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CORROSION AND WEAR OF WASTEWATER PUMPING SYSTEMS

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Abstract

The submersible pumps are submerged in the fluid that must be pumped, this type of pump is capable to push out large volumes of water. The watertight subassembly of this equipment includes a variable power engine that can be used for various household applications or industrial purposes. Wastewater transported by pumps corrodes and wear the transport system. The materials used for the construction of these pumps must withstand the acidity of the water, capitation phenomenon, the wear caused by the particles in the suspension and maintain their operating properties. The paper presents an analysis of the wear and corrosion effects on the wastewater pumps and an analysis of the pump impeller material.

Keywords: *wastewater, corrosion, wear.*

Introduction

For the transport of domestic or industrial fluids, surface or submersible pumps are used to push through a pipeline system contaminated waters with various impurities. These pumps are used at pumping station that feeds water to the treatment plant prior to discharge into rivers and are also used for drainage of surface water (floods) and sewage [1].

Thus equipments are also used for residual fluids from domestic activities, industrial operations or cleaning of organic residues from livestock farms contain chemical solvents such as dust, sand, colloidal substances and suspensions; fluids containing air or gas bubbles at the surface or dissolved in the interior; sludge; rain water; wastewater with feces [2].

The submersible pumps may also be provided with a chopper that will smash the containing solid materials, slurries or large particles from the liquid waste.

The pumps for wastewater (domestic and industrial) are generally high power centrifugal pumps that work under extreme conditions because the transported liquid contains strong organic and inorganic corrosive agents as well as abrasive particles of various sizes and shapes in suspension [3-5].

The influence of wastewater chemical composition on pumping systems corrosion

Wastewater is a chemically aggressive environment because of presence of corrosive and abrasive elements, such as:

- dissolved oxygen;
- domestic wastes: chlorides, fluorides, sodium hydroxide or organic matter;

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- acids from decomposition of biological substances;

- sulfur compounds (SO_2, H_2S, H_2SO_4 etc.);

- aerobic and anaerobic bacteria that produce biogenic amines (produced by a biological process);

- mushrooms and biological residues suspension, gravel, sand and other solids of organic and inorganic nature [6 - 9].

The chemical composition of wastewater is variable, containing sewage waste including pathogenic bacteria, organic and inorganic particles, emulsions, dissolved gases, etc., the pH ranging from 6 to 9 (especially acid pH). The most corrosive component is sulfuric acid usually found in high concentration in this waste liquid [2, 10].

During operation, a mechanical wastewater pump must withstand various mechanical and chemical stresses, such as:

a) mechanical stresses;

- different intensities mechanical shocks at variable contact angles of the particles, the degree of abrasion varying depending to their shape and size [11];

- heat and mechanical action because the pumps are used outdoor, in winter temperatures are up to -35 °C (the danger of water freezing at temperatures below 0°C is high because the increasing with 9% of liquid volume can produce micro cracks) and up to 50°C during summer; the submersible pumps must withstand at abrasive particles from the high velocity water;

- cavitation effect due to turbulent wastewater flow can also affect the integrity of the pump sub-assembly;

- operating irregularities due to the variable viscosity of the waste water and the presence of different sizes particles matter in suspension [12, 13];

b) chemical stresses

- acid pH of water, which increases the number of active ions and chemical reactivity of the liquid;

- the corrosion of sulphuric acid and sulphur dioxide dissolved in water, resulting from the decomposition organic of substances;

- enhanced corrosion due to the presence of dissolved oxygen in the transported liquid, which changes the water acidity [14];

- the flow assisted corrosion is removing the protective oxide layer from the pump metal (especially in low-alloy steels and gray cast iron). The intensity of this process depends of the oxygen content, velocity of the liquid and chlorine content [15, 16];

- the action of aerobic and anaerobic bacteria on the pump metal;

- the chemical attack of hydrogen sulfide (H_2S), which is produced by sulfur-reducing bacteria from the sewage.

In addition to factors such as pH, temperature and organic matter are the flow velocity and the effect of specific liquid compounds such as sulfur reactions and bacterial growth.

Glass and heavy organic particles are deposited on the bottom while bacteria develop on the walls of the channel to form a biofilm or slurry layer. This biofilm layer provides an excellent environment for bacteria growth, protected by the shear forces of the flowing wastewater.

