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Surface Roughness Detailed Investigation in Pocket Milling Operation on VMC

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***Abstract*: With the more exact requests of current manufacturing items, the control of surface roughness with dimensional precision has turned out to be increasingly significant. It is examined that, surface roughness enormously impacts on working of the machined parts. Surface roughness and material removal rate plays a vital role in deciding about the productivity in global manufacturing. There are numbers of factors which influences the Surface Roughness. Machining Parameters play vital role in achieving good Surface Finish. Impact of Machining Parameters, Cutting Tool Parameters and Physical Parameters on Surface Roughness of Mild Steel is analyzed experimentally and their Optimization and percentage contribution is determined by Taguchi Method.**

***Keywords*: Machining Parameters, MRR, Surface Finish, Taguchi Method.**

1. Introduction

Production Engineering includes different procedures to convert crude materials to finished products to be utilized for an assortment of purposes. In Global Competition, Quality is a significant characteristic considering Customers Choice and Surface Finish is a major symbol of Quality. Whatever might be the Manufacturing procedure utilized, it is absurd to expect to create superbly smooth surface. Machining is one of the most versatile manufacturing processes most frequently, milling involves the generation of flat faces and slots. Cutting parameters such as speed, feed, depth of cut, affect the production rate, Quality and cost of component, during a milling operation. Owing to the significant role that milling operations play in today's manufacturing world, there is a vital need to optimize milling machining for this operation, particularly when CNC machines are employed.

2. Problem Statement

Due to continuous production on machine there is wear and tear of machine parts

- There is need to optimize machine parameters to achieve High Surface Roughness.
- Environmental conditions also affect operating machine parameters.
- Due to variable parameters, Cycle Time is not fixed hence production rate cannot be determined.

Uneven parameters create uneven fitment of job with respect to clamp

- Clamping force should be optimized.
- Machine operating parameter optimization. Such as air pressure, coolant, environmental temperature, vacuum pressure, etc.

3. Experimental Setup

- Material Used- Mild Steel (EN – 4 to EN – 6)
- Carbon – 0.15% to 0.35%
- Tensile strength –1200/1420MPA
- Yield strength – 750/1170 MPA
- Size- 200mm X 200mm X 10 mm
- Quantity- 04
- Operation- Pocket Milling
- Pockets- 04
- Machine used- VMC (Jyoti- Huron EX 1680)
- Software: Master CAM
- Operating Language: Fanuik

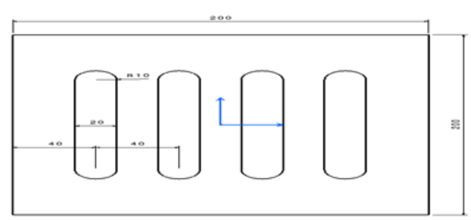

Fig. 1. Sample drawing

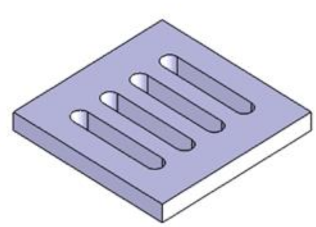
Fig. 2. Sample after machining

4. Parameters Used

A. Operating Parameters

Table 1
Machine Parameters

Sample No.	Cutting Speed (m/min)	Feed rate (m/tooth)	Depth of cut (m)
1	60-80	0.10	0.012
2	80-100	0.11	0.011
3	100-120	0.12	0.010
4	120-140	0.13	0.009

B. Cutting tool parameters

Table 2
Cutting Tool Parameters

Sample no	Nose radius (mm)	Tool stage	Run out
1	3.2	0.13	0.008
2	3.4	0.14	0.007
3	3.6	0.15	0.006
4	3.8	0.16	0.005

C. Physical Parameters

Table 3
Cutting Parameters

Sample No.	Chip formation (μ/mm)	Acd^n (mm/sec)	Cutting Force (N)
1	0.16	0.008	2.8
2	0.17	0.007	2.9
3	0.18	0.006	3.0
4	0.19	0.005	3.1

By using set of above parameters, four samples are manufactured. Each Sample is machined by using Particular Set of Parameters. The Experimental Analysis is done to obtain best set of Parameters.

