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Analysis & Optimization of Surface Roughness in CNC Milling Machine by Controlling Machining Parameters of EN 19 Steel

Hiren R Patel[1], V D Patel[2]

[1]P.G. Student Production (mechanical), LDRP-ITR, Gandhinagar, Gujarat, India

[2]Assistance Professor, Mechanical Engineering, LDRP-ITR, Gandhinagar, Gujarat, India

Abstract: ***By optimization of various parameters of CNC milling process like spindle speed, feed rate and depth of cut, improvement can be achieved in surface finishing & MRR. Various methods are used for predict Surface Roughness & MRR in CNC milling machine. Here Genetic Algorithm will implemented for better and nearest result. Number of experiments will done by using CNC milling machine. An L9 Taguchi standard orthogonal array (OA) will choice for design of experiments and the main influencing factor will determined for each given machining criteria by using Genetic Algorithm(GA). The predicted values are confirmed by using validation experiments.***

Keyword: CNC, MRR, SR, GA, ANOVA, Taguchi

1. Introduction

1.1Milling Process

Milling is the process of removing extra material from the work piece with a rotating multi-point cutting tool, called milling cutter. The machine tool employed for milling is called milling machine. Milling machines arebasically classified as vertical or horizontal. These machines are also classified as knee-type, ram-type,manufacturing or bed type, and planer-type. Most milling machines have self-contained electric drive motors,coolant systems, variable spindle speeds, and power-operated and table feeds. The three primary factors in anybasic milling operation are speed, feed and depth of cut. Other factors such as kind of material and type of toolmaterials have a large influence, of course, but these three are the ones the operator can change by adjusting the controls, right at the machine.

1.2 Surface Roughness

Surface roughness is an important measure of product quality since it greatly influences the performance ofmechanical parts as well as production cost. Surface roughness has received serious attention for many yearsand it is a key process to assess the quality of a particular product. Surface roughness has an impact on themechanical properties like fatigue behavior, corrosion resistance, creep life, etc. It also affects other functionalattributes of parts like friction, wear, light reflection, heat transmission, lubrication, electrical conductivity, etc.Surface roughness of turned components has greater influence on the quality of the product. Whenever twomachined surfaces come in contact with one another the quality of the mating parts plays an important role inthe performance and wear of the mating parts. The height, shape, arrangement and direction of these surface irregularities on the work piece depend upon a number of factors such as:

a) The machining variables which include
   - Cutting speed
   - Feed and
   - Depth of cut

b) The tool geometry
Some geometric factors which affect achieved surface roughness include:
   - Nose radius,
   - Rake angle,
   - Side cutting edge angle and
   - Cutting edge.

c) Work piece and tool material combination and their mechanical properties
d) Quality and type of the machine tool used,
e) Auxiliary tooling and lubricant used and
f) Vibrations between the work piece, machine tool and cutting tool.

1.3 Vertical Milling

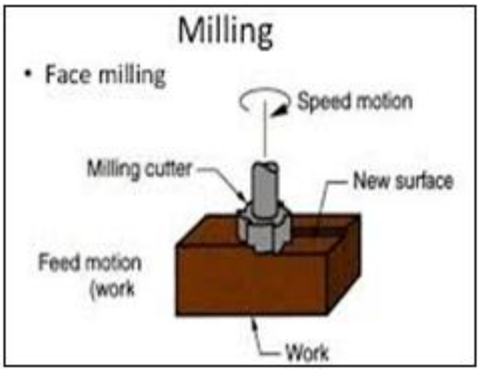
The vertical mill has a vertically arranged spindle axis and rotate by staying at the same axis. The spindle can also be extended and performing functions such as drilling and cutting. Vertical mill has got two further categories as well: turret mill and bed mill.

The turret mill has got a table that moves perpendicularly and parallel to the spindle axis in order to cut the material. The spindle is, however, stationary. Two cutting methods can be performed with this by moving the knee and by lowering or raising the quill.

The other is the bed mill in which the table moves perpendicular to the axis of the spindle and the spindle moves parallel to its axis.