The channel space contains several micro-media: the space above the liquid is usually filled with oxygen with abundant oxygen; the liquid may be either aerobic or anaerobic, depending on the oxygen demand and the reaction rate; the layers of silica and biofilm may also be aerobic or anaerobic.

Wastewater may contain iron oxides or iron chlorides, their presence giving a red earth color to water and the presence of manganese or manganese oxides giving a black color. Oxides can also be found in granules form or as fine powders in mud or sludge after dissolving in water [17].

The transport pipelines are clogged with powdered substances and solid microparticles forming wall-adherent protuberances.

The presence of chlorides and sulphides in water increases the thickness of deposition from pipe walls and the corrosion of the transport system. At a laminar flow of fluid, the possibility of chemical corrosion reactions occurs (oxidations, etc.) by ionization and low speed diffusion [18].

In case of turbulence flows, the layer from the pipe walls is thin and the corrosion intensity is higher. Whirlpool is accentuated by the presence of deposits on the walls. So, the corrosion increases with the decrease of the deposited layer.

Therefore, in wastewater, turbulences formed at high flow velocities allow oxygen to reach the walls of the pipeline more quickly and corrosion rates are higher.

Types and concentrations of contaminants from domestic wastewater are well known: fats, oils, soaps, organic matter, dirt, human waste, food waste, etc.

Common chemical contaminants in domestic water are chlorides, nitrogen compounds and a wide variety of organic compounds. Sulfate and phosphate ions are also present.

Sewage and other wastewater contain significant biological and organic materials compounds, including many active bacteria.

From the corrosive point of view, the most important types of bacteria are those that metabolize sulfur compounds, because this microbiological activity can produce acidic chemicals that are corrosive to concrete, steel or iron. Some bacteria also oxidize ferrous ions to ferric ions, creating a corrosive environment for carbon steel [19, 20].

Mechanical degradation of the waste water transport system

Types of materials degradation in sewage treatment plants are:
- freeze-thaw damage;
- wear;
- impact erosion produced damages;
- cavitations attack [18], (fig.1).

Freeze- thaw damage occurs in relatively fragile materials, such as metal, stone, concrete and wood, exposed to temperature cycles above and below water freezing point when ice penetrate in cracks or material pockets. A surface treated metallic material will withstand at freeze-thaw cycles for many years, even under severe conditions.

Because the pumping system and pipe materials are characterized by hardness rather than tenacity, the dilations and compressions aren't deformation effects, so cracking risk is high.

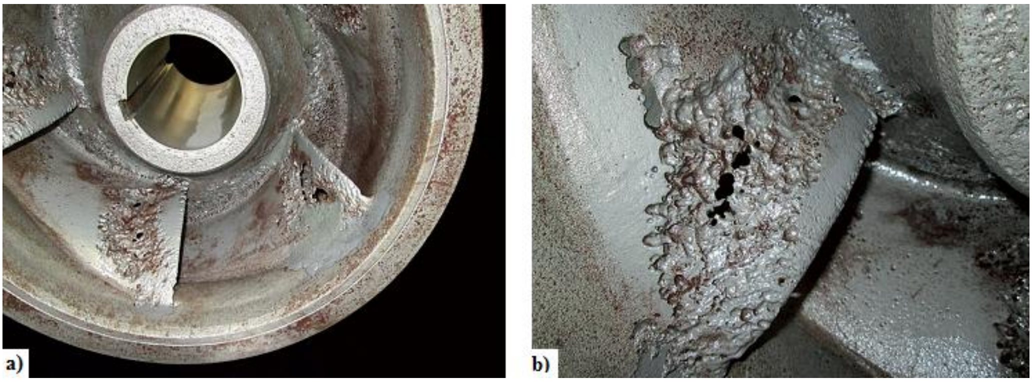

Fig. 1. Images of some used pump impellers: a) Cavitation wear; b) Detail.

The transport system goes through repeated thermal variations, which causes not only priming cracks danger, but also growth of intragrain cracks along maximum tension area, in tension vector direction.

The number of freeze-thaw cycles is an important parameter the lower temperature it is the more severe frost-thaw damage it is.

Corrosive elements from water infiltrates into microcracks increasing the freezing stresses in the pump material. It results a growing of cracks in the water infiltration direction, the formed ice creating open cracks [21-24].