5. Experimental Analysis

Experimental Analysis consists of following Tests,

A. Test Name: Dimensional Accuracy for Inter Pocket Distance. (Min 20 mm)

- Instrument Used – Digital Vernier Caliper (LC- 0.01 mm)

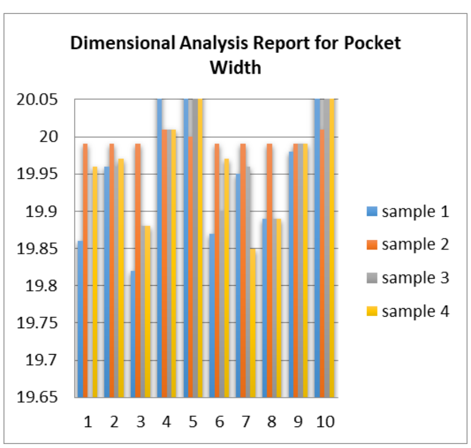

Fig. 3. Dimensional analysis report for pocket width

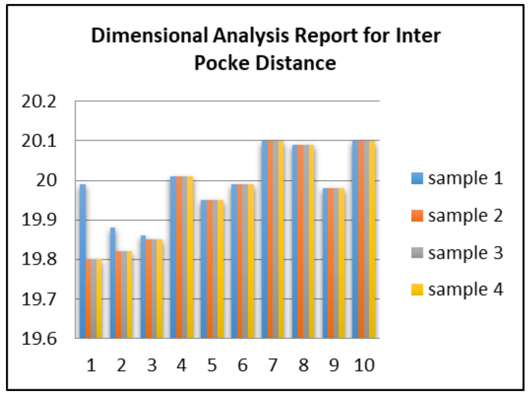

Fig. 4. Dimensional analysis report for inter pocket distance

B. Test Name: Dimensional Accuracy for Pocket Length. (Min 150 mm)

- Instrument Used – Digital Vernier Caliper (LC- 0.01 mm)

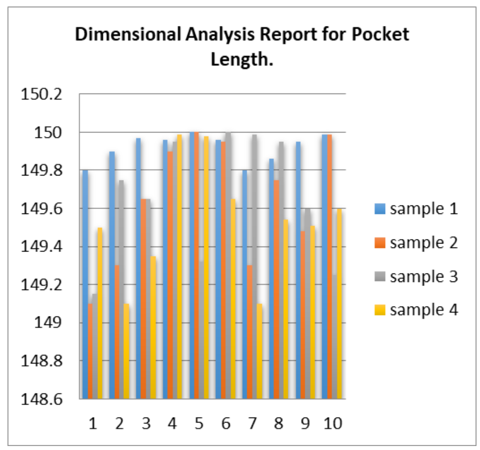

Fig. 5. Dimensional analysis report for pocket length.

C. Test Name: Surface Roughness

Instrument Used –Mitutoyo 178-923E SJ210
Roughness parameter: Ra, Rz, Rq

Table 4
S.R. Analysis

Roughness value	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4
Ra	0.04	0.039	0.03	0.025
Rz	0.02	0.021	0.025	0.02
Rq	0.03	0.026	0.02	0.02

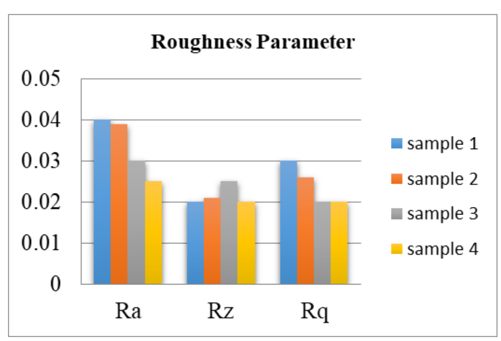

Fig. 6. Surface roughness analysis.

