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ЗМІСТ

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STUDY OF THE FORMS AND PURPOSE OF MACRO-RELIEF ON THE WORKING SURFACES OF CYLINDRICAL PARTS

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Modern trends in engineering and agricultural industry emphasize the importance of using methods and tools to improve the reliability of individual parts and products as a whole, as well as to reduce the cost of products. The reliability of machine parts is determined by a number of parameters, such as strength, wear resistance, vibration and thermal resistance. In order to achieve these criteria for the reliability of machine parts, it is necessary to take into account various manufacturing methods and improve material processing technologies. An important aspect is also the use of composite and innovative materials that can significantly improve the characteristics of products. In addition, the introduction of automation and digital technologies allows to optimize production processes and reduce the probability of defects.

The study of the forms and purpose of macroreliefs on the working surfaces of cylindrical parts is an actual problem in the field of metalworking and mechanical engineering.

The subject of analysis was the properties and effectiveness of macroreliefs in the metalworking process, in particular their influence on the quality and functionality of products. The work includes an overview of various types of macroreliefs, their purpose and application in production conditions, taking into account the specific requirements of the technological process.

The methods of forming macroreliefs, including processing technologies and their influence on the technical characteristics and quality of the final product, are highlighted. The results of the study showed that the use of macroreliefs can improve the technological capabilities of processing parts, ensure an increase in their strength and stability, as well as improve the appearance and aesthetics of the product.

The obtained results are of practical importance for engineers and designers engaged in the development and production of cylindrical parts in various industries, such as automotive, mechanical engineering, aerospace and other industries where it is important to achieve optimal quality and production efficiency.

Key words: *research, macroreliefs, working surfaces, cylindrical parts, forms, purposes.*
Fig. 14. Ref. 8.

1. Problem formulation

One of the methods of improving the physical and mechanical properties of cylindrical parts is the formation of macroreliefs with an integrated tool during deforming drawing.

Macroreliefs are profiles of the work surface that create channels for parts caused by physical and technological processes. In materials science, macroreliefs can be visible on the raw surfaces of materials or created specifically for certain functions. These channels can vary in shape, size, and depth, and they affect the distribution and movement of lubricant, coolant, or gas across the surface, which is important for various applications. Macro reliefs help reduce friction and wear, providing longer life for materials in mechanical systems.

Macrorelief profiles are channels on the surfaces of parts (Fig. 1.1.), which can be of different depths and shapes, used to control the physical processes of machine nodes. Macrorelief profiles include hand tool enhancements, firearms and explosives enhancements, jointing and rolling for a variety of needs and materials, efficient milling cutters for woodworking and other materials, and embossed shafts for better blade retention and aesthetic appeal. the appearance of parts and products.

It is promising to use macroreliefs in nodes and mechanisms to control fluid flows, reduce friction and wear, supply lubricating and cooling fluid, create residual reservoirs for lubricants or dirt, improve the frictional properties of parts, use to control longitudinal movement in connection with rotating and in general, increasing the reliability, functionality and service life of parts.

In Autodesk Fusion 360, for example, several different types of reliefs were designed on the machining surface for forced chip separation (Fig. 1.)

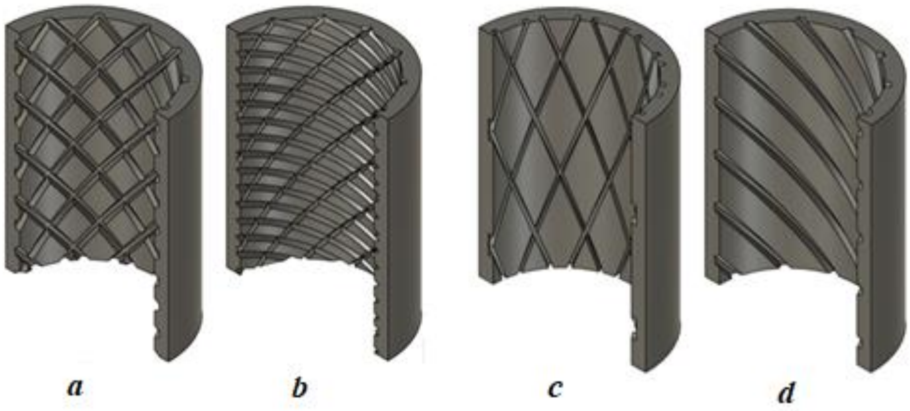


Fig. 1. Types of macrorelief profile:

a) relief formed due to two self-rotating relief-forming sections with the same angle of deforming elements on them, left and right rotation; b) relief, where on one relief-forming section the angle of the deforming element has been changed to a greater side relative to the first section, where the angle of the deforming element has remained unchanged; c) when the angle of the deforming elements is reduced, the groove formation step increases; d) with unilateral rotation of one relief-forming section.

