EXPERIMENTAL INVESTIGATION OF EFFECTS OF CUTTING PARAMETER BY DIFFERENT CUTTING PATHS OF FACE MILLING OF WORK PIECE

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Abstract— In end milling which is often encountered in die manufacture, the demand is to narrow the interval between the surface roughness values obtained at finish milling and the surface roughness values will be met by further finishing operations as far as possible. The implementation and selection of cutting path strategies with appropriate cutting parameters have significant effect on surface roughness. The effect of every single variable on surface roughness is known, however, what kind of results is revealed in their combinations cannot be clearly estimated. The aim of this study is, first, to investigate optimum cutting characteristics of OHNS steel on cutting path strategies using high-speed steel end mills. The cutting parameters considered are spindle speed, feed rate, and depth of cut. The second aim is to identify the effects of cutter path strategies when employing in face milling. The both aims will be addressed by means of using Taguchi parameter design.

Keywords-end milling, cutting path strategies, surface roughness, Taguchi method, ANOVA

I. INTRODUCTION

Milling is the name given to the machining process in which the removal of metal takes place due to the cutting action of the revolving cutter when the work is fed past it. Milling machine has acquired an indispensable position in all modern production workshops. Its specific significance lies in its capability to perform a large number of operations which no other single machine tool can perform. In the milling process, many operating parameters like feed rate, tool speed, depth of cut, step over, tool diameter etc. influence on the cutting parameters of surface finish of the work piece, tool wear and dimensional accuracy of the work piece. Most influencing factor is that the cutter tool path strategies in the face milling process. There are many cutter tool paths strategies used in the milling process given as one way, back forth, zig-zag, true spiral, constant overlap spiral, parallel spiral, parallel spiral clean corner, high speed etc. These cutter tool paths strategies very effective on the producing the surface finish of the work piece. The factor of cutter path strategies greatly influenced to the surface finish of the work pieces. The different cutter path strategies generate the different surface finish on the work piece. In any machining operations, the surface finish of the work piece is most desirable outcome. The operating parameters like feed rate, depth of cut, cutting speed, spindle rpm, etc. significantly influence to surface roughness of work piece. Proper selection can lead to substantial savings in machining time, improvement of work piece surface quality and improvement in tool life, thereby leading to overall cost reduction and higher productivity. **Abhishek Kumar Saroj** et.al [9] has performed on the Simulation of Tool Path for Machining Sculptured Surfaces on CNC end milling process. They represent the zigzag path strategy takes minimum time for roughing operation and broken zigzag path strategy takes minimum time for finishing surface. **Abhishek Kumar Saroj** et.al [3] has performed on the Analysis of Different Parameters on Tool Path for Machining Sculptured Surfaces. They use seven different tool path strategies like zigzag, constant overlap spiral, parallel spiral, parallel spiral clean corners, high

speed, true spiral and one way for machining of particular model taking different machining time as shown in figure 1 given below.
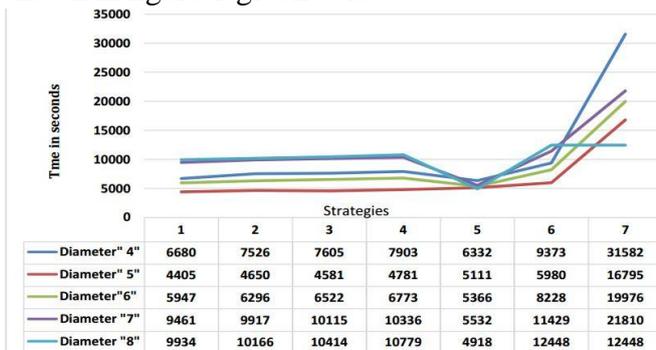

	1	2	3	4	5	6	7
Diameter" 4"	6680	7526	7605	7903	6332	9373	31582
Diameter" 5"	4405	4650	4581	4781	5111	5980	16795
Diameter"6"	5947	6296	6522	6773	5366	8228	19976
Diameter"7"	9461	9917	10115	10336	5532	11429	21810
Diameter"8"	9934	10166	10414	10779	4918	12448	12448

Figure 2.1: Relationship between Times spent in Machining to Different Strategies

That conclude that (1)Tool path generations strategies for roughening and finishing operation directly depend upon the type of surface and the machining time obtain from strategies are different for different diameter of tool used, for an appropriate diameter of tool gives minimum machining time.(2)The zig-zag motion strategy is tacking least machining time. But it is not applicable for all surface. High speed strategy also give minimum machining time but for this strategy defects are generated.

