Method for repairing steel crankshaft joints

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Abstract. The paper presents the results of a study aimed at ensuring the maintainability of crankshafts, as well as the importance of the need to restore worn crankshaft journals, an analysis of existing methods and an innovative method developed by the authors. The essence of which lies in the fact that each neck of the shaft is subjected to copper plating by contacting at the moment of rotation with a swab dipped in a solution of copper sulphate in water and in an electrolyte. Then, on each neck, plates obtained by rolling from a mixture of brass powder and powders of hard alloy materials (tungsten carbides, titanium, etc.) are mounted by wrapping around the neck, with layers of pasty flux from borax, brass powder, and soldering fat deposited on their surface. Further, with the help of a detachable inductor fixed in the tool holder of the machine, each neck is subjected to heating in turn. Moreover, when the inductor is turned on, a low frequency is first used to increase the depth of heating, and then the frequency increases.

1 Introduction

In the developing science of machine repair, the tasks of increasing their reliability and durability are becoming increasingly important, the solution of which will improve the quality of repaired equipment, increase labor productivity and use its resource more fully and efficiently, which will ensure significant savings in material and labor resources in the national economy. It is known [1] that the engine life is largely determined by the state of the crankshaft journals, the wear of which leads to a loss of oil pressure and the engine out of operation. During operation of internal combustion engines, crankshafts wear out. The only way to restore a crankshaft is to apply a metal coating to worn journals. Numerous methods for restoring crankshaft journals have been developed and technologies for their use have been described, however, in the practice of repair enterprises, their use is limited due to significant shortcomings. These include significant warping of the shaft, the presence of cracks and pores, a decrease in fatigue strength, low machinability of metal coatings, and high energy costs for applying metal coatings.

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In connection with this, there is a problem of restoring worn crankshafts.

To solve this problem, we set the following research tasks:

- Briefly analyze the existing methods for restoring worn crankshaft journals;
- Develop an innovative way to restore worn crankshaft journals.

2 Materials and methods

Materials and methods for the implementation of research tasks are carried out on the basis of exploratory research. First, analogues are determined, then they are analyzed. The analysis showed [2-7] that a "Method of restoring the necks of steel crankshafts" is known, which includes preparing the surface of the necks by cleaning from corrosion and shot blasting, installing the said shaft on a screw-cutting lathe and rotating the shaft on the machine, performing flame spraying of the coating, with its simultaneous sealing with the help of a disk of carbide material mounted on a device for rotation, which is located in the tool holder of a screw-cutting lathe, by rotating it along a helical line in the direction coinciding with the direction of rotation of the crankshaft, while applying copper-containing material with subsequent grinding of the restored surface of the necks, characterized in that the application of a copper-containing material to the surface of the necks is carried out before the flame spraying of the coating by making one turn of the helical groove on each neck along its entire length using a cutting universal disk rotating in the direction opposite to the rotation of the crankshaft installed on the said device for rotation, located in the tool holder of the screw-cutting lathe, while the pasty flux for soldering iron and copper alloys and a copper wire with a diameter corresponding to the repair size are placed in the said groove, which is fixed pointwise by soldering using a gas burner.

The disadvantages of this method are the high complexity of the repair, which limits its use.

The closest in terms of technical essence and achieved economic effect is the "Method of restoring the necks of steel crankshafts" [8], including dismantling, washing, flaw detection and grinding of the worn shaft surface, preparation of the surface of the necks by cleaning from corrosion and shot blasting, and flame spraying of the coating, at the same time, simultaneously with the flame spraying of the coating, it is compacted with a disk of carbide material by rotating it along a helix in the direction coinciding with the direction of rotation of the crankshaft, while after grinding, finishing antifriction ugly treatment is carried out with a disk of copper-containing material by rotating it in the opposite direction direction of rotation of the crankshaft, moreover, flame spraying of the coating with simultaneous sealing and finishing anti-friction ugly processing is carried out by means of disks installed in the tool holder of the screw-cutting lathe.

The disadvantage of this method is the relatively low technical and economic indicators, such as wear resistance, scuff resistance.

On the basis of exploratory studies in order to improve technical and economic indicators, namely, improve the quality of the applied coating, increase the service life and reduce the cost of restored crankshafts in comparison with new ones, we proposed an improved method [9].

