56	-12.55	-12.48
2	-12.44	-12.46	-12.40
3	-12.32	-12.31	-12.43
Delta	0.24	0.24	0.08
Rank	1	2	3

Table:5.5 Responsible Table value for Machining Timing

Level	Speed	Feed	DOC
1	4.247	4.240	4.210
2	4.187	4.197	4.170
3	4.130	4.127	4.183
Delta	0.117	0.113	0.040
Rank	1	2	3

Table:5.6 Means Table value for Machining Timing

5.7 Analysis of Variance for MT, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	F	P	% Contribution
Speed	2	0.020422	0.010211	24.84	0.039	47
Feed	2	0.019622	0.009811	23.86	0.040	45
Doc	2	0.002489	0.001244	3.03	0.248	6
Error	2	0.000822	0.000411			2
Total	8	0.043356				100

Table: 5.7 ANOVA value for MRR

MT = 4.18778 + 0.05889 Speed_1000 - 0.00111 Speed_1500 - 0.05778 Speed_2000

+ 0.05222 Feed_1200 + 0.00889 Feed_1400 - 0.06111 Feed_1600 + 0.02222 DOC_0.25 - 0.01778 DOC_0.50 - 0.00444 DOC_0.75\

5.8 Graphs

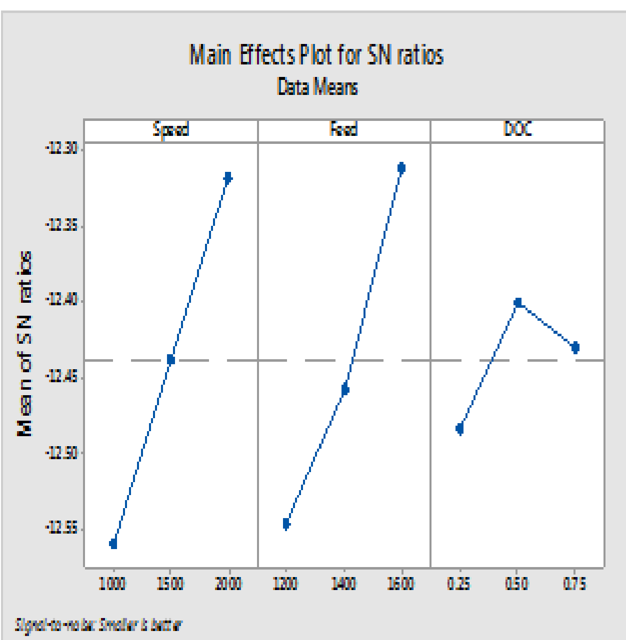

Fig 5.2 : Main effects plot for S-N Ratio-MT

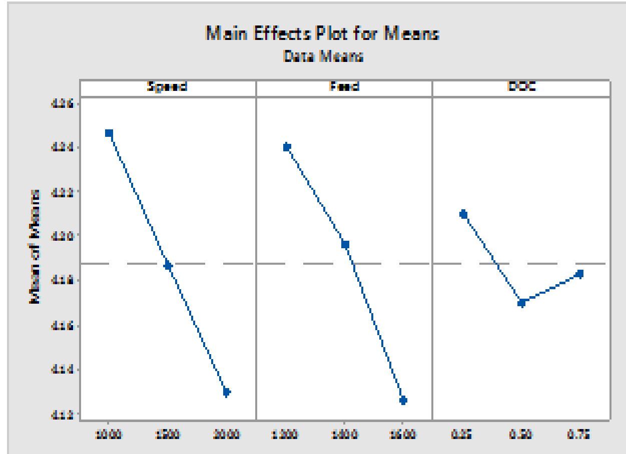

Fig 5.3 Main effects plot for Means Ratio-MT

5.8 Surface Roughnesses (Analysis of Result)

Trial	Designation	Speed	Feed	DOC	Ra	SNRA1
1	A1B1C1	1000	1200	0.25	1.392	-2.87278
2	A1B2C2	1000	1400	0.50	1.156	-1.25916
3	A1B3C3	1000	1600	0.75	0.974	0.22882
4	A2B1C2	1500	1200	0.50	0.623	4.11024
5	A2B2C3	1500	1400	0.75	0.586	4.64205
6	A2B3C1	1500	1600	0.25	1.026	-0.22295
7	A3B1C3	2000	1200	0.75	1.177	-1.41553
8	A3B2C1	2000	1400	0.25	0.486	6.26727
9	A3B3C2	2000	1600	0.50	1.348	-2.59380

