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RESEARCH INTO THE RESTORATION OF PARTS BY PLASTIC DEFORMATION

Olena IVANKOVA, Candidate of Technical Sciences, Associate Professor
Vitalii FEDIN, Postgraduate Student
Poltava State Agrarian University

ІВАНКОВА Олена Володимирівна, к.т.н., доцент
ФЕДІН Віталій Олексійович, аспірант
Полтавський державний аграрний університет

Increasing the durability of machines is a priority task of the technical maintenance and repair industry. In modern conditions, the development and implementation of progressive technologies for the restoration of worn machine parts is of particular relevance, which is one of the priority tasks for our country. At the same time, the processes of plastic deformation in the repair of parts currently have limited application, despite their significant potential. This necessitates the need for targeted research into the use of plastic deformation for the restoration of specific machine parts.

Hydraulic systems are important components of most machines and mechanisms, and their reliability largely determines the performance of the equipment as a whole. Gear pumps, as key elements of hydraulic systems, operate under conditions of increased loads and intense friction. The main causes of their failures are violations of the adjustment gaps in the mating parts, which arise as a result of reaching the limit of wear, in particular bushings.

The article provides an analysis of the operating conditions of gear pumps, as well as characteristic defects and types of wear of their parts. The results of the analysis showed the possibility of restoring worn bushings using plastic deformation methods. The restoration method, the choice of equipment, tools and technological process modes are substantiated, and a rational heat treatment mode is proposed. The conclusion is made about the feasibility and possibility of using plastic deformation to restore gear pump bushings in order to increase their durability.

The use of plastic deformation in the restoration of bushings allows you to compensate for the worn layer of material due to a controlled change in the geometric parameters of the part and the formation of a wear-resistant material structure without the formation of a heat-affected zone. The deposition and distribution processes provide an increase in the physical and mechanical properties and dimensional stability of the restored parts, which contributes to the increase in their operational reliability.

Key words: *pump, bushing, technology, durability, wear resistance, plastic deformation, deposition.*
Eq. 1. Fig. 4. Ref. 12.

1. Problem formulation

A significant number of parts of agricultural machinery, in particular, hydraulic system units, are operated under conditions of fairly severe loads and intense friction. Therefore, the development of technologies for restoring and strengthening the surfaces of such parts is one of the important ways to achieve high durability of agricultural machinery.

The use of plastic deformation in the repair of worn machine parts makes it possible to form a wear-resistant metal structure that does not have a thermally affected zone. In addition, it has good economic and environmental performance of the restoration process.

Regarding bushing-type parts, the processes of distribution and deposition deserve attention.

The deposition of bushings consists in the fact that by reducing the height of the bushing, its worn layer is compensated. When depositing bushing-type parts, the nature of the stress-strain state of the material and the change in the volume of the bushing are important and depend on the parameters of the mode [1].

Therefore, there is a relevance of conducting research to study the parameters and develop modes of the technological process of deposition and distribution of gear pump parts.

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2. Analysis of recent research and publications

A large number of studies are devoted to the study of ways to increase the durability of agricultural machinery. The results are based on theoretical, experimental studies and practical experience in the operation of machines.

The use of plastic deformation methods in mechanical engineering in the manufacture of parts is widely covered in the literature.

Plastic deformation in the field of technical service in the repair of machine parts has not been studied enough.

Tribophysical properties of materials and mating parts are the basis on which research on the development of technologies aimed at increasing the reliability of equipment is based [2].

In order to develop a methodology for assessing the stress-strain state of parts, studies of non-monotonic plastic deformation in the processes of metal processing by pressure are being conducted [3, 4, 5]. Ukrainian scientists in their works investigate the mechanism of development of processes of local deformation of parts. Criteria for assessing the deformability of the material of blanks in the process of direct and reverse extrusion by stamping steel parts have been developed.

Understanding the action of internal stresses in deformed parts is extremely important. The determination of residual stresses in deformed parts is carried out by teams of scientists [6].

One of the least studied areas in the theory and practice of metal processing by plastic deformation is the study of the nature of deformation during the restoration of worn parts. In particular, research on strengthening the outer surface of cylindrical parts is of great importance for increasing the durability of critical parts of machines and mechanisms [4, 10].

Specialists of the school of Professor Dudnikov A.A. [9, 11] are engaged in solving problems of increasing the service life of worn parts using plastic deformation. As a result of their research, technologies for restoring specific parts using vibrodeformation have been developed.

