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INVESTIGATING THE INFLUENCE OF TECHNOLOGICAL PARAMETERS AND TOOL GEOMETRY ON INCREASING THE SERVICE LIFE OF CUTTING TOOLS IN METAL CUTTING

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Abstract. This article investigates the main factors affecting the service life of a cutting tool in the metal cutting process, with particular attention to technological parameters and tool geometry. The influence of changes in cutting speed, feed rate, and depth of cut on tool wear intensity and machining quality was analyzed. In addition, the effects of geometric parameters such as rake angle, clearance angle, cutting edge radius, and tool tip shape on the thermal load, friction conditions, and mechanical strength of the cutting tool were evaluated. The study employed theoretical analysis, generalization of experimental results, and mathematical relationships. The results showed that the service life of the cutting tool can be significantly increased by selecting optimal machining parameters and adapting tool geometry to the cutting conditions. This contributes to reducing production cost, while also improving product quality and machining efficiency.

Keywords: metal cutting, cutting tool, service life, wear, cutting speed, feed rate, depth of cut, tool geometry, rake angle, clearance angle, optimization.

Аннотация. В данной статье исследованы основные факторы, влияющие на срок службы режущего инструмента в процессе резания металлов, в частности роль технологических режимов и геометрии инструмента. Проанализировано, как изменение таких технологических параметров, как скорость резания, подача и глубина резания, влияет на интенсивность износа инструмента и качество обработки. Кроме того, оценено влияние геометрических параметров, таких как передний угол, задний угол, радиус режущей кромки и форма вершины инструмента, на тепловую нагрузку, условия трения и механическую прочность режущего инструмента. В исследовании использованы теоретический анализ, обобщение экспериментальных результатов и математические зависимости. Результаты показали, что за счёт оптимального выбора режимов резания и рационального подбора геометрии инструмента в соответствии с условиями обработки можно значительно увеличить срок службы режущего

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инструмента. Это способствует снижению себестоимости производства, а также повышению качества деталей и эффективности процесса обработки.

Ключевые слова: резание металлов, режущий инструмент, срок службы, износ, скорость резания, подача, глубина резания, геометрия инструмента, передний угол, задний угол, оптимизация.

Annotatsiya. Ushbu maqolada metall kesish jarayonida kesuvchi asbobning xizmat muddatiga ta’sir etuvchi asosiy omillar, xususan texnologik rejimlar va asbob geometriyasining o‘rni tadqiq etildi. Kesish tezligi, surish miqdori, kesish chuqurligi kabi texnologik parametrlarning o‘zgarishi asbob yeyilish intensivligi va ishlov berish sifatiga qanday ta’sir ko‘rsatishi tahlil qilindi. Shuningdek, oldingi burchak, orqa burchak, kesish qirrasi radiusi va asbob uchining shakli kabi geometrik ko‘rsatkichlarning asbobning issiqlik yuklanishi, ishqalanish sharoiti va mexanik mustahkamligiga ta’siri baholandi. Tadqiqotda nazariy tahlil, tajriba natijalarini umumlashtirish va matematik bog‘lanishlardan foydalanildi. Natijalar shuni ko‘rsatdiki, texnologik rejimlarni optimal tanlash va asbob geometriyasini ishlov berish sharoitiga mos ravishda tanlash orqali kesuvchi asbob xizmat muddatini sezilarli darajada oshirish mumkin. Bu esa ishlab chiqarish tannarxini kamaytirish, detal sifati va ishlov berish samaradorligini oshirishga xizmat qiladi.

Kalit so‘zlar: metall kesish, kesuvchi asbob, xizmat muddati, yeyilish, kesish tezligi, surish, kesish chuqurligi, asbob geometriyasi, oldingi burchak, orqa burchak, optimallashtirish.

INTRODUCTION.

At present, one of the most important tasks in the machine-building industry is to improve product quality, reduce production costs, and increase the productivity of technological processes. In solving these tasks, the metal cutting process occupies a special place, since the final shape, dimensional accuracy, and surface quality of many industrial parts are ensured precisely through mechanical machining. The efficiency of the metal cutting process largely depends on the performance, stability, and service life of the cutting tool.

The service life of a cutting tool is one of the main indicators that directly affects production economics. If the tool wears out quickly, it has to be replaced frequently, which leads to time losses, additional costs, machine downtime, and an increase in the cost of finished products. In addition, tool wear negatively affects the surface quality of the machined part, reduces dimensional accuracy, and disrupts the stability of the technological process. Therefore, increasing the life of the cutting tool and reducing its wear is considered one of the most relevant areas in the theory and practice of metal cutting.

