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THE TECHNOLOGY OF INCREASING THE DURABILITY OF RESOURCE-DETERMINING PARTS OF THE INTERNAL COMBUSTION ENGINE

Formulation of the problem. It is possible to optimize the process of operation by substantiating the dependence of the change in the technical condition of the engines since the start of operation and the criterion of the boundary state of the engine units, which will allow determining the optimal service life of the engine before theist overhaul. The main reasons for changes in the technical condition of the engine units are wear, fatigue, thermal and corrosion damage, which depend on the intensity of changes in dimensions, the geometric shape of parts and their relative location [1-4]. Wear occurs under the influence of three groups of factors: constructive - depend on the design of the engine, technological and operational - the quality of fuels and oils used, and operating conditions. Realizing the share of wear caused by various conditions of engine operation in the general wear, it is possible to determine the factors that have the main influence on the wear of units. This makes it possible to identify the most effective ways to increase the durability of engines with a small expenditure of time and money, as well as to predict the resource of engines before overhaul [2-5].

Analysis of current research.

Research on increasing wear resistance can give the maximum technical and economic effect if the design developments are primarily aimed at eliminating the factors that cause maximum wear. Various operational factors that affect the wear of engine units and its efficiency during operation are usually divided into three groups [4-8]:

1. Load and speed modes of engine operation, which mainly determine the amount of molecular mechanical (adhesive) wear.

2. The thermal mode of engine operation, including start-up and warm-up periods, which determine the amount of corrosion-mechanical and molecular-mechanical wear.

3. Air dust and protection of the engine and its separate parts from mechanical pollution particles, which determine the amount of abrasive-mechanical wear.

The aim of the work is to increase the durability of resource-determining parts by applying external friction, it is necessary to take into consideration that the shear strength of the surface layer is less than the strength of the main material.

Research material and methods.

With an increase of engine speed mode, the friction path is shortened, and at a constant temperature regime, the intensity of wear should decrease. The intensity of wear of engine parts is also greater at unstable speed modes. Moreover, with increasing acceleration, the growth rate of wear intensity decreases [5-9]. The water, that has penetrated into the oil and condensed there at low heat mode, causes intensive coagulation of impurities and hydrolysis of additives with the formation of precipitates - sludge. This leads to the destruction of oil filters, contamination of the grid of oil receivers of pumps and oil channels, which can sharply reduce smooth operation of the engine and cause increased wear of parts to the point of emergency. At high thermal modes of engine operation, oil oxidation processes intensify, leading to deterioration of its properties, activation of additives, especially alkaline ones. Basically, engine reliability indicators are determined by the technical condition of such resource-generating elements as crankshaft bearings, cylinder-piston group (CPG), engine block, which account for 37% of failures and 62% of repair costs [7-11]. The resource of these parts, even if new or restored parts were installed during the repair, to the original size of the parts, will always be less than of a new engine (unit), due to an increase in the rate of their wear, due to distortion of dimensional and kinematic relationships of previously used units and aggregates with worn or distorted parts (within permissible limits). This refers to such resource-generating parts of the power unit as: - the engine cylinder block - the bed of the block, the surfaces under the liners of the root necks of the crankshaft, which during repair of the unit must be checked for the alignment of the beds of the block; - connecting rod - the connecting surface of the lower connecting rod head with the liner, as well as the connection of the upper connecting rod head with the liner, the parallelism of the lower and upper connecting rod holes, deformation of the connecting rod body; - crankshaft - dimensions and shape of necks, presence of cracks on them, shaft deflection; In addition, the inter-repair resource is also determined by the quality of the completed repair. The secondary resource is about 58% of the primary resource, and this is due to fatigue stress in engine elements, the formation of cracks and their development, a change in the alignment of the support surfaces of the cylinder block, which leads to crankshaft breakage, the formation of cracks in the block, etc. [8-13]

To increase the durability of engines, it is necessary to monitor changes in the technical condition of their resource-generating elements during repair work, to improve the technology and quality of repair. The analysis of operational defects of engine elements that have failed indicates a fundamental possibility of improving the operational characteristics of power units due to the use of modern restoration and strengthening technologies.

