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Analysis of methods of hardening and restoration of worn parts

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Abstract. *The restoration of worn parts is an important aspect in the field of machine repair and maintenance of machinery. It allows you to significantly reduce repair costs and is a priority issue in the development of a machine maintenance and repair system. The main causes of performance loss products are abrasive wear, fatigue breakdowns, corrosion and other types of destruction. When choosing a recovery method, the type of coupling, types of friction and operating conditions of the machines are important factors. An increase in wear resistance can be achieved by changing the chemical composition of the material, mechanical influences and the application of wear-resistant coatings.*

Keywords: *wear resistance, restoration, surfacing.*

1. Introduction

In the structure capital cost repairs of machines, 60-70 % of the costs are accounted for by the cost of spare parts [1]. At the same time, the cost of restoring most parts does not exceed 25-40 % of the price of a new part [2]. Currently, advanced restoration technologies have been developed, which, in addition to restoration, strengthen it, significantly increasing wear resistance [3]. Restoration of worn parts is one of the main ways to save material and energy resources, solve environmental problems, since the cost of energy, metals and other materials is 25-30 times less than the cost of manufacturing new parts. When remelting worn parts, up to 30 % of the metal is irretrievably lost.

The restoration of worn-out parts can significantly reduce the cost of repairing machinery and is therefore a priority issue in the development of a machine maintenance and repair system [4].

Methods for restoring machine parts provide for compensation of surface layers of the main structural material lost during operation (restoration of nominal drawing dimensions and operational properties) by applying new masses (layers) of material of the same or another brand to worn areas. In some cases, when restoring, the boring method is used for the next repair size, while changing the mating part. Special treatments are also required – annealing to relieve stress, hardening to increase wear resistance [5].

The rapid destruction of products operating at high speeds, loads and temperatures, as well as under conditions of abrasive, corrosive and other types of exposure, requires the development and introduction into production of new methods for their hardening and restoration. The main causes of loss of performance of products are abrasive and other types of wear, fatigue breakdowns and discoloration of the material, various kinds of corrosion and cavitation damage, liquid and gas erosion and various combinations of the above reasons [6], [7].

2. Analysis

The various details in mechanical engineering are characterized by shape, dimensions, materials, weight, balance, as well as tolerances (shapes and locations of surfaces): straightness, flatness, roundness, cylindricity, parallelism, perpen-dicularity, alignment, symmetry, positional deviation, axis intersection, radial and end runout, tilt, shape of a given profile. During operation, in addition to changing the shape, size, weight and location of surfaces, cracks, fragments, chips, nicks occur, and balancing is disrupted. Of all the surfaces to be restored, the outer and inner cylindrical surfaces make up 53.3 %, threaded – 12.7 %, spline – 10.4 %, toothed – 10.2 %, flat – 6.5 %, all others – 6.9 %. Except for the parameters of the surfaces to be restored (shape, dimensions, physical and mechanical properties, accuracy, roughness, integrity, type of thermal or chemical-thermal treatment, the presence and material of the coating) to choose the recovery method, very important factors are: the type of coupling, types of friction and relative movement of surfaces during the operation of machines. These factors are combined by a common concept – indicators of working conditions [8].

It is possible to increase the wear resistance of the working surfaces of products by changing the chemical composition of the surface material by introducing alloying components to form structures that resist wear processes well; by mechanical and thermal effects on the metal surface, which lead to structural and substructural transformations that increase resistance to various wear processes; by applying wear-resistant coatings on the friction surfaces of parts. According to the above, it is possible to classify a variety of technological methods for increasing wear resistance (Figure 1), considering that they are based on factors of chemical, thermal and mechanical influences that can significantly change the surface properties of products. A variety of operating conditions of machines and mechanisms, combined with modern requirements, necessitate the development and improvement of technological methods for applying wear-resistant coatings in order to obtain bimetallic products and for restoration operations. Among the variety of methods of applying wear-resistant coatings, a special place is occupied by surfacing, in which the surface of the coated material and the deposited alloy are melted due to the heat of an external source, as a result of which their interaction occurs with the formation of a metallurgical bond [9].

