COMPARISON OF DIFFERENT TOOL PATH IN POCKET MILLING

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ABSTRACT
Pocket milling, which involves the removal of all material inside a closed boundary, makes use of Computer Aided Manufacturing (CAM) generated tool paths to remove material to a fixed depth. This project investigates the optimization of Computer Numerical Control (CNC) pocket milling operation parameters for stainless steel 304 using Taguchi methodology and Grey Relational Analysis approach. The operation involves for two different tool path of zig-zag tool path and contour parallel tool path. Surface Roughness (Ra), Material Removal Rate (MRR) where selected as the quality, productivity target respectively. The experiments were conducted based on Taguchi’s L9 orthogonal array by selecting spindle speed (mm/min), feed rate (mm/rev) and depth of cut (mm) at three levels. The grey relational analysis was used to obtain multi objective relation between the machining parameters and performance characteristics. Response table and graphs were used to find the optimal levels of
parameters in CNC pocket milling process and found to be spindle speed 500rpm, feed rate 30mm/rev and depth of cut 0.2mm for zig zag tool path and contour parallel tool path. The confirmation experiments were carried out to validate the optimal results.

**Keywords:** Pocket Milling, MRR, GRA.


1. INTRODUCTION

Milling is an operation of removing excess material by plunging a rotating cutter onto a stationary work piece. Pocket milling is one of the critical operations employed in industrial applications to produce internal recess for accommodating certain parts into it. Such pocket milling operation is widely found in various industrial applications. Accurate pockets are highly essential to have a perfect fit. In recent times Computer Numerical Controlled (CNC) machine tools have been implemented to utilize full automation in milling and they provide greater improvements in productivity, increase the quality of the machined parts and also its require less operator input. Basic drawback found in CNC machine is the production cost.

These pockets may have straight edges, curved edges or a combination of both. 2.5D machining is useful in that tool path control can be achieved easily and quickly, and a wide range of parts can be machined using this method. The tool axis in pocket milling is strictly fixed with respect to the work piece, therefore only the direction of the milling feed can be considered.

Pocket milling has been regarded as one of the most widely used operations in machining. It is extensively used in aerospace and shipyard industries. In pocket milling the material inside an arbitrarily closed boundary on a flat surface of a work piece is removed to a fixed depth from figure 1. Generally flat bottom end mills are used for pocket milling. Firstly roughing operation is done to remove the bulk of material and then the pocket is finished by a finish end mill. Most of the industrial milling operations can be taken care of by 2.5 axis CNC milling. This type of path control can machine up to 80% of all mechanical parts. Since the importance of pocket milling is very relevant, therefore effective pocketing approaches can result into reduction in machining time and cost.

![Figure 1 Pocket milling operation](http://www.iaeme.com/ijmet/index.asp)
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Mayer et al [1] presented a new adaptive spiral cutting method and its implementation in CAD/CAM software applications. A visual basic (VB) macro automatically generates a spiral tool path for the machining of pockets in aircraft wing components. Kariuki et al [2] a review on the work done in generating efficient tool paths optimizing already existing tool paths strategies and optimizing the selection of tool paths during machining is presented. Martin Held et al [3] described a contour offset approach to subdivide 2-D contours into regions for different tools. Dinesh et al [4,5] studied about the machining of AISI 4340 steel and attempted to optimize the input parameters using GRA, RSM and Taguchi methods. A.M.Rameshbabu et al [6] has analysis nanocrystalline equiatomic AlMgNiCrTi high entropy alloy has been successfully synthesized by mechanical alloying and consolidated by spark plasma sintering at 800°C with 50 Mpa pressure. B. Radha Krishnan et al [7] the paper, classification algorithms ANFIS and random forest are used to classify the test data samples for determining the error rate by comparing its classification response with its corresponding actual response.