When the crankshaft deflection is more than 0.9 mm, it is impractical to restore it due to the formation of fatigue cracks in it, while up to 90% of shafts with such a deflection are subject to rejection. Analysis of these data shows that the deflection of the removed crankshafts is 8.6 times greater than that of the crankshafts to be restored. The work of frictional forces causes wear of the cylinder liner and the working surface of the ring. The work of friction forces is influenced by the ratio of physical and mechanical properties of the materials of the ring and the cylinder liner condition of the lubricant and the presence of abrasive in it; the temperature of the parts to be joined. The work of the frictional forces of the second and the third rings is lower than the first one, which is explained by better lubrication conditions, and on the other hand by lower gas pressure in the labyrinth seal. During the compression and working stroke, intensive wear of the cylinder liner occurs, aggravated by the effect of high gas temperature, which leads to burning of the lubricant on the surface of the cylinder. As the piston moves down the work of the frictional forces of the rings in the joint decreases. The conditions in the engine combustion chamber determine: a) the strength of the walls under the action of gas pressure forces on them; b) wear resistance of the cylinder mirror during long-term operation of the engine; c) small frictional losses when moving the piston with rings in the cylinder liner; d) anti-corrosion resistance of the inner and outer surfaces of the liner; e) reliability of sealing in places of gas joints and water cooling joints; f) free expansion in the axial direction for wet cylinder liners. Cylinder lineres are exposed to corrosive substances, abrasive particles, high temperatures and pressure [9-13].

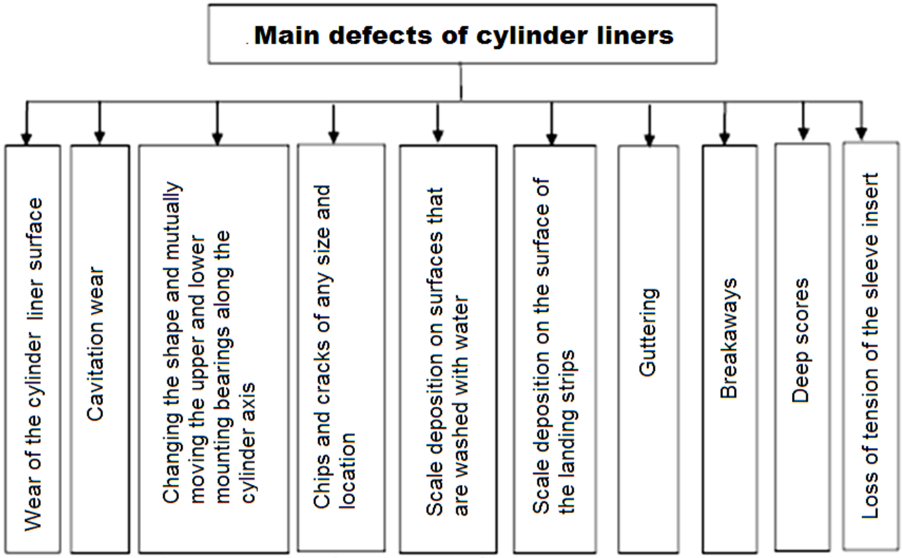


Fig. 1. Main defects of cylinder liners

The surface layer formed on the friction surface localizes adhesive, abrasive damage, embitterment and loosening processes in minimal surface volumes. This layer should have pliable volumes of metal with minimal shear resistance and deconcentrate stresses on the friction contact.

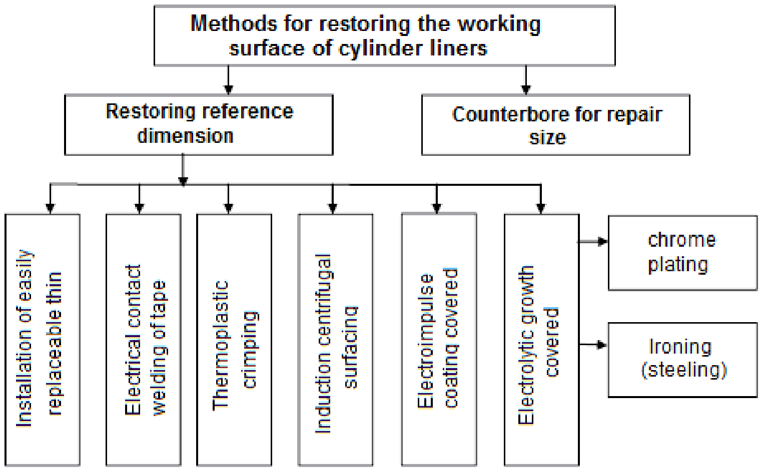


Fig. 2. Methods of restoring the working surface of cylinder liners.