3. The purpose of the article

The purpose of the work is to increase the durability of parts of hydraulic systems of equipment by improving the technology of repairing worn bushings of gear pumps.

To do this, it is necessary:

- to analyze the operating conditions of gear hydraulic pumps of equipment and characteristic defects and wear of pump bushings;
- to analyze methods of restoring bushings;
- to develop working tools for depositing parts;
- to develop a temperature regime to increase the wear resistance of restored bushings.

4. Results and discussion

Hydraulic systems are important components of any agricultural machinery: in the drives for controlling mounted and trailed implements of tractors, in the steering units of autotractor machinery and other mechanisms [7].

Two gears in the pump housing are in mesh with each other. During the operation of the pump, the working fluid (mainly mineral oil) fills the gaps between the gear teeth and enters the inner part of the housing from the suction cavity into the discharge cavity. Then, it is supplied to the hydraulic system units.

Main malfunctions: reduction of the volumetric flow rate of the pump due to the formation of limit wear of parts, which can lead to disruption of the adjustments of the connections of parts and deterioration of machine control [8]. Parts of hydraulic units have mainly hydroabrasive and abrasive types of wear. Gear pump bushings are subject to abrasive and thermal wear, which is the result of relative movements of mating surfaces at high speeds. In this case, the friction pair is subjected to a significant specific load. This is the reason for the drop in the volumetric flow rate of the pump.

Since the disassembly of the mating units reduces the durability of hydraulic system units, their malfunctions are determined by diagnostic methods, namely, by testing on stands. If the pump flow rate is less than 0.65, the pump requires repair [7, 10]. The main wear of the bushings: wear of the end surface in mating with the gear, wear of the inner cylindrical surface of the bushing, wear of the outer cylindrical surface and the small end surface in connection with the housing and the sealing collar.

A study was conducted of the wear of the end and outer surfaces of 10 pairs of bushings [11]. As a result, the maximum wear value of the connections of the end gears and the bushing surfaces was determined.

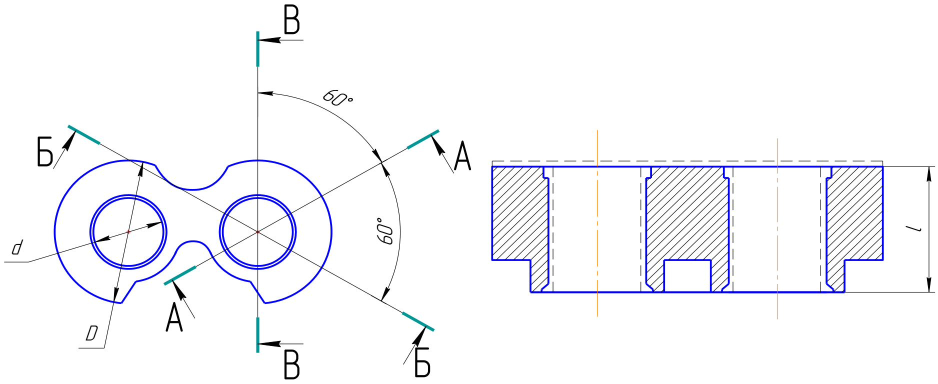

Fig. 1. Scheme of measurement of worn bushings [11]

As a result, we concluded that the average wear of the inner diameter of the bushing is in the range from 0.15 mm to 0.20 mm, the wear of the outer diameter of the bushing is 0.08…0.16 mm. The taper of the outer diameter of the bushings is in the range from 0.02 mm to 0.03 mm.

In the case of intensive wear with the formation of aluminum abrasions, scoring and adhesion of aluminum particles to the surface of steel gears, the friction coefficient increases. This can lead to jamming and failure of the entire assembly.

Studies have shown that the greatest intensity of wear is observed in the connection "gear end - bushing end". But with auto-compensation of end gaps, it does not significantly affect the reduction in pump flow.

The quality of bushing restoration directly affects the wear resistance and durability of the repaired gear pump.

Most often, several methods are used in production to repair gear pump bushings: 1 - by remelting rejected parts, 2 - by building up worn layers, 3 - by plastic deformation, 4 - by sleeving [1, 8]

The method of restoring rejected bushings by remelting has significant disadvantages: significant energy consumption and costs for mechanical processing of the manufactured bushing. In addition, the chemical composition of the bushing material is disturbed, so remelting cannot be progressive.

