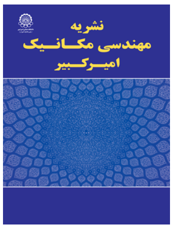

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Simulation of Pitting Corrosion on Gas Turbine Compressor Blade

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ABSTRACT: The First row rotating blades of four axial-flow compressors were prematurely fractured. Previous investigations showed that the site atmosphere contains corrosive compounds which lead to an increase in possibility of pitting on the blades. To this end, experimental and numerical studies are considered. Replica testing, scanning electron microscope (SEM) and fractography of the broken blade indicate that the pits join together and make one bigger pit under SCC mechanism which reduces the failure time. 3-D models of the pitting on the blade under existing forces are analyzed by COMSOL Multiphisics software. Finite element analysis shows good similarities with fractography photos. Stress concentration and interaction of stresses around the pits are two mechanical reasons for initiation and growth of cracks. Calculations show that the occurrence of SCC at the location of the pit reduces the crack initiation time to half. The presence of pits increased the stress by approximately 130 MPa relative to the healthy blade. The part between the two pits with a stress of approximately 180 MPa showed the interaction of the two pits in the operating conditions of the compressor blade.

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1. INTRODUCTION

The operational environment of compressors has significant values of sodium, potassium, sulfur, and ammonium salts. Low values of gases available in the air entering the compressor can create acidic conditions. In near-sea installations, chloride salts are very common compounds found in the air flowing to the compressor. The surface of the blades is damaged by pitting corrosion due to contact with corrosive materials [1].

During the several past decades, numerous high-spatial-resolution microscopic techniques have been introduced and improved in corrosion science, which can be divided into in situ observation and ex-situ observation. In the microtechnology of observation under special conditions, such as Scanning Electron Microscopy (SEM), it is typically required that the sample be scrutinized under high vacuum conditions, which makes the investigation of local corrosion growth problematic. The microtechnology of simultaneous observation, such as Atomic Force Microscopy (AFM), Scanning Tunneling Microscopy (STM), Scanning Electrochemical Cell Microscopy (SECCM), Confocal Laser Scanning Microscopy (CLSM), and Scanning Electrochemical Microscopy (SECM), has a high spatial resolution [2-4]. Therefore, electrochemical experiments with the help of relevant tools present useful information with respect to corrosion [5]. Previous research works have not addressed the prediction of pitting corrosion growth and the calculation of the stress in the pit. The main goal of this research is to numerically investigate the pitting corrosion under the actual operating conditions of a gas turbine compressor. The stoichiometry equations governing the corrosion of the Custom 450 alloy in a chloride solution are then extracted and applied to the models. The results of this simulation are validated by comparing the depth of the simulated pits and experimental samples. Subsequently, the simulation is conducted for 48 months on a compressor having pits, and the results are compared to the experimental ones.

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2. METHODOLOGY

This section presents the simulation of pitting corrosion in chloride medium using COMSOL software. The goal is to calculate the depth of the developing pit. The results of the simulation are then validated by the experimental results. For this simulation, the following is considered as input to the COMSOL software.

2.1. Application of mechanical specifications

The required physical and mechanical specifications in Table 1 are applied to the sample in the software.

2.2. Loading and mechanical boundary conditions

The most important forces acting on the blade include centrifugal and aerodynamic forces. The angular velocity of the rotor corresponding to the rated speed at full load is

Table 1. Physical and mechanical specifications of Custom 450 alloy [6, 7]

Name	CUSTOM 450
Density (kg/m^3)	7800
Young module (GPa)	200
Poisson's ratio	0.29
Yield stress (MPa)	1060

