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DEVELOPMENT OF REPAIR TECHNOLOGIES

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Annotation: *The article presents the history, types, areas of application, advantages, disadvantages and development prospects of repair technologies. A new technology for the restoration of worn parts - methods of laser coating has been considered and analyzed. Based on the results of the analysis, it is possible to increase the resource of details by 2.5 times.*
Keywords. *Welding, fusion coating, laser, powder, plasma, hybrid laser-plasma.*

In Russia, since 1887, engineer N.G. Slavyanov was engaged in repairs by welding and casting. In 1891 he received patents No. 86 and 87 for the method of electric welding of metal castings and the method of electric welding of metals, in 1890-1892 - patents for his inventions in France, England, Austria-Hungary, Belgium, Germany, USA, Sweden, Italy.

All the advantages of electric welding were immediately appreciated abroad. N.G. for repair welding. Slavyanov chose parts that could be inspected when working after repairs, such as stepper pulleys from lathes, gears, and flywheels for drilling rigs. In 1907, N.G. Slavyanov successfully used welding in the restoration of a strong press stanina at one of the plants in St. Petersburg.

The emergence of fusion coating technology abroad dates back to 1896, when the British engineer M.S. Spencer received a patent for this invention.

In the United States, repair welding and the industrial use of surface coatings began a little later. In particular, in 1922, the Studdy brothers first coated the ends of an oil well by welding a steel pipe filled with chromium alloy in a gas flame. Around the same time, the valves of the internal combustion engine were melted using a stellite-alloy invented by engineer D. Haynes (USA). Initially, gas welding was used to coat the surface, but later with the development of new heat sources, other fusion coating methods began to be used.

The beginning of automatic coating dates back to 1939, when Soviet experts G.P. Mikhailov and V.A. Larionov performed the fusion coating using rectangular cross-section coated electrodes. It is now widely used to apply corrosion-resistant coatings to high-pressure vessels of nuclear reactors, to strengthen rolling mills and other large-scale products. Research in the field of fusion coating in Japan began in 1955.

Melt coating has played a major role in the production, operation and maintenance of industrial equipment, increasing labor productivity, improving product quality and saving raw materials. In the future, it will be necessary to master new developments to create welding materials with high technological and operational characteristics and high-efficiency equipment.

The economic and technological conditions of the emergence of repair technologies are a significant part of resource costs in the production of new parts, as well as the restoration of obsolete and damaged parts in the repair of machines. Thus, even in specialized factories, they account for 50% of machine repair costs and 40% of labor costs. Reducing costs is therefore an important task, and one way to solve it is to repair defective parts. Typical defects of parts and assembly units:

incompatibility between transferable surfaces;

dimensions, geometric shape of surface details and

violation of the relative position in space;

deterioration of material properties;

deterioration of appearance.

The task of restoring defective transitions and missing properties of parts: transitions, shapes, relative positions in surface space, material properties and appearance of the external part. The following methods can be used to restore compatibility between the transfer surfaces of parts:

1) processing of the worn surface of a part and processing of the connecting part (method of repair sizing);

2) use of additional repair part (wear compensator);

3) by restoring the original dimensions of the connecting surfaces of the parts.

You can restore a part or its individual surfaces using the following methods:

1) growth of a defective surface of a part of another material (coating of metal and polymeric materials, spraying, electrolytic and chemical deposition, etc.);

2) transfer of the material of the part from one part to another by plastic deformation (by breaking, distribution, compression, scratching and biting);

3) restoration of the integrity of the body of the part (methods include welding, brazing and gluing);

4) removal of material from the surface of the part (including turning, grinding and milling);

5) restoration of the relative position of the surfaces of the part in space (including static loading, embossing, local heating).

The economic feasibility of the repair is that about 45% of the machine parts accepted for repair are obsolete within acceptable limits and about half of the parts related to reuse can be used after replacement at a cost of 15 ... 30% of the cost of new parts. Only 5 ... 9% of the details cannot be restored. Restoration of parts is a major source of cost-effective repair, a technically sound and cost-effective measure.

Rehabilitation of spare parts allows repair and maintenance enterprises to reduce the downtime of machines for repair, improve the quality of their maintenance, have a positive impact on improving the reliability and use of machines. It was found that with wear of no more than 0.2 ... 0.3 mm, 85% of the parts lose their function. This is confirmed by the large size of the repair fund and the expediency of its restoration.