The use of macroreliefs of various profiles and groove shapes in hydro, pneumatic and other nodes where the bypass of technical fluids plays a significant role, makes it possible to improve the uniformity of pressure distribution and reduce friction, can provide control of speed and direction of movement, and in nodes such as shock absorbers serve to improve absorption of shocks and stability of the car during movement.

2. Analysis of recent research and publications

In modern mechanical engineering, high demands are placed on processed materials, in particular, on the quality of structural carbon steels. The specifics of these requirements cover aspects such as the range of blanks, which include pipe rolls, as well as mechanical properties such as tensile strength (δв), which is in the range of 260 to 610 MPa, and the hardness according to the HV method, which is from 650 to 2000 MPa.

One of the examples of the use of macroreliefs is the manufacture of carvings.

In this case, macroreliefs are used to create ridges and grooves of different profiles (Fig. 2.), which form threads necessary for connecting various elements of machines, equipment, mechanisms and creating gears.

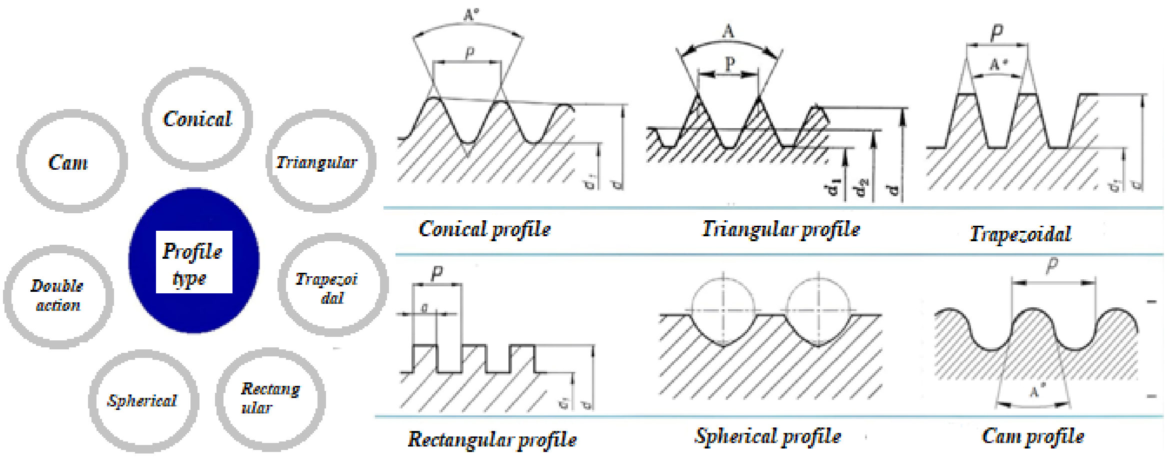


Fig. 2. Kinds of macrorelief groove profile

Fig. 3. Ball-screw transmission

An illustrative example of the formation of such macroreliefs is a ball-screw transmission (Fig. 3.) where the motion transmission method uses a screw shaft with grooves of a spherical profile, in which balls are placed. As the shaft rotates, the balls circulate in the grooves, which causes the nut with the same relief to move along the shaft.

Such a system provides high efficiency and accuracy of movement, and also saves electricity, as it requires less torque for operation. It is worth noting that the formation of such reliefs is possible in many ways, but the most effective can be considered the rolling method, which has forming rollers as working elements (Fig. 4) and uses the method of surface plastic deformation.