Table 5
Experimental Result Analysis

Test Name	Sample 1	Sample 2	Sample 3	Sample 4
Dimensional Accuracy for Pocket Width	20.02	20.01	19.97	20.04
Dimensional Accuracy for Inter Pocket Distance	20.05	20.04	20.08	20.09
Dimensional Accuracy for Pocket Length	149.98	150.01	149.7	149.7
Ra	0.04	0.039	0.03	0.025
Rz	0.02	0.021	0.025	0.02
Rq	0.03	0.026	0.02	0.02
Amount of Burr Removal	895	888	891.5	890.89

Table 6
Variety of process parameters and reaction variables

Exp. No.	Process Parameters Response Variables				Response Variable
	Cutting Speed (mm/min)	Feed Rate (m/tooth)	Depth of cut (m)	Nose Radius (mm)	Material Removal rate (gms/sec)
1	60	0.12	0.0111	3.2	3.2584
2	65	0.12	0.012	3.2.	3.6515
3	70	0.12	0.010	3.4	3.4524
4	75	0.12	0.012	3.3	5.0397
5	80	0.10	0.0111	3.2	5.5215
6	85	0.10	0.012	3.32	5.22
7	90	0.13	0.010	3.4	3.444
8	95	0.11	0.012	3.25	3.4177
9	100	0.10	0.0110	3.2	3.2271
10	105	0.11	0.012	3.3	5
11	110	0.12	0.012	3.5	5.04536
12	115	0.12	0.012	3.6	5.1261
13	120	0.12	0.0111	3.6	3.6058
14	125	0.2	0.012	3.5	3.6538
15	130	0.13	0.012	3.7	2.9796
16	135	0.13	0.012	3.8	4.9573
17	140	0.12	0.012	3.2	4.9573

Table 7
Summary of ANOVA Calculation for S.R.S

Source of variation		Sum of Squares	Variance (Mean Squares)	Variance ratio F	Percentage contribution
Factor-A, Cutting Speed	4	0.272	0.07116	7.3061	17.35
Factor-B, Feed rate	1	0.0143	0.0144	1.552	0.87
Factor-C, Depth of cut	2	1.1205	0.56031	57.4919	63.48
Error -E, Nose Radius	22	0.2138	0.00964	1	13.03
Total	29	1.6347			

D. Test Name: Burr Analysis

Instrument Used – Weighbridge

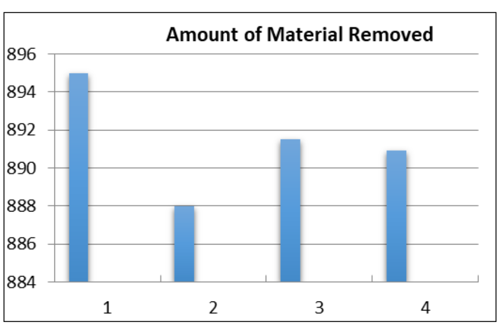

Fig. 7. Burr analysis

Above observations shows that-

- Dimensional Accuracy of Sample 2 is maximum.
- Ra value is 0.039, Rz value is 0.021, Rq is 0.025.
- Amount of Burr Removal is minimum for Sample 2.

6. ANOVA Analysis

The Analysis of Variance (ANOVA) is the factual treatment most normally executed to the outcomes of the trials to choose the rate commitment of each factor.

Analysis of Variance for Surface Roughness
Total no of Trials (n) = 30
Total degree of freedom $fT = n - 1 = 29$
Three factors and their levels:
Cutting Speed A: A1, A2, A3, A4, A5
Feed Rate B: B1, B2
Depth of Cut C: C1, C2, C3
Degree of freedom:
Factor A – Number of level of factor A - 1 = $fA = 4$
Factor B – Number of level of factor B - 1 = $fB = 1$
Factor C – Number of level of factor C - 1 = $fC = 2$
For error $fE = fT – fA – fB – fC = 29 – 4 – 1 – 2 = fE = 22$
T = Total of all SR value results = 20.635
Correction factor C.F. = (T2 / n) = (20.6352 / 30) = 14.1934

Table 8

Source of variation		Sum of squares	Variance (Mean square)	Variance ratio F	Percentage contribution
Factor-A, Cutting Speed	4	4.3507	1.08772	15.7925	12.15
Factor-B, Feed rate	1	29.5743	29.5741	429.3746	83.1
Factor-C, Depth of cut	2	0.1458	0.07323	1.0639	0.33
Error – E, Nose Radius	22	1.5151	0.06864	1	4.17
Total	29	35.588			