The building up of worn bushing surfaces can be performed: by applying a layer of galvanic coatings to the worn surfaces, by thermal diffusion building up methods, by applying a layer of polymers. All methods have advantages, disadvantages and application limits. But they all require complex technological equipment. The method of installing additional parts, namely, sleeving, is not currently used in the repair of hydraulic system units [1, 5].

The restoration of parts using methods based on plastic deformation is possible due to the ability of their material to change shape and size due to the redistribution of material. Plastic deformation methods can be used both in the cold and in the heated state of the part. For bushing-type parts, the most acceptable are distribution and deposition.

The essence of the technology of deposition of parts such as bushings is to compensate for the worn layer of the part by reducing their height. The height of the gear pump bushing in this case is restored by reducing the height of the housing wells, or by setting an additional washer.

Studying the nature of deformation during restoration by deposition. The laws of load changes during plastic deformation over time are complex [3, 5]. The change in the dimensions of the part that occurs during the deformation of metals is explained by the occurrence of deformations. In this case, the total deformation is the total result of small deformations for the entire deformation process.

When deforming a hollow sample (bush), the deformation state is described by three types of deformations: in the radial direction - by two compression deformations, in the axial direction - by tensile deformation. The equality of deformations in the radial direction is important for this process [4]. To determine the magnitude of the total deformation along the cross-section of the bushing, the law of volume constancy is used [6]. The deformation of the bushing is determined by the total (total) degree of deformation.

The axial compressive stresses in the undeformed part of the bushing cannot exceed the proportionality limit of the metal:

$$\sigma_z = \frac{P}{F} \leq \sigma_{d\ddot{o}} \ , \quad (1)$$

where σ_z – axial stress; σ_{do} – limit of proportionality of the sleeve (the highest stress up to which the action of Hooke's law is preserved).

If this condition is violated and the axial stress increases to the yield point, the deformation condition will change and the compression of the sample will begin.

The deposition of the sleeves was carried out using an experimental setup [9] at a pressure of P=430...450 MPa with a holding time of 2...3 s.

The laboratory setup for restoration by the method of plastic deformation consists of three main units: the working body, the base, the hydraulic system for lifting and lowering the working body.

Before deposition, the sleeves were heated in a muffle electric furnace MP 15/1000 to a temperature of T=380...400°C to increase the plastic properties of the AMO-3-7 alloy. The heated sleeve was placed in a matrix preheated to a temperature of 100-120°C. During deposition, a cylindrical punch is located inside the sleeve (Fig. 2) to limit the flow of the alloy through the internal cavity.

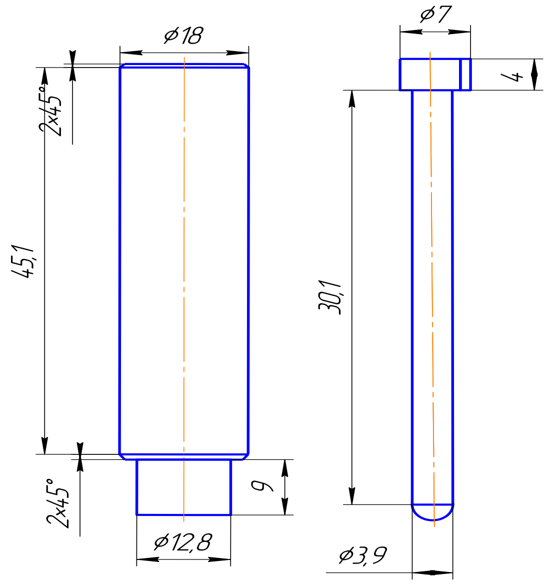

Fig. 2. Punch

After deposition, the inner diameter of the sleeve was machined to the required size with a special mandrel. After that, the outer surface of the sleeve was machined to the required size on a 1K62 screw-cutting lathe.

Advantages of the proposed method: simplicity of implementation and low metal consumption. Disadvantages: additional aluminum washer is required.

Justification of the modes of restoration of bushings. It was established that for the aluminum alloy AMO-3-7 the minimum hardness and the corresponding maximum plasticity, at which it is necessary to carry out plastic deformation, are in the temperature range of 450-500 °C.

The effect of temperature on the hardness of the alloy AMO-3-7 during deformation is shown in Fig. 3.