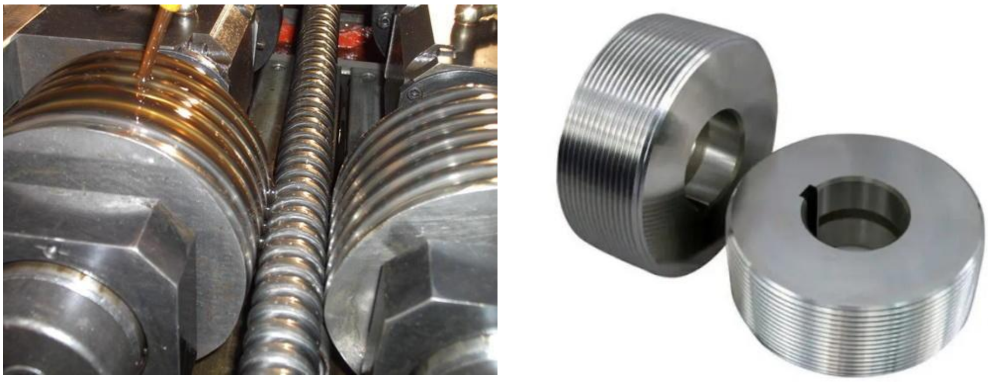


Fig. 4. Rolling method and forming rollers

The method of surface plastic deformation includes mechanical impact on the surface layer of the material in order to change its crystal lattice and structure. During this process, deformation forces force the atoms of the material to move, which can lead to a change in their position in the crystal lattice.

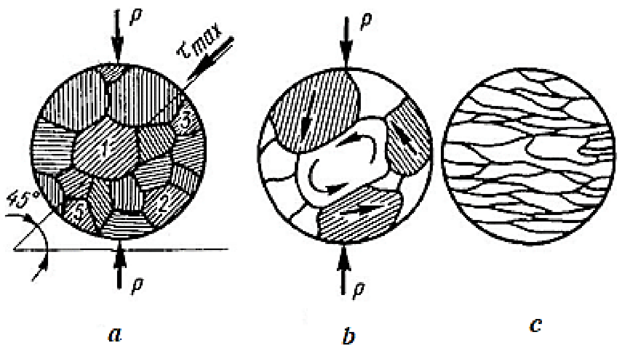


Fig. 5. The process of surface plastic deformation

The sliding of atomic layers takes place, first of all, along those planes, the direction of which forms an angle of 45° (Fig. 5, *a*) relative to the direction of action of the compressive force R. As a result of plastic deformation (Fig. 5, *b*), the crystals are stretched in the direction of the greatest flow of metal and acquire elongated shape (Fig. 5, *c*).

A similar method can be used to create macroreliefs on various hand tools, devices, buttons and other objects. For example, they can be used on medical instruments to facilitate their maintenance, identification and cleaning.

The following are important functions of macroreliefs:

1) Improved grip: the macro-relief structure of such tools provides a better grip, which makes it easier to hold onto the handle when using various tools or tools, such as medical tools, wrenches, screwdrivers, dumbbells, vultures, weapons, etc.;

2) Improved control: Macro relief helps provide better control over tools or implements, reducing the risk of losing control or slipping while working. This contributes to the improvement of safety and efficiency of tasks;

3) Reducing the load on the hands: macroreliefs allow you to distribute the weight over a larger surface area of the hand, which reduces stress and the risk of injury to the hands during work. This helps to maintain comfort during long-term use of work tools or tools.

Many technological processes can be used to form such macroreliefs (Fig. 6), but it is worth paying attention to those methods that make it possible to form them on cylindrical surfaces:

1) Laser engraving;
2) Milling or lathe engraving;
3) Knurl.

Fig. 6. Macroreliefs on hand tools

Although macroreliefs can be formed through laser engraving, there are a number of disadvantages that make this method ineffective and unattractive for constant use, namely:

– limited Engraving Depth: Laser engraving can be limited in processing depth, meaning the macro reliefs may not be deep enough to effectively improve grip and perform the desired functions;

– high costs: Laser equipment and its operation can be extremely expensive, especially for small production or individual projects;

– potential for thermal warping: The laser engraving process can heat up the metal surface, which can cause thermal warping, especially in thin or small parts;

– material limitations: Some materials may be less suitable for laser engraving due to their composition or structure. For example, some metals can be difficult to process due to high thermal conductivity or reaction to laser exposure.