Total sum of squares:

$$S_T = \sum_{i=1}^{n} y_i^2 - C.F. = 15.8293 - 14.1933 = 1.636$$

Analysis of Variance for Material Removal Rate
Total no of runs (n) = 30
Total degree of freedom $_T$ = n - 1 = 29
Three factors and their levels:
Cutting Speed A: A1, A2, A3, A4, A5
Feed Rate B: B1, B2
Depth of Cut C: C1, C2, C3
Degree of freedom:
Factor A – Number of level of factor A - 1 = $_A$ = 4
Factor B – Number of level of factor B - 1 = $_B$ = 1
Factor C – Number of level of factor C - 1 = $_C$ = 2
For error $_E$ = $_T$ – $_A$ – $_B$ – $_C$ = 29 – 4 – 1 – 2 = $_E$ =22
T = Total of all depth value results = 119.00334
Correction factor **C.F.** = $(T^2 / n) = (119.00334^2 / 30)$ = 472.05983
Total sum of squares:

$$S_T = \sum_{i=1}^{n} y_i^2 - C.F. = 507.6487 - 472.05983 = 35.58887$$

7. Summary of ANOVA Analysis

From the above ANOVA evaluation, we are able to finish that,

1) Percentage Contribution of Different Factors on Surface Roughness

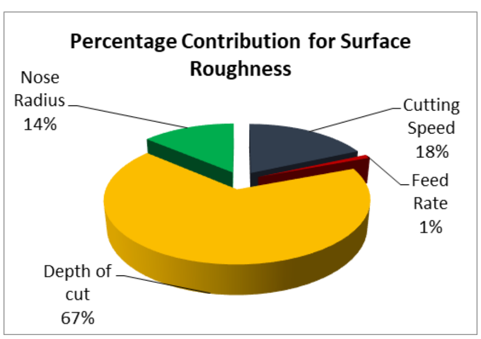

Fig. 8. Percentage contribution for surface roughness

Table 9
Quality characteristics of the machining performance

Machine Characteristic	Quality Characteristic
S.R.	Min.
M.R.R.	Max.

2) Percentage Contribution of Different Factors on MRR

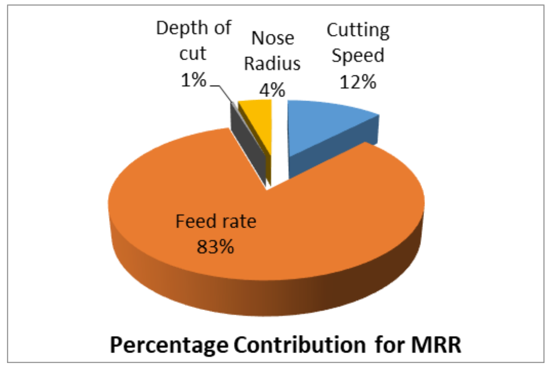

Fig. 9. Percentage Contribution for MRR

8. Multi Response Optimization

The Gray Relational Analysis (GRA) is one of the effective gentle-tool to research various techniques having a couple of overall performance tendencies. GRA approach is used to treatment the issues of the structures which might be complicated and multivariate. Generally, GRA is accomplished for fixing complicated troubles which have interrelationships maximum of the distinct overall performance characteristics. GRA is normalization based totally evolution approach in which the pleasant developments of the measured data are first normalized beginning from zero to one.

Optimal parameter combination for surface roughness and material removal rate with different combinations of 30 experimental runs.

