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SURFACING PARTS IN UNLOADING DEVICE OF CENTRIFUGAL PUMPS

O.S. Kostornoi, M.O. Laktionov and **K.Yu. Kholosha**
Joint-Stock Company «Research and Design Institute for Atomic and Power Pump Building»
2, 2nd Zaliznychna Str., 40003, Sumy, Ukraine. E-mail: laktionov@vniiaen.sumy.ua

Leveling of axial forces on the shaft of centrifugal pumps depends on characteristics of end slotted rings of the unloading device that determine the stability of a slotted gap between them. This paper presents the methods to improve wear resistance of surfaces mating between a slotted rings by their surfacing with coatings from a composite alloy reinforced by tungsten (relit) carbides. The advantages and disadvantages of electric arc, plasma-powder and furnace surfacing of slotted rings are shown, and a significant improvement in the process at a replacement of chipped tungsten carbide by spherical one is noted. 6 Ref., 4 Figures.

Keywords: slotted rings, tungsten carbides (relit), wear resistance, arc surfacing, plasma-powder and furnace surfacing

A feature of the centrifugal pump is the presence of axial force acting on the impeller shaft. In high-pressure multistage centrifugal pumps, one of the ways to balance the large axial forces acting on the rotor is to use a self-regulating automatic unloading device — hydraulic balancing device. It consists of two combined units: rotating unloading disc on the rotor shaft and «pad» fixed in the pump housing. Balancing of axial forces occurs in the process of self-regulation of a slotted end gap between the unloading disc and the «pad» of hydraulic balancing device. The principle of its operation is as follows: during axial movement of the rotor, a slotted end gap between the discharge ring and the «pad» of hydraulic balancing device changes, which entails a change in fluid flow in the hydraulic balancing device and appearance of fluid pressure on the rotor in the opposite axial direction. Thus, the axial forces on the rotor are equalized and its location is restored.

The functional reliability of hydraulic unloading device depends on the stability of dimensions of the end slotted gap between the surfaces of unloading disc and the «pad» of hydraulic balancing device. The optimal gap (0.06–0.10 mm) provides a minimal flowing of the pumped fluid and a slight reduction in the efficiency of the pump [1].

During operation of pumps, a slotted gap and the quality of surfaces connected in a gap zone are influenced by the following factors:

- at starts and stops of the pump, the gap can decrease to zero, that will lead to wear of contact surfaces;
- probability of contact of the rotor with the stator because of a high level of vibrations or deformations of the rotor during operation, especially in the transient conditions, can lead to tear or seizure of the metal of contact surfaces;
- presence of suspended particles in the pumped fluid leads to erosive wear of slotted gap surfaces;
- specific medium in fluid can cause corrosion wear on the surfaces of parts in the area of a slotted gap.

The wear of parts in the area of an end slotted gap caused a need in replacing the units of hydraulic balancing device. Therefore, a rational designing solution was the use of so-called slotted rings in the area of an end slotted gap, which are attached to the unloading disc and the «pad» of hydraulic balancing device.

In order to minimize the influence of these factors on the end gap of hydraulic balancing device in pump building, a special attention is paid to the choice of materials for manufacture of slotted rings. These materials should have a high resistance to tear and possible seizure of contact surfaces. The loss of metal in the gap zone as a result of corrosion or erosion corrosion should be insignificant during operation to avoid increase in the gap, reduction in the efficiency of the pump and rotor damping.

The hardness of rings in the area of a slotted gap can be adjusted in a wide range, using not only different base materials, but also using different methods of surfacing wear-resistant surface layer [2, 3]. The joint-stock Company «Research and Design Institute for Atomic and Power Pump Building» (JSC «VNDIAEN») in its developments of centrifugal pumps for the oil industrial complex used mainly arc surfacing of slotted rings with alloys based on cobalt type Stellite 6. For example, such surfacing was used in manufacture of serial centrifugal pumps of TsNS-180 type for pumping water into oil pools in order to maintain a pool pressure. However, in many fields, where quite aggressive and contaminated reservoir waters with solid particles are used, the rings of hydraulic balancing device, which were manufactured of steel 12Kh18N12M3T and deposited with Stellite 6, had a limited service life during operation.