Macroreliefs can be created by engraving on milling and turning machines using various cutters and cutters. However, for the effective formation of such reliefs, it is recommended to use CNC machines with at least four axial directions. This is explained by the fact that the specifics of the work of traditional lathes and milling machines do not always allow to effectively form such reliefs.

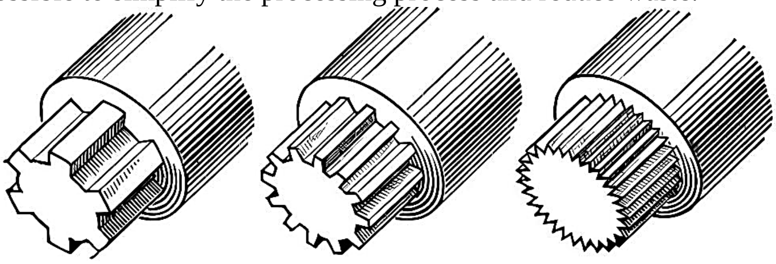
The most effective method of creating relief for improving the grip on various tools and instruments is the rolling method. In this method, a special tool is fixed, usually on the lathe, in the cutter holder or tailstock. It is a highly efficient multi-roll device that allows you to create a macrorelief in the form of a grid in a single pass, without the need to spend time repositioning or readjusting the tool, as is necessary with the single-roll method.

This method is also effective for the manufacture of slotted joints with a triangular profile (Fig. 8 c), we can separately emphasize the tool shown in Figure 7, which is an effective solution for the formation of short longitudinal reliefs (slots), such a tool ensures high accuracy of their formation and reducing the load on the machine components (reducing the compression of the part).

Fig. 7. Rolling tool

The tool is based on the method of surface-plastic deformation, which makes it possible to form macroreliefs in the form of a grid, thread, notch and other reliefs.

The method is based on the plastic properties of the metal, which allows obtaining residual deformation without violating the integrity of the material, forming takes place without removing chips. The tool (roller or rollers) is pressed into the material, which leads to surface deformation and forms the corresponding profile. This approach makes it possible to simplify the processing process and reduce waste.



a ***b*** ***c***

Fig. 8. Profile types of slotted joints: a) – rectangular profile; b) – involute profile; c) – triangular profile

Macroreliefs in the form of longitudinal straight channels on the surface make it possible to form slots, which is an effective and reliable way of connecting various types of moving (sliding) and static shafts, such as half-axles, cardan shafts, couplings, etc.

Such connections have a higher load capacity compared to the alternative key method, which creates a lower stress concentration in the shafts, which ensures their higher durability, contributes to better centering of parts on the shafts, and is more convenient for mass and serial production.

They are also distinguished by the types of reliefs (Fig. 8).

Slotted joints can have different types of profiles, such as rectangular (Fig. 8, *a*), involute (Fig. 8, *b*) and triangular (Fig. 8, *c*). The choice of a specific profile depends on specific requirements for strength, load and other factors that affect the functionality of the slotted connection.

Rollers, or rollers, are specialized equipment designed for grinding, crushing, pressing loose materials and grain crops. They are used both in food and in other industries where they are of great importance.

As an example, the flour mill rollers shown in Figure 9 a are used for grinding cereals and are a key component of mills in flour mills, which can be manufactured by rolling.

The grain grinding process is carried out by rolling the grain between a pair of rolls with macroreliefs on them, which rotate in opposite directions, and due to the pressure, the grain is split, then in turn it is divided into fractions for further processing, from which bran and flour are formed.

In Figure 9. b depicts rollers, or as they are also called rollers, intended for use in granulators that directly press raw materials into the matrix, which contributes to the formation of finished granules. For better performance and productivity, macrorelief is formed on them in the form of longitudinal grooves and, unlike flour mill rollers, they have a larger step around the circumference and depth of the groove, which complicates their manufacture by rolling.

a ***b***

Fig. 9. Rollers of flour milling and granulation equipment: a) – flour mill rollers; b) – granulator rollers

Slotted joints can have different types of profiles, the choice of a specific profile depends on the strength requirements and other factors affecting the functionality of the joint.

Markroreliefs on the shells of fragmentation warheads are geometric features on their surface, specially created to optimize the mechanism of destruction during an explosion. These reliefs consist of a system of ridges and grooves located along the contour of the shell. When an explosive is triggered, they play the role of controlling the destruction mechanism, directing the energy of the explosion and maximizing the formation of fragments.