The high roughness and pore presence on the pipes walls increase the freeze-thaw effect. The most severe frost-thaw damage appears on multiple medium pores surfaces. Surfaces with large pores are less likely to be damaged, because the pores are not completely filled with water. In general, abrasion damage involves scratching, wear, scraping or percussion forces at small angles on surfaces of metallic material.

The most important parameter that is related with abrasion wear resistance of materials is the compressive strength.

Abrasion damage is also common at pipes used for sewage waters, where sand and gravel penetration occurs.

Cavitation erosion involves the explosive impact of gas bubbles stuck in liquids when the liquid flow is turbulent or disturbed. The resulting impacts affect the pipeline surfaces, causing perforation and erosion. The intensity of cavitation damage increases with the increase of surface roughness.

Early signs of cavitation erosion include crevices and numerous craters in the surface, resulting, in the end, in a holing of wall. The cavitation erosion often is similar to acid attack effects.

The tear plate material is created by cavitation damages by removing of the protective layer, which increases the intensity of erosion.

Results and discussions

The wastewater pumps materials must be compatible with the pumped liquid, therefore the wear and corrosion of the pump channel and pumping elements are within accepted limits. Since the pump is the most important component of the filter system, it must have the ability to supply and maintain the desired flow and pressure, as the dirt accumulates on the filters [8, 9].

The presence of the cavitation phenomenon in the pump is related to the high level difference between the pump position and the liquid surface, mainly for submersible pumps, such as the studied pump. When the inlet pressure is too low, the liquid vaporize inside the body and cavitation phenomenon generating pump faults [3].

A single-channel, low-pressure centrifugal pump was analyzed, both macroscopically and SEM microscopy, to highlight areas with significant corrosion wear. Figure 2 presents highly corroded zones of the pump impeller used for domestic wastewater activities.

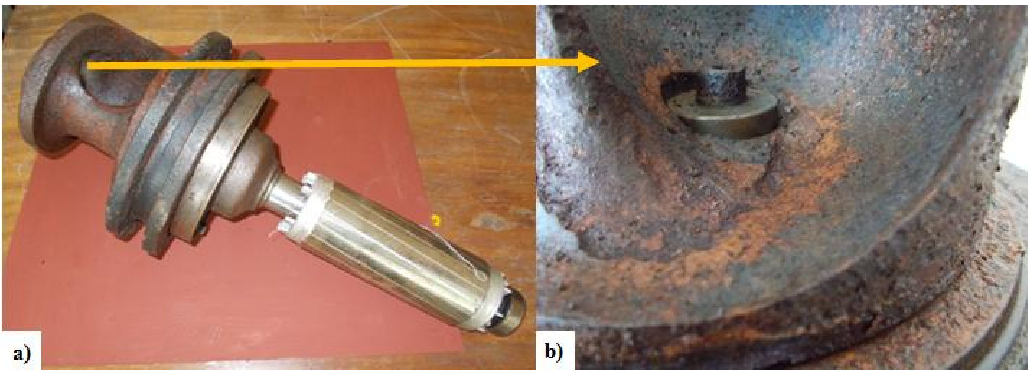

Fig.2. One-channel centrifugal pump for low pressure; a) impeller; b) corrosion wear zone of impeller.

The impeller material analyzed by Foundry Master Spectrometer is a Ni and W alloyed spheroidal cast iron. The chemical composition is shown in Table 1.

Table 1. Chemical composition of impeller pump material

Chemical element	Fe	C	Si	Mn	P	S	Mo	Ni	W	Cr	Others
Percent %	78,10	4,50	2,55	0,15	0,80	0,15	0,20	9,34	2,29	0,08	1,83

Metallographic investigations (fig. 3) were carried out on piece cut from maximum wear and corroded zones of the impeller. The impeller material is a spheroidal cast iron with partially spheralized nodules, present in a ferrite-perlite matrix (mainly nickel alloy perlite and tungsten as a secondary element).

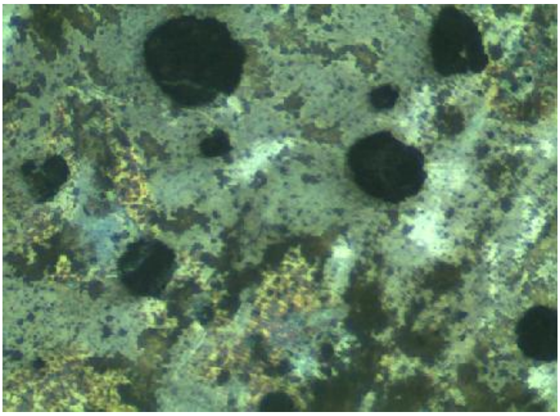

Fig.3. Optical metallography, X200. Nodular graphite pearlitic-ferrite matrix.