It is appropriate to provide information on the restoration of parts abroad. By restoring obsolete parts in Japan, they meet the demand for spare parts up to 40%, in the USA, Germany, Austria - up to 30 ... 35%.

In economically developed countries, the spare parts market is dominated by restored parts, which are 1.5-2.5 times cheaper than new ones and, as a rule, they are not inferior to them in terms of resources. This is achieved primarily through participation in the repair of machine-building enterprises and enterprises specializing in the restoration of worn-out parts. For example, the engine repair plant of the British company Binz Industries Limited repairs about 60,000 Ford car engines a year and restores their cylinder blocks, block heads, distribution shafts, crankshafts, connecting rods, sleeves and other valuable parts. Rehabilitation of similar parts has been set up at Perkins repair plants. An example of the modern organizational and technological level of restoration of parts is the Swiss company Castolin-Eutectic, which has subsidiaries in Europe and the United States. Documents for the development of technology, equipment and materials, restoration of parts are carried out in a scientific center with about two thousand specialists, as well as in scientific laboratories located in different countries.

Particular emphasis should be placed on the cost-effectiveness of restoring parts that exclude the metallurgical production process, which is harmful to the environment and requires energy. Therefore, when restoring 1 ton of steel parts, they save 180 kWh of electricity; 0.8 tons of coal; 0.8 tons of limestone; 175 m3 of natural gas.

The cost of refurbished parts is significantly lower than the cost of new parts, as the restoration of obsolete parts requires 5-8 times less technological operations than the production of new parts.

The problem of organizing the preparation of production and the restoration of parts is much more complicated than the production of new parts. Deformations, worn foundations, residual heat treatment, cracking and fatigue resistance have been reduced in the parts supplied for restoration. All this requires detailed study and consideration in the development of technological processes.

However, the restoration and hardening of the parts allows the machine to renew its service life and in some cases significantly increase it. Studies show that by restoring and strengthening the surfaces of parts, their resource can be increased by 2.5 times.

It is estimated that in 2011-2013. the cost of updated parts will remain at 35 ... 50% of the cost of new parts; the resource of the restored parts is 85 ... 95%, and the resource of the parts restored using hardening technologies is 120 ... 150%.

Development of production to restore obsolete parts will reduce the cost of maintaining an obsolete vehicle fleet and keeping equipment in working condition. According to the research of experts, it is necessary to develop two priority areas in which the problem of restoration of parts should take a worthy place.

1. Rehabilitation or creation of new locations for repair of fuel equipment, hydraulics, gearboxes and other aggregates. These plots should provide all the equipment of the enterprise with repaired units.

2. Industrial modernization of the existing fleet of specialized repair plants and workshops.

There, first and foremost, the restoration of parts, including the restoration of their base surfaces, should take precedence on a large scale.

Laser casting emerged as a coating method in the late 1970s - early 1980s.

One of the most important points in surface coating technology is the delivery of the coating material to the base. The study of laser welding and surface coating technologies has shown that the wire transfer process is carried out in an arbitrary spatial state, the advantage of powdered materials is that they absorb laser radiation more efficiently [2]. In the lower case, painting can be done by pre-distributing the powder on the treated surface. The use of powdered materials in other spatial positions usually requires pre-coating of the washing paste by methods such as flame spraying, plasma spraying, or oven drying. If it is not possible to pre-distribute the powder to the surface, it is given

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with special dispensers. If it is not possible to pre-distribute the powder to the surface, it is supplied with special suppliers. To date, the most commonly used method of laser coating using filler powder materials is to transfer the powder directly to the laser radiation area using special powder dispensers of various shapes.