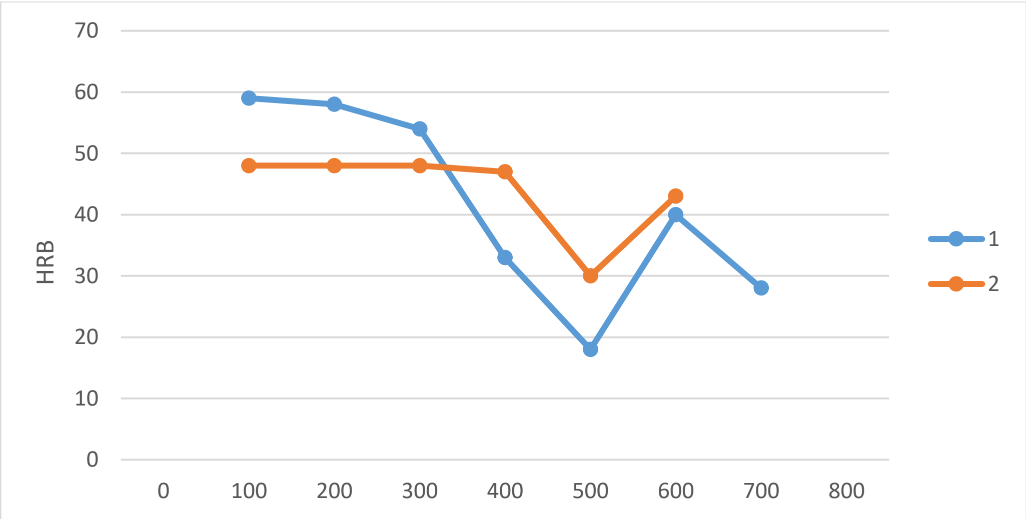

Fig. 3. Effect of temperature on the hardness of the alloy: 1 – sleeve before restoration; 2 – restored sleeve

From the above graph it is clear that the minimum hardness of the aluminum alloy is obtained in the temperature range from 450 to 550°C.

When the alloy heated to a high temperature is cooled rapidly, the atoms of the elements are fixed in an unstable state, that is, a supersaturated solid solution is formed. It is characterized by high hardness and low plasticity. Aging of the alloy leads to the decomposition of this supersaturated solution, the atoms form small particles (precipitate) in the crystal lattices, and resist the movement of dislocations, thereby increasing the strength and hardness of the alloy [12].

Therefore, after the deposition process of the bushings, artificial aging [11] was performed at 180°C for 6 hours. In this mode, the maximum hardness of the material was achieved. The effect of the holding temperature on the hardness of the restored bushings is shown in Fig. 4.

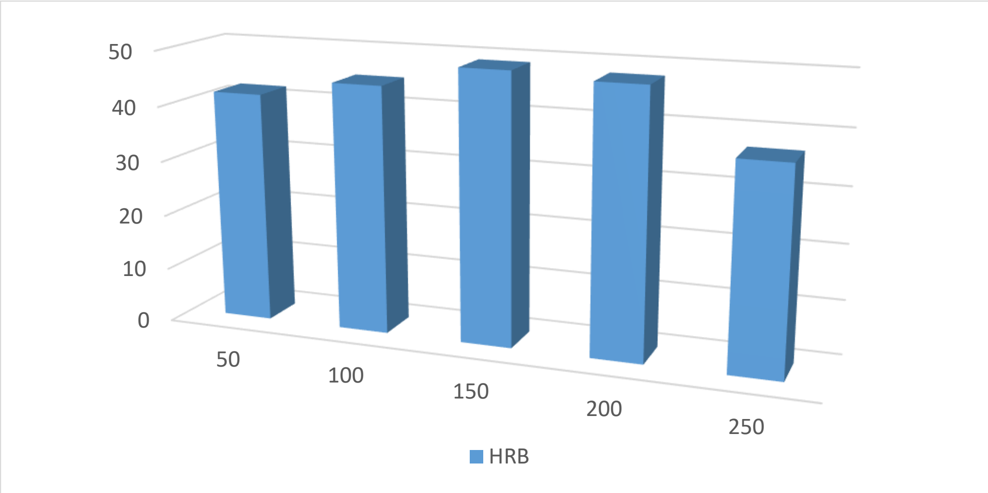

Fig. 4. Effect of aging temperature on the hardness of restored bushings

Therefore, the optimal aging temperatures for restored bushings are in the range from 150 to 200^{0}C.