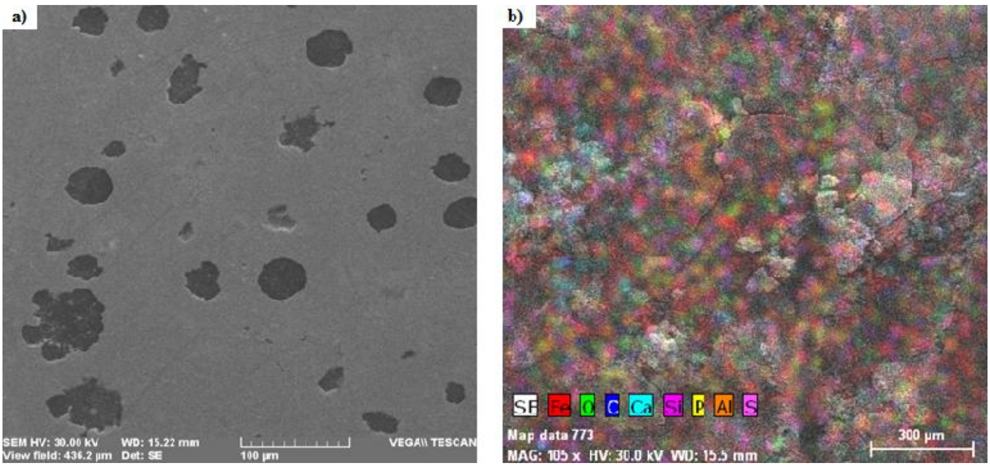

Fig. 4. The microstructure obtained with the Scanning electron microscope of the pump impeller: a) SEM microstructure, 100 µm; b) EDX microstructure, 300 µm.

SEM analysis (fig. 4) shows the presence of a mixed oxide particles of waste substances from the wastewater. An EDX analysis was also carried out showing a distribution of the substances on the corrosion film area.

Conclusion

The material from which the carcasses and impeller of the wastewater pumps are made shall possess good corrosion characteristics in acidic, bacteria contaminated and fungal environments. In addition to corrosion resistance, the material has good behavior at temperature variations, so it does not crack in the range -50 ºC + 50 ºC due to expansion and compression.

An important factor is resistance to wear because the wastewater is includes abrasive powder or even large particles that can damage the walls of the installations at high speed.

The analysis of corrosive factors in the working environment requires relatively cheap solutions to improve the wear and corrosion resistance of the water channels of the pumps.

The materials used in the construction of pumps (brass, medium and high Cr and Ni alloyed steel, cast iron alloys) possess good corrosion resistance characteristics, but are limited to wear resistance.

The analyzed pump is made of chromium tungsten cast iron and presents in the water channels breakages and small missing due to contact with solid particles from wastewater.

References

[1] G. Pracht, N. Perschnick, *A material challenge – Pumps in sulphuric acid application*, **Procedia Engineering**, **138**, 2016, pp. 421 – 426.

[2] I.J. Karassik, (2001), (Ed.) **Pump handbook** (3rd ed.) McGraw-Hill.

[3] J.A. Escobar, A.F. Romero, J. Lobo-Guerrero, *Failure analysis of submersible pump system collapse caused by assembly bolt crack propagation by stress corrosion cracking*, **Engineering Failure Analysis**, **60**, 2016, pp. 1–8.

[4] K.D. Swapan, M. Parikshit, G.C. Sandip, D. Goutam, S. Raghuvir, *Effect of microstructures on corrosion and erosion of an alloy steel gear pump*, **Engineering Failure Analysis, 40**, 2014, pp. 89–96.

[5] P. Christoph, *Do coatings protect against corrosion and wear?*, **World Pumps**, **2005**, 2005 pp. 32-38.

[6] T.E. Larson, *Corrosion by Domestic Waters. Illinois State Water Survey*, **Urbana Bulletin, 59**, 1975, pp. 1-28.