The lower bearing layer must have a high resistance to plastic deformation, seizure, fatigue processes and abrasive damage. Active layers during the operation of engines must retain the ability to be regenerated and be constantly renewed [12]. High pressure and temperature lead to burning and thinning of the oil film with the fuel-air mixture and increases the friction conditions.

Presenting main material.

Let's consider the most widely used ways of increasing wear resistance (Fig. 3).

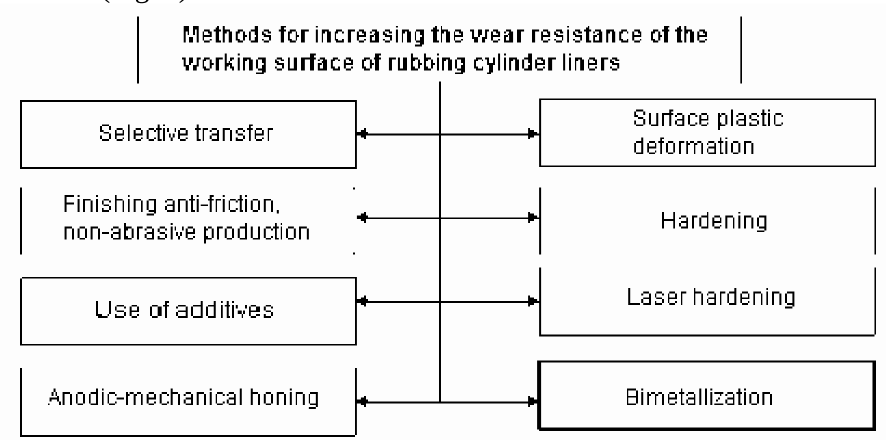


Fig. 3. Ways to increase the wear resistance of the friction working surface of cylinder liners

Such methods include finishing anti-friction non-abrasive treatment (FANAT). The essence of FANAT consists in coating a layer of brass, bronze or copper using the phenomenon of metal transfer during friction. The advantage of FANAT over other finishing operations lies in the simplicity of the equipment. FANAT gives the steel or cast iron surface high antifriction properties. The experience of using FANAT for cylinders allows you to reduce the time of additional work and increase the wear resistance of cylinder liners by 1.6 ... 1.75 times, and the piston rings working with them - by 1.35 ... 1.4 times. Special additives, which are used both at the engine break-in stage and during its operation, have become widespread. Additives form a strong adhesive film that reduces friction and prevents increased wear when working with heavy loads. The disadvantage of the composition is the difficulty of preparation in a factory environment. The additive is characterized by a general toxic effect [12-17]. It is possible to increase the wear resistance of cylinder liners by the method of anodic mechanical honing (AMH) with the use of metal honing bars made of copper, brass, steel or cast iron, which will allow the use of not only electrochemical, but also electroerosive components of the process, as well as the application of an anti-friction layer. With AMH, metal consumption occurs due to electroerosion and electrochemical phenomena. In any mode, appropriate electrochemical processes take place in the interelectrode gap, since the working fluid is an electrolyte. Electric discharges that occur between electrodes and cause electroerosion can be considered as separate heat sources of rapid movement on the surface of the electrode work piece. At the same time, heat spreads deep into the metal according to the laws of heat conduction. The depth of penetration is determined by the power of the electric discharge, the speed of movement of the electrodes, the properties of the environment, etc.

