Diagnostics and repair of centrifugal oil transfer pump rotor shaft

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Abstract. Materials on methods for diagnostics and repair of centrifugal oil transfer pump rotor shaft are considered. Results of research on reconditioning worn-out pump shaft journals are presented with provision of surface low roughness by a method of mechanical and ultrasound surface ruggedizing final finish. Analysis of the results attained by the ultrasound ruggedizing finish of a pump shaft and inspection of the superficial layer quality has shown the method, when applied, to considerably increase equipment availability, reliability, and serviceability.

1. Introduction

The oil industry is advancing today at a tremendous pace: newer resources and oilfields are developed. Our country constantly boosts oil production creating a fuel and power complex second to none in its ampleness over the world. The up-to-date oil pipelines are grandiose transport engineering structures.

The energy necessary for transportation of petroleum products along pipes is provided by pumping stations.

The design flowrate of oil transport through the entire length of endless manifolds is maintained by intermediate pumping plants which are installed at an average distance of 100 - 150 km from each other.

In due course, affected by environmental and technological factors, processing equipment undergoes wear and tear, aging, and even destruction. As this takes place, component parts and assembly units degrade and lose their original robustness.

One of the main constituents of an oil transfer pumping station is a main line pump. On-stream pump plants need constant maintenance service and supervision.

For stable high-quality performance as well as for prevention of untimely breakdown of a pump it needs a scheduled complex maintenance turnaround *("PPR - planned preventive refreshment")*.

A centrifugal pump construction comprises a housing, a rotor, a shaft, also bearing supports for assemblies and face seals. The pump housing is cast with a horizontal connecting plane.

A rotor is an assembly comprising a shaft, an impeller, and bushes. An impeller is a cast and welded double-entry structure. The rotor shaft is supported by sliding bearings with forced lubrication [3].

A basic element of a centrifugal pump is a shaft (2) carrying an impeller (5), which by means of blades imparts energy from the motor to a pumped fluid. The pump housing (3) contains a spiral inlet (7) and a volute outlet (6). The housing has a horizontal joint.

Seals: 1) impeller slotted seal (4) and 2) shaft end face seal (9).

Sliding bearings (10). Radial-thrust bearing (1). Separating bushes (13). Outlet pipes (12). Gear clutch (11).

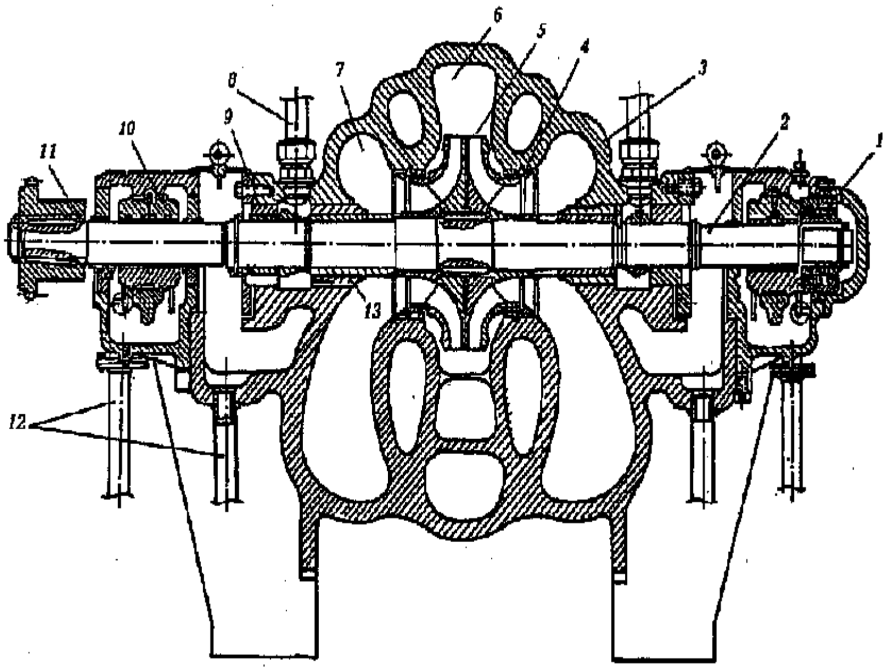

Figure 1. A sectional view of a NM-type main line pump

2. Diagnostics

Diagnostics is an essential element of maintenance service and an indispensable factor of fail-safe operation of pumping equipment. Diagnostics is carried as a constituent both of routine service and an overhaul. Diagnostics is conducted to estimate equipment operability, to clean, wash, and purge it, to repair or replace insulation components, to find out defects resulting from operational process, to specify scope and types of work to be executed as routine maintenance or major repairs.

Nondestructive evaluation techniques serve to check component condition. Depending on physical principles involved, there are nine methods of nondestructive testing (NDT).

Visual and optical observation allows finding relatively big cracks, mechanical defects, and residual deformations.

Capillary examination is based on increasing contrast between defects and a defectless material with the help of special liquid penetrants.

Ultrasound scanning aids to determine coordinates and area of a defect. The transmitter should bear against the scanned surface of a specimen.

