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QUESTIONS OF INCREASING THE PRODUCTIVITY OF THE MATERIAL CUTTING PROCESS

Akbarov Khatam, *c.t.s., professor,*
E-mail:lpi1982@mail.ru,
Andijan State Technical Institute

Abstract: *The article analyzes the operational characteristics of cutting tools and the capabilities of metal cutting. The relationship between tool life (T) and cutting speed (v) is experimentally studied. Optimal cutting conditions for increasing process productivity are determined.*

Annotatsiya: *Maqolada kesuvchi asboblarning ekspluatatsion xususiyatlari va metallarni kesish imkoniyatlari tahlil qilingan. Kesish jarayonida asbobning mustahkamligi (T) va kesish tezligi (v) o‘rtasidagi bog‘liqlik eksperimental ravishda o‘rganilgan. Jarayon unumdorligini oshirish uchun optimal kesish rejimlari aniqlangan.*

Аннотация: *В статье анализируются эксплуатационные характеристики режущих инструментов и возможности резания металлов. Экспериментальным путем изучена зависимость между стойкостью инструмента (T) и скоростью резания (v). Определены оптимальные режимы резания для повышения производительности процесса.*

Keywords: *workpiece, metal cutting, end mills, machining, cutting tools, carbide, milling cutter, cutting speed, surface quality, physical and mechanical properties of processed materials.*

Kalit so‘zlar: *zagotovka, metallni jilvirlash, o‘qli barmoq frezalar, mexanik ishlov berish, kesish asboblari, qattiq qotishma, frezalash, kesish tezligi, sirt sifati, ishlav berilgan materiallarning fizik-mexanik xususiyatlari.*

Ключевые слова: *заготовка, шлифование металла, фрезы осевые концевые, механическая обработка, режущий инструмент, твердый сплав, фреза, скорость резания, качество поверхности, физико-механические свойства обрабатываемых материалов.*

Introduction. Cutting is one of the most popular types of metal processing. This type of processing is used in the creation of aerospace equipment as well as for household products. For cutting metal, a cutting tool and special technological equipment are used [1–4].

Basic metal cutting tools used in machining are classified according to their design and the type of surface being processed. In addition, each class is further subdivided into specific categories. According to their design, blade tools can be classified into the following types. Turning tools are classified into through (straight), parting, threading, and grooving types. They can also be categorized as left-hand and right-hand tools. Some tools operate with a standard feed of the carriage with the tool mounted on it, while others are used with reverse feed [5–8].

Drills are an axial type tool

They can be manufactured with one or more blade edges. They are used to form holes in the workpiece. They are formed when the drill rotates around its axis and feeds it into the body of the workpiece. Drills are divided into right and left; the latter are used in mechanized drilling of parts. For example, when preparing holes in car engine housings. This class also includes reamers, countersinks, counterbores, etc. They are designed for processing holes after drilling. For example, with the help of reamers, the resulting holes are finished, that is, they are brought to the required size and surface roughness.

Files are a tool in the form of rods or plates, on the surface of which a large number of cutting teeth are formed. Designed for manual work with metal. With their help, burrs and irregularities are removed from the product [7–10].

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Broaches are rods with blades applied to the surface. They are used to produce shaped holes, for example, keyway or splined grooves in pulleys or gears. The broach is a rod, the diameter of which gradually increases towards its tail.

Mills are an axial blade tool designed for turning workpieces that are fixed on the work table and move with it relative to a rotating cutter. They are divided into cutters for general use, worm cutters, for producing gears, engraving cutters, key cutters, etc. They are used to produce complex surfaces, for example, in the production of molds or dies intended for metal forming [11].

To obtain external and internal threads, two main types of cutting tools are used – taps and dies (dies). The tap is a steel rod on the surface of which there are longitudinal flats and grooves that form cutting edges. The die is a disk with cutting blades formed inside it. External threads are produced using dies. They produce two types of taps - manual and machine. The first ones are used for manual processing. The second ones are installed in machine tools. It should be noted that machine taps can also be used for manual processing of holes [12–15].

For the production of gears, cutters, gear cutters, and shaver are used. Abrasive and cutting wheels are used for rough and finishing metal processing. This tool is a circle made of an abrasive material, such as silicon carbide. Small particles of abrasive remove a specified layer of metal. Such circles are used for cleaning surfaces from traces of corrosion and processing products after heat treatment.

