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Ю.В. Муравинець[1], О.О. Івановський[1], О.П. Козарь[2]

ЗАСТОСУВАННЯ МОДЕРНІЗОВАНОЇ ТЕХНОЛОГІЇ ЧОРНОВОЇ ОБРОБКИ ДЕТАЛЕЙ ПРИ ВИСОКОШВИДКІСНИХ ТРАЄКТОРІЯХ

Луцький національний технічний університет[1]
Мукачівський державний університет[2]

У статті наведено результати дослідження застосування модернізованої технології чорнової обробки деталей з використанням високошвидкісних траєкторій інструменту. Розглядається вплив оптимізованих стратегій обробки на продуктивність, якість обробленої поверхні та знос інструменту. Проаналізовано переваги та обмеження використання даного підходу для підвищення ефективності виробничих процесів.

Key words: *roughing, high-speed machining, tool path, performance, surface quality, tool wear.*

Y.V. Muravinets, O.O. Ivanovsky, O.P. Kozar

APPLICATION OF MODERNIZED TECHNOLOGY OF ROUGH PROCESSING OF DETAILS AT HIGH-SPEED TRAJECTORIES

The article presents the results of a study of the application of modernized technology of rough processing of parts using high-speed tool trajectories. The impact of optimized machining strategies on productivity, quality of machined surface and tool wear is considered.The advantages and limitations of using this approach to increase the efficiency of production processes are analyzed.

Ключові слова: *чорнова обробка, високошвидкісна обробка, траєкторія інструменту, продуктивність, якість поверхні, знос інструменту.*

Introduction. In the modern machine building industry, the requirements for productivity and quality of workpiece processing are constantly growing. Roughing, as the initial stage, plays a key role in ensuring the efficiency of the entire production cycle. It determines the subsequent processing stages, the accuracy of the final dimensions and the surface quality of the product.

The use of high-speed machining (HSM) technologies in combination with optimized toolpaths opens up new opportunities for significant productivity gains and production cost reductions. HSM allows for shorter machining times, fewer tool passes and improved surface finish. This is achieved through the use of high cutting speeds and feeds, as well as the use of specialized tools and equipment.

However, the effective use of these technologies requires a thorough understanding of their impact on the cutting process, including tool wear and surface finish. High cutting speeds lead to an increase in the temperature in the machining zone, which can accelerate tool wear and degrade surface quality. Therefore, it is important to select the optimal cutting conditions, use efficient cooling and lubrication systems, and use wear-resistant tool materials. In addition, optimizing toolpaths reduces tool stress, reduces vibrations, and improves machining quality.

The purpose of this article is to study the application of the modernized roughing technology based on the use of high-speed toolpaths and analyze its impact on key process parameters. An analysis of existing research shows considerable interest in the use of HSS in various industries. The works of many authors are devoted to optimizing toolpaths in order to minimize machining time, reduce vibrations, and improve surface quality.

In particular, studies [1, 2] demonstrate the effectiveness of using trochoidal and spiral trajectories for roughing complex contours. Modernization of roughing technologies includes not only optimization of trajectories, but also the use of new cutting tools with improved characteristics, as well as adaptive strategies for controlling the cutting process [3]. An important aspect is also the modeling of the cutting process to predict forces, temperatures, and tool wear under different machining conditions and trajectories.

Research methodology. In this study, a series of experimental machining of parts from typical structural materials was carried out on a high-speed machining center.

Various roughing strategies have been used, including traditional rectilinear passes and modernized high-speed trajectories (trochoidal, spiral). During the experiments, the following parameters were monitored and recorded:

1.Cutting speed and tool feed.

The cutting speed is the speed of movement of the tool's cutting edge relative to the surface being machined. It is measured in meters per minute (m/min) and is one of the main parameters of the cutting mode. Increasing the cutting speed usually leads to an increase in machining performance, but it can also lead to increased tool wear and an increase in temperature in the cutting zone.

Tool feed is the speed of movement of the cutting tool relative to the workpiece in the direction perpendicular to the cutting direction. It is measured in millimeters per revolution (mm/rev) or millimeters per minute (mm/min). Tool feed affects the thickness of the cut layer, cutting force, and surface finish. Increasing the feed rate usually leads to higher productivity, but it can also lead to poorer surface finish and increased tool stress.

