

# A Milling Technique for the Fabrication of Mechanical Parts with Thin-Walled Ribs

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## ABSTRACT

**Machining is a fundamental manufacturing process deployed to produce a workpiece with precise dimensions and high surface quality, using machine tools. In mechanical components, support ribs are widely applied to increase structural strength while minimizing overall weight. However, due to their thin-walled nature, support ribs are prone to deformation during machining, making the process challenging in terms of maintaining dimensional accuracy and surface integrity. This paper focuses on developing an optimized milling technique specifically tailored for the mechanical parts containing thin-walled support ribs. A detailed milling strategy is proposed, which includes the selection of the appropriate cutting parameters, such as spindle speed, feed rate, and depth of cut, and the use of specialized cutting tools designed to minimize vibration and deflection. The experimental validation shows that the machined parts meet all the required technical specifications in terms of dimensional precision and surface finish, demonstrating the effectiveness and practicality of the proposed milling strategy.**

*Keywords-milling; ribs; thin-walled*

## I. INTRODUCTION

Machining involves shaping, cutting, and finishing a workpiece using machine tools to achieve the desired dimensions and surface quality. It encompasses various techniques and processes, such as turning, milling, drilling, grinding, and broaching [1-8]. Machining processes are critical in the manufacturing industry because they provide the precision and versatility needed to create complex parts and components with various applications, from automotive and aerospace to medical devices and consumer products. Support ribs are commonly used in the machine parts to enhance their structural integrity without significantly increasing their weight [9-12]. They help distribute loads, reduce stress concentrations, and prevent deformation. However, they are inherently thin-walled structures, making their machining particularly difficult [13-16]. The main challenges arise due to low rigidity, high deflection, vibration, and heat accumulation during cutting [17-20]. To address these challenges, various strategies have been developed, including optimizing the cutting parameters,

employing high-speed machining, and utilizing advanced fixture designs to improve stability. Additionally, selecting the appropriate cutting tools with sharp edges and low cutting forces can help reduce the heat accumulation and tool deflection; therefore enhancing the precision of the final machined component.

This paper presents a technological process for milling a product with a thin-walled ribbed structure, proposing a suitable milling strategy, cutting tools and parameters, and providing experimental results to demonstrate the efficiency of the proposed method.

## II. MATERIALS AND METHODS

The mechanical cylinder is a machine part that has one or more holes, whose center lines are parallel to each other or at an angle, as shown in Figure 1. One of its primary functions is to transform the linear motion into rotary motion, enabling an efficient power transmission between different machine elements. This capability is essential in applications, such as



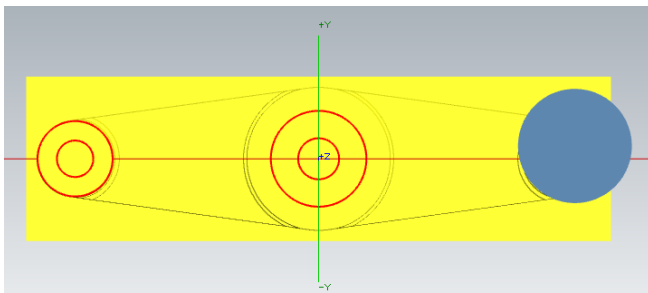


Fig. 4. Face milling to rough out the part.

The semi-finishing face milling process (Figure 5) is also carried out with a 10 mm diameter end mill, but the surfaces are machined to a higher precision, according to the following parameters: a feed rate of  $F = 500$  mm/min, a cutting speed of  $V = 5000$  rev/min, a depth of cut of  $a_p = 2$  mm, and a step-over width of  $a_e = 0.1$  mm. These optimized parameters help refine the surface quality while maintaining dimensional accuracy, preparing the workpiece for the final finishing process.

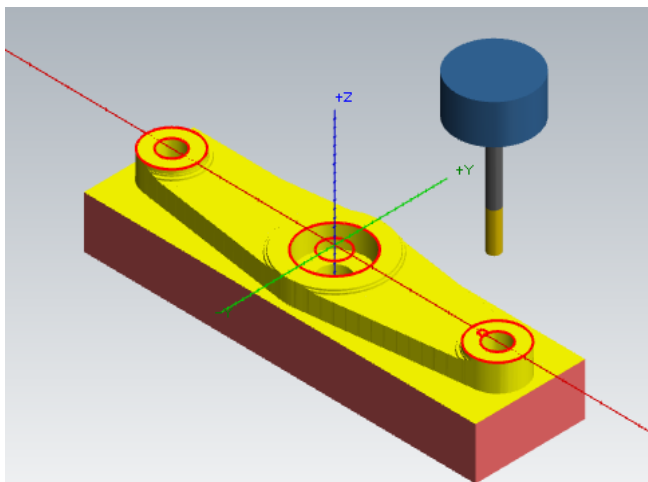


Fig. 5. Semi-finishing face milling.