The above is a general classification of cutting tools. Meanwhile, all tools produced in the country must comply with GOST requirements; there are standards for turning tools, taps and dies.

One of the main regulatory documents that defines some parameters of a cutting tool is GOST 25751-83. It defines terms used in industry and technology, which are common to all types of blade cutting tools, in addition, it defines terms and concepts related to metal-cutting tools [16–18]. All presented tools meet the accuracy standards defined in GOST and TU. In addition to them, some industries use tools manufactured on the basis of industry standards.

Cutters used for turning rotating bodies (turning), planning, used for processing flat work pieces, for example, for removing a layer of metal during major repairs of machine tools. During the formation of the work piece, the cutter moves along the axis of its rotation. The main characteristics of turning tools are the size of the holder. That is, the component on which the cutting plate is fixed has a functional purpose. The grade of material from which the cutting part is made also plays an important role. More we will discuss below.

In the process of cutting metals, the cutting tool is subjected to high pressure from the cut layer and heat, which causes its wear. Therefore, the main requirement for cutting tool materials is wear resistance at high heating temperatures for a long time. This requirement is ensured by the high hardness of the material in the heated state and its red resistance.

Currently, in mechanical engineering, tool carbon, alloy and high-speed steels are used for the manufacture of cutting tools. In addition to the listed steels, plates of hard metal-ceramic and mineral-ceramic materials are also used. Tool carbon steels currently have limited use due to their low red resistance. Although tools made from this steel have hardness after heat treatment of HRC 60–63, when heated to 200–250°C, the hardness drops sharply and the tool becomes dull [19–22]. Cutting tools operating at low cutting speeds ($V \leq 10$ m/min), for example files, hacksaw blades, taps, dies, etc., are made from tool carbon steel grades У10А, У12А.

Let's in this part of this article we will introduce the concept of "operational life", in other words, the service life of a cutting tool, characterizing the operating time until the cutting tool fails, and taking into account the fact that restores ability is an integral part of the technical resource. Time to failure can be assessed by various indicators. The most commonly used indicator in metal cutting is the service life T. Service life T is the operating time of the tool until the tool wear reaches the established dullness criterion. Recommended values for the dullness and resistance criteria for these conditions are given in regulatory documents. Durability values are expressed in

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minutes of machine time. Operating time is characterized not by time, but by the amount of specific work performed during the durability period. Such work includes the length of the cutting path, the number of processed work pieces, etc. Let's consider the indicators for assessing tool life. It should be noted that the dependence of tool life on cutting speed $T = f(v)$ in a wide range of cutting speeds has the form of extreme curves with a maximum in the region of low cutting speeds (picture 1). The formation of a maximum on the durability curves is due to the fact that during operation at given speeds, build-ups are formed on the cutting blade. Cutting speeds, where there is a maximum on the $T = f(v)$ curves, are the most optimal, are recommended and used when processing tools with limited cutting speeds due to technological indicators and operational requirements [22].

Materials and Methods. The aim of the experiment is to establish the relationship between cutting tool life T (min) and cutting parameters (cutting speed v, feed rate s, depth of cut t), as well as to determine the optimal machining conditions that ensure maximum productivity or minimum cost. In accordance with GOST 25751-83, tool life is defined as the operating time of the tool until it reaches the established wear criterion.

To ensure the completeness of the study, a full factorial experimental design method was applied. This method allows evaluating the individual and combined effects of cutting speed v, feed rate s, and depth of cut t. When selecting factor levels, practical recommendations and the machine tool's technical specifications were taken into account.

The main controlled parameter is tool wear. The wear criterion is the width of the flank wear land h_3 (mm). The limiting wear value is established according to regulatory documents (for semi-finish machining, h_3 = 0.3–0.5 mm).

The following materials were used:

– Workpiece: Сталь 45 (HRC 45–50);

– Cutting tool: equipped with carbide inserts of grade T15K6.

The experiments were carried out on a CNC lathe, model 16К20Ф3. The wear criterion (flank wear) was set to h_3 = 0.3 mm. To measure wear, a toolmaker's microscope with a scale division value of 0.001 mm was used.