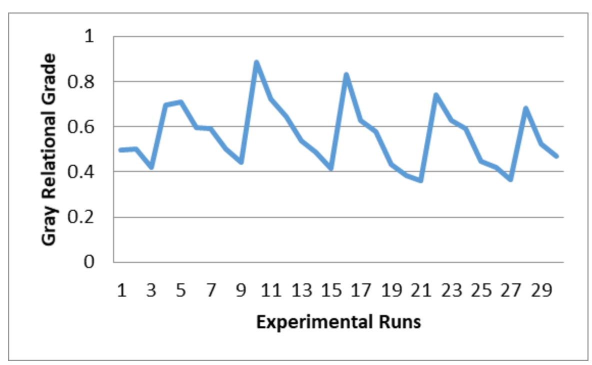

Fig. 10. Graph for grey relational grades

Main effect Plot for Grey Relational Grade

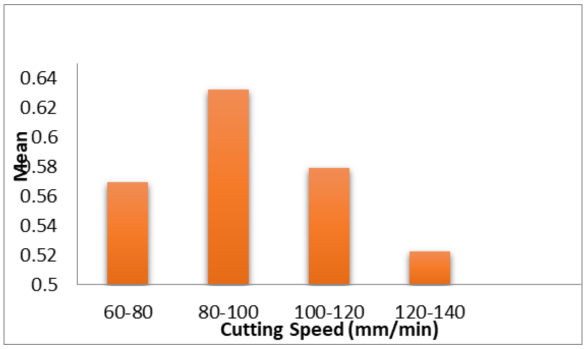

Fig. 11. Graph of grey relational grade v/s Cutting Speed (mm/min)

Fig. 11, shows the effect of Cutting Speed on gray relational grade. From this graph we conclude that at 80-100 mm/min reducing speed, gray relational grade is higher evaluate to 60-80 mm/min, 100-120 mm/min, 120-140 mm/min cutting speed. So, 80-100 mm/min is choicest parameter stage from four level of reducing speed.

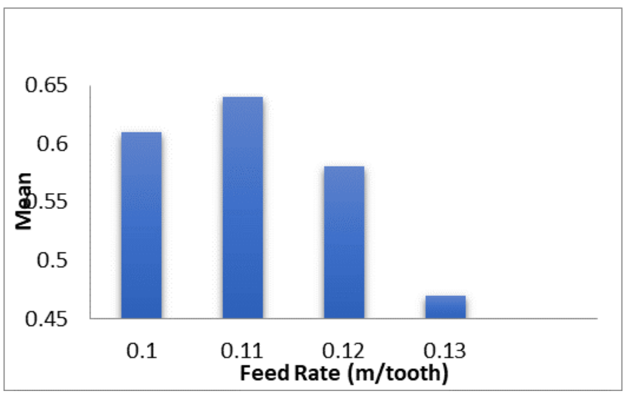

Fig. 12. Graph of grey relational grade v/s Feed Rate (m/tooth)

Fig. 12, shows the effect feed rate on gray relational grade. From this graph we finish that at 0. 11 m/tooth feed rate, grey relational grade is better examine to different feed rate. Therefore 0.11 m/tooth is ideal parameter.

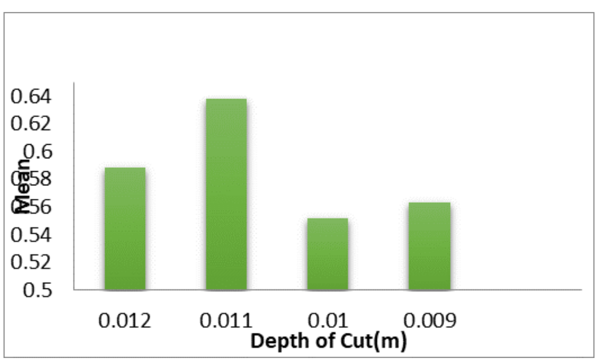

Fig. 13. Graph of grey relational grade v/s Depth of Cut (m)

Fig. 13 indicates the impact of Depth of Cut on gray relational grade. From this graph we finish that at 0.011 m Depth of Cut, grey relational grade is higher evaluate to different parameters. Therefore 0.011m. is most suitable parameter.

The confirmation test with choicest manner parameters if carried out for Pocket Milling Operation and it changed into located that following parameters are maximum appropriate for Pocket Milling Operation.

Table 10
Gray Relational Analysis Report

S. No.	Parameter Name	Value
1.	Cutting Speed (m/min)	80-100
2.	Feed rate (m/tooth)	0.11
3.	Depth of cut (m)	0.011
4.	Nose radius (mm)	3.4

In this topic, we covered most important impact plot for surface roughness, MRR and grey relational grade. These three principal impact plots are mixed with three method parameters Cutting Speed, feed rate and Depth of Cut.

