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Technologies and materials for the renovation of erosion-worn parts of automobile equipment

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Abstract

The article presents the results of the development of a technological method and equipment for the renovation of erosion-worn parts of automotive equipment. In the parts of machines and mechanisms subjected to mechanochemical wear, thin-sheet steel, the specific weight of which in car structures is on average 80%, is especially destroyed, as well as the working organs of machines: threaded joints, welding seams, internal friction surfaces (hubs, bearings, rollers and etc.). The solution to this problem is simplified when surface surfacing is used and it is possible to obtain a relatively flat surface with good separation of the slag crust without sharp height differences in the overlapping area.For welding wear-resistant and corrosion-resistant layers, it is necessary to use wires with a diameter of up to 2 mm, which allow applying thin layers of steel alloyed mainly with Cr, Ni, Mn, Mo during arc welding. The welding of such steels to ensure high quality of the deposited layers from the point of view of achieving high corrosion resistance is quite difficult. This is due to the fact that during the operation of welded parts and even when they are kept for a long time before operation, stripes with low corrosion resistance appear on the welded surface (dark colors on the polished surface of the working layer). In the process of developing the technology of surfacing the surface of worn parts, powders of ultra-fine particles were developed, which were used to fill the core of powder-coated wires with diameters of 1,6 and 2,2 mm. The composition of the charge included exotic additives, in particular chromium, molybdenum and complex liquid and alkaline earth ligatures, in particular yttrium and cerium, which made it possible to significantly increase the wear resistance of the deposited layer.

Key words: surfacing, corrosion, wear, modification, alloying, structure.

Introduction

As evidenced by literary sources [1-9,11] and practice, long-term operation of automotive parts in conditions of mechanochemical wear (mechanical friction) is accompanied by local damage (in the form of ulcers), which lead, as a rule, to loss of performance of the unit or device as a whole.

It is possible to reduce the negative impact of local wear and tear on the performance and, in general, the accident-free resource of the main elements of automotive equipment by performing strengthening procedures in relation to the areas of probable wear predicted in advance. Moreover, it is desirable to do this at the stage of manufacturing parts, and even more so during the repair of parts. This problem is equally characteristic of friction gears, variator cups, thrust of control mechanisms, etc.

Thus, in the process of corrosion and mechanochemical wear, a large proportion of nodes that fail prematurely are lost. Thus, according to the data of the source [1] only in Ukraine in 2001, losses from corrosion and wear and tear were estimated annually at approximately more than 2 million tons. At the same time, 1 million tons are irretrievably lost annually. For example, up to 2 million tons of metal is lost in the form of scrap, i.e., unusable products for further operation, which are discarded due to high wear and corrosion of individual units and assemblies, i.e., such a part of assemblies is excluded from the active part and goes to scrap metal.

At the same time, it is known [1] that the costs of repairing nodes per day of work are 4 times higher than the costs of repairing cars and 4.5 times higher than the costs of repairing cars, and the costs of repairing imported cars are 8 times higher 10 times.

Studies have established [1] that the intensity of wear of parts of machines and devices subjected to mechanochemical wear increases by 3-4 times and the long-term (fatigue) strength of metal decreases by 40-50%.

It was established that thin sheet steel, the specific weight of which in the construction of automobiles is on average 80%, is especially destroyed, as well as working organs of machines: threaded connections, welding seams, internal friction surfaces (hubs, bearings, rollers, etc.).

Many years of observations have established that parts made of ordinary low-carbon structural steel: St08kp or St10kp without protection, in the non-working period, are subject to corrosion to a depth of .21 mm in the first year. Moreover, the service life of such parts is reduced by 2 times, and the depth of corrosion pitting increases to 50 µm. Without proper conservation and the application of effective anti-corrosion measures (for example, the use of anti-corrosion coatings), automotive equipment will continue to be subject to an intensive process of corrosion damage with severe technical and economic consequences.