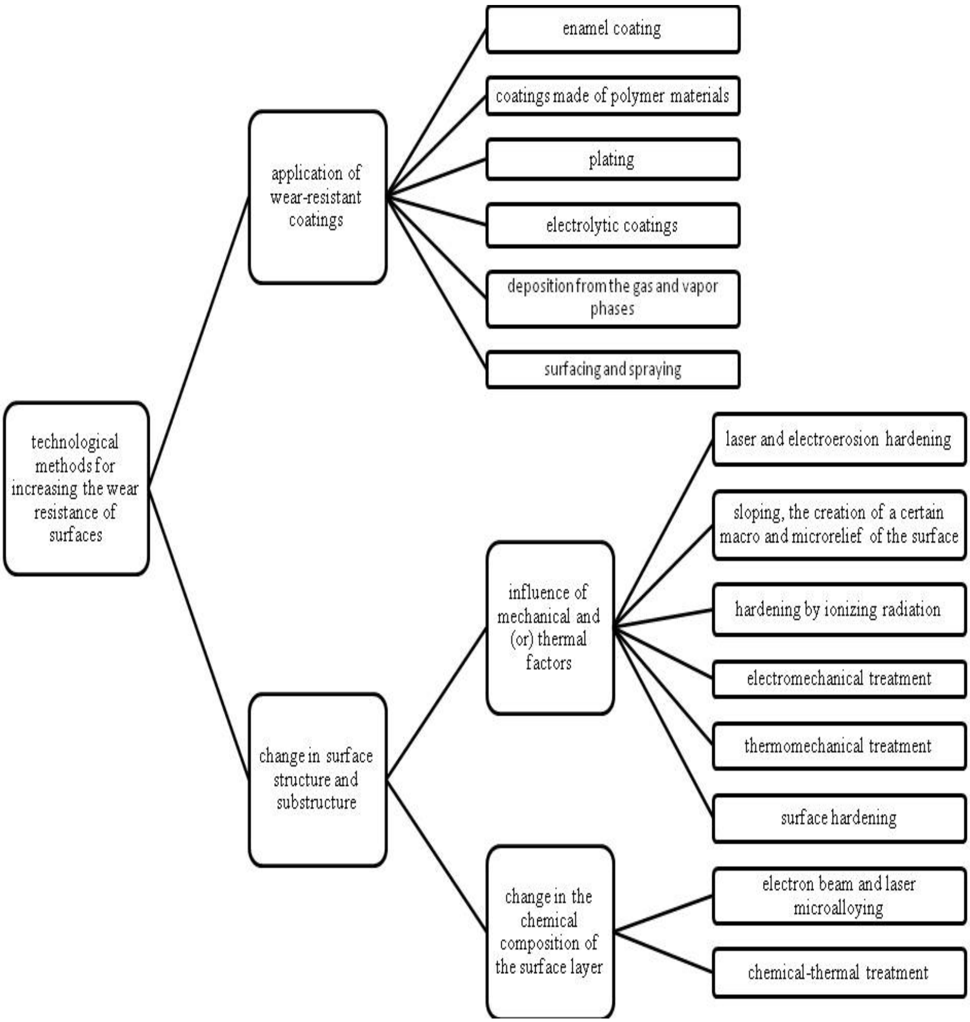

Figure 1. Technological methods of increasing wear resistance

The surfacing technology has the advantages of obtaining a sufficiently large coating thickness, high productivity, and no restrictions on the size of the surfaced surfaces. In this case, a layer with the required chemical composition, high hardness and wear resistance is formed. In the total volume of work on the restoration of parts at repair enterprises, surfacing of various types accounts for about 77%, electrocontact baking — 6 %, electroplating methods – 5 %, electromechanical processing – 4 %, pouring with liquid metal – 2 %, polymer reduction – 4 %, other methods – 5 % (Tables 1 and 2). Currently, many technological methods are widely used for surfacing materials on the surface of the part to be restored. Most of them are quite close in terms of energy parameters (Figure 2).