[7] T. Luukkonen, T. Heyninck, J. Ramo, U. Las, *Comparison of organic paracids in wastewater treatment: Desinfection, oxidation and corrosion*, **Water Research**, **85**, 2015, pp. 275-285.

[8] J. Jin, G. Wu, Z. Zhang, Y. Guan, *Effect of extracellular polymeric substances on corrosion of cast iron in the reclaimed wastewater*, **Bioresource Technoloy**, **165**, 2014, pp. 162-165.

[9] M.R. Choudhury, M.K. Hsieh, R.D. Vidic, D.A. Dzombak, *Corrosion management in power plant cooling system using tertiary-treated municipal wastewater as makeup water*, **Corrosion Science**, **61**, 2012, pp. 231-241.

[10] G.A. Pantazopoulos, *A process-based approach in failure analysis*, **Journal of Failure Analysis and Prevention 14(5)**, 2014, pp. 551–553.

[11] H.H. Tian, G.R. Addie, R.J. Visintainer, *Erosion–corrosion performance of high-Cr cast iron alloys in flowing liquid–solid slurries*, **Wear, 267**, 2009, pp. 2039–2047.

[12] M. Azimian, H.J. Bart, *Erosion investigations by means of a centrifugal accelerator erosion tester*", **Wear, 328–329**, 2015, pp. 249–256.

[13] I. Cimpoesu, S. Stanciu, N. Cimpoesu, C. Munteanu, B. Istrate, A. Dragos Ursanu, D. Dana, A. Alexandru, C. Nejneru, *Chemical and micro-structural characterization of a copper based shape memory alloy*, **Journal of Optoelectronics and Advanced Materials, 15 (11-12)**, 2013, pp. 1392-1398.

[14] P. Smith, T. Kraenzler, *Reducing effects of corrosion and erosion*, **World Pumps**, **2017 (2)**, 2017 pp. 38-41.

[15] P.P. Psyllaki, G. Pantazopoulos, A. Pistoli, *Degradation of stainless steel grids in chemically aggressive environment*, **Engineering Failure Analysis, 35**, 2013, pp. 418–426.

[16] I.A. Metwally, A. Gastli, *Correlation between eddy currents and corrosion in electric submersible pump systems*, **International Journal of Thermal Sciences, 47**, 2008, pp. 800–810.

[17] P.N. Hari, *Sediment Erosionin HydroTurbines* (Ph.D.thesis), Faculty of Engineering Science and Technology, **Norwegian University of Science and Technology** (NTNU), Trondheim, 2010, Norway.

[18] A.N. Adnan, K. Man-Hoe, *Erosion wear on centrifugal pump casing due to slurry flow*, **Wear**, **364-365**, 2016, pp. 103–111.

[19] H.R. Vanaei, A. Eslami, A. Egbewande, *A review on pipeline corrosion, in-line inspection (ILI), and corrosion growth rate models*, **International Journal of Pressure Vessels and Piping, 149**, 2017, pp. 43-54.

[20] J. Hernandez-Sandoval, R. Gonzalez-Lopez, M.A.L. Hernandez-Rodriguez, A.M. Guzmán, *Localized corrosion in an electrical submergible pump (ESP)*, **Engineering Failure Analysis,** 53, 2015, pp. 124–131.

[21] M.S. Baltatu, P. Vizureanu, R. Cimpoesu, M.M.A.B. Abdullah, A.V. Sandu, *The Corrosion Behavior of TiMoZrTa Alloys Used for Medical Applications*, **Revista de Chimie**, 67, 10, 2016, p. 2100-2102.

[22] C. Nejneru, M.C. Perju, A.V. Sandu, M. Axinte, M. Quaranta, I. Sandu, M. Costea, M.M.A. Abdullah, *Corrosion Behaviour of Tin Bronze for Shipbuilding Industry*, **Revista de Chimie**, 67, 6, 2016, p. 1191-1194.

[23] M. Axinte, C. Nejneru, M.C. Perju, A.V. Sandu, M.D. Aelenei, M. Costea, *Corrosion Behaviour of Some Steels in Black Sea Water*, **Revista de Chimie, 66**, 11, 2015, pp. 1846-1851.

[24] A.V. Sandu, A. Ciomaga, G. Nemtoi, M.M.A.B. Abdullah, I. Sandu, *Corrosion Of Mild Steel By Urban River Water,* **Instrumentation Science and Technology**, 43, 2015, pp. 545–557.

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