Based on the analysis of literary domestic and foreign sources, it can be concluded that in order to solve the problem of anti-corrosion protection and effective preservation of automotive equipment, all the efforts of engineers of welding technologies and related processes should be directed to solving the following problems:

- the implementation of modern technological processes and innovative materials for the restoration of corrosion-damaged and mechanochemically worn parts, which were developed at the Institute of Electric Welding named after E.O. Paton of the National Academy of Sciences and extensively tested at various enterprises and specialized repair workshops;
- advance application of anti-corrosion protection to parts during their production in the basic (factory) conditions of the production cycle, i.e., in the process of conveyor production of agricultural machinery;
- implementation of modern repair and storage technologies with reliable conservation of automobile machines and mechanisms;
-training of highly qualified specialists in the field of anti-corrosion protection of automotive equipment;
- car manufacturers and repair organizations to actively cooperate with the scientific centers of the National Academy of Sciences of Ukraine;
- to widely introduce advanced materials into production, first of all, high-strength, corrosion-resistant, alloyed steels, metal-plastic and polymer materials, composite metals for surfacing wear-resistant materials, use ultra-dispersed powders as a charge of powder-coated wires of small diameter (1.6-2.2 mm).

It is necessary to bring the cost of anti-corrosion protection of cars up to 20% of its total cost.

As is known from practice, most of the equipment parts are operated in corrosive and aggressive environments. The most famous representatives of such parts are rods and plungers of various hydraulic and mechanical devices (Fig. 1), in particular, loading and unloading equipment: shafts and threaded connections of construction machines and mechanisms.

To increase the service life of such parts, their working surfaces are already protected with galvanic coatings, mainly chrome ones, during manufacture. The thickness of the applied layer is, of course, 5-50 microns. The high hardness of chromium (HB 800-1000) and a low coefficient of friction (for chrome on steel, the coefficient of friction kc = 0.16; for chrome-on-chrome kx = 0.12, to a certain extent characterizes resistance against abrasive and mechanical wear as a result of friction in combination, strong adhesion to the base metal, which determined the wide use of only this type of coating [6].

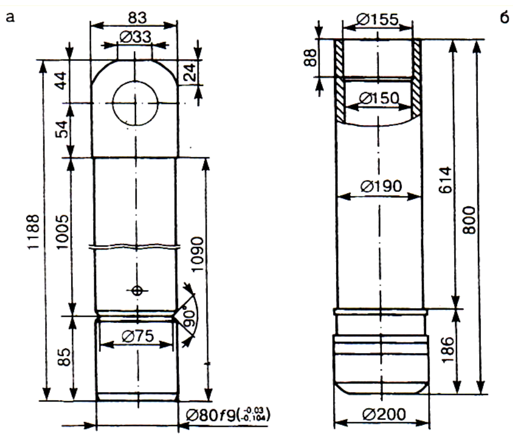

Fig. 1. Rod (a) and plunger (b) of cargo-lifting equipment

One of the methods that allows you to restore worn rods and plungers and friction pairs, as well as to return hydraulic devices and wear nodes to operation is arc surfacing under flux. At the same time, surfacing under the flux of such parts has the following features:

1. Wear of the working surface of these parts is relatively small and is usually within tenths of 1-2 mm. Therefore, surfacing is performed in one layer and powder-coated wires of a relatively small diameter (up to 2 mm) are used;

2. Rods and plungers are mainly made of medium-carbon, low-alloy steels of the type 30ХГСА, 30Х,

which belong to steels with limited weldability. This means that the welding or surfacing of such steels may be accompanied by the formation of cracks. To exclude them, surfacing must be performed using certain technological techniques, in particular, with preheating by applying a soft underlayer;

3. As a result of the mixing of the base and deposited metals during single-layer deposition, it is difficult to obtain the required composition of the deposited metal. To compensate for the effect of mixing, it is necessary to use surfacing materials with a higher degree of doping;

4. On the corroded surface of the parts, areas of chrome coating remain to a greater or lesser extent;

5. Rods and plungers are relatively small in size and weight. At the same time, during their restoration, it is necessary to weld almost the entire outer surface, which leads to overheating of the part and makes it difficult to separate the slag crust. Therefore, it is necessary to apply cooling of the part or interrupt the surfacing process.

Let's consider the technique and technology of welding rods and plungers of hydraulic units. There are two known technologies for surfacing rods and plungers.