Table 1. Technical and economic indicators of coating methods

The method of application	Performance coefficient	Coefficient of technical and economic efficiency	Applicability in repair (shaft-sleeve connection)
Surfacing			
under the flux layer	1,62-1,45	0,436	
vibration arc	0,85-0,72	0,25	limited
in the environment of carbon dioxide	1,82-1,77	0,403	wide
electrical contact	2,3-2,1	0,66	
with powder wires	1,75-1,54	0,4	wide
manual arc	1	0,314	-
plasma	2,2-1,9	0,56	
Spraying			
gas flame	1,68-1,47	0,39	limited
plasma	1,76-1,68	0,4	limited
Electroplating coatings			
chrome plating	0,32-0,022	0,087	-
ironization	1,93-1,77	0,064	-

Restoration of a part is a complex of technological operations to eliminate defects in a part, ensuring the resumption of its operability and geometric parameters established by regulatory and technical documentation.

Recovery methods are conditionally divided into two categories: methods of building up and processing methods.

Depending on the physical nature of the processes, technological and other features, the existing methods are divided into ten groups (Table 3).

Mechanical machining eliminates signs of wear and restores the shape of the part. At the same time, the dimensions after processing differ from the nominal ones. To ensure the necessary fit, mating parts with changed parameters are used or a wear compensator is installed (rings, bandages, bushings, threaded spiral inserts, etc.).

Table 2. Indicators of the restoration of parts in various ways.

The method	Estimated indicators			
	Material consumption, kg/m	Specific labor intensity, h/m	Unit cost, USD/m	Specific energy intensity, kWh/m
Surfacing				
manual electric arc	43-57	30-38	0.65-0.93	580
manual argon	30	23-30	0.64-0.70	520
arc manual gas	38-51	36-33	0.82-0.88	80
electric arc under a layer of flux	38-51	21-24	0.42-0.55	286
vibrating arc	35-30	33-36	0.73-0.77	234-240
electric arc in carbon dioxide environment	30-45	14-21	0.28-0.48	250
Electroplating coatings				
chrome plating	20-24	72-129	0.88-1.48	324
ironization	28-43	15-19	0.32-0.38	120

