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Failure analysis of centrifugal pump impeller

Rui Yu, Jinxiang Liu*

School of Mechanical Engineering, Beijing Institute of Technology, Beijing 100081, China

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ABSTRACT

This paper analyzed the looseness failure between impeller and shaft. In order to determine the cause of the failure, the torque produced by external loads was calculated theoretically. The torque capacity of interference connection was analyzed using finite element method (FEM). The basic mechanical properties of different impeller were tested and applied to the FEM model to find out the influence of mechanical properties on interference connection between impeller and shaft. The analysis results indicate that interference connection condition is greatly affected by mechanical properties. The torque capacity of interference connection decreases with the mechanical properties decrease. The maximum torque transmitted by interference connection being lower than resultant resistance torque is the main reason of looseness failure between impeller and shaft.

1. Introduction

Centrifugal pump is a key part of engine cooling system, taking away excess heat from engine to keep engine working properly. If cooling pump fails during operation, the circulation of the coolant will be affected directly, resulting in overheating failure of engine. Usually, the failure of centrifugal pump can be categorized into bearing failure, seal failure and structural failure, among which structural failure is the most common one. Many scholars focus on the cavitation failure of impeller [1–3], the wear characteristics of the impeller [4, 5], flow field calculation and impeller forces analysis [6]. However, few people concern about the interference fit between impeller and shaft form [7]. The reliable interference connection is the premise of impeller to overcome media resistance and operate properly.

Contact force generated by the interference connection and strength of the connection component are two factors that affect the reliability of the interference connection. They determine the ability of load transmit and service life of interference connection, respectively [8]. In the study of the contact force, the influence of roughness has been investigated, indicating that the roughness was beneficial to improve the strength of the interference connection [9, 10]. Noda [11] analyzed the influence of shrink fitting ratio and friction coefficient on metal shaft and ceramic sleeve interference fit by using the finite element method. The range of the friction coefficient and the interference ratio at which shaft may come out were given. In terms of structural strength, Hao [12] found out friction-induced ratcheting-type displacement of the shaft and the insufficient interference-fit were responsible for the failure of fit planet carrier and shaft assembly. Truman [13] pointed out that improper heat treatment or mechanical processing may affect the microstructure and properties of the material, which may affect geometric dimensions of connection component, reduce interference pressure, and then result in micro slip failure. However, the effect of material properties and microstructure on the interference fit has not been studied specifically.

In this study, failure analysis of interference connection looseness of impeller and shaft is studied using theoretical analysis

* Corresponding author.
E-mail address: liujx@bit.edu.cn (J. Liu).

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Fig. 1. Wear scar of impeller.

method and finite element method. Elastic modulus, hardness and microstructure of impeller material are tested. The influence of material properties and external load on interference connection are discussed. Based on those results, the reason of impeller looseness failure is determined.

2. Failure description of impeller

The centrifugal pumps served as cooling pumps are used in a heavy load diesel engine. The impeller is made of cast iron ISO-200, and the shaft is made of 42CrMoA. The connection mode of impeller and shaft is interference connection, keeping the torque transmission reliable. The speed of shaft is 5250 rpm, the lift of the pump is 29 m, the volume flow rate is 800 L/min, the working medium is water with density of 1000 kg/m^3, and the specific speed of the pump is 186.

In the process of diesel engine test, several engines showed high temperature warning of water temperature. By disassembling the pumps, the failures of pump are presented. Some of the interference connections between impeller and pump shaft are loosen. There is friction and wear between impeller conical surface and pump case during rated working condition due to axial force. However, the wear scar of impeller in circumferential direction is particularly deep as shown in Fig. 1. Also there are some foreign metal bodies attached in the pump case, as shown in Fig. 2.

3. Material property experimental analysis

The material of analyzed impellers is cast iron. Due to the characteristics of the casting itself, the microstructure of cast iron is greatly affected by casting process, resulting in differences in mechanical properties of castings. Hardness and elastic modulus are two parameters which are seriously influenced by the microstructure of the material. They are also essential parameters affecting the use

Fig. 2. Foreign metal bodies' location.