International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 12, Issue 12 [December. 2023] PP: 92-95

Toolpath Strategy in the process of milling multiple enclosed pockets

Tran Phuong Thao[1], Le Thi Nga[1]
1. Thai Nguyen University of Technology
thaodaotao@tnut.edu.vn
lengadaotao@tnut.edu.vn

Abstract
The cutting-edge machining technique known as CNC milling, or Computer Numerical Control milling, has completely changed the industrial industry. Precision is crucial in CNC milling, and it is attained by integrating computer control systems into milling machines. The process starts with a digital model that defines the dimensions and requirements of the required part or component. This model is commonly made using Computer-Aided Design (CAD) software. The next step is translating this digital model into machine-readable code, usually in the form of G-code. The CNC milling machine follows a set of instructions called G-code as it completes the milling process. To enhance productivity and the quality of the machining process, the selection of toolpath strategy is crucial, especially in milling operations. In this paper, we address the investigation of the impact of toolpath strategy selection on the efficiency of the milling process, as demonstrated through milling time, particularly in the case of machining closed pockets.
Keywords: *CNC machining, CNC, Milling.*

Date of Submission: 06-12-2023 Date of acceptance: 19-12-2023

I. Introduction

By employing computer numerical control (CNC) technology, material can be removed from enclosed areas or pockets of a workpiece during the CNC pocket milling process. This sophisticated milling method makes it possible to produce complex and delicate pieces with exact control and automation. Using computer-aided design (CAD) software, a digital model is created at the start of the process. This model is used as a guide to grind material using a CNC machine. This computerized design is interpreted by the CNC machine, which then precisely performs the milling operation.

During pocket milling, material is removed from the inside of the workpiece by means of a cutting tool that follows a predetermined toolpath. This method is frequently employed in the fabrication of parts containing cavities, slots, and pockets. Among the benefits of CNC pocket milling are:

Accuracy: The unmatched accuracy of CNC machines guarantees that the machined pockets adhere precisely to the digital design's parameters.

Automation: The CNC process requires very little manual intervention because it is highly automated. This increases productivity and lowers the possibility of mistakes.

Complex Geometries: CNC pocket milling is an excellent method for producing items with complicated geometries. It makes it possible to produce parts that would be difficult or impossible to produce using conventional machining techniques.

Repeatability: After a CNC program is created, it can be used again to create parts that are the same or similar. For mass production, this reproducibility is essential.

Efficiency: The manufacturing process operates more efficiently because to the automation and accuracy of CNC pocket milling. Shorter production times translate into cheaper costs as a result.

To sum up, CNC pocket milling is a flexible and effective way to consistently and precisely machine complex parts. It is essential to contemporary manufacturing procedures in a number of industries.

1. Toolpath Generation in CAM

In the milling process, there are many parameters that affect the productivity and quality of the process. Machining time determines the productivity of the process, so optimizing machine running time is very important.

Cutting Speed: This is the speed at which the cutting tool moves through the material. It directly affects the milling time, as increasing the cutting speed may reduce milling time but requires the cutting tool to withstand higher speeds [1-3].

Feed Rate: The speed at which the cutting tool moves vertically or horizontally. Increasing the feed rate can reduce milling time, but it must ensure the quality of the machined surface.

Depth of Cut: This is the depth to which the cutting tool penetrates the material in each cutting cycle. A larger depth of cut can reduce milling time but also affects the durability of the cutting tool.