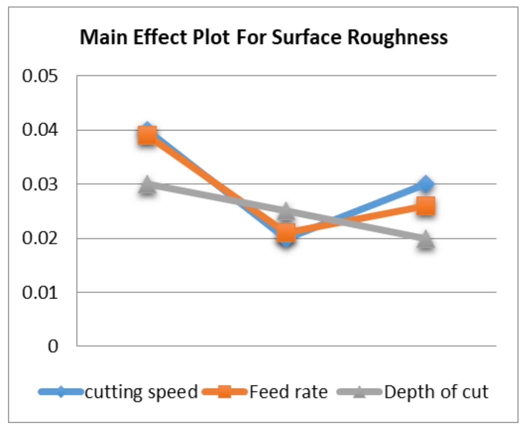

Fig. 14. Graph of main effect plot for surface roughness

Fig. 14, shows the principle impact plot for Surface Roughness. From Fig. 14 it is actually shown that from 80 mm/min to 100 mm/min cutting speed, surface roughness is lower so it concludes that for gain correct SR, cutting speed to be required less.

Now concentrate on impact of feed rate on Surface roughness. From figure 14, it's far certainly proven that with boom in feed rate, surface roughness is lower. So it concludes that for good surface quality, feed rate required have to be greater.

Now give attention to effect of depth of cut on surface roughness. From fig. 14, it's miles simply proven that with increase in depth of cut, surface roughness is increase. So it concludes that for achieve true surface quality, depth of cut to be required much less.

Fig. 15, suggests the main effect plot for MRR. From Fig. 15, it is definitely proven that with growth in Cutting Speed, MRR is Increase. So it concludes that for attain exact MRR, cutting speed must be required greater.

Now focus on impact of feed fee on MRR. From Fig. 15, it's far genuinely proven that with boom in feed fee, material removal charge is increase. So it concludes that for achieve top material elimination rate, feed rate need to be required greater.

Now communicate about effect of Depth of Cut on MRR. From Fig. 15 it is sincerely proven that from 0.012 to 0.011 intensity of cut, MRR is growth and from zero.010 to zero.009 depth of cut, MRR is decrease. So it concludes that for accurate material elimination charge, intensity of cut need to be required less.

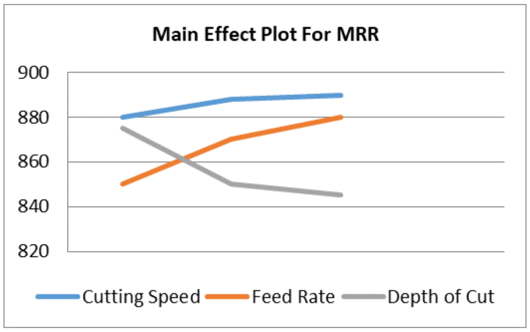

Fig. 15. Graph of main effect plot for material removal rate

9. Interaction Plots for Process Parameters v/s Response Variables

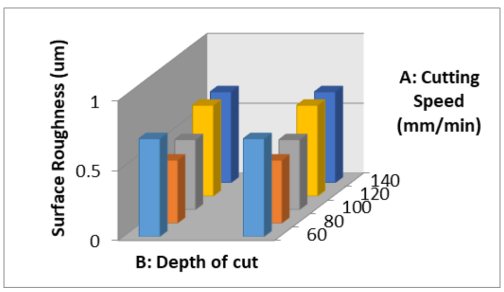

Fig. 16. Interaction effect of cutting speed and depth of cut on surface roughness

Fig. 16 suggests an interaction effect of cutting velocity and depth of cut on Surface roughness with taking common feed rate.

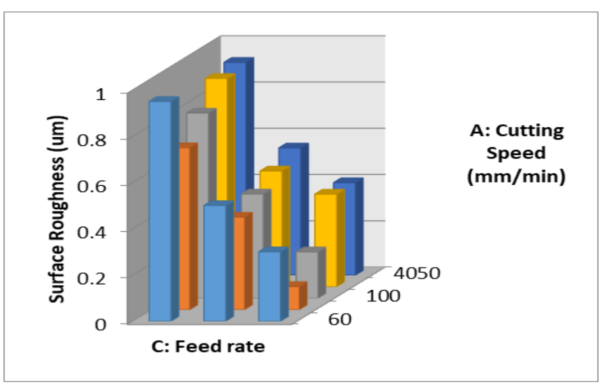

Fig. 17. Interaction effect of cutting speed and feed rate on surface roughness

Fig. 17 indicates an interplay effect of cutting speed and feed rate on SR with taking average Depth of cut.