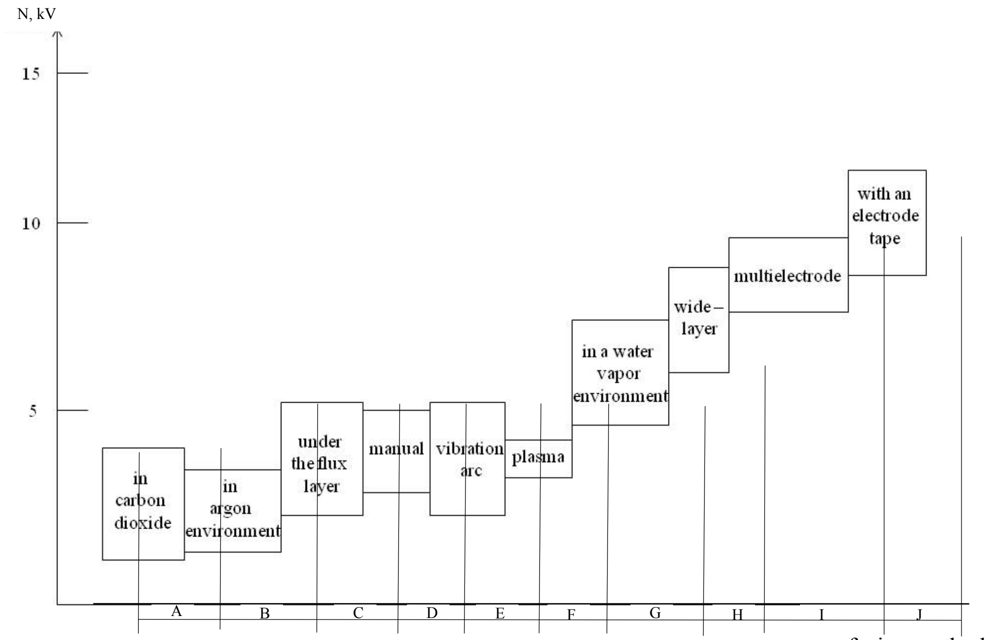

Figure 2. The dynamics of the growth of the working power of the arc from the method of surfacing: N – is the working power of the welding arc, kilovolts; A, B, C, D, E, F, G, H, I, J - surfacing methods

Table 3. Ways to restore parts

Group number	A group of methods	Method
1	Locksmith and mechanical processing	1. Processing for repair size 2. Setting up an additional repair part 3. Processing before removing signs of wear and giving the correct geometric shape 4. Re-assembly
2	Plastic deformation	1. Hood, drawbar 2. Editing (on presses, by riveting) 3. Mechanical distribution 4. Hydrothermal distribution 5. Electrohydraulic distribution 6. Rolling out 7. Mechanical compression 8. Thermoplastic compression 9. Precipitation 10. Extrusion 11. Knurling 12. Electromechanical disembarkation
3	Application of polymer materials	1. Spraying: flame gas, in a pseudo-liquefied layer (vortex, vibratory, vibratory), etc. 2. Crimping 3. Injection molding 4. Application with a spatula, roller, brush, etc.
4	Manual welding and surfacing	1. Gas 2. Arc 3. Argon arc 4. The Blacksmith Shop 5. Plasma 6. Thermite 7. Contact information
5	Mechanized arc welding and surfacing	1. Automatic submerged 2. In the environment of protective gases: argon, carbon dioxide (carbon dioxide), water vapor, etc. 3. With combined protection 4. Arc with flame protection 5. Vibration arc

Group number	A group of methods	Method
		6. With a powder wire or tape 7. Wide - layer 8. With a recumbent electrode 9. Plasma (compressed arc) 10. Multielectrode 11. With simultaneous deformation 12. With simultaneous machining
6	Mechanized arcless welding and surfacing methods	1. Induction (high frequency) 2. Electroslag 3. Contact welding and welding 4: By friction 4. Gas 5. Electron beam 6. Ultrasonic 7. Diffusion 8. Laser 9. Thermite 10. By explosion 11. Magnetic pulse 12. Furnace welding
7	Thermal gas spraying (metallization)	1. Arc 2. Gas flame 3. Plasma 4. Detonation 5. High frequency 6. Electric pulse 7. Ion-plasma
8	Electroplating and chemical coatings	1. Direct current hardening 2. Periodic current hardening 3. Flow-through hydration 4. Local (untreated) ironification 5. Chrome plating 6. Chrome plating is flow-through, jet 7. Copper plating 8. Galvanizing 9. Application of alloys 10. Application of composite coatings 11. Electrocontact application (electronic abrasion)

Group number	A group of methods	Method
		12. Galvanomechanical method 13. Chemical nickel plating
9	Thermal and chemical heat treatment	1. Tempering, vacation 2. Diffusion boration 3. Diffusion galvanizing 4. Diffusion titration 5. Diffusion chrome plating 6. Diffusion chromo-titanization 7. Diffusion chromoazotization 8. Cold treatment
10	Other methods	1. Pouring with liquid metal 2. Freezing 3. Criticism 4. Soldering 5. Soldering welding 6. Electric spark buildup and alloying

Plastic deformation recovery methods are based on the plasticity property of metals. During plastic deformation, the metal of the part is redistributed from non-working parts of the part to the working ones, thereby restoring the dimensions of worn surfaces. The volume of the part remains constant. The advantages include the following: no additive material is required, simplicity of methods, relatively high productivity. Disadvantages include: the need for heat treatment of ferrous metals, changes in linear dimensions (for example, the piston pin is shortened after distribution).