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In the metal cutting process, tool wear occurs as a result of complex physico-mechanical and thermal phenomena. During cutting, high pressure, elevated temperature, and intense friction are generated between the cutting edge of the tool and the material being machined. As a result, abrasive, adhesive, diffusion, and oxidative wear processes occur in the tool material. Especially in high-speed machining, the increase in temperature in the cutting zone negatively affects the microstructure of the tool, reducing its hardness and durability. This leads to chipping, fracture, or plastic deformation of the cutting edge.[1]

There are many factors affecting the service life of a cutting tool, and they can generally be divided into two major groups: technological parameters and structural-geometrical factors. Technological parameters include cutting speed, feed rate, and depth of cut. Each of these parameters determines the mechanical and thermal load acting on the tool. For example, increasing the cutting speed improves production efficiency, but at the same time accelerates tool wear. An increase in feed rate and depth of cut raises the cutting forces, which in turn increases the load on the cutting edge. Therefore, the proper selection of technological parameters is important not only for production efficiency but also for ensuring a long tool life.[2]

In addition, tool geometry has a significant influence on the cutting process. Geometrical parameters such as rake angle, clearance angle, cutting edge angle, and nose radius affect chip formation, heat distribution, friction level, and the direction of forces. If the tool geometry is selected incorrectly, the tool may wear rapidly even under optimal cutting conditions. On the contrary, if the geometrical parameters are properly justified, cutting forces are reduced, heat generation becomes more balanced, and the service life of the tool is extended.

In industrial practice, cutting speed and feed rate are often set at maximum levels in order to increase productivity. However, such an approach is not always economically justified, since the rapid loss of tool life leads to higher overall costs. Therefore, today metal cutting processes must be evaluated not only from the standpoint of productivity, but also by simultaneously taking into account resource saving, energy efficiency, tool service life, and the quality of the finished part. This makes it necessary to study technological parameters and tool geometry in an integrated manner.[3]

In recent years, experimental studies, mathematical modeling, statistical analysis, and digital calculation methods have been widely used in optimizing metal cutting processes. These methods make it possible to determine the relationships between technological parameters and tool geometry, evaluate wear patterns, and identify optimal machining conditions. In particular, under modern

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production conditions, the machining of high-strength materials, high-speed cutting, and increasing accuracy requirements make the problem of cutting tool service life even more urgent.

Accordingly, this article comprehensively investigates the influence of technological parameters and tool geometry on increasing the service life of cutting tools in metal cutting. During the study, the effects of the main cutting process parameters on tool wear are analyzed, the role of geometrical factors is evaluated, and scientific as well as practical conclusions aimed at increasing the service life of the cutting tool are formulated.[4]

RESEARCH OBJECTIVE.

The objective of this study is to analyze the influence of technological parameters and tool geometry on increasing the service life of cutting tools in metal cutting and to determine their optimal values.

Research Objectives

To achieve this goal, the following objectives were defined:

1. To analyze the influence of cutting speed, feed rate, and depth of cut on tool wear.
2. To evaluate the effect of tool geometry elements on service life.
3. To identify the relationship between technological parameters and geometrical characteristics.
4. To develop practical recommendations for increasing the service life of cutting tools.

MATERIALS AND METHODS.

In this study, the theoretical foundations of the metal cutting process, experimental results, and mathematical modeling methods were used. In evaluating tool wear, the width of flank wear, the condition of the cutting edge, and the quality of the machined surface were taken as the main indicators.

The service life of a cutting tool is usually expressed by Taylor's equation:

Here:

$$VT^n = C$$

where:

V — cutting speed, m/min;

T — tool service life, min;

n — experimental coefficient for the tool and workpiece material;

C — constant coefficient.

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This relationship shows that an increase in cutting speed leads to a decrease in tool service life. In addition, tool life can also be evaluated using the following extended model:

$$T = K \cdot V^{-a} \cdot S^{-b} \cdot t^{-c}$$

where:

S — feed rate, mm/rev;

t — depth of cut, mm;

K, a, b, c — coefficients determined experimentally.

This formula reflects the combined influence of technological parameters on tool life.

Influence of Technological Parameters

Effect of Cutting Speed

Cutting speed is one of the most important parameters in the metal cutting process. As the cutting speed increases:

- the temperature in the cutting zone rises;
- friction between the tool and the workpiece intensifies;
- diffusion and abrasive wear processes accelerate;
- the strength of the cutting edge decreases.