With the finishing milling process (Figure 6), the part achieves the final, precise dimensions and surface quality, using a 10 mm diameter end mill. The cutting parameters are carefully selected to achieve high surface quality and precision. These are: a feed rate of  $F = 2500$  mm/min, a cutting speed of  $V = 6000$  rev/min, a depth of cut of  $a_p = 0.2$  mm, and a step-over width of  $a_e = 0.1$  mm. These parameters minimize the cutting forces and vibrations, ensuring a smooth surface finish and an accurate dimensional control.

The next step is the rough milling of the remaining face (Figure 7), with a 10 mm diameter end mill. The cutting parameters for this operation are: a feed rate of  $F = 4000$  mm/min, a cutting speed of  $V = 4200$  rev/min, and a depth of cut of  $a_p = 0.5$  mm. These settings are optimized for an efficient material removal while maintaining machining stability and minimizing the tool wear.

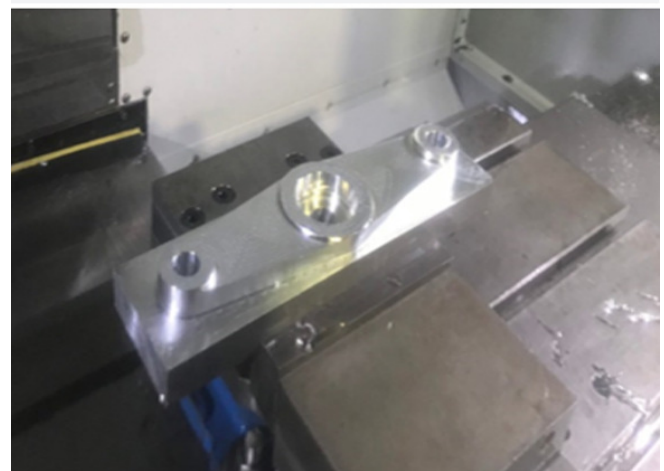
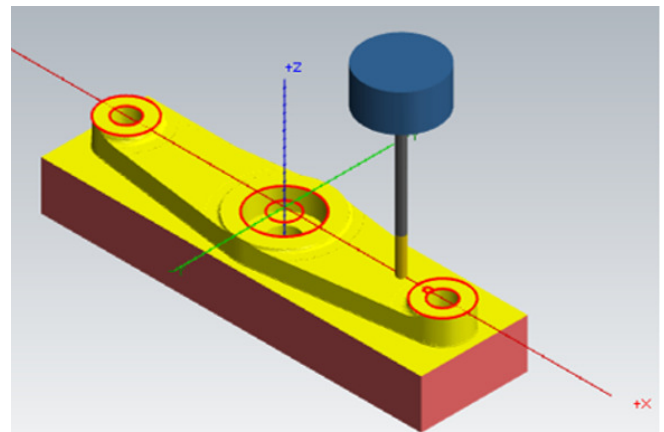


Fig. 6. Finishing face milling.

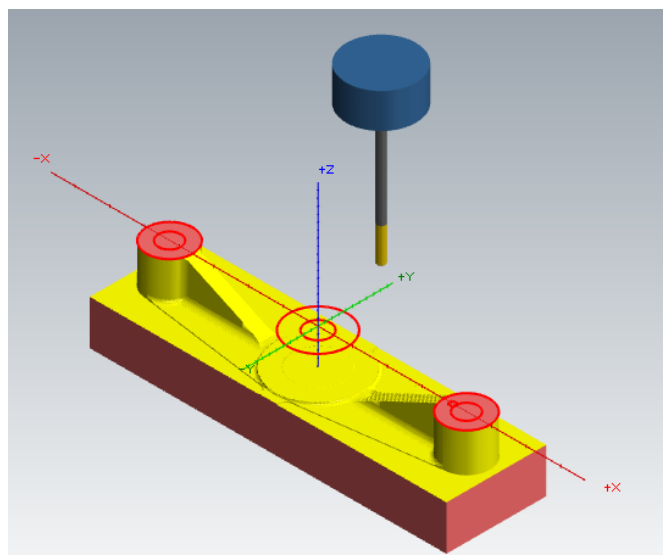


Fig. 7. Rough milling of the other face.

The end milling process (Figure 8) for the thin-walled ribbed structures is a critical step that requires high precision to avoid the deformation of the thin ribs, utilizing a 4 mm diameter end mill. The cutting parameters are: a feed rate of

$F = 600$  mm/min, a cutting speed of  $V = 6000$  rev/min, a depth of cut of  $a_p = 2$  mm, and a step-over width of  $a_e = 0.1$  mm.