3. EXPERIMENTAL PLAN

The experimentation was carried on CNC vertical machine having 12 kW power and maximum spindle speed of 8000 rpm. Figure 2 shows experimental setup for machining stainless steel 304 using carbide end mill cutter. All experimental runs were carried out under wet condition. For studying the degree of influence of the process parameters during CNC pocket milling of SS 304. Surface roughness after machining was measured using surface roughness tester. Roughness measuring principle of tester was based on stylus method having 0.5 mm/sec measuring speed.

5. RESULTS AND DISCUSSION

5.1. Taguchi method analysis

The analysis made with the help of software package MINITAB 16. The main effect plots are shown in figure 5.1, 5.2, 5.3, and 5.4. These show the variation of individual response with the three parameters i.e. spindle speed, feed rate and depth of cut. In the plots, the X axis indicates the value of each process parameters at three level and Y axis the response values.

Figure 2 Photographic view of experimental setup for machining
Horizontal line indicates the main value of the response. The main effect plots are used to determine the optimal design condition to obtain the optimum MRR and surface roughness. For **MRR** in “Larger is better” condition.

![Main Effects Plot for SN ratios](image)

**Figure 5.1** SN ratios for MRR (zig zag tool path)

From the figure 5.1 shows the main effect plots for MRR. According to the main effect plots, the optimal condition for higher MRR

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Level</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spindle speed</td>
<td>Level 3</td>
<td>1500 rpm</td>
</tr>
<tr>
<td>Feed rate</td>
<td>Level 3</td>
<td>30 mm/rev</td>
</tr>
<tr>
<td>Depth of cut</td>
<td>Level 3</td>
<td>0.5 mm</td>
</tr>
</tbody>
</table>

**Table 5.1** Optimal parameters for higher MRR (zig zag tool path)

From the table 5.1 the higher MRR can be obtained at the spindle speed of 1500 rpm, feed rate of 30mm/rev and depth of cut of 0.5mm.

For **Surface roughness** in “smaller is better” condition
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Figure 5.2 SN ratios for surface Roughness (zig zag tool path)

From the figure 5.2 shows the main effect plots for surface roughness. According to the main effect plots, the optimal condition for smaller surface roughness.

Table 5.2 Optimal parameters for smaller Ra (zig zag tool path)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spindle speed</td>
<td>500 rpm</td>
<td>1000 rpm</td>
<td>1500 rpm</td>
</tr>
<tr>
<td>Feed rate</td>
<td>10 mm/rev</td>
<td>20 mm/rev</td>
<td>30 mm/rev</td>
</tr>
<tr>
<td>Depth of cut</td>
<td>0.2 mm</td>
<td>0.35 mm</td>
<td>0.5 mm</td>
</tr>
</tbody>
</table>

From the table 5.2 the smaller surface roughness can be obtained at the spindle speed of 1500 rpm, feed rate of 20mm/rev and depth of cut of 0.5mm.

6. CONCLUSION

The approach to this paper is the analysis of CNC milling parameters to achieve optimized values of above said output parameters based on experimental results of machining time, material removal rate and surface roughness majorly with respect to speed, feed rate and depth of cut. The evaluation has done for machining by Taguchi design.

The feed rate is a dominant parameter that the surface roughness increases rapidly with the increase in feed rate and decreases with an increase in spindle speed and machining time decreases with an increase in feed rate and increases with decrease in feed rate whereas considering the same depth of cut. The performance evaluation has been done for experimental results with Taguchi design.

From the Taguchi design analysis the optimized parameters are chosen from GRA, the spindle speed is 500rpm, feed rate 30mm/rev and depth of cut 0.2mm are the best parameters for both zig-zag and contour parallel tool path in CNC pocket milling operation.
The maximum MRR can be obtained by increasing the depth of cut. The type of chip formation is also based upon the selection of feed, speed and depth of cut. The spindle speed of the machine is not influenced with the machining time. This work can be extended to other pocket geometries using more tool paths with different cutting tools and work piece materials. The same problem can be elaborated with optimization technique to find the optimal solutions and the computer-aided process planning can also be adopted.

REFERENCES


