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Investigation on the Impact of Cutting Approach Angle on Processing Duration in Flat Milling Processes

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Abstract
Milling is a versatile and widely used machining process that involves the removal of material from a workpiece using rotary cutters. It is employed in a variety of industries to create parts with complex geometries, precise dimensions, and fine surface finishes.This report investigates the influence of the cutting angle on machining time during flat milling processes. The study evaluates how different cutting angles affect machining efficiency and surface quality. The findings aim to provide insights into optimizing cutting parameters to enhance productivity and product quality in manufacturing.
Keywords: *Milling, Flat Milling, Machining time…*

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I. Introduction

Milling plays a vital role in the manufacturing industry by utilizing rotary cutters to eliminate material from a workpiece. This versatile process is indispensable for producing components with accurate dimensions, intricate shapes, and smooth surface textures [1-3]. There are two main types of milling operations: face milling and peripheral milling, each tailored for specific purposes and applications.

Face Milling:

Face milling is a machining process where the cutting action mainly occurs at the corners of the milling cutter, which is placed perpendicular to the workpiece surface. It is a technique utilized to create flat surfaces and is frequently used for finishing tasks.

Peripheral Milling

Peripheral milling involves cutting along the circumference of the cutter, with the cutter's axis running parallel to the surface being machined. This method is particularly suitable for creating deep slots, threads, and gear teeth, as it ensures precise dimensional control.Components of a Milling Machine

Spindle: The spindle holds and rotates the milling cutter, providing the necessary power and torque for cutting.

Worktable: The worktable supports the workpiece and can move in multiple directions (X, Y, and Z axes) to position the material accurately under the cutter.

Cutting Tool: Milling cutters come in various shapes and sizes, each designed for specific applications. Common types include end mills, face mills, and ball nose cutters.

Control System: Modern milling machines often feature computer numerical control (CNC) systems for precise control over the machining process, enabling complex and repetitive operations with high accuracy.

Flat milling is a frequently utilized machining technique for producing flat surfaces on workpieces. The rake angle, also known as the cutting angle, of the milling tool plays a crucial role in determining cutting forces, tool longevity, and the duration of the machining process [4-6]. This study delves into the correlation between the cutting angle and machining time in order to pinpoint the most effective conditions for enhancing milling operations.

Prior studies have indicated that the angle at which cutting is done has a notable effect on the dynamics of machining. Higher cutting angles are linked to lower cutting forces and enhanced tool longevity, whereas lower cutting angles may boost cutting speed but also raise the risks of tool wear and vibration. Research utilizing CNC milling machines has proven that fine-tuning the cutting angle can result in superior surface quality and reduced machining durations [7-9].

II. Methodology

The research comprised a sequence of trials conducted with a CNC milling machine. Different cutting angles (ranging from 0° to 60°) were examined on a regular flat milling cutter. The workpieces utilized were constructed from medium carbon steel. Essential factors like spindle speed, feed rate, and depth of cut were maintained at a consistent level to analyze the impact of the cutting angle. The duration of machining for each angle was documented, and the surface quality was evaluated through a surface roughness tester.

To experiment with selecting an appropriate toolpath strategy, we simulate the process on a component with dimensions (Fig 1) and material properties (Table 1, 2) as listed below.

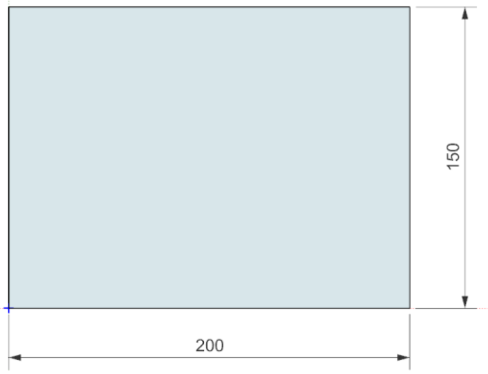

Fig 1. The dimension of part

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

Element	Carbon	Silicon	Manganese	Phosphorus	Chromium	Niken
Symbol	C	Si	Mn	P	Cr	Ni
Content%	0.42-0.50	0.16-0.36	0.50-0.80	0.04	0.25	0.25

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

Tensile Tension	1584 MPa
Yield Stress	1487 MPa
Elongation	24%
Hardness	55 max
Elastic Modulus	210 GPa

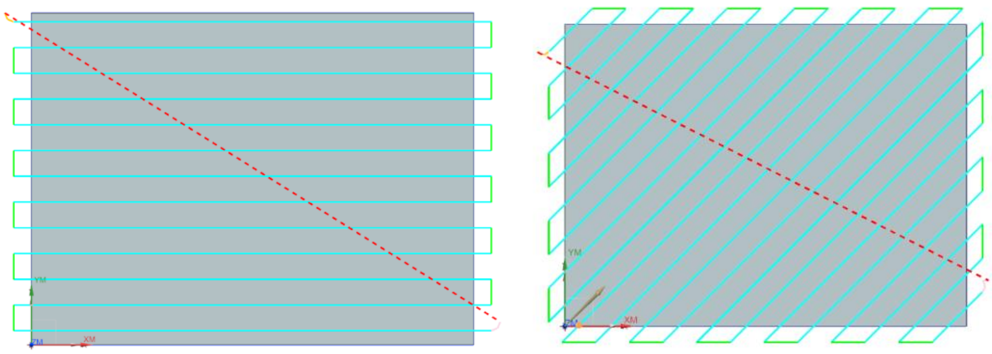

Fig 2. *Cutting approach angle*

III. Results

The simulation of the flat milling process was conducted under the same technological conditions (cutting speed, feed rate, depth of cut...). The results indicated a clear correlation between the cutting angle and machining time:

Cut Angle (Degree)	*Cutting time (mm:s)*
0	35: 36
10	40 : 52

15	40 : 44
25	40 : 44
35	40 :04
45	40 : 21
60	40 : 09

Based on the results obtained, we observe that within certain limits, the machining time increases as the cutting approach angle increases. However, beyond a certain threshold, the machining time does not increase further and may even decrease. The range of these limiting angles will depend on the size and orientation of the workpiece.The findings confirm that the cutting angle is a critical factor in flat milling. Large cutting angles are advantageous for prolonging tool life and achieving high-quality surfaces, but they may not be suitable for time-sensitive operations. Conversely, small cutting angles can expedite machining processes but at the cost of higher tool wear and suboptimal surface quality. Medium cutting angles emerge as a practical compromise, offering efficient machining times and satisfactory surface quality.

IV. Discussion

Optimizing the cutting angle in flat milling is essential for balancing machining time, tool life, and surface quality. For operations prioritizing speed, small cutting angles may be preferable, while larger angles are better for durability and finish. Medium angles provide a versatile solution for most milling applications. Future work should explore the impact of other parameters, such as feed rate and cutting speed, in conjunction with cutting angles to develop comprehensive optimization strategies.

Acknowledgment

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