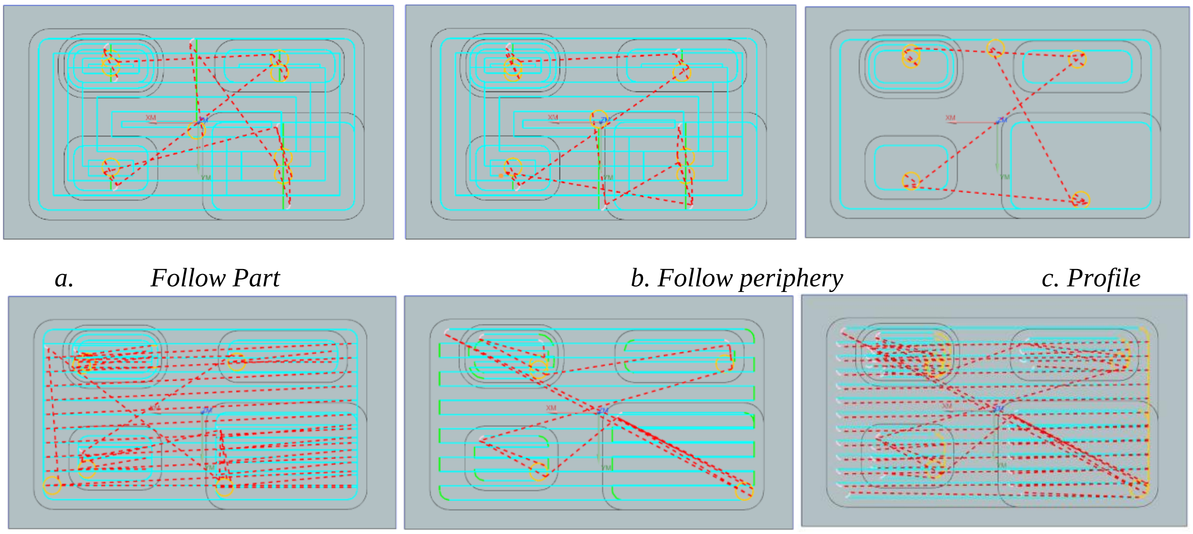
Number of Passes: The number of times the cutting tool needs to move through the material to complete the milling process. A fewer number of passes may increase milling time but improve surface quality.

Tool Geometry: The design of the cutting tool, cutting angle, and the number of cutting edges all influence milling time and surface quality.

Material Type: The material to be milled also determines milling time. Harder materials often require lower cutting speeds to ensure machining quality.

CNC Machine Properties: The capabilities of the CNC machine, especially the spindle power, also determine milling time.

When adjusting these parameters, finding an appropriate balance is crucial to ensure machining quality, cutting tool durability, and milling time efficiency.



a. Follow Part *b. Follow periphery* *c. Profile*

d. Zig with contour *e. Zigzag* *f. Zig*

Fig 1. Some type of toolpath in milling

We simulate the process on a component material parameters (Table 1, 2) as given below, in order to experiment with choosing an optimal toolpath technique.

Table 1. *Chemical composition of alloy steel En24* [4].

Element	Carbon	Silicon	Manganese	Phosphorus	Chromium	Molybdenum
Symbol	C	Si	Mn	P	Cr	Mo
Content%	0.36-0.44	0.11-0.31	0.45-0.71	0.036	1.02-1.47	0.23-0.34

Table 2. *Mechanical and physical properties of En24 alloy steel.*

Tensile Tension	855-1000 N/mm^2
Yield Stress	675 N/mm^2
Elongation	13.3%
Impact Strength	54 J
Hardness	Hardness
Elastic Modulus	207.3×109

Machining time has a direct impact on the effective productivity of the machining process, both in CNC and conventional machining [5-7]. The machine's power consumption, tool life, wear, and manufacturing process advancement are all largely determined by the machining time [8–10]. The choice of toolpath technique has a direct effect on machining time, from approach to retract after cutting. The apparatus offers users multiple appropriate choices based on the features of the machined component. Additionally, the machined material, the intended cutting mode, and the technological features of the current equipment must all be taken into consideration when selecting the toolpath.

II. Results

The users are suggested to apply different toolpath tactics in the mutil close pocket milling procedure. We routinely examine the machining times of various toolpath techniques under varied cutting conditions for pocket milling, such as the part used in this study.

Table 3. *Process variables and their Ranges.*

S1.No	Process Parameter		
	Cutting speed (RPM)	*Feed (mm/Min)*	*Depth of cut (mm)*
1	2800	250	0.8
2	3000	250	1.0
3	3200	250	1.2

The machining time for each cutting process is based on the simulation results.

S1.No 1

Toolpath	*Cutting time (mm:s)*
Follow part	43: 23
Follow periphery	52:05
Profile	62:03
Zig	49:07
Zig zag	55:05
Zig with contour	40:06

S1.No 2

Toolpath	*Cutting time (mm:s)*
Follow part	38: 36
Follow periphery	47:21
Profile	58:06
Zig	55:40
Zig zag	43:17
Zig with contour	56:42

S1.No 3

Toolpath	*Cutting time (mm:s)*
Follow part	46:18
Follow periphery	45:33
Profile	56:16
Zig	62:09
Zig zag	51:32
Zig with contour	63:31

It is clear from the machining process results that every toolpath strategy and cutting condition has a corresponding specific machining time. These results allow us to conclude that the toolpath strategies referred to as "Follow Part" and "Follow Periphery" may be more beneficial when it comes to freeform surface machining.