The first, the simplest, is surfacing with a low-alloy wire of the 30KhHSA type under the AN-348 flux. Application during cooling of the deposited part with running water allows surfacing along the spiral line of rods and plungers with a diameter of 70-90 mm. The deposited metal in this case is not corrosion-resistant and therefore the deposited surfaces are subjected to chrome plating in the future, as provided by the usual manufacturing technology. The main drawback of the technology is the two-stage recovery scheme with preservation of ecologically polluted production (chroming).

The second technology involves the application for surfacing of corrosion-resistant steels and the exclusion of chrome-plating operations in this connection. The main task in the implementation of this technology is the correct choice of surfacing material. Also, different groups of stainless steels are used in different industries.

The first is martensitic steel. They contain 12-17% Cr and 0.1-0.5% carbon. Hardness cannot reach HPC55.

The second group includes steels of the ferritic class, which contain 16-20% Cr. Their carbon content is usually very low with a low chromium content. With an increase in chromium to 30%, the carbon content can also increase to 0.35%.

As noted above, the considered parts wear out not only as a result of corrosion, but also due to abrasive wear. Therefore, the surfacing of austenitic steels offered by some companies allows to achieve increased corrosion resistance but does not protect the working surface from abrasive wear. For conditions of operation of automotive equipment with increased technological danger, it is most rational to use steels of the martensitic class. However, machining of such steels is difficult due to their increased hardness. The solution to this problem is simplified when, during surfacing, it is possible to obtain a relatively flat surface with good separation of the slag crust without sharp differences in height in the area where the rollers overlap. When considering the influence of chemical elements on the properties of alloy steels, the following can be noted. The minimum chromium content, at which the increased resistance of steel against corrosion in a humid atmosphere and various mildly aggressive solutions is manifested, is approximately 12%. With this chromium content, dense gas-impermeable oxide films are formed on the surface of the metal [2,3,11].

Considering the information presented above from a theoretical point of view, for surfacing wear-resistant and corrosion-resistant layers, it is necessary to use wires with a diameter of up to 2 mm, which make it possible to apply thin layers of steel alloyed mainly with Cr, Ni, Mn, Mo during arc surfacing. However, as the practice of welding such steels has shown, it is quite difficult to ensure the high quality of the deposited layers from the point of view of achieving high corrosion resistance. This is due to the fact that during the operation of welded parts and even when they are kept for a long time before operation, stripes with low corrosion resistance appear on the welded surface (dark colors on the polished surface of the working layer). These strips are located in the overlap zone of the welded rollers.

On the basis of the performed literature review, during the welding of parts such as the rods of hydraulic cylinders, powder-coated wires 30X20MN and 30X22MN were developed and tested, which provide the desired, stainless chromium metal of the martensitic-ferrite class already in the first deposited layer. Based on the fact that metals of type 30X20MN and 30X22MN are characterized by sufficiently high indicators of operational properties, it was decided to bring them to the optimal level by testing during surfacing using various technological methods. In addition, this approach to the selection of the deposited metal was due to the fact that its composition is relatively simple in comparison with the metal 08X20N10G7T recommended for surfacing the cutting edges of mining machines and various devices, which contains an order of magnitude less expensive nickel (with a more than 2 times increased hardness). As can be seen from the composition, the wires contain an increased proportion of chromium to compensate for mixing with the base metal during single-layer surfacing. Since the carbon content in the wire is at the level of the content in the base metal, the composition was not adjusted for carbon.

Development of a new type of powder-coated wire charge type PP-PN-30X20MN with the selection and manufacture of equipment for its production and development of the technology of surfacing with the developed wires

Despite the fact that we proposed two types of flux-cored wires for welding rods - PP-PN-30X20MN and PP-PN-30X22MN, which differ in the content of the alloying element - chromium, which is responsible for the resistance of the deposited metal, the main research was carried out with wire PP- PN-30X20MN, as the most economically favorable.

Arc surfacing under flux was performed in one layer with 30% overlapping of the rollers. The deposited surface was subjected to grinding, as in the previously performed studies.