The technology of restoring parts with polymer materials is characterized by simplicity and accessibility (used in the field), low cost, high productivity and good quality. The durability of bearing seats increases many times after restoration with polymer materials.

Manual welding and surfacing methods are widely used due to the simplicity and possibility of performing the process in hard-to-reach places. The disadvantages include: low productivity, material consumption and not always high quality.

Mechanized welding and surfacing methods can be automatic and semi-automatic. Most of these methods provide high performance and quality.

In arc methods, the heat source for melting the filler material and the surface of the part is the heat of the electric arc. In arcless methods, such a source is losses from eddy currents (HDPE), Joule heat (electroslag surfacing, contact welding), heat of combustible gases, etc.

Manual and mechanized welding and surfacing methods have received the greatest application (75–80% of the total recovery volume). Their disadvantages are thermal effects on the base metal, including non–recoverable surfaces, deformation of parts, significant allowances for machining. The use of most of these methods is advisable for the restoration of heavily worn parts [10].

During spraying, the molten filler material (wire or powder) is sprayed with compressed air and applied to the prepared surface of the part. Spraying methods are distinguished depending on the heat source: arc – the heat of an electric arc, gas–flame – the heat of a gas flame, etc. The process of metal spraying is called metallization. Most spraying methods are characterized by high performance, which allows you to accurately adjust the thickness of the coating and the allowance for machining. A serious disadvantage of spraying is the low adhesion of coatings to the substrate. To increase it, a special sublayer is applied, followed by reflow, etc.

Electroplating methods are based on the phenomenon of electrolysis. They are distinguished by the type of metal deposited, the type of current used, the method of deposition, etc. Electroplating methods are high-performance, do not have a thermal effect on the part, allow you to accurately adjust the thickness of coatings and minimize or completely eliminate mechanical processing, ensure high quality coatings with cheap starting materials. Such methods are used to restore poorly worn parts. The disadvantages of electroplating are the multi–operability, complexity and environmental harmfulness of the technology [11].

Heat treatment is used to harden and restore the physical and mechanical properties of parts (spring elasticity, etc.). With chemical thermal methods, diffuse saturation of the surface of the part with refractory metals (chromium, titanium, etc.) occurs with some size change. These methods are used to restore and increase the wear resistance of poorly worn parts (plungers, etc.).

Figure 3 shows the distribution of methods for restoring worn machine parts.

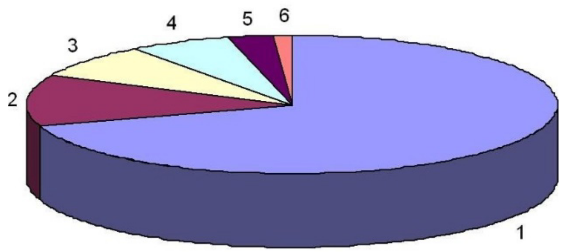

Figure 3. Distribution of methods for restoring worn machine parts: 1 – surfacing and welding (70 %); 2 – repair dimensions (12 %); – electrolytic coatings (8 %); 4 – polymer materials (6 %); 5 – installation of an additional repair part (3 %); 6 – surface plastic deformation (1 %).

As follows from Figure 3, more than 70 % of worn parts are restored by surfacing and welding.

3. Conclusion

An analysis of methods and methods for restoring machine parts, classifications used for restored parts, and principles of production organization allows us to draw the following conclusions:

– the share of parts restored at enterprises of the agro-industrial complex by gas-thermal methods is 26.1 %;

– the most promising methods for restoring machine parts are gas-thermal spraying, which make it possible to ensure the life of the restored parts at and above the level of new parts;

– the organization of the processes of restoration of parts, based on the use of classification of elements of mating parts, is the most cost-effective, since it allows the development of modular technological restoration processes.

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