2.Cutting depth (axial and radial).

The depth of cut is a parameter that determines how deeply the cutting tool penetrates the material being processed. There are two main types of cutting depths: axial and radial.

Axial depth of cut: this is the distance the cutting tool penetrates the material along its axis. For example, in turning, this would be the depth to which the cutter cuts into the workpiece in one pass. In milling, it is the depth to which the cutter plunges into the material in a direction parallel to the axis of rotation of the cutter.

Radial depth of cut: this is the distance that the cutting tool cuts into the material in a direction perpendicular to its axis. In turning, there is no radial depth of cut.In milling, it is the width of the cut layer of material perpendicular to the direction of the cutter feed. Both of these parameters are important when selecting cutting modes, as they affect cutting force, tool wear, machined surface quality, and process performance.

3. Processing time for each part.

4. Roughness of the treated surface (Ra, Rz). Machined surface roughness is the micro-irregularities formed on the surface of a part during machining by cutting, pressure, etc. These irregularities can have different shapes, heights, and pitches, and they affect the performance properties of the part, such as wear resistance, strength, tightness, and appearance.

5. Wear of the cutting tool (behind the back surface). Cutting tool wear is the gradual deterioration of the cutting edge of a tool during the cutting process, which leads to a loss of its cutting properties. Wear can manifest itself in the form of wear, chipping, plastic deformation, and other types of damage.

6. Spindle power consumption. Spindle power consumption is the amount of energy that the machine's spindle (shaft) uses to perform a machining operation. This parameter is measured in watts (W) or kilowatts (kW) and reflects the load on the spindle drive during cutting. Factors that affect spindle power consumption:

- cutting speed;
- feed rate;
- depth of cut;
- workpiece material;
- type of cutting tool;
- cutting mode.

The methods of mathematical statistics and comparative analysis were used to analyze the obtained data. A visual examination of the machined surfaces and tool wear was also carried out using an optical microscope.

Research results. The results of the conducted experiments showed that the use of modernized high-speed trajectories during the rough processing of parts allows to achieve a significant increase in productivity compared to traditional methods. In particular, the use of trochoidal trajectories made it possible to reduce the processing time by [specify a specific value]% when processing contour elements.

Analysis of the quality of the processed surface showed that with optimal cutting modes and the use of high-speed trajectories, it is possible to achieve comparable or even better roughness indicators compared to traditional processing.

However, incorrect selection of parameters can lead to deterioration of the surface quality.

The study of tool wear revealed that when modernized trajectories are used, more uniform wear of the cutting edges is observed, which can positively affect the overall service life of the tool.

However, at high cutting speeds and great depths, more intensive wear is observed, which requires a careful selection of processing modes.

An analysis of the spindle power consumption showed that high-speed machining with optimized trajectories can lead to a more stable load on the equipment, which is important for its durability.

Discussion of results. The obtained results confirm the potential of modernized roughing technologies using high-speed trajectories to increase the efficiency of production processes.

Reduction of processing time without significant deterioration of the surface quality and while maintaining an acceptable level of tool wear are important advantages of this approach.

The effectiveness of using high-speed trajectories largely depends on the correct choice of cutting modes, the properties of the processed material and the characteristics of the cutting tool.

Further research into optimal combinations of these parameters for various production tasks is necessary.

Conclusions. The application of modernized technology of rough processing of parts at high-speed trajectories is a promising direction for increasing the productivity and efficiency of machine-building production.

Optimization of tool trajectories allows you to reduce processing time, improve surface quality and ensure more uniform wear of the cutting tool with the correct selection of cutting modes. Further research will be aimed at developing recommendations for the implementation of this technology for a wide range of materials and production tasks.

The use of modernized technology for rough processing of parts at high-speed trajectories opens up significant prospects for increasing the efficiency and quality of production processes.It should be noted that the effective implementation of modernized roughing technologies at high-speed trajectories requires:use of high-performance and accurate machine tools.

Use of modern cutting tools with appropriate characteristics, thorough development and optimization of instrument movement trajectoriescareful development and optimization of tool movement trajectories using specialized software, ensuring effective cooling and removal of chipsraining of qualified personnel to work with new equipment and technologies.

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