It is known [2] that a technically effective and economically expedient method of increasing the corrosion resistance of welded metal structures is the microalloying of weld metal with rare-earth, alkaline-earth elements - modifiers. A sharp inhibition of the corrosion process was observed when metal alloying Ce, Y, Ba, Ca. The deposited metal of welding seams, economically modified with micro additives, is characterized by a low content of dissolved gases (oxygen, nitrogen and hydrogen), as well as harmful impurities (sulfur, phosphorus). The low content of gases in the metal containing micro-additives is explained by the high chemical affinity of Ce, Y, Ca and Ba to them, as a result of which thermodynamically strong and almost insoluble in liquid metal oxides, nitrides and hydrides are formed, which are removed into slag during the melting process. that is, the metal is refined.

The positive effect of modifying the deposited metal of type 15X8H2M1 with yttrium in the amount of 0.005-0.013% consists in crushing the primary structure, changing the composition, shape, size and nature of the distribution of non-metallic inclusions, as well as increasing their dispersion. These factors ultimately have a favorable effect on the mechanical properties, wear resistance and heat resistance of the deposited metal. And although the corrosion resistance was not studied in detail in this work, by analogy with the results [1,12] we can assume a positive effect of yttrium on the resistance of the deposited metal to the occurrence of corrosion.

In the experiments, samples made of 40X steel, 40 mm thick (the blanks are similar to those used in the previous experiments) were welded with three flux-cored wires, which differ in micro-additives introduced into the charge:

- sample -1, Al-Ce in the amount of 3% was additionally introduced into the charge of 2.2 mm powder-coated wire;

-sample 2, yttrium in the amount of 3% was additionally injected into the powder wire charge Ǿ2.2mm;

-sample 3, Si-Ca (CK30) in the amount of 3% was additionally introduced into the charge of powder wire Ǿ2.2mm.

The welding mode of all samples I= 250A; U = 30V; V=18m/h; wire protrusion 20-25mm; AN-20P flux.

Preparation of a flux-cored wire charge with components manufactured using ESH

The ability to successfully resist the influence of the environment, in particular corrosive, turns out to be one of the most stringent requirements for modern structural materials, first of all for steels. For stainless steels, the indicated capacity is the main, i.e., the main quality criterion.

The positive effect of electrometallurgical remelting (ESM) on the properties of the deposited metal was shown earlier in experiments using powder wire charge for surfacing tool steel made from a ligature of ESM and ferroalloys [1].

As a remelting component of the charge, we chose the main alloying component - high-carbon ferrochrome FH-800.

In order to fulfill the task, technologies and equipment were used for non-compact material EES without the use of any additional electrodes that support the electroslag process. As a result, a device was produced - a 90 mm current-powered crystallizer, which provides simultaneous performance of three technological functions - support of the electroslag process; rotation of the slag and metal bath and the formation of the remelted ingot. In order to exclude the arc process and increased chromium fumes, the beginning of melting was carried out by pouring molten slag into the crystallizer (liquid start). Melting of the flux and accumulation for its pouring into the crystallizer was performed in a special device (Fig. 2). The process of melting the flux in this device and pouring it into the crystallizer are presented respectively in Fig. 3.

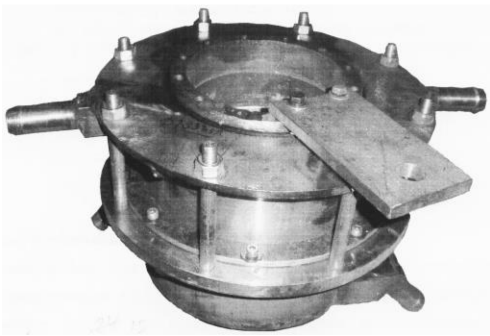

Fig. 2. Current-driven crystallizer Ǿ90 mm

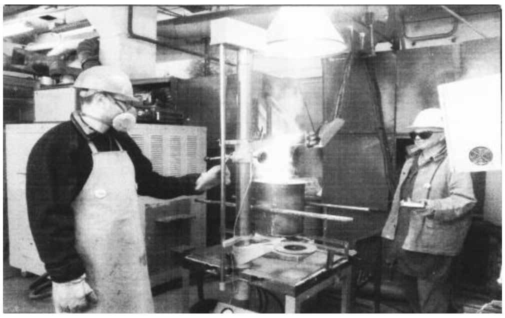

Fig. 3. The process of melting the flux and accumulating slag in the ladle

The ingot obtained as a result of ECP was crushed and dispersed on sieves to obtain powder grains with a size of ≤ 0.3 mm. Later, ferrochrome powder (ligatures) was introduced into the composition of the charge, which was prepared according to the production technology of ordinary powdered wire.