The new elements of the method are that, first, after shot-blasting, on the shaft installed on the machine, its necks are treated with copper plating by contacting at the moment of rotation with a swab dipped in a solution of copper sulphate in water and in electrolyte, then, on each neck, plates are mounted by wrapping around the neck of the plate, obtained by rolling, from a mixture of brass powder and powders of carbide materials (tungsten carbides, titanium, etc.), with layers of pasty flux from borax, brass powder, soldering fat deposited on their surface, then using a detachable inductor fixed in the tool holder of the machine, each neck is heated in turn, and when the inductor is turned on, first a low frequency is used to increase the depth of heating, and then the frequency increases, thanks to this operation, the plate is soldered and sintered, then the surface of the necks is restored by grinding when they rotate on the machine.

3 Results

Schemes explaining the essence of the method of repairing the journals of steel crankshafts are shown in Figures 1-5.

The method of repairing the necks of steel crankshafts includes preparing the surface of the necks 1 by cleaning from corrosion and shot blasting and installing the said shaft on a screw-cutting lathe 2 to ensure its rotation. Next, a solution of copper sulfate is prepared in distilled water and electrolyte and poured into a copper plating device, which is installed in the tool holder 3 of machine 2 (Figure 1).

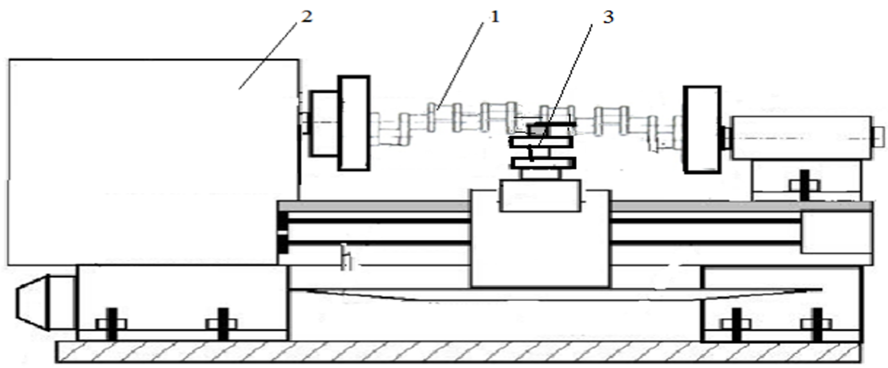

Fig. 1. The layout of the crankshaft journals on a screw-cutting lathe. 1 - crankshaft journals, 2 - screw-cutting lathe, 3 - machine tool holder 2.

The device for copper plating (Figure 2) has a container 4 connected by holes 5 with a foam rubber swab 6, a fixed sleeve 7 on the bracket 8. Next, each neck 1 of the shaft is subjected to copper plating by rubbing it with a swab when the shaft rotates. After making sure that the coating is of high quality without gaps, the neck 1 is dried with a hair dryer, and then the rotation of the shaft is turned off.

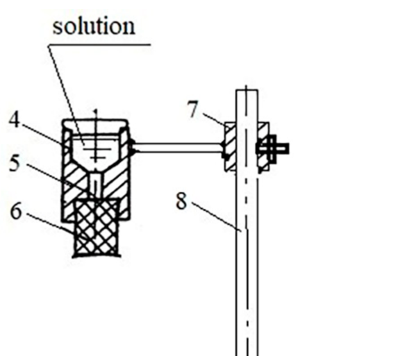

Fig. 2. Device for copper plating. 4 - container, 5 - hole, 6 - foam rubber tampon, 7 - fixed sleeve, 8 - bracket installed in tool holder 3 of machine 2.

Then, by rolling (Figure 3, a), a mixture of 10 brass powder and powders of carbide materials in the form of tungsten carbides, titanium, etc., coming from hopper 9, is made, passing it between rollers 11, repair plates 12. At the same time, plate 12 is adjusted in width, cutting off the excess. Next, a pasty flux is prepared by thoroughly mixing soldering fat, borax and brass powder, which is applied in a uniform layer 13 on repair plates 12 (Figure 3, b). Then, repair plates 12 with flux layer 13 are mounted on each neck 1 by wrapping around it (Figure 3, c).