2. Literature Review

Milon D. Selvam, et. al. had investigated the use of Taguchi technique and Genetic Algorithm (GA) for minimizing the surface roughness in machining mild steel with three zinc coated carbide tools insertedinto a face miller of 25 mm diameter. The experiments have been planned using Taguchi"s experimental design technique. The experiment has been performed on Mild Steel and obtained data has been analyzed using Taguchi technique and Genetic algorithm. It has been observed that, Taguchi"s orthogonal array provides a large amount of information in a small amount of experimentation. The surface roughness evaluated through Taguchi technique is 0.975 μm with 4.308 % error from the predicted value and for genetic algorithm it is 0.88 μm with 4.625 % error from the predicted value.[1]



Pinki Maurya et. al. have study on CNC end milling, influence of various machining parameters like, tool feed (mm/min), tool speed (rpm), tool diameter (mm) and depth of cut (mm). In the present study, experiments are conducted on AL 6351 –T6 material with three levels and four factors to optimize process parameter and surface roughness. An L9 (3*4) Taguchi standard orthogonal array (OA) is chosen for design of experiments and the main influencing factor are determined for each given machining criteria by using Analysis of variance (ANOVA).. In this experiment we were found that order of significant of main parameter decreasing order is M3>N2>O2>P1.(Tool feed(M), Tool speed(N), Tool diameter(O) and Depth of cut (P)).[2]

Avinash A. Thakre had applied Taguchi methodology for optimize the processparameters for surface roughness in CNC milling machine. They have taken Cutting speed, Feed, Depth of cut & Coolant as input parameters. The results showed that coolant flow with the contribution of 60.69% is the most important parameter in controlling the surface roughness followed by spindle speed The optimal parameters for surface roughness was obtained as spindle speed of 2500 rpm, feed rate of 800 mm/min, 0.8 mm depth of cut, 30 lit/min coolant flow.[3]

T. K. Barman et al. have conducted experiments based on Taguchi L 27 orthogonal array to investigate the effect of process parameters such as Cutting speed, Feed and Depth of cut on surface roughness in CNC milling. They selected AISI 1040 steels as work material and CVD coated carbide tools for performing experiments. They concluded that the spindle speed was the most significant factor affecting the fractal dimension. With increase in spindle speed, fractal dimension also increases.[4]

T R Raguramanhave concluded in his project on OHNS steel that Feed rate is a dominating and influencing parameter and optimum milling process parameters for achieving lower surface roughness are 1000 rpm of spindle speed, 0.08 mm of feed rate and 0.8 mm depth of cut. However the OHNS steel plates are probable for manufacturing tools and having good machinability property by using TiAlN coated milling cutter with optimum cuttingparameters.[5]

John D. Kechagiaset al had taken process parameters like core diameter, flute angle, rake angle, peripheral 2 nd relief angle, cutting speed, feed and depth of cut to investigate to expose their Impact on surface finish using Taguchi Methodology. They had taken L 9 orthogonal array to perform experiments. Eighteen pockets were manufactured having different combination of parameters values according to Taguchi L 18 orthogonal array. In order to establish a relationship between the performance measures and the process parameters, a set of additive models was produced. The experimental results shown that the cutting speed, the peripheral relief angle 2 nd , and the core diameters were the most important parameters that significant effect the surface texture indicators and other rest process parameters negligible effect on the surface texture parameters.[6]

3. Objective

- To evaluate optimum cutting condition base on Surface Roughness & MRR.
- Functional relationship of various variables (speed, feed, depth of cut, SR and MRR) will be produced that will be close to the experimental results.
- Perform statistical analysis with TAGUCHI.

4. Experimental Set Up

In this work input parameters considered for milling machine are machining parameters. Input parameters are cutting speed (m/rev), cutting feed(mm/rev), depth of cut(mm). Output parameter is surface roughness. Work piece material is EN31 tool steel. Tool material is 16 BM insert with 25 mm diameter, 30mm diameter used.

Max Stress	850-1000 n/mm^2
Yield Stress	700 N/mm^2 Min
0.2% Proof Stress	680 N/mm^2 Min
Elongation	9% Min
Impact KCV	55 Joules Min
Hardness	248-302 HB

The Chemical Composition &Mechanical properties of EN 19 is

Carbon	0.36-0.44%
Silicon	0.10-0.40%
Manganese	0.70-1.00%
Sulphur	0.040 Max
Phosphorus	0.035 Max
Chromium	0.90-1.20%
Molybdenum	0.25-0.35%

5. Design of Experiment

By using minitab-16 software insert the 3 factors and 3 levels in taguchi design of experiment method I got the following array and design of steps to perform experiment.