Table:5.8 S-N Ration value for Surface Roughness

5.9 Taguchi Analysis: Ra versus Speed, Feed, Doc

Response Table for Signal to Noise Ratios Smaller is better

Level	Speed	Feed	DOC
1	-1.30104	-0.05936	1.05718
2	2.84311	3.21672	0.08576
3	0.75265	-0.86264	1.15178
Delta	4014415	4.07936	1.06602
Rank	1	2	3

Table:5.9 Responsible Table value for Roughness

Level	Speed	Feed	DOC
1	1.1740	1.0640	0.9680
2	0.7450	0.7427	1.0423
3	1.0037	1.1160	0.9123
Delta	0.4290	0.3733	0.1300
Rank	1	2	3

Table:5.10 Means Table value for Roughness

5.10 Analysis of Variance for Ra, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	F	P	% Contribution
Speed	2	0.27996	0.13998	0.79	0.557	30
Feed	2	0.24534	0.12267	0.70	0.590	27
DOC	2	0.02552	0.01276	0.07	0.933	3
Error	2	0.35270	0.17635			40
Total	8	0.90353				100

Table:5.11 ANNOVA value for Roughness

5.11 GRAPHS FOR S-N RATIO AND MEANS-ROUGHNESS

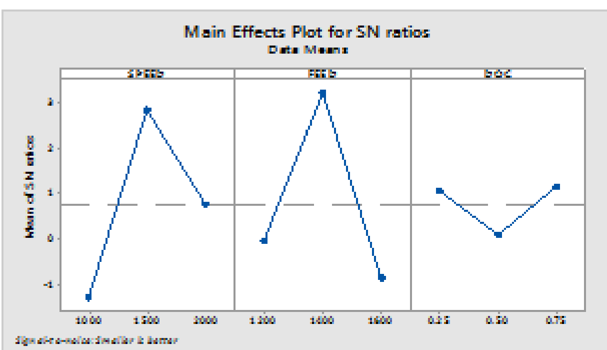

Fig: 5.4 Main effects plot for S-N Ratio-Roughness

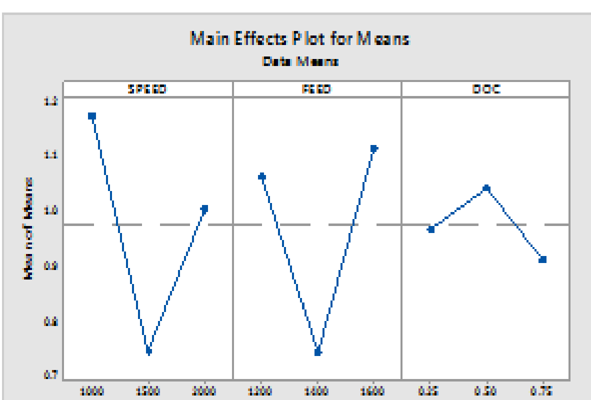

Fig:5.5 Main effects plot for Means Ratio-Roughness

5.11 MRR (ANALYSIS OF RESULT)- S/N Ratios values for the experiments

Trial	Designation	Speed	Feed	DOC	MRR	SNRA1
1	A1B1C1	1000	1200	0.25	2.401	7.60784
2	A1B2C2	1000	1400	0.50	2.444	7.76202
3	A1B3C3	1000	1600	0.75	2.491	7.92747
4	A2B1C2	1500	1200	0.50	2.467	7.84338
5	A2B2C3	1500	1400	0.75	2.479	7.88553
6	A2B3C1	1500	1600	0.25	2.497	7.94837
7	A3B1C3	2000	1200	0.75	2.479	7.88553
8	A3B2C1	2000	1400	0.25	2.503	7.96922
9	A3B3C2	2000	1600	0.50	2.563	8.17497