Electromagnetic flaw detection method is based on the principle when imperfections of an article excite distortion of the magnetic field induced in this article.

Gamma-radiography defectoscopy using portable and maneuverable instruments exposes latent flaws.

The key features of nondestructive testing methods are sensitivity and efficiency. Sensitivity is defined by minutest dimensions of detectable defects. The majority of the above techniques is able to detect cracks over 0.001 mm.

The gammagraphic method enables examination of specimens of 5 through 200 mm thickness.

For nondestructive survey of pump motors and shafts, visual, ultrasound, and magnetic particle methods are used during incoming inspection as well as during maintenance and reconditioning. These modes of inspection reveal superficial and internal defects as well as cavitation and other kinds of material continuity violation. Checking is performed in intervals of 10 thou to 16 thou running hours of a shaft depending on a pump capacity and number of starts.

While in service, such parameters as vibration, temperature, head pressure, efficiency, positive suction head (PSH) and others should be continuously monitored. Systems of automation, telemechanics and automated control (ACS) should provide reliable monitoring and logging of the equipment pumping mode and operation parameters.

An unscheduled nondestructive defectoscopy is performed if a visual inspection or vibration diagnostics detect presence of flaws.

Shafts of main line pumps and charge pumps after 72 000 running hours should be replaced or reconditioned. Shafts of auxiliary pumps are visually dimensionally inspected during reconditioning. In case of flaw detection, a shaft undergoes defectoscopic checking by ultrasound, eddy-current, magnetic-particle, and capillary methods according to the technique presented in RD 153-39TN-010-96 [1].

Flawed pump shafts are not operated, but substituted for new ones. In case of an overhaul, troubleshoot all the main components of a pump: shaft, impellers, bearings, and etc.

Most frequently shaft defects occur on the bearing mounting surfaces [8].

It is recommended to recondition:

- bearing mounting surfaces at wear of more than 0.017 to 0.060 mm,
- fixed joint surfaces (hub mounting areas) at wear of more than 0.04 - 0.13 mm,
- movable joint surfaces at wear of more than 0.4 - 1.3 mm,
- seal surfaces - at wear of more than 0.15 - 0.20 mm,
- spline surfaces - at wear of more than 0.2 - 0.5 mm,
- lateral surfaces of key grooves - at wear of 0.065 - 0.095 mm.

3. Centrifugal oil pump rotor shaft repair

There are two basic types of repair works: routine maintenance and major overhaul. An overhaul is executed as required (typically, after 25 000 - 26 000 operation hours) and includes:

- the full scope of maintenance works *(TO)* and technical regulations *(TR)*;
- a diligent checkup of all assemblies and components;
- if required, replacement of impellers, shafts, housing seal rings, gland bushes, distance sleeves, gland packing sleeves;
- pump housing removal from the base plate, weldup and boring seats on the housing;
- for sectional pumps - replacement of separate sections;
- pump hydraulic testing at a pressure exceeding the working pressure by 0.5 MPa.

For an overhaul, completely disassemble a pump. Clean the housing from dirt and rust and review for defects.

Wear of shaft journal should not exceed 0.025 mm, shaft axial play should be within 0.15 - 0.35 mm. Using a dial gauge, one can check the shaft for beating in several points.

There are two possible ways to restore worn-out journals of a shaft: to introduce a repair size or to restore the initial size by weldup. In both cases, eliminate journal irregular form (ovality, conicity) and surface imperfections (wear-out, scorings, scratches) by turning down in a lathe with subsequent polishing or in a grinder.

Significantly worn-out shaft journals or having other considerable defects are lathed down to a repair size, if it is possible due to the construction and strength of a mating part. In dependence on the shaft active load, diminution of the journal diameter for 5 - 10% is permitted. In other cases, the nominal size may be restored by different types of weldup (short-circuited arc surfacing, carbonic-dioxide-shielded arc welding, and so forth), metallization, and chromium coating. At specific pressures above 65 MPa, wear resistance of the majority of welded-up metal grades becomes insufficient, largely because of inferior strength and hardness at operating temperatures. The impact of high specific pressures in combination with the medium aggressiveness may cause plastic deformation of sealing surfaces, occurrence of scorings, dents and other defects on them, which reduces the pump's service life. The materials and weldup processes applied should provide a specified structure and stable degree of metal ruggedness over the entire welded-up working surface.

Scientific research in this field testifies that welded-up surfaces with a higher degree of ruggedness demonstrate a higher scoring resistance. At that, however, such surfaces' resistance against cracking and processability sharply drop, especially when the hardness is above 44 - 46 HRC. Because of this, no inclusions and pores are tolerable in the welded-up metal [5, 9].

Main-line-pump impellers lathing down to the outside diameter is often in pipeline oil transportation. Depending on a pump speed coefficient ns, lathing of the impellers may be accomplished within the following limits: at 60 < ns < 120 impeller lathing is allowed down to 20% of the outside diameter; at 120 < ns < 200 - down to 15%; at ns = 200... 300 - down to 10%, as also after weld deposit.

A chisel is set to a specified cutting depth. After the chisel pass, the processed journal diameter is checked in several sections, as well as the surface roughness. The journal is turned down to the nearest repair size.