Fig. 10. Fragmentation projectile

Each of the methods of forming macroreliefs on the shells of shrapnel combat units or similar has its own unique characteristics that should be taken into account when choosing the optimal approach to processing materials.

Boring machines are known for their ability to create deep and detailed grooves, which can be important for certain applications that require a specific depth of relief. However, the process of working on tanning machines can require considerable effort and time, which can complicate production processes.

Planers, on the other hand, typically provide a smooth surface with less roughness, which can be important for some applications where high surface quality is a priority. However, they can be less effective in creating complex shapes, and require specialized tools to achieve certain geometric configurations.

Multi-axis CNC lathes and milling machines open up wide possibilities for creating complex and detailed reliefs thanks to the software control of the movement of the tool. However, they can require significant hardware, cutting tool and programming costs, as well as specialized expertise to set up correctly and use effectively.

a ***b***

Fig. 11. Types of cutters for gear cutting machines: a) – corn; b) – a shaper layer.

Gear cutting machines are known for their ability to provide a strong and stable relief, which can be important in demanding operating conditions. However, they can be limited in creating complex geometric surfaces and require specialized tools to achieve certain shapes.

It is worth noting that most of the milling cutters used on tooth-cutting machines have a corn-type macrorelief (Fig. 11, *a*).

As an example, controlled grooves make it possible to form cutting elements. A shaper (Fig. 11, *b*) used for performing intermediate and final planing operations, as well as for processing surfaces that have both curved and straight shapes, according to the established template.

In addition, this type of milling cutter is often used for processing arched decorative products, and finds its application in other areas of material processing.

The common disadvantages of these processing methods include the fact that they are all performed by cutting, without significant impact on the processed surface, which can reduce the effectiveness of using such reliefs, for more effective operation, it is necessary to change the material structure in the groove zone.

3. The purpose and objectives of the research

The purpose of the experimental study is to determine the potential possibilities of using macroreliefs in the nodes and mechanisms of machine-building and agricultural equipment to control fluid flows, reduce friction and wear, improve the functional characteristics of parts and increase their reliability and service life.

To achieve the set goal, you need to solve the following tasks:

– to analyze modern trends in mechanical engineering and agriculture related to the use of macrorelief;

– to compare the physical and mechanical properties of cylindrical parts with macroreliefs during deforming drawing

– determine the influence of the profile of macroreliefs on the performance characteristics of machine components, in particular, control of fluid flows and reduction of friction;

– to assess the effectiveness and practical application of the developed methods and technologies for the formation of macroreliefs in various industries;

– taking into account the received information, draw conclusions.

4. Results of the researches

Broaching machine with broaching is an important element of metal cutting equipment, which is used for processing through holes and outer surfaces of parts. Its functionality allows you to quickly and efficiently perform cutting, milling and processing of materials, ensuring high accuracy and quality of manufactured parts.

This tool is capable of working with many types of materials, including metals, plastics and composite materials, making it a versatile production tool. The use of a broaching machine with broaching allows you to increase processing productivity, reduce the time of manufacturing parts and ensure high quality of the final product.

In addition, this tool can be equipped with a variety of additional features, such as automatic control systems, cooling and lubrication systems, which further increase its efficiency and productivity. As a result, the broaching machine is an essential tool for production processes where it is important to achieve high speed and precision in processing parts.

The modern industry of tools in mechanical engineering and metalworking actively uses optimal designs of tools specially developed for the relevant production conditions [4]. This series includes combined broaches and other complex tools that work according to the kinematic broaching scheme. They are characterized by high productivity, as they can simultaneously operate many working edges, the total length of which can vary from several hundred to several thousand millimeters. Combined broaches can be the basis for creating tools for forming reliefs.

There are five types of broaching, depending on their configuration and the method of interaction with the part:

1) Round and slotted parts: The broaching type has a round shape at one end and a slotted shape at the other, allowing it to be used for machining parts with different types of holes or cutouts;

2) Slotted and round parts: The slotted shape is located closer to the end of the broach, which makes it easier to cut or mill parts with protrusions or protruding elements;

3) Round, slotted and chamfered parts: the broach has a round shape at one end, slotted at the other, and chamfered at the side, which allows cutting, milling and chamfering to be performed simultaneously;

4) Chamfered, round and slotted parts: the chamfered form is located closest to the end of the broach, which allows for chamfering, as well as cutting and milling;

5) Chamfering, slotting and round parts: the chamfering part is also located closer to the end of the broach, which allows chamfering, cutting and milling to be performed with optimal efficiency.

