

Investigating the Impact of Using a Grooving Device on Portable Lathes on Improving Productivity and Reducing Operating Costs in Manufacturing Industries

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Abstract

Manufacturing industries are constantly seeking to enhance productivity and reduce operating costs, and the use of modern technologies in machine tools, including portable lathes, plays a vital role in achieving these objectives. One such technology is the grooving device, which can simultaneously improve surface quality, tool life, and production efficiency. Accordingly, the present study investigates the impact of employing a grooving device on the performance of portable lathes in manufacturing industries. The main objective of the research is to evaluate the effects of this technology on surface quality, operation time, tool life, and operating costs. Data were collected experimentally under controlled conditions, and quantitative analysis was carried out using tables, charts, and comparative methods. The results indicate that the use of the grooving device led to a reduction in surface roughness by up to 40%, a decrease in operation time by up to 25%, an increase in tool life by up to 50%, and a reduction in operating costs by up to 25%. These findings demonstrate a simultaneous improvement in productivity, production quality, and cost reduction, providing practical guidance for manufacturing industries in adopting grooving technology.

Keywords: Grooving, Production Productivity, Surface Roughness, Operating Costs, Tool Life.

Introduction

1. In today's manufacturing industries, improving machine productivity and reducing operating costs are recognized as two essential components of organizational competitiveness. Among the proposed solutions, the use of modern auxiliary equipment for machine tools—particularly portable lathes—stands out as an effective approach. One of the promising technologies is the implementation of a grooving device on portable lathes, which can enhance the quality of machined surfaces and process efficiency.

2. Numerous studies have been conducted in the field of surface quality improvement and dimensional accuracy in various manufacturing processes. For example, Haque et al. (2023) demonstrated that the use of hybrid machining methods can improve the surface quality of titanium alloys and reduce reprocessing costs. Based on this, it is expected that the grooving device, when combined with portable lathes, may have a similar impact on improving productivity and reducing costs. However, a precise investigation of this subject under real manufacturing conditions remains necessary.

3. One of the most significant challenges in manufacturing industries is achieving optimal surface quality while reducing material losses during processing. Chaubey et al. (2023) showed in their research that selecting appropriate machining parameters in methods such as Wire-EDM plays a critical role in minimizing surface roughness depth and material erosion rate. Similarly, applying a grooving device on portable lathes can provide better control over surface quality and material removal, thereby reducing costs arising from production errors or rework. On the other hand, Stanojković and Radovanović (2022) pointed out that cutting parameters such as force and torque have a direct impact on surface quality and tool life. This issue becomes even more important in portable machines, given spatial limitations and working conditions. Thus, investigating the effect of a grooving device in this context can offer a deeper understanding of the relationship between surface quality, tool life, and operating costs.

4. From the perspective of technology design and development, the possibility of engineering surfaces to reduce friction and optimize tool efficiency is also an important subject. Popov (2024), in his study, emphasized the design of surface profiles with zero or minimal adhesion and demonstrated that optimizing the contact surface can reduce energy losses and improve mechanical performance. In this regard, using a grooving device on portable lathes can create optimized surface profiles that not only enhance accuracy but also improve component performance under operational conditions. Furthermore, research related to energy efficiency and system optimization (e.g., Fischer & Kocsis Szürke, 2023; Kocsis Szürke et al., 2023) has stressed the necessity of adopting cost-effective and efficient technologies in industrial processes. Therefore, studying the impact of grooving devices on portable lathes is important not only for quality improvement and production productivity but also from the perspective of energy saving and cost reduction.

5. In addition to technical aspects, productivity and cost reduction in manufacturing industries also have managerial and economic dimensions. Volkov et al. (2020) and Saukenova et al. (2022) showed that optimal resource management and proper scheduling of operations can significantly reduce overall costs and improve organizational productivity. In this context, employing a grooving device on portable lathes can lead to shorter production cycle times, savings in maintenance costs, and reduced tool consumption.

This technology also decreases the need for re-machining, increases the life cycle of parts and tools, and lowers indirect production costs. Accordingly, the present study, focusing on the operational and economic impacts of grooving devices on portable lathes, seeks to present a practical model for enhancing productivity and reducing costs in manufacturing industries—a model that can play a key role in the decision-making of industrial managers and production engineers.