Experiments on arc welding were carried out with experimental flux cored wire on the regimes that were previously taken as a basis.

Production of a charge in the form of ultra-dispersed powder wire particles

The technological method of using ultra-dispersed particles in order to improve the quality of the metal and give it high operational characteristics is based on two scientific representations, the so-called structural heritage in the "charge-molten metal-solid casting" system and the effect of changing the crystallization process of the liquid metal in the presence of a relatively small number of "seed" particles.

The idea of structural inheritance in the charge-molten metal-solid casting system is associated with the dependence of the structure and properties of the casting on the structure and properties of the charge materials observed in practice.

A sensitive modifying effect is provided by the introduction of a small amount of fine-grained (ultradisperse) charge particles into the liquid metal [8]. At the same time, the following processes take place in the liquid metal: the number of inherited particles per unit volume of the melt treated with such particles is much greater than in the untreated melt; the presence of fine-grained particles has an exciting effect on embryogenesis; the dispersed particles themselves turn out to be potential centers of crystallization.

It was assumed that the dispersed component (size < 50 μm) in the charge would be 30% on average. The transformation of a conventional charge into a dispersed charge was carried out in a high-energy device - a planetary mill in a time of 1 hour.

The production of experimental flux-cored wires showed that the presence of a fine-dispersed component in the charge sharply worsens its flow (fluidity) - separate local layers, which differ in color from the rest of the charge, are formed on the dispenser tape of the state of flux-cored wire drawing. Drying of the charge (150oC exposure in the oven for 2 hours and cooling with the oven) does not improve its fluidity.

Therefore, technological techniques used in powder metallurgy and spraying were used - before dosing, the charge was flocculated, followed by sifting of lumps (wiping) on sieves. At the same time, two methods of flocculation were tested. According to the first, the charge is mixed with polyvinyl alcohol, forming a conglomerate after drying. Second, the same process is performed on the KMC glue.

The fluidity of the powder obtained after wiping was evaluated according to DSTU 2640-94 "Metallic powders. Determination of particle sizes by dry sieving". By both methods, it was possible to obtain a charge with satisfactory flowability, which made it possible to produce a suitable powder wire from it with stable arc burning, which ensures high-quality surfacing.

Conclusions

1) The experimental method, which provides for the selection of a relatively low-alloy composition of the deposited metal and the improvement of its properties due to changes in the technology and technique of surfacing, has shown its promise.

2) One-layer surfacing of metal type 30X20MN with any amount of overlap does not allow to achieve high corrosion resistance of the superimposed layer.

3) An increase in the chromium content in the 30X20MN type metal by approximately 2% does not significantly increase the corrosion resistance of the metal due to reaching the lower limit of the chromium content in the remelted metal (base + deposited metal), at which the positive effect of the chromium content in the deposited layer is manifested.

4) Multi-layer deposition improves the corrosion properties of the deposited metal, but its application significantly reduces the cost-effectiveness of the deposition process.

5) By adjusting the surfacing welding cycle, it is possible to improve the corrosion resistance of the

surfacing metal, but this approach complicates surfacing conditions and may have a negative impact on its economic feasibility.

6) It was established that the introduction of RZM into the composition of the charge changes the indicators of metal corrosion in a positive direction.

7) The use of ultradisperse components in the charge of powdered wires should be considered a promising technological method, especially when they are obtained with the help of a binding CMC.

8) The positive effect of ESH on reducing the number and shape of non-metallic inclusions, and, therefore, on the corrosion resistance of the deposited metal obtained by melting powder-coated wire, in the charge of which a ligature was partially used, and not ferroalloys, was confirmed.

9) The use of small current pulses during welding allows you to significantly influence the penetration of the base metal and heat deposition in the metal of worn parts.

References

1. G.L. Sheldon. The influence of surface hardness and other material properties on the erosion wear of metals under the influence of solid particles // Proceedings of the American Society of Mechanical Engineers: Theoretical Fundamentals of Engineering. – №. 2.– 2001. – P. 38-43.

