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ScienceDirect

Energy Procedia 112 (2017) 75 – 82

Energy Procedia

Sustainable Solutions for Energy and Environment, EENVIRO 2016, 26-28 October 2016, Bucharest, Romania

Structural aspects of silt erosion resistant materials used in hydraulic machines manufacturing

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Abstract

The corrosion effects caused by cavitation and silt erosion (abrasive erosion) phenomena lead to serious modifications in the structure of metallic materials from which are manufactured the important active components of hydraulic machines. In the first part of the paper, a brief presentation of the mechanism of silt erosion phenomenon comparatively with the cavitation one is made. The synergy between cavitation-erosion-corrosion is approached. The structure elements of the most used metallic materials corrosive resistant are described, too. It follows a comparative synthesis of specific structures stainless steels resistant to cavitation erosion and abrasive erosion. The structures of new stainless materials, originally obtained in the laboratory, are discussed on Schaeffler's diagram showing the influence of alloying elements on these forms of corrosion.

Peer-review under responsibility of the organizing committee of the international conference on Sustainable Solutions for Energy and Environment 2016

Keywords: corrosion; silt erosion; cavitation; synergy; austenite-ferrite-martensite; Schaeffler's diagram

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Peer-review under responsibility of the organizing committee of the international conference on Sustainable Solutions for Energy and Environment 2016
doi:10.1016/j.egypro.2017.03.1064

1. Introduction

Corrosion is the reaction of material with its environment. The effect of corrosion is a change in the material structure leading to corrosive damage. So, the corrosive damage is the result of the chemical reaction of metallic surface with constituent elements of the environment. If the process of corrosion interacting with other environmental factors, as suspend solid particles, or different operating conditions, as pressure change or flow velocities, the corrosion process can be extend to erosion. Two types of extend corrosion phenomena are developed in hydraulic machines (hydraulic turbines and turbo-pumps): cavitational erosion and abrasive erosion, one more destructive than another, [1, 2, 3].

Cavitation is defined as the phenomenon of the formation, growth and rapid collapse of bubbles or cavities in a liquid, [4, 5]. Cavitation phenomenon can be produced in different ways. There are four types of cavitation looking for the method of producing it, [6]:

- *hydrodynamic cavitation*, produced by pressure variation in a flowing liquid when the pressure drops to around the liquid vapour limit; vapour bubbles tend to form around any free-gas nuclei. If the nuclei are carried downstream to regions of higher pressure, the nuclei collapse rapidly producing high pressures and temperatures;
- *acoustic cavitation*, produced by the pressure variation in a liquid when ultrasound waves pass through it;
- *optic cavitation* produced by high-intensity light (e.g. laser) which will rupture the liquid;
- *particle cavitation*, produced by any type of elementary particle (photon, proton, neutron) which break down the liquid.

As a corrosion mechanism, in hydrodynamic cavitation, when cavitation bubbles implode on the solid surface of hydraulic machine component, the local pressure developed is high and can exceed the fatigue strength, yield point or compression strength of the material. Pitting of the material appears and the cavitation erosion process will be developed.

Abrasive erosion is a process of gradual degradation in structure under the action of solid particles suspended in the water or in another working fluid. Two main categories of abrasive erosion are approached in the literature: impact and sliding erosion, considering the mechanisms of which the abrasive particles act on the metallic surface, [2].

Since 1983, Duan C. G. has been reviewed the abrasive erosion phenomenon of hydraulic turbines because it became in the last decades a major problem for the efficient operation of hydropower plants, [7, 8].

In this paper are discussed the metallic material structure high resistant to cavitational erosion and abrasive erosion developed in hydraulic machineries, especially hydraulic turbines. In chapter two the synergy of cavitation-erosion is approached and then metallic materials cavitational resistant are discussed. Conclusion regarding improved materials high resistant to cavitation and abrasive erosion are proposed.

2. Synergy of cavitation-erosion

The association of corrosion with time is wear, a mechanical failure mode. From a metallic material, wear is erosion and the effects of wear are the material deformation and removal. Both cavitation and silt erosion are losing material in time although the wear mechanisms in both situations are different.

Cavitation wear occurs from the collapse of cavitation bubbles, when a shock wave appears and spreads in the liquid. In its way the shock wave can met a single bubble located near the solid surface and collapse in a micro-jet. A pit appears in the metallic solid surface as a result of the repeated hits caused by high velocity liquid micro-jet impact, [9]. At the beginning the surface is plastically deformed and no material loss is present. Implosion bubble repetition will produce in time an eroded surface. Flow velocity and water gas content will accelerate the cavitation erosion.

Surface appearance under cavitational attack is rough, with pit holes and sharp projections, Fig. 1. If cavitational erosion is combined with corrosion the surface will be colored in shades of rust, Fig. 2.

Abrasive erosion (silt or sand) results at the impact of a two-phase flow (water and solid particles) with the metallic solid surface of a hydraulic machine. The impact of the solid (abrasive) particle with the metallic surface can break the protective oxide layer in the metal surface and corrosion conditions are created to accelerate the degradation process. The result of sediment erosion is an abrasive wear or erosive wear. The difference between