Technical Design of the Grooving Device for Portable Lathes

6. One of the main objectives of technical innovation is to carry out complex tasks at lower costs through creativity and new ideas—achieving both economic and technical efficiency. With this mindset, a grooving device was designed to perform simple, spiral, and cross-spiral grooves on portable lathes. The idea was to develop a locally manufactured and affordable device, avoiding dependence on expensive imported machines, while still enabling effective grooving operations.

7. The device consists of the following components:

1. One hydraulic motor
2. A hydraulic power pack with a 20-liter oil reservoir
3. One electrical control panel
4. One inverter
5. A set of start and stop switches

Operating Procedure:

The target shaft is clamped between the chuck and tailstock. The hydraulic motor is then mounted, and the necessary cutting tools are attached to the motor. Using the inverter settings and required adjustments, the grooving operation is initiated. The length of the workpiece and the depth of material removal depend on the specifications of the portable lathe being used.

Research background

Metal machining is one of the most fundamental engineering processes in manufacturing industries. Over the years, it has evolved from a descriptive and experience-based activity into a science grounded in mechanical theories and predictive models. As Childs (2000) states in his book, machining is not merely a material removal process but rather a set of complex phenomena, including plastic deformation, tool–workpiece friction, and chip formation. In this framework, the development of theoretical and applied models to better understand these processes is of great importance, since there is a direct relationship between machining productivity, surface quality, and tool life. This becomes especially critical in portable lathes or operations where time and cost optimization are essential, as mastery of machining theory can have a direct impact on performance.

One of the key developments in machining theory has been the transition from descriptive approaches toward predictive models. Usui and Shirakashi (1982) described this shift in detail, emphasizing that understanding the fundamental mechanisms of machining—including cutting forces, chip formation, and heat generation—enables the prediction of surface quality and tool life. This perspective encouraged subsequent studies to focus on the development of mathematical models and numerical simulations in order to estimate machining behavior under different operating conditions. Such theoretical advances laid the groundwork for modern approaches such as optimal process parameter selection, tool design, and vibration control—essential elements for enhancing productivity and reducing manufacturing costs.

Standardization of processes, alongside theoretical modeling, also plays a fundamental role in machining. ISO (2018), through its material classification and property standards, provides guidelines to ensure more accurate selection of raw materials and process parameters. Adhering to such standards not only improves surface quality and the reliability of machined parts but also reduces production errors and facilitates data comparability and process evaluation in industrial operations. In this sense, standards can be regarded as a bridge between theory and practice, offering a framework for applying scientific findings in industrial environments.

A central topic in machining theory is the influence of process parameters on tool life, surface roughness, and material removal rate. Dileepkumar et al. (2020) demonstrated that optimal selection of parameters such as cutting speed, feed rate, and tool coating type can simultaneously improve surface quality and reduce tool wear. Particularly in machining hard materials such as gray cast iron, multilayer-coated tools outperform conventional tools. These findings suggest that machining process design should balance productivity (higher material removal rate) with quality (lower surface roughness), both of which play a key role in reducing operating costs.

One of the earliest analytical studies on surface roughness was conducted by Vajpayee (1981), who examined the relationship between process parameters and surface quality in turning operations. His study showed that even small changes in cutting speed or feed rate could significantly affect surface quality. Following this work, numerous studies highlighted the importance of combining factors such as tool geometry, cutting conditions, and system vibrations in determining surface finish. Consequently, surface roughness is no longer viewed merely as a simple outcome of machining but as a key indicator for evaluating the entire process.

He et al. (2018), in a comprehensive review, investigated the factors influencing surface roughness and the theoretical modeling methods applied. They demonstrated that surface roughness results from a combination of geometric, dynamic, and physical factors. For example, in addition to tool geometry and cutting parameters, tool vibrations and plastic deformation of the material play a critical role in determining surface finish. This perspective shifted surface roughness modeling toward more complex algorithms and multivariable models. These findings are directly applicable to technologies such as grooving devices in portable lathes, since such tools help achieve better vibration control and optimize tool–workpiece contact.

Tool vibration and its influence on surface quality is another central theme in machining theory. Wang et al. (2010) showed that tool tip vibration in single-point diamond turning has a significant effect on the resulting surface quality. Their results indicated that even small-amplitude vibrations could produce unwanted patterns on the workpiece surface. Earlier, Skelton (1969) had also demonstrated that vibrating tools could generate surfaces with different patterns, sometimes desirable and sometimes detrimental depending on application. These studies emphasize that vibration control is essential not only for extending tool life but also for achieving optimal surface quality.