2. Zarechenskyi A.V., Nevler E.G., Karelyna A.G. Coating of cones of charging devices of blast furnaces // Welding production. – №. 7. – 1967. – P. 30-31.

3. Cheylyakh A. P., Prekrasnyy S. V., Klymanchuk V. V. Development and research in TSO conditions of a new economically alloyed heat-resistant alloy for grates of sinter machines // Metal and Casting of Ukraine. – №. 11-12. – 2006. – P. 11-14.

4. Utyn I. A., Shandrenko G. I. Mechanized surfacing in the manufacture and restoration of metallurgical equipment parts // Welding production. – №. 4. – 1975. – P.45-46.

5. Utyn I. A., Shandrenko G. I. Automatic surfacing of the surfaces of rolling mills and furnaces // Svarochnoe proizvodstvo. – №. 3. – 1973. – P. 40-42.

6. Utyn I. A., Shandrenko G. I. Restoration of equipment parts and structures made by surfacing and welding // Welding production. – №. 10. – 1971. –P. 45-47.

7. Utyn I. A., Shandrenko G. I. Mechanized surfacing and welding of parts of pipe-rolling equipment // Automatic welding. – №. 5 (218). –1971. – P. 65-66.

8. Utyn I. A., Polishchuk F. Ya. Restoration of large-sized parts of metallurgical equipment // Automatic welding. – №. 5 (158). – 1966. – P. 54-55.

9. Vasylenko I.V., Karpov G.A., Tereshchenko A.D., Akopdzhanyan V.A. New technology for manufacturing guide rolls of the piercing mill of a pipe rolling mill with pilgrim mills // Metallurgy and Black Industry. – №. 2. – 1968. – P. 36-39.

10. Dolynskaya L. A., Chernenko E. N. Durability of long mandrels for a continuous mill // Steel, – №. 8 1968. – P. 724-727.

11. Makarenko V.D., Kuskov Yu.M., Maksimov S.Yu. Destruction of mining and metallurgical equipment // Kyiv: NUBiPU Publishing Center. – 2021. – 320 p.

Макаренко В.Д., Максимов С.Ю., Мєшков Ю. Є., Селіверстов І.А. Технології та матеріали з реновації ерозійно-зношених деталей автомобільної техніки

В статті наведені результати розробки технологічного методу та обладнання з реновації ерозійно-зношених деталей автомобільної техніки. В деталях машин і механізмів, піддатих механохімічному зношуванню особливо руйнується тонколистова сталь, питома вага якої в конструкціях автомашин складає в середньому 80%, а також робочі органи машин: різьбові з'єднання, зварювальні шви, внутрішні поверхні тертя (втулки, підшипники, ролики та ін.).

Рішення цієї задачі спрощується, коли застосовується наплавлення поверхні і є можливість отримати відносно рівну поверхню з добрим відокремленням шлакової кірки без різких перепадів висот в зоні перекриття.

Для наплавлення зносостійких і корозійностійких шарів необхідно використовувати дроти діаметром до 2 мм, які дозволяють наносити при дуговому наплавленні тонкі шари сталі, легованої головним чином Cr, Ni, Mn, Mo.

Наплавлення таких сталей, щоб забезпечити високу якість наплавлених шарів з точки зору досягнення високої стійкості проти корозії достатньо складно. Це пов'язано з тим, що під час експлуатації наплавлених деталей і навіть при їх тривалій витримці до експлуатації на проплавленій поверхні появляються смуги з низькою стійкістю проти корозії (темні кольори на шліфованій поверхні робочого шару).

В процесі розробки технології наплавлення поверхні зношених деталей були розроблені порошки з ультрадисперсних частинок, якими наповнювали серцевину порошкових дротів діаметрами 1,6 і 2,2 мм. В склад шихти були введені екзотичні добавки, зокрема хром, молібден та комплексні рідко та лужно-земельні лігатури, зокрема ітрій та церій, що дозволило суттєво підвищити зносостійкість наплавленого шару.

Ключові слова: наплавлення, корозія, зношування, модифікування, легування, структура