Temperature zones of spherical shape are quickly formed around the objects. In the zone where the heating reaches the melting temperature and higher, the metal melts, partially evaporates and, moving away with the flow of the working fluid and the electrode tool, forms holes. In the following lower zones, a change in structure occurs. A so-called "white" layer appears in the zone where the temperature reaches the tempering temperature and higher one. Using these properties of the "white" layer, you can increase the resource of the cylinder liners. However, the "white" layer has an uneven thickness and continuity, and is also full of pores and cracks. Therefore, obtaining a "white" layer by the anodic-mechanical method turned out to be an impractical one. Processing of cylinder liners should be carried out in modes that allow the appearance of a "white" layer of small thickness. Laboratory and operational studies have shown that the wear resistance of processed AMH is 20 ... 22% higher than the wear resistance of the surface after diamond honing. The surface finishing time also decreased [13-17]. Rolling with balls or rollers is usually used, both in the form of an independent operation and combined with operations of boring, honing, and proofing [8]. During the laser strengthening of the cylinder liner, separate equally spaced strips are applied with a laser on its inner surface at an angle of 45° to the forming liner so that the strips form a grid on the surface. The depth of the hardening zone is 0.6 ... 1.12 mm, the track thickness is up to 0.5 mm, allowance for final machining is 0.13...0.24 mm. As a result of processing, there is a decrease in wear intensity by 1.35...1.58 times [15].

The use of laser processing is advisable in flow and mass production in the case when other strengthening methods do not give the desired result [17]. A method of bimetallization of the friction surface by creating ordered or disordered inserts, inclusions, layers, etc. in the body of the main material from a material that has physical and mechanical properties different from the main one is proposed [17]. During wear and tear, the main material (cast iron liner) and more ductile non-ferrous metal (copper, brass) are destroyed. Copper and its alloys are characterized by plastic deformation due to the interaction of micro-uniformities. Plastic non-ferrous metal and particles of its wear, being directly in the friction zone, interact with the shaking micro-irregularities, "smear" on the contact areas of the micro-irregularities. The film formed between them has low shear resistance and is held on the friction surfaces due to molecular forces. Micro-uniformities present on the friction surface, falling into the zone of plastic deformations (copper, brass), deepen by a value greater than what happens in the zone of elastic deformations. When leaving the zone of plastic deformations in the zone of elastic deformations. The micro-irregularities fall on the cutting edge of the elastic layer and are cut, and the wedge of plastic material located in front of the micro-irregularities separates the connected surfaces and is captured by the moving micro-irregularities to the nearest depression, filling it.

At the same time, chemical processes of formation of spinel occur, which, falling into the depressions of the surface, rise increases its resistance to normal loads [15-18]. The advantage of this method is that there is no need for constant replenishment, as in the case of micropowders, of copper reserves, which participate in the friction process. In addition to being formed as a result of chemical reactions, ZnFe2O4 spinel is a high-temperature neutralizer of the exhaust gases of the combustion chamber. The thickness of the layer of non-ferrous metal that is formed on the surface of the liner, has 2-3 microns, and the presence of some non-ferrous metals, for example, copper or brass, directly in the combustion chamber leads to a decrease in the toxicity of engine exhaust gases. The technical and economic advantage of the liner with the use of fusible inserts is to increase the durability of the cylinder-piston group by reducing the coefficient of friction of its connected parts without adding, for example, expensive anti-friction additives to the lubricant, which must be applied at each oil change. The simplicity of the design of the modernized liner allows it to be produced at any repair plant, even in conditions of non-specialized production. Implementation of the method of bimetallization of the liner surface is currently a rather difficult task. It would be most appropriate not to cover the entire surface with non-ferrous metal, but to use metal inserts.

However, in this case, the question arises as to how the inserts should be located in the surface of the cylinder liners. For this, it is necessary to justify the geometric parameters of the liner with inserts. It should be noted that the angle of inclination of the insert will be limited by the geometric parameters of the liner and the stroke length of the piston. Therefore, it is necessary to take into account these parameters. Knowing the angle of inclination of the insert, we will calculate the geometric parameters of the groove and the volume of the necessary metal to ensure wear reduction (Fig. 4).