It is known [4] that during the work with fluids containing abrasive particles, rings of tungsten carbide are successfully used. Also during surfacing of drill pipes operating in the conditions of intensive wear, a high efficiency was shown by a composite alloy based on cast tungsten carbides (further relit). Because of the growing requirements to the reliability of hydraulic balancing devices of pumps, the studies on surfacing of slotted rings of end sealing with a composite alloy reinforced by relit (further relit) were performed.

The process of surfacing with relit has two stages: dilution of welding pool on the basis of chromium-nickel alloy (matrix) and at the same time supply of relit grains to the welding pool. Relit grains have high hardness, high melting point values and specific weight. Slotted rings of end sealing are deposited in the flat position, which significantly simplifies the reinforcement of the matrix.

Initially, the works with relit surfacing were performed in relation to the pumps TsNS-180 on the rings of steel grade 12Kh18N12M3T with a diameter of 250/150 mm and a thickness of 27 mm. For experiments and implementation of the process of electric arc surfacing, the robotic complex Limat-RT280 was used, as a matrix material, welding wire Sv-07Kh25N13 with a diameter of 1.6 mm, as a reinforcing phase, chipped relit of grade «Z» according to TS U 322-19-005–96 were used.

In the process of testing the technology of electric arc surfacing, the following issues were solved:

• dosing device to supply chipped relit was designed;

• place and angle of supplying relit to the welding pool were determined;

• amount of relit in the composite alloy was optimized;

• optimal surfacing conditions were selected.

The influence of different factors on the quality of surfacing was evaluated on macrosections by the amount of relit on the working surface of slotted rings and by the absence of defects in the deposited metal (Figure 1).

Figure 1. Typical macrostructure of deposited metal

The performed experimental works allowed providing:

• by more than 40 % higher content of relit in the deposited metal after mechanical treatment of deposited layer to a height of 2–3 mm;

• good wettability of relit grains with chromium-nickel metal in the welding pool;

• absence of cracks and other defects in the deposited metal.

The developed technology was successfully implemented and provided a significant increase in wear resistance of slotted rings in unloading device of centrifugal pumps in terms of providing the content of relit on working surfaces of at least 40 %.

However, chipped relit has a number of disadvantages associated with the technology of its production. A significant part of relit grains is characterized by heterogeneity of composition, nonequiaxiality and sharpness of shapes, as well as the presence of cracks. Ultimately, this negatively affects the serviceability of deposited composite layers [5]. This problem was solved after industrial development of the technology for producing a spherical shape relit. Such relit has a spherical shape of a set grain-size composition, which provides maximum flowability and, accordingly, reliable operation of dosing devices relit. Stable stoichiometric composition and fine-globular structure foster an increase in hardness and strength of spherical tungsten carbide granules [5]. These factors led to a widespread use of spherical relit for plasma-powder surfacing of different wear-resistant parts.

Plasma-powder surfacing of slotted rings in unloading device of pumps was performed in robotic specialized equipment of the Plasma-Master Company (Figure 2). Surfacing was performed on a ring of steel 08Kh21N6M2T with a diameter of 358/278 and a thickness of 30 mm. Welding materials: spherical tungsten carbide of grade KVS-1 according to TSU 24.1-19482355-001, matrix binding is the powder of grade PG-SR2 according to GOST 21448–75. The self-fusing alloy PG-SR2 on nickel base has a low melting point (1000–1100 °C), well moistens relit grains and has a high wear resistance [6].

In the process of testing the surfacing technology, the optimal process conditions, scheme of supplying relit and matrix powder were determined. The content of relit in the mixture was maintained at about 50 vol.%. According to data of [6], exceeding the specified optimal content of relit causes a significant increase in the surfacing current, which causes a marked dissolution of relit particles, embrittlement of matrix and, as a consequence, a reduced wear resistance. The microhardness of undissolved relit particles is 180–190 MPa, for semi-dissolved relit par-

Figure 2. Installation PM-302 for plasma-powder surfacing

ticles it is 130–160 MPa [6]. The macrohardness of surfacing after grinding of its surface to the working height (2–3 mm) is within *HRC* 50–56. The content of relit on the working surface of depsoited metal is more than 50 vol.% (Figure 3). The developed technology provides a high quality of deposited rings (Figure 4) and is successfully realized in pump building.