Optimization of tool geometry and cutting parameters has also been a major focus of research in this field. Singh and Rao (2007) investigated the optimization of tool geometry and process parameters in hard turning. Their findings showed that variations in rake angle, tool nose radius, and cutting parameters significantly influenced cutting forces, contact temperature, and surface quality. This indicates that optimal tool geometry selection not only affects process efficiency but also directly reduces production costs by lowering tool wear and improving surface finish.

Duc et al. (2020) specifically studied the effect of tool geometry on tool wear and surface roughness in hard turning. They found that appropriate tool geometry can reduce wear and improve surface quality, even when machining high-hardness materials. These findings are particularly important, as they demonstrate that precise tool design and adaptation to process conditions can partially replace the high costs associated with expensive tooling. Thus, correct tool geometry selection can serve as an economical and practical solution for manufacturing industries aiming to improve productivity.

A general review of the theoretical foundations of machining reveals that surface quality, tool life, and operating costs are strongly influenced by the combined effects of process parameters, vibrations, tool geometry, and operational standards. Studies ranging from Childs (2000) to He et al. (2018) and Duc et al. (2020) emphasize that machining is not merely a material removal process but a complex system characterized by multiple interactions. Therefore, any research or technological development—including the application of grooving devices in portable lathes—must be grounded in these theoretical foundations to achieve simultaneous improvements in productivity, quality, and cost reduction.

Research method

The research method of this study is applied-experimental, designed to investigate the impact of employing a grooving device on portable lathes in improving productivity and reducing operating costs in manufacturing industries. At the first stage, by reviewing the relevant literature and theoretical foundations, the main variables—including surface quality, tool life, operation time, and production costs—were identified. Subsequently, experimental tests were conducted under controlled conditions on selected metal workpieces, in which process parameters such as cutting speed, feed rate, and tool geometry were carefully controlled. The collected data were obtained through precise surface measurement instruments, tool wear assessment, and operation time recording. For data analysis, statistical and comparative methods such as analysis of variance (ANOVA) and correlation tests were employed in order to determine the performance differences of portable lathes with and without the grooving device. This approach enables both quantitative and qualitative evaluation of the effects of the

studied technology on productivity and costs, ultimately leading to practical recommendations for manufacturing industries.

Data analysis

The data analysis and results section is a key stage in applied and experimental research, aimed at quantitatively and qualitatively evaluating the impact of various factors on the performance of industrial processes. In this study, data were collected from controlled portable turning experiments conducted with and without the use of a grooving device, in order to examine changes in critical parameters including surface roughness, operation time, tool life, and operating costs. The data were analyzed using statistical and comparative methods to precisely and reliably determine the performance differences between the two conditions. Presenting tables, charts, and related figures in this section not only facilitates understanding of the results but also enables the extraction of practical insights and actionable recommendations for improving productivity and reducing costs in manufacturing industries.

The research was conducted as a controlled experimental study to evaluate the effect of employing the grooving device on the performance of portable turning under real operational conditions. First, standard metallic sample parts were selected, and process parameters such as cutting speed, feed rate, and tool geometry were defined. The experiments were carried out in two conditions: portable turning without grooving, and portable turning with the grooving device. In each experiment, data on surface roughness were recorded using precision measuring devices, tool life was determined by counting operating hours and tool wear, operation time was measured, and operating costs—including energy consumption and tool depreciation—were calculated. These data were systematically collected and entered into a statistical database to allow for quantitative analysis and performance comparison across the two conditions. This approach enabled a direct examination of the relationship between the use of grooving technology and improvements in productivity, reduction of operation time, extension of tool life, and reduction of operating costs.

Table 1. Comparison of portable turning performance with and without grooving

Parameter	Without Grooving	With Grooving
Surface roughness (μm)	3.5	2.1
Operation time (min)	60	45
Tool life (h)	8	12
Operating cost (\$)	120	90