Taking into consideration the increasing requirement to quality of the equipment for oil trunk pipelines and the necessity to ensure durability of parts in the operational process, it is actual to study structure formation of the surface and near-surface layers of welded-up metal, and creating - on the friction couples - surfaces with minimal roughness, which provide high technological properties, bettering of hardness and antifriction behavior of the surface welded overlay.

Very often, conventional methods of finishing by grinding, polishing, and fine finishing by abrasives do not provide optimal quality of the surface layer, while it is practically impossible to obtain by these methods a high-quality surface for soft metal components. When fine abrasive powder is utilized, its particles intersperse into the treated surface and cause charging. Moreover, surfaces after grinding represent a plurality of micro traces of abrasive grains, have burns and micro cracks. The surface layer is saturated with abrasive particles. These surface defects become stress concentrators and initiate destruction of the surface layer of parts in operation.

Some disadvantages inherent in these methods may be eliminated by such techniques of surface plastic deformation as diamond smoothing, ball and roller rolling. [6, 7]

Improvement of the surface layer quality is possible through a more complete utilization of the reserve encompassed in substitution of the static deformation method for an impulse one, i.e. by superimposing ultrasound oscillations on a tool. Under the impact of ultrasound, complex processes start in the surface layer: superposition of alternating loads on the static load, local absorption of ultrasound energy, which finally leads to a change in the metal flow and facilitates plastic deformation, and as a result makes it possible to obtain a small roughness on the surface, a hardened layer and compressive residual stresses [2, 4].

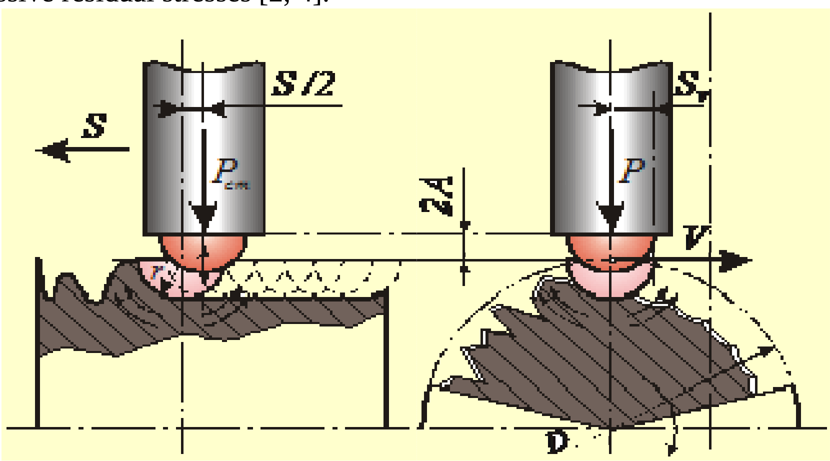

Figure 2. Schematic of a shaft journal surface plastic deformation by ultrasound ruggedizing final finish *(UZUFO)*

Surface roughness inspection after mechanical and ultrasound treatment was performed with TR-100 profilograph.

Figure 3. Small-sized TR-100 profilograph. After cutting and turning pump shaft journals, roughness was - Ra 3.2.

As a result of ultrasound ruggedizing finish, the surface with roughness of Ra 0.1 was obtained. Surface roughness profile record (profilogram)

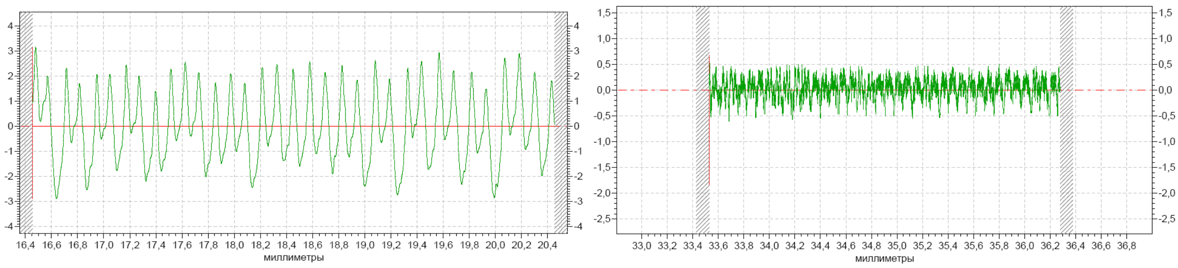

Figure 4. Prophylogram of shaft journal surface roughness. a) After-cutting roughness - Ra 3.2 b) roughness after UZUFO - Ra 0.1

After repair, the pump undergoes flaw detection inspection verified by an appropriate certificate form.

4. Conclusion

As a result of the accomplished work, the problems of a centrifugal oil pump rotor shaft troubleshooting were considered.

Studies on restoration of worn-out pump shaft journals and obtaining low surface roughness after machining and ultrasound treatment have been carried out.

Analysis of the results of ultrasound ruggedizing finish, quality inspection of a surface layer state demonstrates that application of this technique allows for considerable improving the quality, reliability and service life of equipment.

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