5. Conclusion

The article is devoted to solving the issue of increasing the wear resistance and durability of parts of hydraulic systems of agricultural machinery.

The operating conditions of gear pumps of hydraulic systems were analyzed, defects and wear of pump bushings were analyzed. Worn bushings can be restored. The methods of restoring bushings were analyzed, it was recognized that the use of plastic deformation, namely, precipitation, can be effective in restoring bushings. Working tools and devices for restoration were developed. It was proposed to use artificial aging to increase the wear resistance of parts. The influence of aging temperature on the hardness of bushings was studied and recommendations on process modes were developed.

The use of the technology of precipitation of worn bushings when repairing gear pumps will contribute to increasing the wear resistance and durability of hydraulic systems of agricultural machinery.

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ДОСЛІДЖЕННЯ ТЕХНОЛОГІЙ ПЛАСТИЧНОГО ДЕФОРМУВАННЯ ПРИ ВІДНОВЛЕННІ ЗНОШЕНИХ ДЕТАЛЕЙ

Збільшення довговічності машин є пріоритетним завданням галузі технічного обслуговування і ремонту. У сучасних умовах особливої актуальності набуває розробка та впровадження прогресивних технологій відновлення зношених деталей машин, що є одним із першочергових завдань для нашої країни. Водночас процеси пластичного деформування при ремонті деталей нині мають обмежене застосування, незважаючи на їх значний потенціал. Це зумовлює необхідність проведення цілеспрямованих досліджень щодо використання пластичної деформації для відновлення конкретних деталей машин.

Гідравлічні системи є важливими складовими більшості машин і механізмів, а їх надійність значною мірою визначає працездатність техніки в цілому. Шестеренні насоси, як ключові елементи гідросистем, працюють в умовах підвищених навантажень та інтенсивного тертя. Основними причинами їх відмов є порушення регулювальних зазорів у спряжених деталях, що виникають унаслідок досягнення граничного зношування, зокрема втулок.

У статті наведено аналіз умов експлуатації шестеренних насосів, а також характерних дефектів і видів зношування їх деталей. Результати аналізу показали можливість відновлення зношених втулок із застосуванням методів пластичного деформування. Обґрунтовано спосіб відновлення, вибір обладнання, інструментів і режимів технологічного процесу, а також запропоновано раціональний режим термічної обробки. Зроблено висновок про доцільність і можливість використання пластичної деформації для відновлення втулок шестеренних насосів з метою підвищення їх довговічності.

Застосування пластичного деформування при відновленні втулок дозволяє компенсувати зношений шар матеріалу за рахунок контрольованої зміни геометричних параметрів деталі та формування зносостійкої структури матеріалу без утворення зони термічного впливу. Процеси осаджування і роздачі забезпечують підвищення фізико-механічних властивостей та стабільність розмірів відновлених деталей, що сприяє зростанню їх експлуатаційної надійності.

Ключові слова: *насос, втулка, технологія, довговічність, зносостійкість, пластичне деформування, осаджування.*

Ф. 1. Рис. 4. Літ. 12.

INFORMATION ABOUT THE AUTHORS

Olena IVANKOVA – Candidate of Technical Sciences, Associate Professor, Associate Professor of the Department of Agricultural Engineering and Road Transport, Poltava State Agrarian University (1/3 Skovorody St., Poltava, Ukraine, 36003, e-mail: olena.ivankova@pdau.edu.ua, https://orcid.org/0000-0003-1825-0262).
Vitalii FEDIN – Postgraduate Student (PhD candidate) in specialty 133 *Industrial Mechanical Engineering* at Poltava State Agrarian University (1/3 Skovorody St., Poltava, Ukraine, 36003, e-mail: vitalii.fedin@pdau.edu.ua, https://orcid.org/0009-0001-6646-5906).

ІВАНКОВА Олена Володимирівна – кандидат технічних наук, доцент, доцент кафедри агроінженерії та автомобільного транспорту Полтавського державного аграрного університету (вул. Сковороди, 1/3, м. Полтава, Україна, 36003, e-mail: olena.ivankova@pdau.edu.ua, https://orcid.org/0000-0003-1825-0262).
ФЕДІН Віталій Олексійович – аспірант за спеціальністю 133 «Галузеве машинобудування» Полтавського державного аграрного університету (вул. Сковороди, 1/3, м. Полтава, Україна, 36003, e-mail: vitalii.fedin@pdau.edu.ua, https://orcid.org/0009-0001-6646-5906).