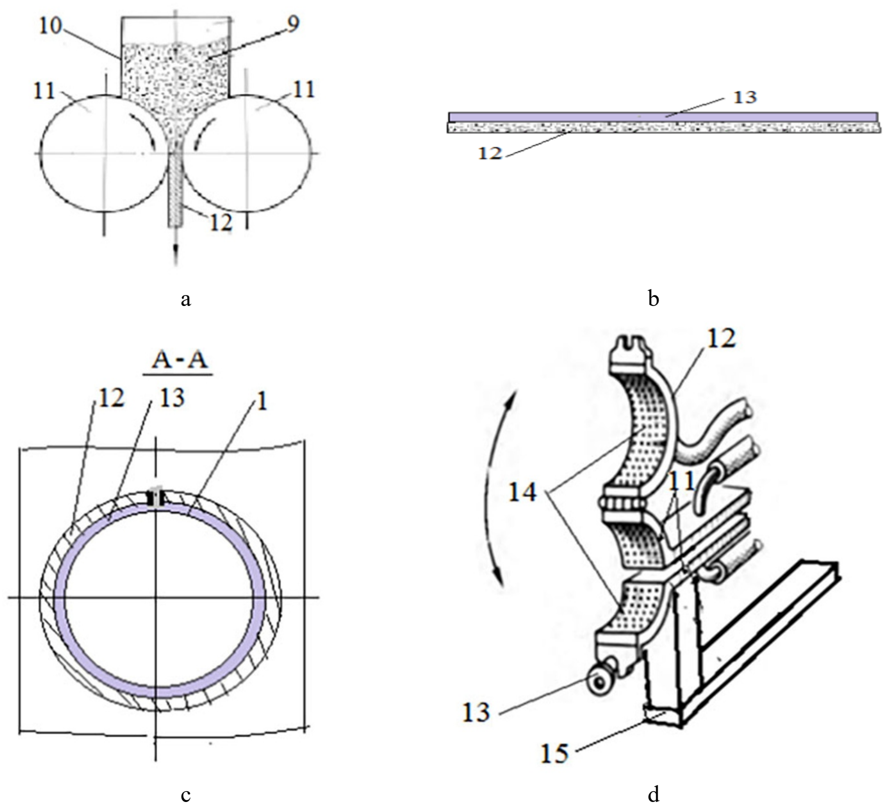

Fig. 3. Production of repair plates, mounting on necks and an inductor for soldering: a - a device for making a repair plate by powder rolling; b - prepared repair plate with a layer of solder fat applied (side view); c - installation of a plate with soldering fat on the neck; d - inductor for soldering). 9 - hopper, 10 - a mixture of brass powder and powders of hard alloy materials in the form of tungsten carbides, titanium, etc., 11 - rollers, 12 - repair plate, 13 - a uniform layer of pasty flux from soldering fat, borax and brass powder, then in the tool holder 3, a detachable inductor is installed (Figure 3, d), containing fixed sections 14, detachable part 15, latch 16, holes for cooling water outlet 17 and water supply hoses, fastening 18.

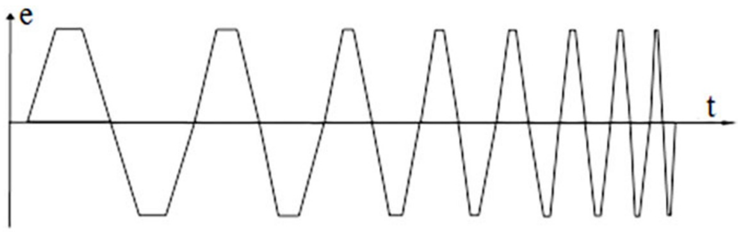

Fig. 4. The program for switching on the inductor during soldering.

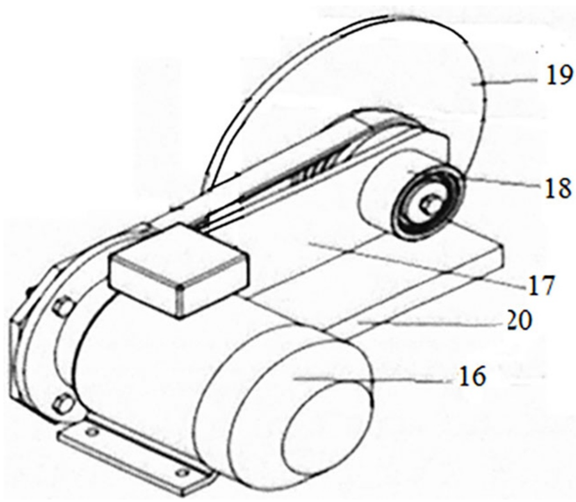

Fig. 5. Sanding attachment. 19 - frame, 20 - electric motor, 21 - belt drive, 22 - replaceable grinding wheels.