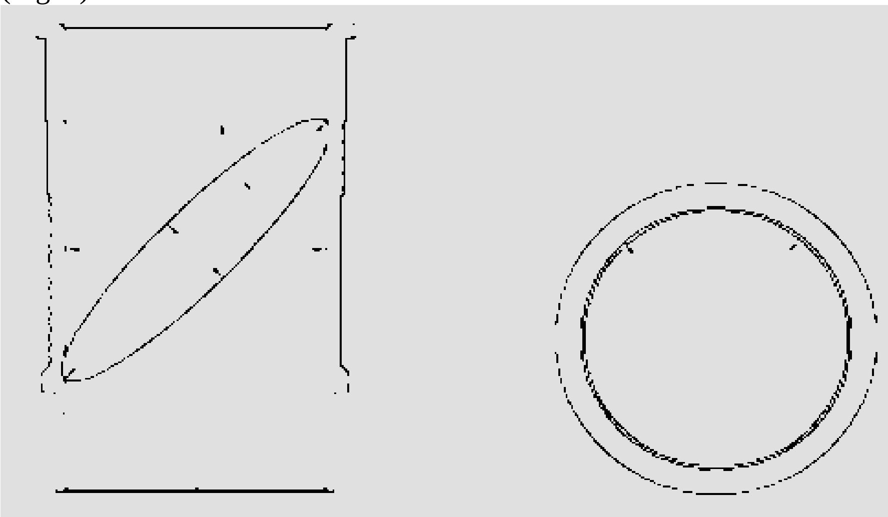


Fig. 4. Scheme of the geometric parameters of the insert.

Based on the condition of covering the entire rubbing surface of the cylinder liner with metal, and observing the requirements of a positive mechanical gradient, we will determine the amount of metal in the inserts. This can be done only if the depth of insertion of the piston rings does not exceed the thickness of the coating of the surface of the liner with the metal of the insert. Based on this and knowing the height of the surface irregularities of the cylinder liner, we will determine the amount of metal required to cover the rubbing surface of the liner.

$$V_{м} = \pi \left(r^2 - r_1^2 \right) L \qquad (1)$$

where r is the liner radius, mm, r_1 is the radius of the liner covering with metal, mm; L - stroke of the piston, mm. At the same time, it is necessary to comply with the terms:

$$r^2 - r_1^2 \geq h_{\max} \quad (2)$$

where h_{max} is the maximum height of the surface irregularities of the cylinder liner, mm.

To calculate the number of inserts in the cylinder liner and specify their geometric parameters, it is necessary to calculate the amount of metal removed from one insert by piston rings. Volume of removed metal:

$$V_0 = hS_B \quad (3)$$

where h - the depth of the introduction of the piston ring into the metal insert, mm.

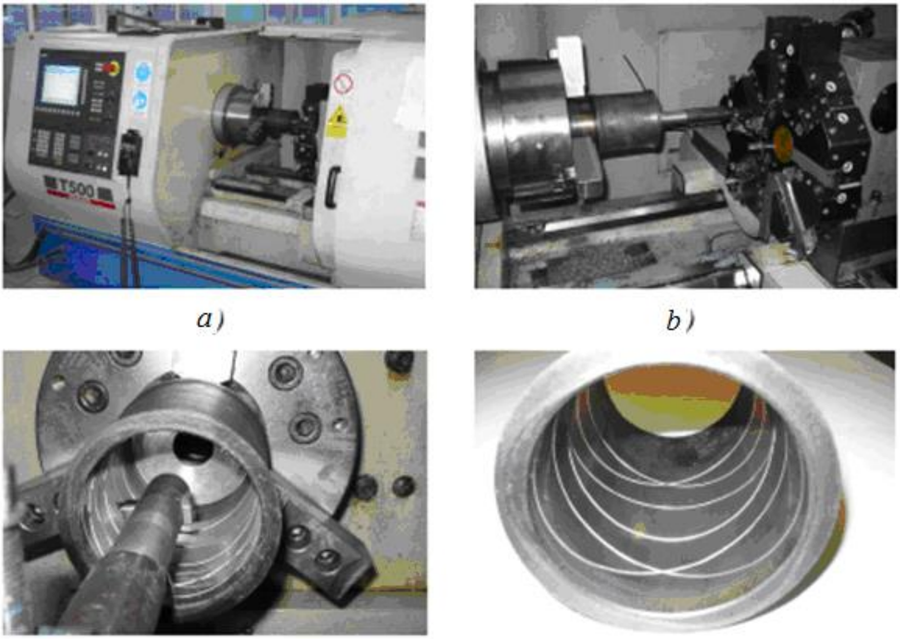
In the real operating conditions of the CPG, the depth of the introduction of the piston rings into the metal insert will decrease with each reciprocating cycle, and will reach zero when the friction surface is leveled (uniform coverage of the surface of the cylinder liner with a layer of non-ferrous metal). When the layer of non-ferrous metal (wear of the metal film) on the friction surface of the liner is reduced, there will be a difference in the height of the metal layer in the zone of the insert and the friction surface of the liner, which will cause an increase in the depth of insertion and the removal of the next layer of the insert metal with its further "smearing" on the friction surface liners The cycle is repeated, which is the key to the bimetallization of the friction surfaces.