Each type of broaching has its own characteristics and applications, which depend on specific production needs and requirements for processed parts.

For the most part, broaches are used in multi-series and mass production, which makes it a progressive metal-cutting tool of a highly specialized series, which is due to its high price.

The deforming-cutting broach (Fig. 12) consists of several main components. The first is the front shank (1), which serves as the basis for the entire structure. Next come the deforming elements (2), which are located among themselves and are separated by distance bushings (3), all these elements are strengthened on the mandrel (4). The last component is the cutting part (5), which is connected to the mandrel by welding.

- The following parts are distinguished in the drawing:
- front guide (A);
- deforming section (B);
- intermediate guide (C);
- draft (D);
- auxiliary (E);
- cleaning (F);
- calibrating (G) part of the cutting section (5);
- rear guide (H).

The cutting section is made of P6M5 high-speed steel according to the group scheme, taking into account the previous cold deformation hardening of the processing material (PM) and the parameters of the non-contact deformation wave. Longitudinal chip splitting in the case of drawing deep holes is also taken into account [4].

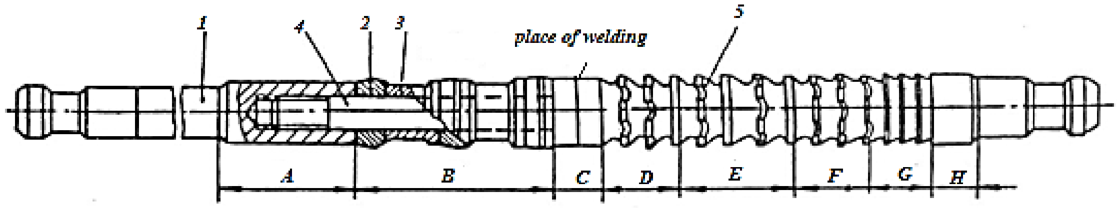


Fig. 12. Deforming-cutting broaching.

The method consists in the fact that one or two dividing elements 2 are installed on the drawing (Fig. 13) behind the deforming element 1 at an angle to the axis of the tool, the working edges 3 of which have the profile of the formed grooves.

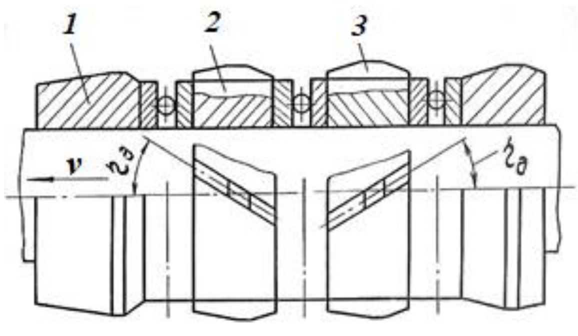


Fig. 13. The working part of the broaching with deforming sections.

Thanks to this, when these elements enter the hole, a tangential force occurs, under the action of which the element rotates, which makes it possible to provide a system of helical grooves, including intersecting ones, if necessary, and opens up new possibilities in metalworking.

For example, most types of firearms, with the exception of shotguns and special smoothbore weapons, have grooves in the middle of the barrel, fig. 14.

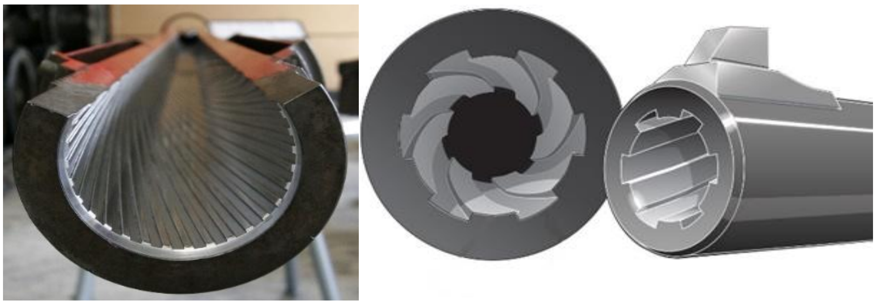


Fig. 14. Macroreliefs on the elements of barrel weapons

They ensure the rotation of the bullet, which, in turn, can have a similar relief to the barrel, in order to stabilize its movement during flight, which contributes to increasing the range and accuracy of shooting.