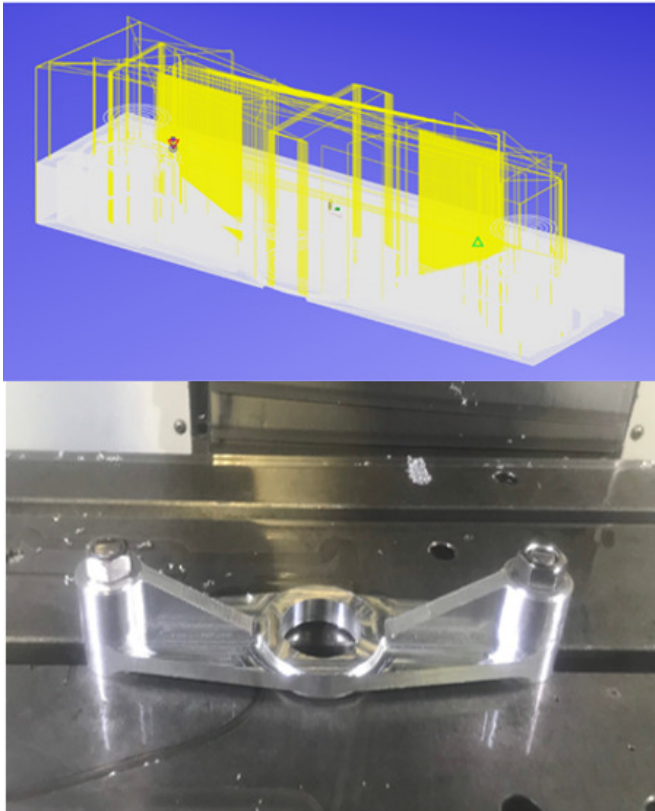


Fig. 8. Thin walled ribbed end milling.

#### IV. RESULTS AND DISCUSSION

The finished mechanical product (Figure 9) meets the technical requirements specified in the engineering drawing, as illustrated in Figure 3. After machining, the actual hole dimensions are carefully measured to verify compliance with the specified tolerances, ensuring minimal deviation and consistency across all produced parts.

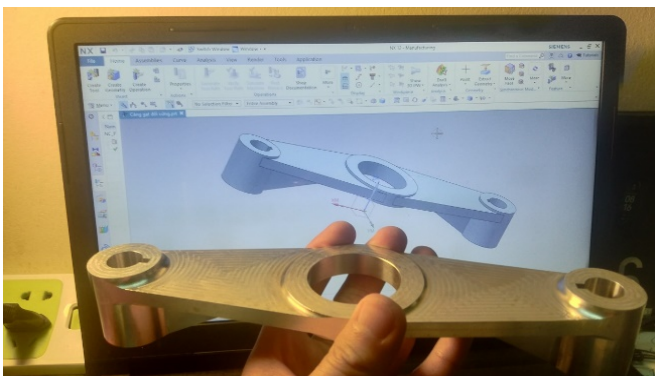


Fig. 9. The completed mechanical product.

The thickness of the key surfaces after machining, including 8 mm and 12 mm, is maintained within the required tolerances, ensuring structural integrity and compatibility with the mating components. Additionally, the 10 mm rib reinforcement thickness is machined according to exact specifications.

The parallelism between the centerlines of the holes is precisely controlled within 0.05 mm, ensuring an accurate alignment and reducing the potential assembly errors. This level of precision helps maintain the smooth operation of the moving parts and prevents the excessive wear or misalignment.

The perpendicularity between the end surfaces and the hole center is maintained within 0.05 mm, ensuring that the holes are correctly positioned relative to the part's reference surfaces. This is crucial for maintaining the proper fit and function of the components in an assembled system.

Furthermore, the non-parallelism of the main hole end faces falls within the acceptable technical range, ensuring that any deviations remain within allowable limits. This certifies that the machined part maintains its intended performance characteristics, stability, and durability in operation.

#### V. CONCLUSION

The results of this study demonstrate that the proposed milling technique for machining thin-walled components is highly effective in achieving the required dimensional precision and structural integrity. The technique successfully maintains strict tolerances for the key dimensions, including hole diameters, surface thicknesses, and rib reinforcement thicknesses, ensuring that the machined parts meet the design specifications. With deviations within  $\pm 0.02$  mm for hole dimensions,  $\pm 0.05$  mm for surface thicknesses, and precise parallelism and perpendicularity control, the method proves capable of delivering consistent and reliable results.

The machining process also ensures minimal deformation, maintaining the stability and strength of the thin-walled components without adding excess weight. The careful control of the critical dimensional parameters, such as hole alignment and surface positioning, guarantees proper fit and functionality in the assembled systems. Additionally, the obtained surface roughness values further highlight the quality of the machining process, making it suitable for high-precision applications in industries like aerospace, automotive, and precision engineering.

The proposed milling strategy not only addresses the challenges posed by the thin-walled structures, but also provides a viable, efficient solution for manufacturers requiring high-precision components. The findings contribute significantly to the field of machining, offering valuable insights for engineers and manufacturers aiming to enhance the efficiency, accuracy, and overall quality of their products.

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