The experiment was conducted according to the following procedure:

1. Initial wear (run-in): The tool was run in at an initial cutting regime to reach the steady-state wear period.

2. Short-duration turning: Cutting was performed over a time interval $\Delta\tau$, while monitoring the wear increment.

3. Sequential pass method: After each pass, tool wear was measured; the process was repeated until the limiting wear value was reached.

Results. Dependency graphs Efficiency indicators are characterized by dependencies that include vT (speed times durability). For example, the volume of metal Q removed from the work piece during turning can be calculated using the formula:

$$Q = \frac{100st(D-t)}{D} vT$$

where s is feed; t–depth; D–diameter of the work piece; v–cutting speed; T - tool life.

Figure 1 shows the dependence of tool life T on cutting speed v. The curve has a maximum in the region of low cutting speeds. This is explained by the formation of a build-up edge on the cutting blade, which temporarily protects the tool from wear. For the tested material and tool, the optimal cutting speed range is v=60–80 m/min, where the tool life is maximum (T>90 min). A further increase in speed leads to intense heat generation and a sharp decrease in tool life.

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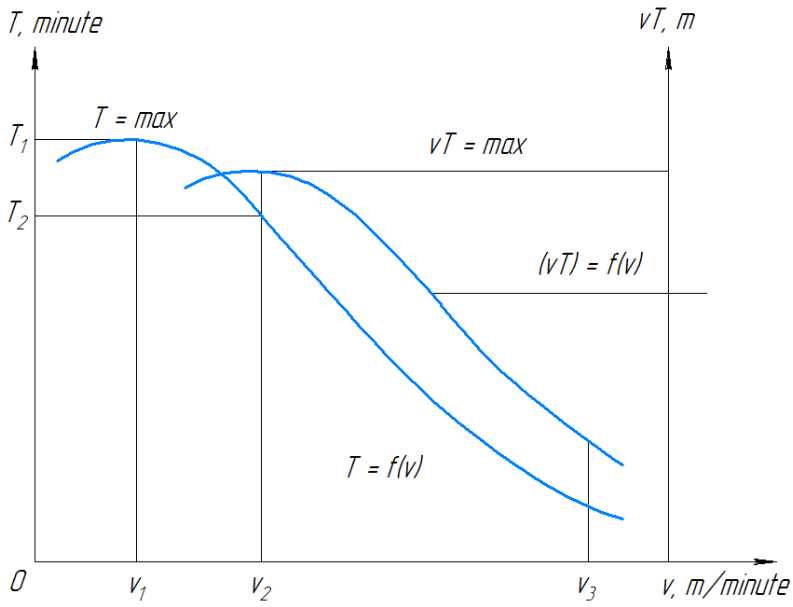

Figure 1. Dependence of tool life *T* on cutting speed *v*

Using the following formulas, you can calculate, respectively, the area of the machined surface A, the volume Q or the mass of metal m/p removed from the work piece, the total nominal length of the hole L, machined with axial tools:

$$A = 0{,}001vTs; Q = 10 - 6vTs; m_p = 6pvTst$$

$$L = \frac{100s_0}{\pi D}vT$$

It is known that the tool wear curve has a characteristic shape: the run-in period (intensive wear), the normal wear period (a linear section of length L, accounting for up to 90–95% of the total tool life), and the catastrophic wear period.

In the presented graph showing the dependence of tool life T on cutting speed v, the curve exhibits a maximum in the low-speed range. This is explained by the formation of a built-up edge on the cutting blade, which temporarily protects the tool from wear. Tool life depends nonlinearly on cutting speed, which necessitates conducting experiments over a wide range of speeds. The tool life is at its maximum ($T > 90$ min) at cutting speeds of $v = 60$–80 m/min.

Conclusion. Thus, the stability of the cutting tool is determined based on the maximum productivity of the machine and the lowest cost of the part. Such stagnation is called economic stagnation, and the corresponding rate of shift is called the economic rate of shift.

Based on the experimental data obtained, the following conclusions can be drawn:

1. The tool life T depends nonlinearly on the cutting speed v, with a maximum in the range of v=60−80 m/min for carbide tools on steel45.

2. The economic tool life (ensuring minimum cost per part) is achieved at v=75 m/min, while the maximum productivity (minimum machining time) is achieved at v=85 m/min.

3. The proposed dependencies can be used to optimize cutting conditions on CNC machines.

4. To increase productivity, it is recommended to use adaptive control systems that maintain optimal cutting speed as the tool wears.

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