The rifling forms macroreliefs from spiral grooves cut inside the barrel, which works by rotating the projectile on its axis, causing gyroscopic forces that stabilize the rotation throughout flight; tight threads will spin the ball faster, while loose threads will spin the ball slower. The speed at which the ball spins is very closely related to how stable it will be; too slow and the bullet will flip in the air, too fast and the bullet may fly apart. The rate of rotation caused by rifling is determined by the pitch or rate of twist, their depth, and the shape of the rifling, which describes how loosely or tightly formed the rifling is inside the barrel of the weapon.

5. Conclusions

A broaching machine with a broaching machine is a key element of metal cutting equipment capable of processing through holes and external surfaces of parts. Its functionality allows you to quickly and efficiently perform cutting, milling and material processing operations with high precision and quality.

A broaching machine can work with a variety of materials, including metals, plastics and composites, making it a versatile tool for manufacturing needs. The use of a broaching machine with broaching allows you to increase the productivity of processing, reduce the time of manufacturing parts and ensure the high quality of the final product.

Modern industry actively uses optimal draft designs that allow to increase productivity and efficiency of processing.

There are five types of broaches depending on their configuration and method of interaction with the part, each of which has its own characteristics and application. Broaches are used mainly in multi-series and mass production, which is due to their high price and specialization in specific types of processing.

Deforming-cutting broaches consist of several components that ensure their functioning and efficiency in the processing process.

The method of using broaches with deformable sections allows obtaining macroreliefs on parts, which expands the possibilities of metalworking and ensures high quality and stability of products

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ДОСЛІДЖЕННЯ ФОРМ І ПРИЗНАЧЕННЯ МАКРОРЕЛЬЄФІВ НА РОБОЧИХ ПОВЕРХНЯХ ЦИЛІНДРИЧНИХ ДЕТАЛЕЙ

Сучасні тенденції в машинобудуванні та сільськогосподарській промисловості підкреслюють важливість використання методів та засобів для поліпшення надійності окремих деталей та виробів в цілому, а також для зниження вартості продукції. Надійність деталей машин визначається рядом параметрів, таких як міцність, стійкість до зношування, вібраційна та термічна стійкість. Для досягнення цих критеріїв надійності деталей машин, необхідно враховувати різні методи виготовлення та вдосконалення технологій обробки матеріалів. Важливим аспектом є також використання композитних та інноваційних матеріалів, які можуть суттєво покращити характеристики виробів. Окрім того, впровадження автоматизації та цифрових технологій дозволяє оптимізувати виробничі процеси і зменшити ймовірність дефектів.

Дослідження форм та призначення макрорельєфів на робочих поверхнях циліндричних деталей є актуальною проблемою в галузі металообробки та машинобудування. Розгорнута анотація:

Предметом аналізу стали властивості та ефективність макрорельєфів у процесі металообробки, зокрема їх вплив на якість та функціональність виробів. Робота включає огляд різних типів макрорельєфів, їхнє призначення та застосування у виробничих умовах, з урахуванням конкретних вимог технологічного процесу.

Висвітлено методи формування макрорельєфів, включаючи технології обробки та їх вплив на технічні характеристики та якість кінцевого продукту. Результати дослідження показали, що використання макрорельєфів може покращити технологічні можливості обробки деталей, забезпечити підвищення їхньої міцності та стійкості, а також поліпшити зовнішній вигляд та естетичність виробу.

Отримані результати мають практичне значення для інженерів та дизайнерів, що займаються розробкою та виготовленням циліндричних деталей у різних галузях промисловості, таких як автомобілебудування, машинобудування, аерокосмічна та інші галузі, де важливо досягти оптимальної якості та ефективності виробництва.

***Ключові слова**: дослідження, макрорельєфи, робочі поверхні, циліндричні деталі, форми, призначення.*

Рис. 14. Літ. 8.

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