The proposed technological process of manufacturing bimetallized cylinder liners includes the operations of cleaning the cylinder liners, their defecting, eliminating cavitation damage, building up the landing strips and their processing, trimming the support edge, cutting annular grooves and their surfacing, cleaning the inner surface after surfacing, grinding the inner surface, honing it , control, conservation and packaging.

In contrast to the existing technological process, the proposed one contains operations of bimetallization of the friction working surface: cutting annular grooves, surfacing them, cleaning the inner surface after surfacing.

Instead of the boring operation, the rough and fine grindings of the inner surface of the liner were applied on center-grinding or internal grinding machines due to the risk of breaking of the boring head cutter and metal chips on the border of the annular grooves.

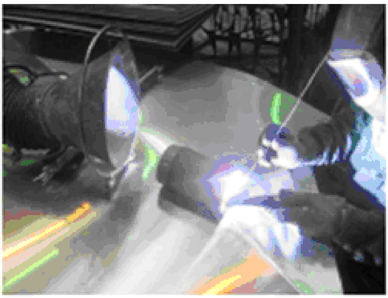
Ring grooves are cut on a centering lathe (Fig. 5). The cylinder liner is fixed in a three-jaw chuck during processing.



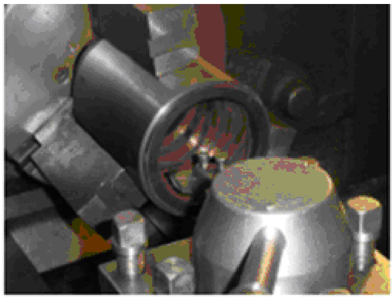
c) d)

Fig. 5. Cutting ring grooves:
a) type of centering lathe; b) three-ball cartridge; c) VC 8 sharps; d) liner with annular grooves.

Liners are installed by checking their position in the horizontal and vertical planes on 0.032...0.054 mm. Processing is carried out with a WNr cutter (German) or SS cutter (Sweden), which is chosen taking into account the processed material, the type of allowance and the recommended cutting depth. When processing, Universal cutting emulsion (UCE) is used. A vertical milling machining center, such as the M-450 model, equipped with a universal rotary table, can be used for cutting annular grooves. While processing, the cylinder liner is fixed in a three-jaw chuck installed on a universal rotary table, which in time is installed and fixed on the machine table with an angle of 170. The liner is installed by checking its position and beating with an accuracy of 0.032. ..0.054 mm. The processing is carried out with disk shaped cutters with a small tooth. The trapezoidal cross-section of the ring grooves is ensured by appropriate sharpening of the cutter teeth. The necessary step and direction of the ring arrays is ensured by the vertical feed of the machine and the rotation of the liner on the rotary table. The cutting depth and feed are determined taking into account the hardness of the processed material, the type of operation, the tool material, the type of cutter, and the method of its attachment. Ring grooves are filled by manual argon arc surfacing (Fig. 3.3 a). A wire with a diameter of 0.82 ... 1.12 mm is used for surfacing ring grooves; the material is copper C 1100. Taking into account the dimensions of the cylinder liners, surfacing is performed with an argon arc torch АРГ-250 with a tungsten electrode, with filler metal supplied in the form of a wire directly into the zone.