Next, a detachable inductor is installed in the tool holder 3 (Figure 3, d), containing fixed sections 14, a detachable part 15, a latch 16, holes for the exit of cooling water 17 and water supply hoses, fastening 18. After that, each neck 1 is placed in turn in a detachable the inductor, and subjected to heating for some time to solder and sinter the plate 12. In this case, the inductor is turned on according to the program - first, a low frequency is used to increase the heating depth, and then the frequency is increased (Figure 4). Powerful currents of various frequencies (from tens of Hz to several MHz) are induced in the inductor using a special generator, as a result of which an electromagnetic field arises around the inductor. The electromagnetic field induces eddy currents in the workpiece. Eddy currents heat the workpiece under the action of Joule heat.

For steel, for example, the penetration depth of an electromagnetic wave at a frequency of 50 Hz varies between 1 - 2 mm, and at a frequency of 5000 Hz - within 0.1 - 0.2 mm. Thus, when using solid steel, it may turn out that not all the steel section is filled with magnetic field lines, and the magnetic field strength decreases from the surface into the depth of the body.

The penetration depth of an electromagnetic wave is determined by the formula:

$$\Delta = \frac{1}{\sqrt{\mu\mu_0 \pi f \sigma}}, \text{ m} \quad (1)$$

where μ is the relative magnetic permeability of the material, o. e.; μ0 is the magnetic constant (4 · π · 10-7, H·m); f is the inductor current frequency, Hz; σ is the conductivity of the material, (Ω-1 · m-1).

After warming up, shower cooling with water from holes 17 is carried out to allow the inductor to be reinstalled. At the end, the restoration of the surface of the necks 1 is performed by grinding during their rotation on a lathe using a grinding device fixed in the tool holder 13 (Figure 5), containing a frame 19, an electric motor 20, a belt drive 21 and replaceable grinding wheels 22.

4 Discussion

The technological process of restoring worn crankshaft journals consists of the following sequential operations, the fulfillment of the requirements of which guarantees the quality and reliability of crankshaft repair: preparation of crankshaft journals 1 for restoration by cleaning from corrosion and shot blasting; installation of the crankshaft on the screw-cutting lathe 2; preparation of a solution of copper sulfate in distilled water and electrolyte; copper plating of the necks 1 with a solution by rubbing with a swab 6 using a copper plating device installed in the tool holder 13; production by rolling from a mixture of 10 powder of brass and powders of carbide materials repair plates 12; preparing a pasty flux for applying layer 13 to plates 12 and then mounting them on necks 1; placement of the necks 1 in a detachable inductor fixed in the tool holder 13; heating for soldering and sintering plate 12 by connecting the inductor to a special generator according to the program - first, a low frequency to increase the depth of heating, and then the frequency increases; shower neck cooling with 1 water; machining of necks 1 with soldered plates 12 by grinding to the nominal size.

After the final grinding on the neck 1, the soldered sintered plate 12 has hard inclusions of carbide powder and a soft copper-zinc alloy base, which will equip its surface with copper for the entire operational period, reducing wear, eliminating the tendency to seize surfaces, reducing running-in time, increasing the service life, energy savings as a result of reduced mechanical friction losses.

5 Conclusion

The proposed method will improve the quality of repaired equipment, increase labor productivity and use its resource more fully and efficiently, which will provide significant savings in material and labor resources in the national economy. Based on the analysis of the wear of the crankshaft journals, the paper proposes technological methods for their restoration. The necessary tools and fixtures have been developed, and processing modes have been determined. However, despite the great variety of methods for applying metal coatings to worn crankshaft journals, the problem of their restoration, especially in small-scale repair production, remains relevant. The use of carbide powder and a soft base of copper-zinc alloy, which equips the neck surface with copper for the entire service life, increases the reliability and durability of propulsion systems, including agricultural machinery, cars, tractors, etc.

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