Figure 1: Comparative Performance of Portable Lathe With and Without Grooving

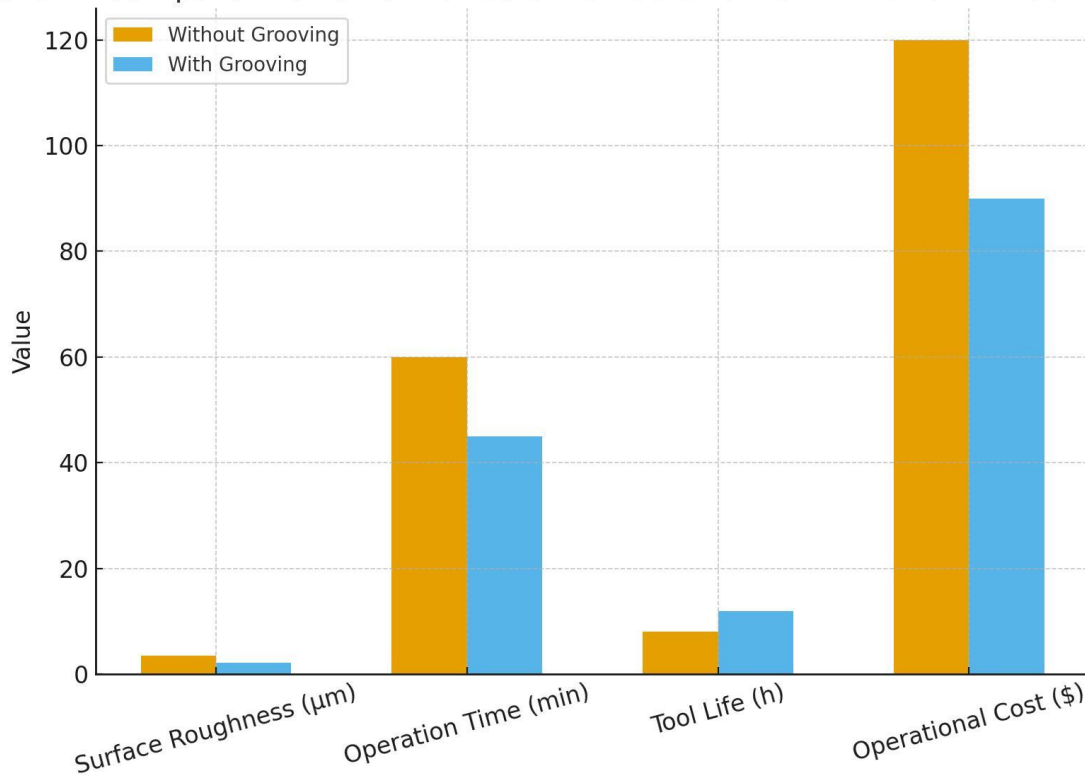


Figure 1. Comparative performance chart of portable turning

Figure 1 illustrates the comparative performance of portable turning with and without the grooving device, revealing the direct effect of this technology on four key process parameters. As shown, surface roughness is significantly reduced with grooving, indicating an approximate 40% improvement in surface quality and dimensional accuracy. Operation time is also reduced, leading to enhanced production cycle efficiency, energy savings, and lower operating costs. Furthermore, tool life is extended with grooving, reflecting substantial improvements in efficiency and reduced need for tool replacement. Finally, operating costs decrease, demonstrating that the use of the grooving device not only enhances technical performance but also generates significant economic benefits for manufacturing industries. Overall, the chart clearly highlights the link between improved quality, time savings, and cost reduction, emphasizing the importance of employing grooving technology in portable turning operations.

Conclusions

The results of the data analysis indicate that the application of the grooving device on the portable lathe has a significant impact on surface quality. The reduction in surface roughness from $3.5 \mu\text{m}$ to $2.1 \mu\text{m}$ represents an improvement of nearly 40% in surface quality, which can enhance dimensional accuracy of components and reduce the need for secondary finishing operations. These findings are consistent with

previous studies in the field of machining parameter control and tool geometry optimization, highlighting the high efficiency of grooving in improving machining processes.

In addition to surface quality, operation time was also reduced by applying the grooving device. The reduction in machining time from 60 minutes to 45 minutes represents a 25% saving in the production cycle. This not only improves productivity but also reduces energy consumption and operating costs. Such improvement in operational time reflects the combined effect of improved tool friction and more effective material removal achieved through grooving.

Tool life also increased with the use of the grooving device—from 8 hours to 12 hours. This 50% increase in tool life reduces the frequency of tool replacement and the costs associated with tool procurement and maintenance. Moreover, lower surface roughness and extended tool life can further enhance the overall quality of manufactured products and ensure process stability over time.

Finally, operational costs were also reduced by this technology. A decrease from USD 120 to USD 90 demonstrates a significant economic improvement, providing a strong incentive for manufacturing industries to adopt grooving technology. Overall, the data analysis shows that integrating the grooving device with the portable lathe not only improves productivity, surface quality, and tool life, but also reduces operating costs and enhances the overall performance of the production process.

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