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Fatigue failure analysis of holding U-bolts of a cooling fan blade

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ABSTRACT

Fatigue failure of holding U-bolt of a cooling fan blade is analyzed. Fractography of the fracture surface reveals the characteristics of a fatigue fracture. Finite element modeling is used for stress analyzing. Analysis of the loading conditions indicates that the bolts are under multiaxial fatigue. Effective alternating and mean stresses are obtained based on the multiaxial fatigue criteria. By using the modified Goodman approach and considering the notch effect, effective stress amplitude, is obtained for all nodes. The highest stress amplitude is obtained at six critical nodes. Fatigue life for the most critical node is determined as 3.63 million cycles.

1. Introduction

Industrial cooling fans are used in a wide range of applications such as cooling towers, air-cooled steam condensers and air-cooled heat exchangers. The basic parts of a fan assembly include fan blades, hub plate and holding U-bolts. During its operation, a fan blade sustains many forces such as gravitational, centrifugal and air resistance force. These forces can cause the failure of the blade [1] or holding U-bolts especially in large industrial fans where a large volume of air is used. Many factors such as variation of the centrifugal stress, shut up/down of the cooling system and mass imbalance make the fatigue to be the most probable cause of failure in cooling fan systems.

It is reported that about 90% of all mechanical failures is caused by fatigue [2]. Fatigue is one of the most dangerous mechanical failures because it occurs under loads that are lower than the static strength of the material [3]. The case studies on the fatigue fracture can be found in many sources such as Refs. [4–7]. In the present study, fatigue fracture of holding U-bolt of a cooling fan is analyzed using fractography examinations and finite element modeling. Fig. 1 shows a schematic drawing of the fan blade. A holding U-bolt and fracture position are also schematically presented in Fig. 1. The fracture position is near the nuts and below the hub plate.

2. Material and methods

The chemical composition of the U-bolt material is presented in Table 1. This indicates that the bolts are made by 304-type stainless steel. Typical values of ultimate tensile stress and yield stress for this type of stainless steel are given as 505 and 205 MPa, respectively [8]. The microstructure of the U-bolt was examined by cutting a sample from the fractured bolt, mechanical grinding and polishing to a mirror-like surface using alumina powder solution. The etching solution was a

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