Milan D. Selvan et.al [8] performed in Mild Steel work piece of size (55 mm x 21 mm x 21 mm). The processing of the job was done by three zinc coated carbide tools inserted into a face miller of 25 mm diameter. The machining parameters considered were Number of passes (P), Depth of cut (dc), Spindle speed (N), and Feed rate (f). That concluded by experiment the effects of those machining parameters of number of passes, depth of cut, spindle speed and feed rate on surface roughness is evaluated & the optimum cutting condition for minimizing the surface roughness is determined. **J. Caldeirani Filho** et.al [7] has established the significant influence of cutting condition such as cutting speed, feed rate per tooth, feed velocity on the tool life, tool wear and surface finish in the face milling operation by performing number of design of experiments. They conclude that Values obtained for average surface roughness were always below the expected values. **Cevdet Gologlu** et.al [1] has performed significant conclusions of the studies on the effects of cutter path strategies on surface roughness of pocket milling of 1.2738 steel based on Taguchi method are as follows. According to result obtained, the most influential effects within the range of specified cutting conditions are feed rate for one direction and spiral cutter path strategies, and depth of cut for back & forth cutter path strategy. Confirmation experiments at optimal conditions were carried out. The outcomes for one direction and back and forth cutter path strategies were better than predicted results. However, the outcome for spiral cutter path was not at the desirable level. One of the reasons was that the chip stayed between the cutter and the periphery of the pocket could worsen the surface. **J.A.Ghani** et.al [6] has performed on the cutting parameters in the end milling when machining hardened steel AISI H13 with TiN coated P10 carbide insert tool under semi-finishing and finishing conditions of high speed cutting. The milling parameters evaluated are cutting speed, feed rate and depth of cut. The analysis of the result shows that the optimal combination for low resultant cutting force and good surface finish are high cutting speed, low feed rate and low depth of cut. Using Taguchi method for design of experiment (DOE), other significant effects such as the interaction among milling parameters are also investigated. **Bo H.Kim** et.at [4] was purposed a machining time model that consider the acceleration and declaration of the CNC machines. Using proposed model, compare the machining efficiency of the tool paths currently employed in molds and dies manufacturing-three types of direction parallel tool path (one way path, pure zig-zag path and smooth zig-zag path) and contour parallel tool path. From above tool paths smooth zig-zag is most efficient and effective regardless of the feed rate and the tool path interval. **Khairul Akmal Shamsuddin** et.at [10] was compared milling cutting path strategies for thin- walled aluminum alloys fabrication and concluded that the best machining strategies to achieve good surface roughness of upper and lower areas is parallel spiral strategy which is better than the other machining strategies. One of the reasons was that the chip stayed between the cutter and the periphery of the pocket could worsen the surface. **Shaghayegh Shajari** et.at [11] was performed on the Influence of Tool Path

Strategies on Cutting Force and Surface Texture during Ball End Milling of Low Curvature Convex Surfaces. They concluded that resultant cutting force is the highest when using spiral tool path as a consequence of tool-chip contact area. As a result, poor surface texture is obtained regardless of the cutting condition. Overall, the use of spiral cutter path strategy on finish milling of low curvature convex surfaces is not advisable at all.

II. METHODOLOGY

In order to achieve the objective of this experimental work, OHNS steel, which is commonly used in die manufacturing industry, was chosen. The tests were performed on a Vertical CNC machining center, HAAS VF-1, with 3-fluted end mills of diameter 10 mm, helix angle $30°$ (DIN844/BN), having no tooth tip radius. After rough machining of the pockets with the sizes of 55 mm×50 mm, the finish pocket milling operations with the determined cutting conditions were carried out. The different cutters were employed for each of cutter path strategies.

To evaluate which cutting parameters affect the surface roughness in face milling a number of experiments have been conducted for each of cutter path strategies. Spindle speed, feed rate and depth of cut were determined as controllable cutting parameters to be used in the experiments and each parameter having three levels of values. Selecting of cutting input parameter ranges depends on variety of conditions such as cutter, work piece material, cutting strategy, coolant, etc. However, here cutting speed and feed rate values are mostly manufacturer dependent. The ranges are determined by the cutter producers taking mainly cutter and work piece materials into consideration. So the low and high ranges of these parameters have taken from firm catalogue. The amount of depth of cut is determined based on a typical finishing operation for which roughing operation is let to leave about 0.1-0.3 mm material on the surface. Ranges of step over parameter are function of tool diameter. The tool decided has 10 mm of diameter, therefore step over values, smaller than the half of tool diameter, here step over (4.9 mm) is constant decided. Lastly, as it is known in Taguchi experimental design minimum number of levels of process parameters are two and the interval between the levels must be equal (Taguchi et al., 1989). Therefore, all process input parameters have been ranged in three levels considering the low and high limits. By using Taguchi method here L27 orthogonal array employed for experimentation.

III. CONCLUSION

The surface roughness of the each experiment measured by the Mitutoyo Surftest SJ-400 instrument and results from that instrument analyzed by ANOVA method.

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