- Taguchi Orthogonal Array Design L9(3**3)
- Factors: 3
- Runs: 9

Factors	Level 1	Level 2	Level 3
Speed (mm/min)	1000	1200	1500
Feed (mm/min)	120	150	180
Depth of cut (mm)	0.20	0.25	0.30

The experimental has been performed and reading aretaken for the insert at different cutting sped, feed and depth of cut to find out the surface roughness andmaterial removal rate in each case. These value of cutting speed are utilized and for each of these three value, three different feed rate are employed. Again for each feedrate three different depth of cut are introduces.the valueof surface roughness is measured for every time and theresults show in table.

For 25mm Diameter

Table 1

SR.NO	*Speed (RPM)*	*Feed (mm/min)*	*DOC (mm)*	*MRR (m3/min)*	*SR (µm)*
1	1000	120	0.20	0.0088	1.841
2	1000	150	0.25	0.0106	3.105
3	1000	180	0.30	0.0122	3.998
4	1200	120	0.20	0.0098	1.542
5	1200	150	0.30	0.0108	2.605
6	1200	180	0.25	0.0100	3.505
7	1500	120	0.25	0.0096	1.115
8	1500	150	0.30	0.0112	2.278
9	1500	180	0.20	0.0102	3.368

For 30mm diameter

Table 2

SR.NO	*Speed (RPM)*	*Feed (mm/min)*	*DOC (mm)*	*MRR (m3/min)*	*SR (µm)*
1	1000	120	0.20	0.0029	1.961
2	1000	150	0.25	0.0068	3.145
3	1000	180	0.30	0.0100	4.02
4	1200	120	0.20	0.0031	1.492
5	1200	150	0.30	0.0072	2.675
6	1200	180	0.25	0.0068	3.617
7	1500	120	0.25	0.0054	1.112
8	1500	150	0.30	0.0072	2.289
9	1500	180	0.20	0.0068	3.23

6. Results and Discussion

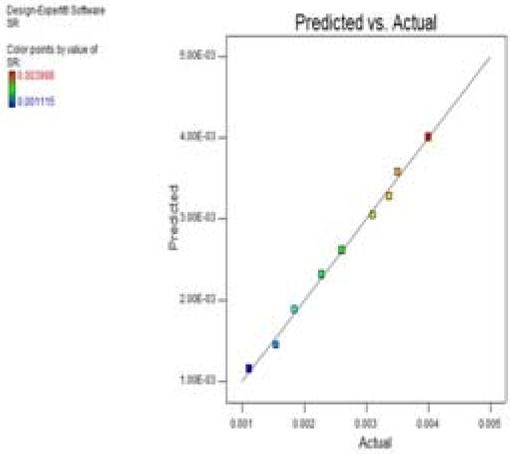


Figure 1

Figure 1 indicates the validity of DOE methodused for performing the experiment as the predictedvalues and the actual values are near to the average line.

Figure 2 as cutting feed increases with increasingcutting speed at depth of cut of 0.25 mm hasreduces the surface roughness. Surface roughness hasobserved minimum at 0.002micron with Cutting feedof 120 mm/min, maximum cutting speed of 1500 rpm.