The abovementioned surfacing technologies allow producing composite layers with the reinforcement by tungsten carbides in the amount of 40–60 vol.% on the working surface of slotted rings. In addition to these methods of surfacing, while producing composite layers, the furnace method of surfacing is currently used. During furnace surfacing, relit grains are uniformly distributed in the composite layer and their partial melting is almost absent. For furnace surfacing of slotted rings, grain relit according to TS U 322-19-005–96 was used, and as a binder, chromium-nickel powders according to TS U 323-19-004–96 were used. The working thickness of the coating is 1.5–2.0 mm. The volume fraction of relit grains in a wear-resistant coating is in the range of 80–90 %.

In the domestic pump building, all three methods of applying a composite layer to slotted rings reinforced with relit are used: electric arc, plasma-powder and furnace surfacing. The choice of surfacing method is determined by production capabilities, operating conditions of pumps and economic factors. In the technological process of electric arc surfacing of slotted rings mainly universal welding equipment is used: small-sized manipulator, welding head with oscillating mechanism and dosing device for relit supply. Plasma-powder surfacing was initially introduced in the equipment of the Plasma-Master Company with

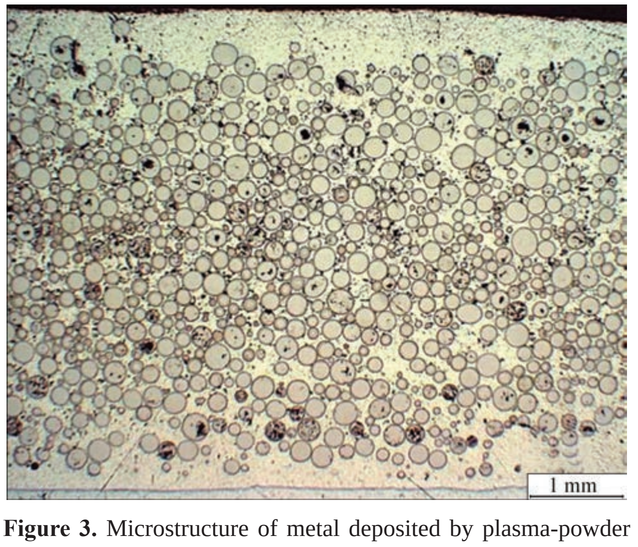

Figure 3. Microstructure of metal deposited by plasma-powder method using spherical relit

Figure 4. Slotted ring deposited by plasma-powder method

the use of spherical relit. The cost of spherical relit is much higher than chipped one, but in general, the advantages of using this process are obvious:

- stability, high manufacturability of surfacing process;
- uniform distribution of relit grains on the working surface of slotted rings;
- significant reduction in the amount of melted grains of relit;
- matrix binder on nickel base by itself has a high wear resistance;
- absence of defects inherent in the grains of chipped relit.

A composite wear-resistant layer reinforced with a spherical relit in the amount of not less than 50 vol.% in plasma-powder surfacing of slotted rings increases service life of pumps also in the conditions of growing loads and increase in corrosion and erosion influence.

Furnace surfacing is a rather complex technological process, but as to the advantages of the plasma-powder method it adds an important property of a composite deposited metal — it provides a more dense packing of relit in the matrix melt. The presence of more than 80 % of spherical relit on the working surface of slotted rings significantly improves their wear resistance and allows them to be successfully used during operation of pumps in rigid conditions.

Under the same operating conditions of pumps, the service life of end slotted rings have a successive significant growth when using surfacing with alloys based on cobalt of type Stellite 6; composite alloys reinforced by relit — electric arc, plasma-powder and furnace method. In this case, much better results were obtained when as a solid phase spherical relit was used.

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