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Review

The fatigue of impellers and blades

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ABSTRACT

Impellers and blades are the key components of turbomachines, and fatigue is the main failure mode of impellers and blades. The status and progress of fatigue research on impellers and blades were systematically introduced through reviewing fatigue failures, numerical simulations of fatigue, and fatigue tests of impellers and blades in several typical turbomachines. High cycle fatigue caused by vibration was the main failure mechanism, and fatigue cracks usually initiated from the location of stress concentration. The resonance caused by the aerodynamic load was the main cause of fatigue failure of impellers and blades in a steady operating condition. The coupling of the meshless method and the finite element method and the combined fatigue test of actual impellers and blades are the developmental direction and research focus of the future.

Contents

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1. Introduction

Turbomachines play an important role in heavy industry, and have been widely used as the core driving force in aviation, energy, oil refining, petrochemical, coal chemical, natural gas transportation, metallurgy, and other important areas. The failures of impellers and blades (I&B) which are the key components of turbomachines not only cause significant economic losses to enterprises and society, but also threaten people's lives. In addition, there are many fundamental scientific problems about the failures of I&B. Therefore, research on failures, especially on fatigue, which is the main failure mode of I&B, provides references for the design, manufacture, application, inspection, monitoring, and remanufacturing of I&B. Moreover, the study of the fatigue of I&B is beneficial to guarantee the safe operation of turbomachines and gives supports to intense research on relevant fundamental scientific problems.

Failures of I&B mean that I&B cannot work properly, and include two situations: I&B are severely damaged and unable to work, or I&B cannot efficiently and reliably work. I&B with periodic structures have characteristics of complex geometries, various structural forms, poor working conditions, and multi-field coupling effects in operations. Also, there are many adverse factors in the design, manufacture, and service of I&B which induce I&B to fail. So failures of I&B present the characteristics of multiformity, complexity, and severity.

Failures of I&B are caused by the combined action of “internal reason” and “external reason”. The “external reason” mainly refers to the environmental factor, which includes load, temperature, and medium. The “external reason” is different in various applications. For example, temperature has an important effect on the failures of I&B serving at high temperature [1–3]. Steam turbine blades in the low pressure area work under more adverse conditions and the failure seems to occur more easily than blades in the high or medium pressure areas [4]. The “internal reason” heavily affects failures, and it usually refers to the situation of I&B themselves, which includes material, structure, and processing technology [5–7]. For example, the connection method of disk and blade has a great effect on failures of I&B [8–16].

The difference of “external reason”, such as the alternating load, corrosive medium, erosion medium, and high temperature, leads to the different failure mechanisms of I&B, which usually involve fatigue, corrosion, creep, wear, foreign object damage (FOD), and the combined action of these mechanisms [17–24]. The failure mechanisms are very different for different “external reasons” in various service environments [25–28]. The “internal reason” mainly affects the failure mode, especially the failure position. Fracture, cracking, thinning, and deformation are the main failure modes of I&B, as shown in Fig. 1. Cracking and fracture are more common, and can be caused by most of the above failure mechanisms. Thinning and deformation are relatively rare. Thinning usually appears in situations of serious wear or corrosion, for example, solid particles carried in the air increase blade thinning of centrifugal compressor impellers. Deformation can appear in the fabrication process, such as welding, but it appears

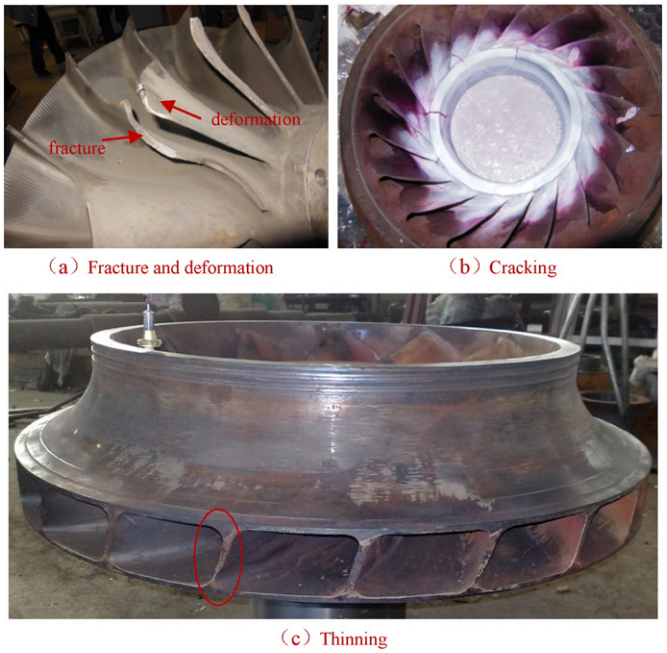

Fig. 1. The main failure modes of I&B.