Table:5.12 S-N Ration value for MRR

5.12 MRR RESPONSE FOR EACH LEVEL OF THE PROCESS PARAMETER

Taguchi Analysis: MRR versus Speed, Feed, DOC Response Table for Signal to Noise Ratios Larger is better

Level	Speed	Feed	Doc
1	7.766	7.779	7.842
2	7.792	7.872	7.927
3	8.010	8.017	7.900
Delta	0.244	0.238	0.085
Rank	1	2	3

Table:5,13 Responsible Table for MRR

Level	Speed	Feed	Doc
1	2.445	2.449	2.467
2	2.481	2.475	2.491
3	2.515	2.517	2.483
Delta	0.070	0.068	0.024
Rank	1	2	3

Table:5.14 Means Table for MRR

5.13 Analysis of Variance for MRR, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	F	P	% Contribution
Speed	2	0.007282	0.003641	25.86	0.037	46

Feed	2	0.007054	0.003527	25.05	0.038	45
Doc	2	0.000918	0.000459	3.26	0.235	6
Error	2	0.000282	0.000414			3
Total	8	0.015534				100

Table:5.15 Variance for MRR Using Adjusted SS

5.14 GRAPHS FOR S-N RATIO AND MEANS-MRR

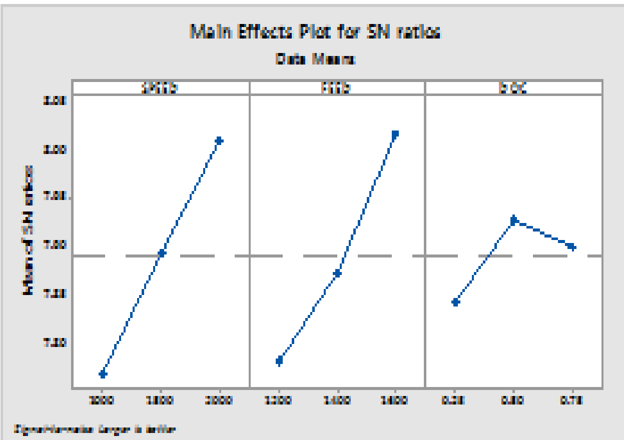

Fig: 5.6 Main effects plot for S-N Ratio-MRR

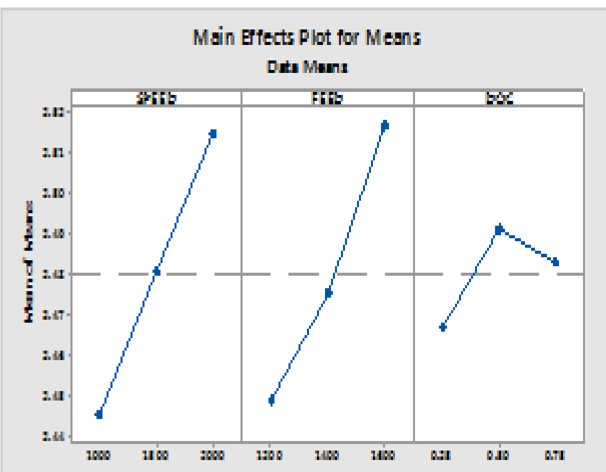

Fig: 5.7 Main effects plot for Means-MRR

6. FLATNESS MEASURING SYSTEM

6.1 Flatness (Analysis Of Result) Error of S/N Ratios Values for the Experiments

Trial	Designation	Speed	Feed	DOC	Flat	SNRA1
1	A1B1C1	1000	1200	0.25	0.003	50.4576
2	A1B2C2	1000	1400	0.50	0.004	47.9588
3	A1B3C3	1000	1600	0.75	0.003	50.4576
4	A2B1C2	1500	1200	0.50	0.004	47.9588
5	A2B2C3	1500	1400	0.75	0.002	53.9794
6	A2B3C1	1500	1600	0.25	0.060	24.4370
7	A3B1C3	2000	1200	0.75	0.025	32.0412
8	A3B2C1	2000	1400	0.25	0.017	35.3910
9	A3B3C2	2000	1600	0.50	0.026	31.7005