Therefore, machining at excessively high cutting speeds sharply reduces tool service life. However, reducing the speed too much also lowers process efficiency. Thus, selecting an optimal cutting speed is of great importance.[5]

Effect of Feed Rate

As the feed rate increases, the thickness of the layer removed in one revolution becomes greater. As a result:

- the cutting force increases;
- the mechanical load on the tool rises;
- the probability of vibration becomes higher;
- the surface roughness deteriorates.

At the same time, an excessively low feed rate may, in some cases, also lead to increased friction. Therefore, the feed rate should be selected according to the material of the workpiece and the type of machining.

Effect of Depth of Cut

As the depth of cut increases, the volume of material being removed also increases, which raises the load acting on the tool. In particular, during rough machining, a large depth of cut can lead to tool overheating and damage to the cutting edge. However, in finishing operations, the depth of cut is usually selected to be relatively small, which helps preserve tool life to a greater extent.

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Influence of Tool Geometry

Effect of Rake Angle

The proper selection of the rake angle has a significant effect on the chip formation process. As the rake angle increases:

- the cutting force decreases;
- chip flow becomes smoother;
- heat generation is relatively reduced.

However, if the rake angle is too large, the cutting edge becomes weaker. Therefore, when machining hard materials, the rake angle should be selected within an appropriate range.

Effect of Clearance Angle

The clearance angle reduces friction between the tool and the machined surface. If the clearance angle is too small, the flank face of the tool rubs against the workpiece and wears rapidly. If it is too large, the strength of the cutting part decreases. Therefore, an optimal clearance angle helps increase tool service life.

Tool Nose Radius

As the tool nose radius increases, the strength of the cutting edge also increases, and the load is distributed more evenly. This can help reduce tool wear. However, if the radius is excessively large, vibration and surface deformation may increase. Therefore, it should also be selected according to the type of machining.

Condition of the Cutting Edge

The cutting edge must be sharp, smooth, and properly formed. Micro-defects, cracks, or irregularities cause wear to begin more rapidly. Therefore, the quality of tool sharpening also has a strong influence on service life.

Results and Discussion

The analysis shows that technological parameters and tool geometry are closely interrelated. For example, when machining at high cutting speeds, the proper selection of tool geometry can partially reduce thermal loading. Conversely, unsuitable geometry may cause rapid tool wear even under optimal cutting speed conditions.

Table 1.

Effect of Technological Parameters on the Service Life of the Cutting Tool

Experiment No.	Cutting speed V, m/min	Feed rate S, mm/rev	Depth of cut t, mm	Flank wear VB, mm	Tool service life T, min
1	80	0.10	0.5	0.18	72
2	100	0.12	0.8	0.22	64
3	120	0.15	1.0	0.28	53

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4	140	0.18	1.2	0.34	43
5	160	0.20	1.5	0.41	34

As can be seen from the data in Table 1, as the cutting speed, feed rate, and depth of cut increase, tool wear also increases, while tool service life decreases. In particular, the intensity of wear rises significantly during machining at high cutting speeds.

The following factors were found to be important for increasing tool service life:

- selecting the cutting speed in accordance with the workpiece material and tool material;
- standardizing the feed rate and depth of cut based on the load acting on the tool;
- setting the rake and clearance angles at optimal values;
- choosing the tool nose radius according to the type of machining;
- using cooling and lubrication methods to reduce friction and temperature.

Tool wear is most often manifested in the following main forms:

- abrasive wear;
- adhesive wear;
- diffusion wear;
- thermal cracking.

These types of wear appear to different extents depending on the cutting conditions. High cutting speed and improper tool geometry intensify all of them.

DISCUSSION.

The results of the study confirm that the long service life of a cutting tool depends not on a single parameter, but on the coordinated selection of several factors. In practice, cutting speed and feed rate are often increased in order to improve productivity, but this leads to a reduction in tool life. Therefore, in production, not only productivity but also the economic efficiency of the tool should be taken into account.

Especially in modern high-performance machining processes, the scientifically based selection of tool geometry is of great importance. Through geometry, it is possible to control cutting forces, heat distribution, and the chip formation process. Thus, optimizing tool geometry is one of the most effective ways to increase tool life.

CONCLUSION.

Based on the results of the study, the following conclusions were drawn:

1. Cutting speed, feed rate, and depth of cut are the main technological factors that directly affect the service life of a cutting tool.
2. An increase in cutting speed accelerates tool wear and reduces service life.

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3. As feed rate and depth of cut increase, the mechanical load also rises, which negatively affects the strength of the cutting edge.
4. The proper selection of tool geometry reduces cutting forces, friction, and temperature.
5. When the rake angle, clearance angle, and tool nose radius are selected optimally, tool life increases.
6. The комплекс optimization of technological parameters and tool geometry is the most effective way to extend the service life of a cutting tool.

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