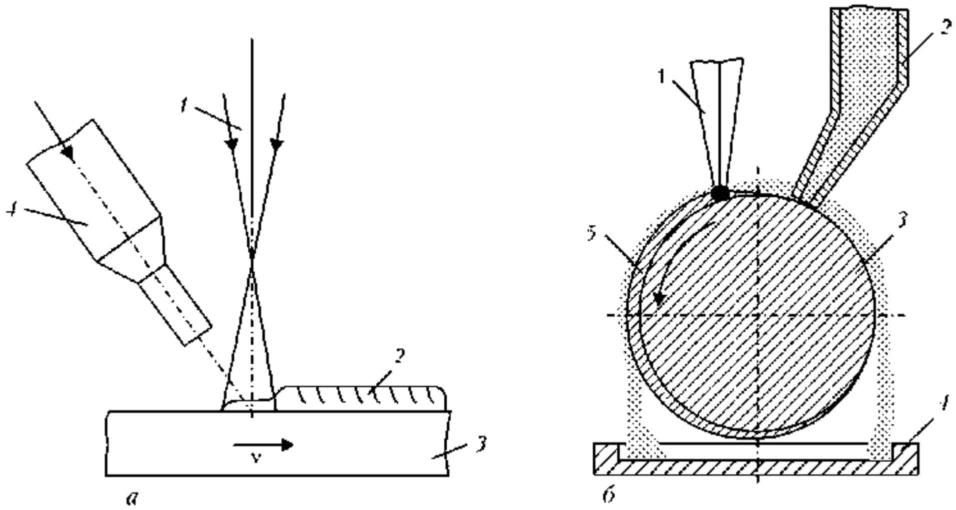

Figure 1. Schemes of laser coating processes: (a) parts of arbitrary geometry (1 - laser irradiation; 2 - cast iron; 3 - moving sample; 4 - base providing shielding gas and filler powder) [1] and cylindrical parts (b) (1) - laser radiation; 2 - powder transmission line; 3 - deposited sample; 4 - container for unused powder; 5 - molten coated metal)

The advantages of laser coating include: the ability to apply layers with the desired properties at a height of 0.1 ... 3.0 mm; a significant weakening of the effect of redistribution of components from the base material to the deposited layer, which helps to increase the accuracy of predicting the results and to bring the properties of the deposited layer as close as possible to the initial properties of the deposited layer. material; obtaining equalized fine crystalline (highly dispersed) structures of the deposited metal and a small (0.1 ... 0.5 mm) heat-affected zone; minimizing the allowance for machining to values between 0.3 ... 0.5 mm for each side due to the low level of bearing surfaces (Ra up to 200 ... 300 microns).

Disadvantages of laser coating include: the presence of transverse cold micro-cracks in the deposited layers, the appearance of which is the result of the release of high internal stresses; non-metallic additives and residual moisture of welding powder, as well as the possibility of forming internal and external holes associated with contamination of the welded surface; the relatively high cost of the process associated with the relatively high cost of laser equipment. The issues of controlling, minimizing and completely eliminating the formation of cracks during laser coating have been studied by many authors at different times. Ukrainian scientists proposed a mathematical model of this phenomenon, which allowed to relate the distances between cracks with the mechanical properties of the coatings and their thickness. Based on the above, promising methods of overcoming the shortcomings of the process include methods that allow to reduce the residual thermal stress in the deposited layers and reduce the amount of weld powder and sediment surface with careful preparation. Such methods include, in particular, changing the thermal cycle of the process by applying an additional heat source (e.g., combining the effects of laser radiation with the effects of plasma current).

Erosion and corrosion resistant microcrystalline, amorphous and amorphous coatings using laser coating are obtained from a very wide range of materials. However, in the first half of the 1980s, laser coating found wider application as a process of restoring worn-out parts of equipment operating under conditions of friction, impact loads, abrasive wear, and so on. Today, even in industrialized countries, laser resurfacing has not lost its importance - it is used to repair expensive products in the restoration of relatively small defects with high thermal location. For example, such technological methods are widely used in the restoration of turbine wings, shaft cradles, molds and other valuable products of complex profile of aircraft engines.

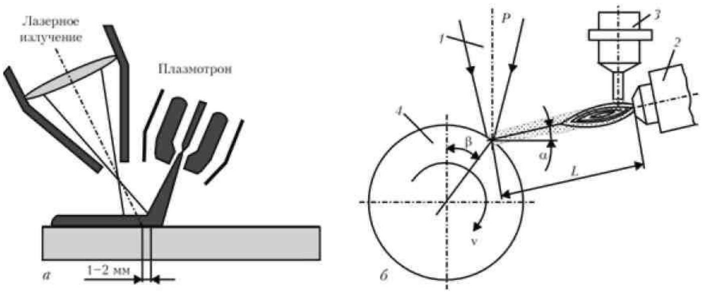

Figure 2. Schematics of powder laser-plasma coating processes using direct plasma torch (a) [10] and indirect plasma torch (b) (1 - radiation; 2 - plasma torch; 3 - powder container; 4 - sample; L). , a, b - distance and welding angles)

