Engineering Failure Analysis 70 (2016) 56–72

Contents lists available at ScienceDirect

Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/engfailanal

# Resonance of torsional vibrations of centrifugal pump shafts due to cavitation erosion of pump impellers

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ARTICLE INFO

*Article history:*
Received 11 January 2016
Received in revised form 28 June 2016
Accepted 29 July 2016
Available online 30 July 2016

*Keywords:*
Impeller pumps
Cavitation erosion
Pump shaft failure
Shaft fractures
Pump shaft vibrations
Mechanical resonance

ABSTRACT

Selected results were gathered during investigation of centrifugal pumps used in a sea water cooling system of one of Diesel power stations are presented in the paper. The main goal of research was to explain the reason of occurring fractures in pump shafts. The investigation has shown that the fractures were caused mainly by the resonance between pump shaft torsional natural vibrations and those following from the pressure fluctuations related to the frequency of the shaft rotational speed and the number of impeller blades. The resonance occurred as a result of intense erosion of pump impellers derived mainly from cavitation phenomenon that caused about 20% of the impeller mass decrease. The scope of the investigation has covered among others: erosion damage recognition, tests of the investigated pumps operating conditions, spectral analysis of pressure fluctuation generated by the pump blade system as well as strength analysis of the pump shaft and the frequencies of its natural bending and torsional vibrations.



## 1. Introduction

The centrifugal pumps supplying the cooling system of two Diesel generator sets in one of the coastal power plants, had experienced breakdowns caused by their shaft fractures. The failures have occurred at four pumps after about 1900, 2100, 2400 and 3000 h of operation, respectively. In each of these cases substantial destruction derived from cavitation of pump impellers and spiral cases had been found.

The authors of this paper, in order to detect the causes of the shaft fractures, have carried out the required comprehensive research and analysis of various conditions of the operation of investigated impeller pumps.

The failures of pumps were not incidental, that means that they were not caused by e.g. material defects. It seemed that breakdowns were caused by some other phenomena that occurred during operation of the pumps and because of operation conditions. It should be noted that there were not any signs that pumps of the same type installed on ships and other marine installations had experienced similar failures - basing on reported cases, pumps of the same type operated at the positive suction head, which seemed to be the main reason for the lack of cavitation erosion threats in such systems. The analysis based on the results of the inspection on site and measurements and tests results as well as appropriate calculations made basing on available documentation of the pumps and the pumping system, as well as the conditions for their joint operation, made it possible to determine the causes of failures.

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http://dx.doi.org/10.1016/j.engfailanal.2016.07.011
1350-6307/

The authors of this study are not aware of any published books and papers on the relationship of the cavitation erosion of pump rotating components with the phenomenon of the resonance vibrations of the pump shaft [3,4,6–8,13,16–18] although there are some papers concerning internal resonance phenomenon in rotors [9] or analysis of this focusing on using such analysis e.g. for crack detection [2].

## 2. Tested pumps and their system

Three identical, single stage centrifugal pumps with double suction pipes were installed vertically in the seawater cooling system of the power plant equipped with two Diesel generator sets - see Figs. 1 and 2. Each pump had similar bronze impeller with five blades ($i = 5$) and the shaft made of stainless steel. The pumps were driven by the electric motors with the rated power of $P_n = 80$ kW and the rotational speed of $n_n = 1475$ min$^{-1}$.

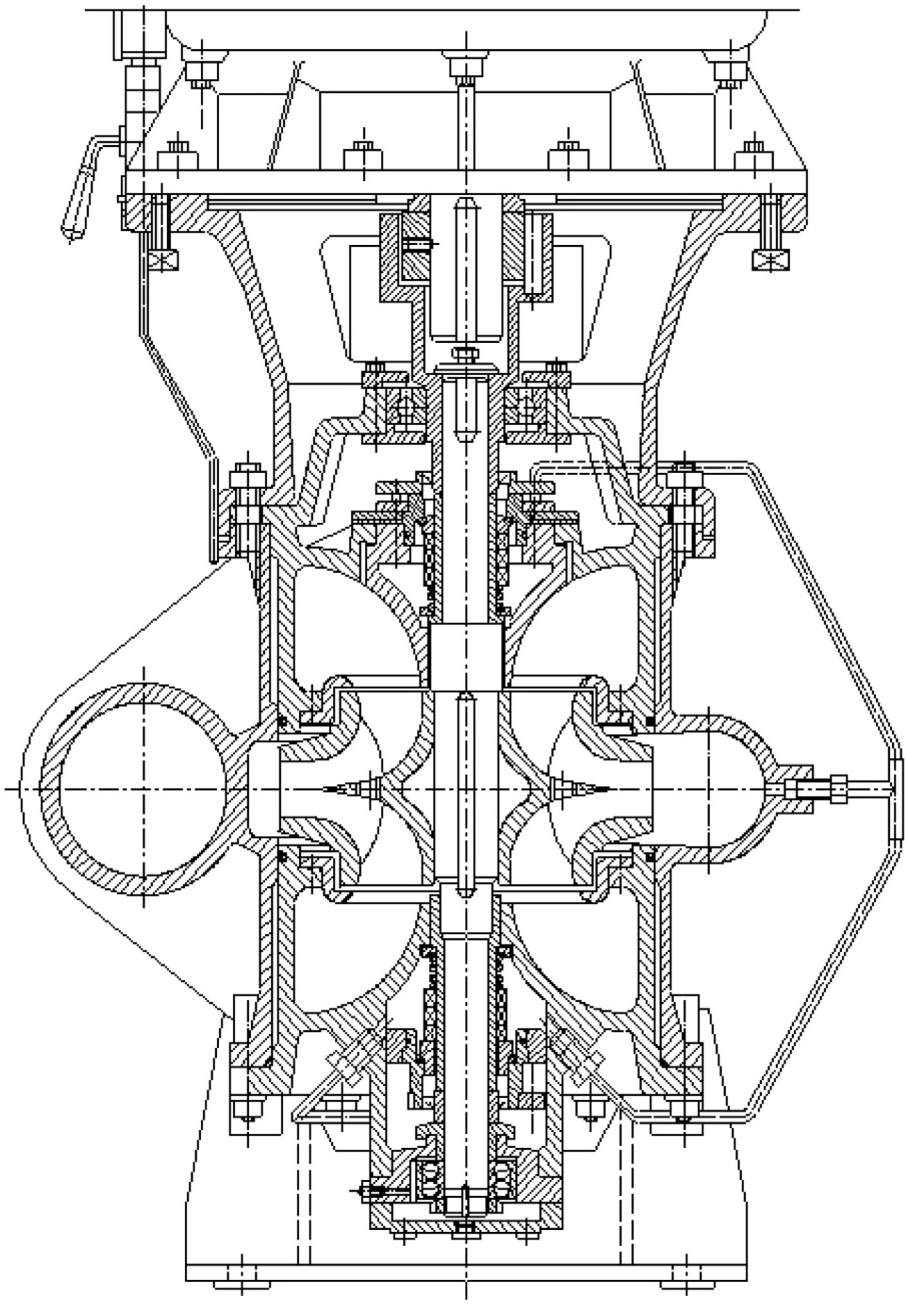

**Fig. 1.** Axial section of the tested pump.