The 'Follow component' technique involves the cutting tool following the shape of the component or workpiece that is being machined. Usually, it entails precisely following the contour of the part while milling along its edges or borders. "Follow Part" is the recommended option when precise measurements and detailed features are essential since it may be used to create complex shapes and profiles with accuracy. Conversely, the 'Follow Periphery' method gives priority to machining around the outside edge or perimeter of the workpiece or freeform surface. This toolpath remains close to the outside edges rather than going through the part's complex inner curves. Because of its more straightforward movements compared to "Follow Part," this strategy is frequently chosen when speed and material removal rate are the most important factors.

A number of unique machining criteria, such as component shape, material properties, desired surface finish, and machining time factors, will determine which of these two procedures is best. 'Follow Periphery' is selected when quick material removal along the outer borders is the goal, and 'Follow Part' is usually used for sections with complex inner features. When making this choice, machinists frequently have to weigh efficiency against accuracy, considering the trade-offs that come with different toolpath tactics.

III. Discussion

The comparative findings show that various parameters, including component geometry, machine specifications, cutting conditions, and toolpath type selection, influence the best toolpath selection. Using comparable techniques and strategies, we can perform evaluations to determine which toolpath strategy is best for a particular machining process. It is important to remember that different technological situations and optimization objectives could lead to different selection criteria. Still, the research findings in this work can be very helpful to engineers and technologists when they are making decisions about which toolpath technique to use for multipocket milling machining.

Acknowledgment

This work was supported by Thai Nguyen University of Technology

References

[1]. Kunwoo Lee, Tae Ju Kim* and Sung Eui Hong - Generation of toolpath with selection of proper tools for rough cutting process - Computer-Aided Design, 26(11), 822–831.

[2]. F. Y. Han, D. H. Zhang, M. Luo & B. H. Wu - Optimal CNC plunge cutter selection and tool path generation for multi-axis roughing free-form surface impeller channel - The International Journal of Advanced Manufacturing Technology volume 71, pages1801–1810 (2014).

[3]. Lazoglu, C. Manav, Y. Murtezaoglu - Tool path optimization for free form surface machining - sciencedirect CIRP Annals Volume 58, Issue 1, 2009, Pages 101-104.

[4]. R. Venkatesh, V. Vijayan, A. Parthiban, T. Sathish, S. Siva Chandran - COMPARISON OF DIFFERENT TOOL PATH IN POCKET MILLING - International Journal of Mechanical Engineering and Technology Volume 9, Issue 12, December 2018, Pages 922-927, Page Count – 6.

[5]. Z.Y. Zhao, C.Y. Wang, H.M. Zhou, Z. Qin - Pocketing toolpath optimization for sharp corners - Journal of Materials Processing TechnologyVolumes 192–193, 1 October 2007, Pages 175-180.

[6]. V. Giri, D. Bezbaruah, P. Bubna, A. Roy Choudhury - Selection of master cutter paths in sculptured surface machining by employing curvature principle - International Journal of Machine Tools and ManufactureVolume 45, Issue 10, August 2005, Pages 1202-1209.

[7]. Jinting Xu, Yukun Ji, Yuwen Sun, Yuan-Shin Lee - Spiral Tool Path Generation Method on Mesh Surfaces Guided by Radial Curves – Journal of Manufacturing Science and Engineering Jul 2018, 140(7): 071016 (13 pages).

[8]. Yu-an Jin, Yong He, Jian-zhong Fu, Wen-feng Gan , Zhi-wei Lin - Optimization of tool-path generation for material extrusion-based additive manufacturing technology - Additive ManufacturingVolumes 1–4, October 2014, Pages 32-47.

[9]. James E. Bobrow - NC machine tool path generation from CSG part representations - Computer-Aided DesignVolume 17, Issue 2, March 1985, Pages 69-76.

[10]. Ming Luo, Dongqing Yan, Baohai Wu & Dinghua Zhang - Barrel cutter design and toolpath planning for high-efficiency machining of freeform surface - The International Journal of Advanced Manufacturing Technology volume 85, pages2495–2503 (2016).