Since the beginning of the 21st century, pure laser technologies have been increasingly replaced by hybrid and combined technologies. This includes laser-plasma processes that use the combined effects of arc plasma and laser energy source. E.O. A study of the interaction processes between the directed radiation of a CO2 laser and the plasma of an electric arc column by the National Academy of Sciences of Ukraine named after Paton showed that in such a system a special type of gas, combined laser - arc discharge, can occur. Its properties differ from both an electric arc and an optical discharge powered by laser radiation. The ability of the combined discharge to form high-temperature plasma that is highly unbalanced even at atmospheric pressure of the surrounding gas makes it attractive for use in plasma-chemical technologies. E.O. Paton, theoretical and experimental studies (Academician of the National Academy of Sciences of Ukraine I.V. Krivtsun, Doctor of Technical Sciences V.S. Gvozdetsky, Doctor of Technical Sciences Yu.S. Borisov, etc.) have shown that such discharge may be the basis. It is based on the creation of a new class of plasma devices - integrated laser-arc plasmatrons.

Direct and indirect plasma torches can be used in hybrid laser-plasma surface coating processes. Powder is mainly used as a surface material. The main advantage of using direct-acting plasma torches is the possibility of additional compression of the plasma arc due to the use of focused laser radiation (Figure 2a). The advantage of using indirect plasma torches is that the electric arc has no direct effect on the parent metal, in particular, it increases the thermal positioning of the process (Fig. 2, b) .. According to the authors of the article, is the ability to provide flexibility across the optical fiber. Laser-plasma coating significantly reduces the residual stresses in the deposited layers

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compared to laser solid coating, but one of its main drawbacks is the significant thermal effect on the welded product.

Analysis of the advantages and disadvantages of plasma, laser and laser-plasma coating processes allows us to emphasize the following. In the case of a plasma coating, the part can overheat significantly, leading to residual thermal deformations. Laser and laser-plasma processes allow to minimize the heating of the part, increase the adhesion strength of the deposited layers to the substrate, avoid the application of substrates and simplify surface preparation. However, there are also drawbacks to laser coating processes. These include the stress state of the deposited layers, the presence of holes and micro-cracks in them. Hybrid (joint) laser-plasma processes allow to partially or completely eliminate the indicated defects due to the interaction of components or their joint effect on the workpiece. Thus, compression and stabilization of the plasma arc by laser irradiation allows to increase the speed of the surface coating process and reduce the total heat input; due to the addition of the plasma component, along with the change of the thermal cycle of the laser processing, preheating the powder reduces the residual stresses, eliminates the formation of pores and cracks, and so on.

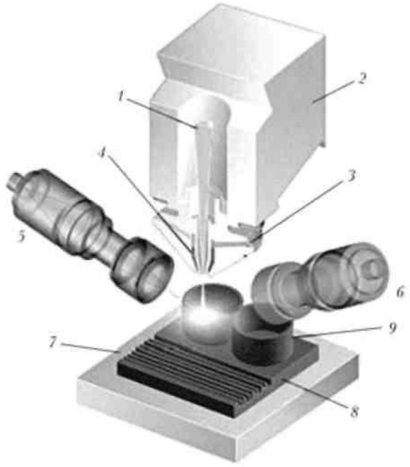

Figure 3. Schematic of the process of three-dimensional synthesis of products using DMD technology: 1 - laser radiation; 2 - focal optics; 3 - powder container; 4 - shielding gas; 5, 6 - sensors of optical communication system; 7 - platform; 8 - basis; 9 - The object being created

Thus, consideration of laser and hybrid (combined) coating processes has shown that the main trends in the development of this direction are: obtaining corrosion and corrosion-resistant coatings with improved physical and mechanical properties; synthesis of three-dimensional objects; creating thin coatings with special properties. Prospects for further development of laser and laser-plasma (laser-arc) coating processes are associated with the possibility of individual elimination of defects specific to each component due to the interaction of these components.

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