Table:6.1 S-N Ratio value for Flatness

6.2 Flatness Error Response for Each Level of the Process Parameter

Taguchi Analysis: FLAT versus SPEED, FEED, DOC

Response Table for Signal to Noise Ratios Smaller is better

Level	Speed	Feed	Doc
1	49.62	43.49	36.76
2	42.13	45.78	42.54
3	33.04	35.53	45.49
Delta	16.58	10.24	8.73
Rank	1	2	3

Table:6.2 Responsible Table for Flatness

Level	Speed	Feed	Doc
1	0.003333	0.010667	0.026667
2	0.022000	0.007667	0.011333
3	0.022667	0.029667	0.010000
Delta	0.019333	0.022000	0.016667
Rank	2	1	3

Table:6.3 Means Table for Flatness

6.3 General Linear Model: FLAT versus SPEED, FEED, DOC

Source	DF	Seq SS	Adj SS	F	P	% Contribution
Speed	2	0.000723	0.000361	0.85	0.540	24
Feed	2	0.000854	0.000427	1.01	0.498	30
DOC	2	0.000515	0.000257	0.61	0.622	17
Error	2	0.000849	0.000424			29
Total	8	0.002940				100

Table:6.4 ANNOVA Table for Flatness

6.4 Graphs For S-N Ratio and Means-Flatness

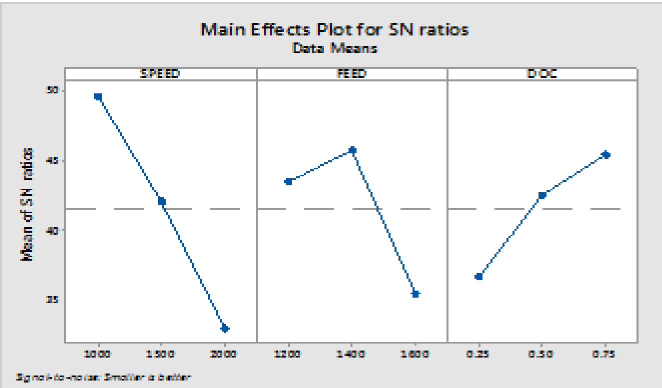

Fig6.1 Main effects plot for S-N Ratio

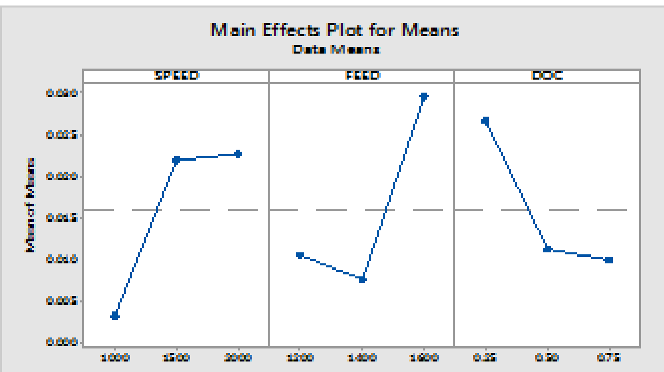

Fig 6.2 Main effects plot for means

7. RESULT & DISCUSSION

In this study, the Taugchi technique and ANOVA were used to obtain optimal milling parameters of HCHCR steel under dry conditions. The experimental results were evaluated using ANOVA. The following conclusion can be drawn. In this study, the Taugchi technique and ANOVA were used to obtain optimal parameters in the Milling of steel under wet conditions. The experimental results were evaluated using Taguchi technique. The following conclusion can be drawn.

7.1 Optimal Control Factor

1. Surface Roughness-A1(Speed-1000) B2(Feed-1400mm/min)C3(DOC-0.75mm)

2. Machining Timing- A1(Speed-1000) B2(Feed-1400mm/min)C3(DOC-0.75mm)

3. Material Removal Rate-A1(Speed-1000) B2(Feed-1400mm/min)C3(DOC-0.75mm)

4. Flatness- A1(Speed-1000) B2(Feed-1400mm/min)C3(DOC-0.75mm)

7.2 Percentage of contribution of Process parameter

1 Surface Roughness- speed 30%

2. Machining Timing Speed-47%

3. Material Removal –- Speed-46%

4. Flatness- Feed-30%

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