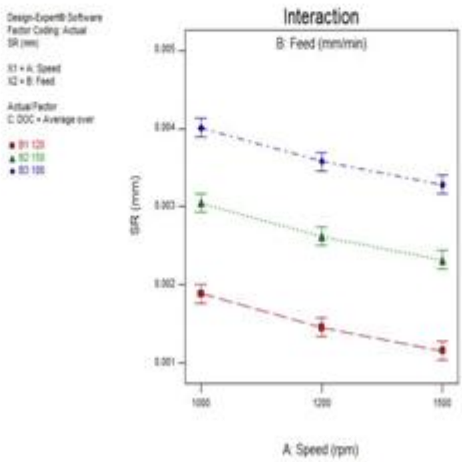


Figure 2

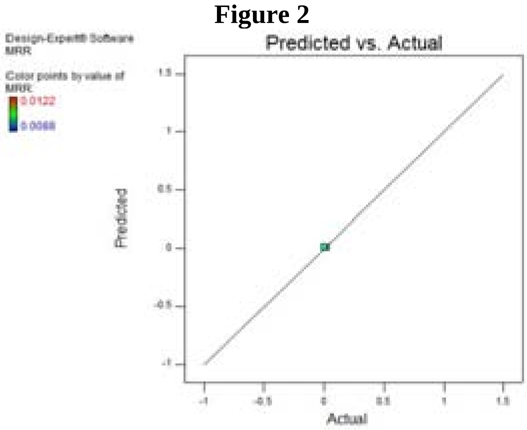


Figure 3

Fig. 3 show the indicates the validity of DOE methodused for performing the experiment as the predictedvalues and the actual values are near to the average line.

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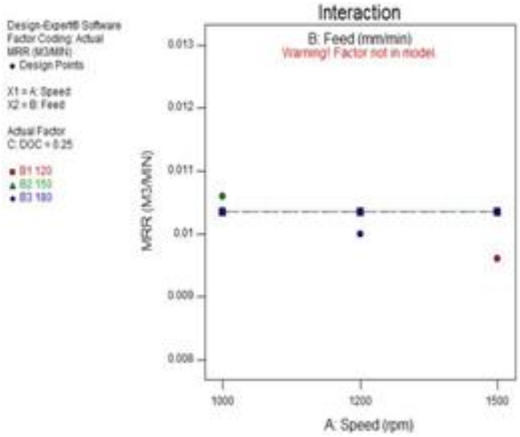

Figure 4

As per the results of ANNOVA the most significant interaction for MRR comes shown above. MRR issignificantly increases from 0.0088m3 /min to 0.0122 m3 /min. as cutting feed is increases from 120 mm/min to 150 mm/min,but as cutting speed decrease 1500 rpm to 1000 rpm.

For 30 mm

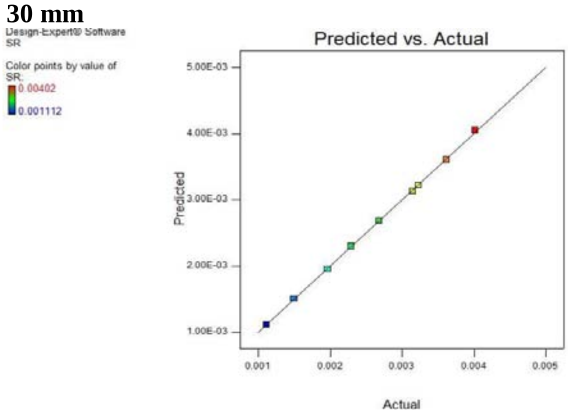

Figure 5

Fig.5 show the indicates the validity of DOE methodused for performing the experiment as the predictedvalues and the actual values are near to the average line.

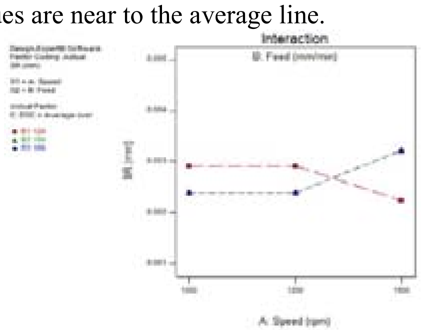

Figure 6

From above graph Surface Roughness value is minimum 0.00022 at100 rpm,150mm/min feed rate &Maximum value 0.0032 at 1500rpm,150 feed.

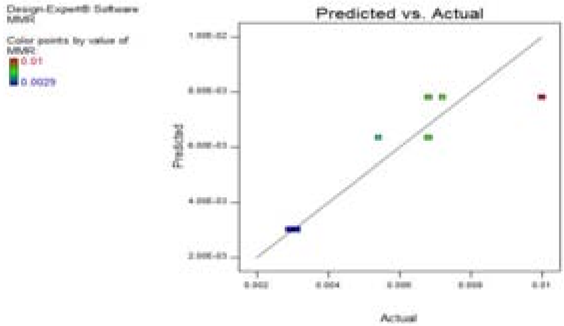

Figure 7

Fig. 7 show the indicates the validity of DOE methodused for performing the experiment as the predictedvalues and the actual values are near to the average line.