a)



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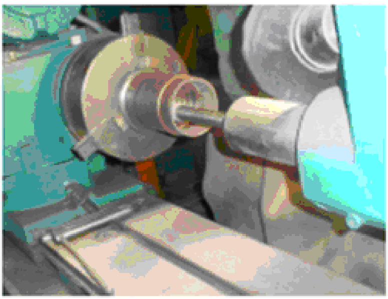

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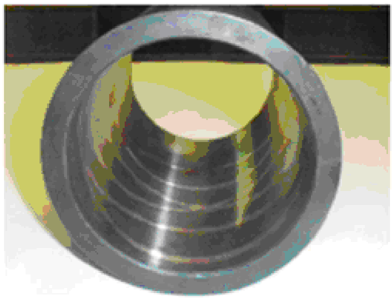

d)

Fig. 6. Bimetalized cylinder liner processing technology:
a) surfacing of grooves with M1 copper; b) cleaning of the inner surface;
c) opkration grinding; d) bimetallized cylinder liner with profiled insert.

As shielding gases, argon of the highest grade according to DSTU (National Standards of Ukraine) 10157-99, helium of the highest quality category of grades A and B according to TU 51-940-90, as well as their mixtures in the ratio of 50 ... 75% argon by volume, have been used. The power of the burner has ensured surfacing of annular grooves and a small zone of thermal influence. First, the inner surface of the cylinder liner was cleaned and degreased. Then the cylinder liner was placed in a thermal furnace and heated to 300 ... 400 ° C. After installation in the frame, copper melting began, to prevent the cylinder liner from warping diagonally, tacks were made at the beginning and end of all annular grooves. The cylinder liner was reheated to 300 ... 400 ° C and welded from the center opposite the grippers. The electrode was located strictly in the plane of the joint; the electrode tilt was 60 ... 80 ° "at a backward angle". Welding modes: arc voltage - 60 V, current - 90 A, gas pressure - 0.05 MPa. To remove slag and metal inflows, after surfacing the screw grooves, the inner surface was cleaned on a lathe and screw-cutting machine, for example, 16K20. Grinding could be performed on honing machines ZG833, ZA83S - 33, and ZU142VM. Rough honing was done with EHU 525 bars or with M27 100% concentration diamond bars with a diamond content of 3.5 carats. Clean honing was carried out with KZM20SM1K bars or ASM20M1 diamond bars of 100% concentration. The material and hardness of the circle, the type of connection, were chosen taking into account the simultaneous processing of cast iron and copper alloys of high hardness. Honing was carried out in the following modes: peripheral speed - 60 ... 80 m / min; - 15 ... 25 m / min; pressure on bars - 0.53 ... 1.13 MPa (rough honing) and 0.43 ... 0.64 MPa (clean); UCE - kerosene; allowance for rough honing - 0.051 ... 0.073 mm, and for finishing - 0.011 ... 0.032 mm. Processing modes were selected taking into account the required accuracy and surface roughness, the hardness of the processed material, the material of the abrasive wheel, the method of fastening the workpiece, the use of lubricating and cooling fluid.

Conclusions

1. Linear wear of the bimetallized cylinder liner is 3.1 times lower than that of a typical liner. The thickness of the anti-friction film on the friction surface of the liner of 2 ... 3 μm is achieved by annular grooves, which corresponds to at least 8.3% of the area of the grooves filled with copper to the area of the working surface of the friction of the cylinder liner.

2. When used copper with angles of inclination in the range of 15^o ... 20^o, wear is reduced on average by 2.7 times, wear intensity by 48 ... 83%,

friction moment by 14.7% compared to a solid sample. There is a 12.5% decrease in roughness in bimetallized samples compared to solid ones.

4. The technological process of manufacturing a bimetallized copper cylinder liner, on the working surface of which grooves are made in the form of three rows of closed rings separate from each other, with elevation angles of 17^o to the diametrical plane of the liner and a step of 13 mm, is substantiated.

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