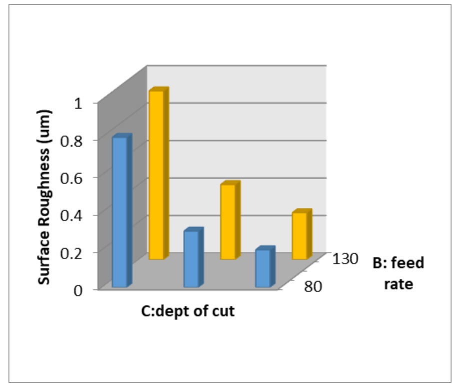

Fig. 18. Interaction effect of feed rate and depth of cut on surface roughness

Fig. 18. suggests an interaction impact of Feed Rate and Depth of Cut on SR with taking common cutting velocity.

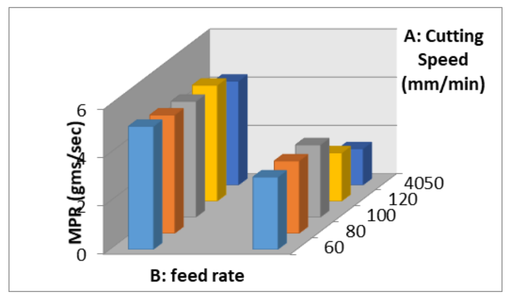

Fig. 19. Interaction effect of cutting speed and arc feed rate on material removal rate

Fig. 19 shows an interplay impact of cutting speed and feed rate on material removal rate with taking common depth of cut.

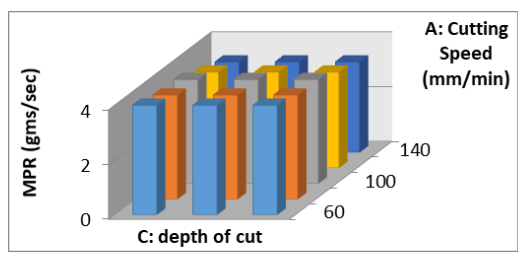

Fig. 20. Interaction effect of cutting speed and Depth of cut on material removal rate

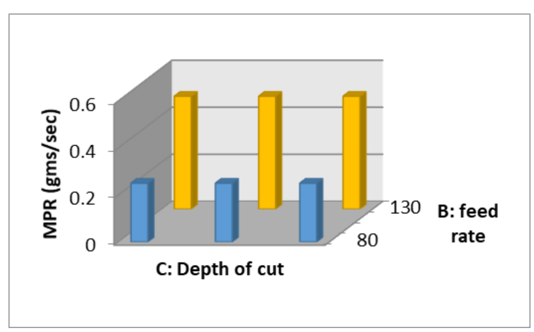

Fig. 21. Interaction effect of feed rate and Depth of cut on material removal rate

Fig. 20. indicates an interplay impact of cutting speed and depth of cut on material removal rate with taking common feed rate.

Fig. 21. suggests an interplay impact of feed rate and depth of cut on MRR with taking common Cutting speed.

10. Result Analysis

From Experimental Analysis, ANOVA Analysis and Gray Relational Analysis it is concluded that following set of Optimized Parameters are most suitable for Pocket Milling Operation.

Table 11
Result Analysis

S. No.	Parameter	Range
1.	Cutting Speed (m/min)	80-100
2.	Feed rate (m/tooth)	0.11
3.	Depth of cut (m)	0.011
4.	Nose radius (mm)	3.4
5.	Tool stage	0.14
6.	Run out	0.007
7.	Chip formation (μ/mm)	0.17
8.	Acd^{n} (mm/sec)	0.007
9.	Cutting force (N)	2.9

11. Conclusion

This paper presented an overview on surface roughness detailed investigation in pocket milling operation on VMC.

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