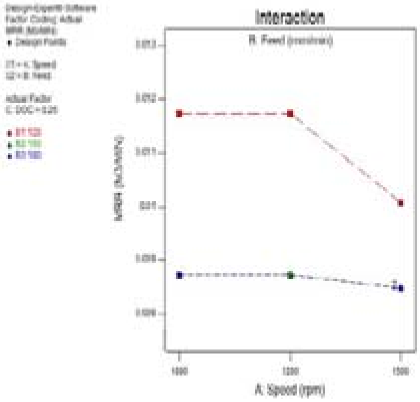

Figure 8

MRR issignificantly increases from 0.0088m3 /min to 0.0122 m3 /min. as cutting feed is increases from 120 mm/min to 150 mm/min,but as cutting speed decrease 1500 rpm to 1000 rpm.

7. Optimization

For 30mm diameter

Constraints

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
A:Speed	is in range	1000	1500	1	1	3
B:Feed	is in range	120	180	1	1	3
C:DOC	is in range	0.20	0.30	1	1	3
SR	is target = 0.0025	0.002	0.003	1	1	3
MMR	maximize	0.0029	0.01	1	1	3

Solutions for 27 combinations of categoric factor levels

Number	Speed	Feed	DOC	SR	MMR	Desirability	w/o Intervals	
1	1200	150	0.30	0.003	0.008	0.616	0.663	Selected

Figure 9

As shown in figure 9 surface finish has set to minimizeand MRR to maximize along with that all otherparameters have set within level range as mention inentire optimization process revile 6 differentsolutions out of that based on maximum desirability of 62% solution with cutting speed of 1200 rpm,cutting feed of 150 mm/min and depth of cut of 0.30 mm. with this set of parameter on existing machine toolone can achieve optimize surface roughness of 3.0 micron and MRR of 0.008 m3 /min.

For 25 mm tool diameter

Constraints

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
A:Speed	is in range	1000	1500	1	1	3
B:Feed	is in range	120	180	1	1	3
C:DOC	is in range	0.20	0.30	1	1	3
SR	is target = 0.0025	0.002	0.003	1	1	3
MRR	maximize	0.0088	0.0122	1	1	3

Solutions for 27 combinations of categoric factor levels

Number	Speed*	Feed*	DOC*	SR	MRR	Desirability	w/o Intervals	
1	1200	150	0.30	0.003	0.010	0.560	0.609	Selected

Figure 10

As shown in figure 10 surface finish has set to minimizeand MRR to maximize along with that all otherparameters have set within level range as mention inentire optimization process revile 6 differentsolutions out of that based on maximum desirability of56% solution with cutting speed of 1200 rpm,cutting feed of 150 mm/min and depth of cut of 0.20 mm. with this set of parameter on existing machine toolone can achieve optimize surface roughness of 3.0 micron and MRR of 0.010 m3 /min.

8. Conclusion

1) In the dissertation work, there are two differentDiameters tool are utilized to get the different surfacequalities of the EN19 tool steel, Out of there 30 mm diameter BM end mill tool is selected based on experimental data,in which it provides better surfacequality compared other with desirability of 62 %.
2) Parametric study shows the effect of differentparameters i.e Speed, feed depth of cut etc. on thesurface roughness.
3) Parametric analysis shows the percentage contribution of individual parameters on surfacequality. The percentage contribution of cutting speed is 64.91%, feed of 31.22% and depth of cut is04.98% for required surface finish.
4) By Full factorial regression analysis, the optimalmachining parameters setting has been obtained forconsidering maximum metal removal rate (0.008 m 3 /min) and minimum surface roughness(3.0 micron at speed =1500 rpm, feed=150 mm/min Depth of cut=0.30 mm. So it reduces the production time aswell as the cost

9. Future Scope

Here, we have selected two cutter having different diameters and of same type. But possible to select different tool of different typeby changing/designing thecutter material to check the surface quality of EN 19.Force analysis can be carried out for further parametric analysis and its effect on surface quality. Surface finish prediction model can be preparedby Artificial Neural Network and it can be helpful toselect the proper parameter to get required surface finishof the EN 19 tool steel.

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