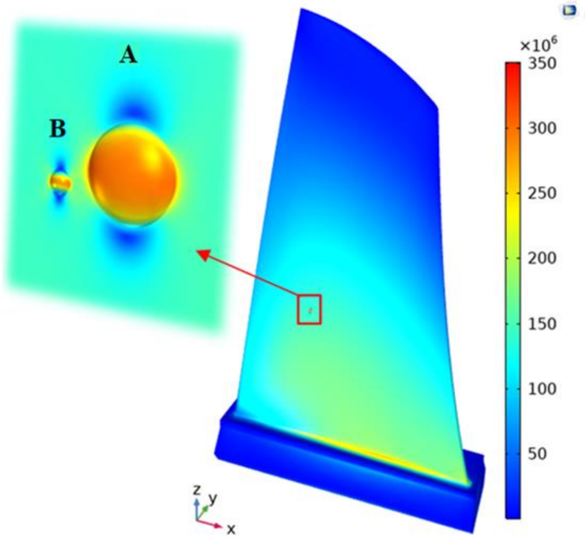

Fig. 1. Von Mises stress distribution in the blade (units in Pa)

5163 rpm, which is equivalent to 540.7 rad/s [32-33]. The aerodynamic forces are applied as a distributed load on the blade surface.

τ is the torsion moment resulting from the air circulation around the blade, which runs along the longitudinal axis of the blade. To produce a torsion moment of 116.6 Nm [8-9], two opposing remote forces are applied so that the coupling resulting from the two forces is equal to 116.6 Nm. Since a trapezoidal distribution of the loads is applied to the blade, the non-uniform trapezoidal pressure on the section is also considered. The pressure distribution on the uppermost and lowermost parts of the concave surface of the blade is 25.22 and 16.24 KPa, respectively [9].

3. RESULTS AND DISCUSSION

To study and show the effect of stress concentration at the site of the corrosion pit, the pits causing cracking in the blade of the first stage of the gas turbine compressor are simulated. Fig. 1 shows the von Mises stress distribution under actual operating conditions of the compressor (chloride medium) in the COMSOL software. According to Fig. 1, the presence of pits causes a stress increase of about 130 MPa at the pit site compared to the blade without pits. The area between the two pits with stress of about 180 MPa shows the interaction between the two pits under the operating conditions of the compressor blade. Two hemispherical pits develop at the point of maximum stress, which join together and cause cracking.

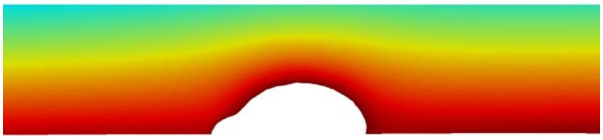

Fig. 2. Joining pits A and B after 4 months

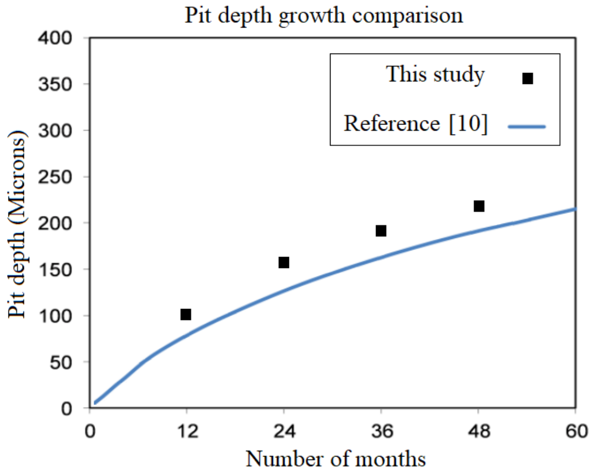

Fig. 3. Comparison of pit depth between experimental and numerical results

The pits A and B develop and join together, forming an equivalent pit. Fig. 2 shows how the pits join after 4 months.

To validate the simulation results of pitting corrosion on the blade with the experimental results, the depth of the pits for different times can be determined by examining the development process of the pits. Fig. 3 compares the pit depth development for the blade simulated with the COMSOL software and the experimental data in [10] under the operating conditions of the gas turbine. According to Figure 3 the validation error is small and thus, the results of this study agree well with the experimental results.

4. CONCLUSION

In this study, numerical investigations of pitting corrosion under actual operating conditions of the gas turbine compressor were conducted. The stoichiometric equations governing the corrosion of the Custom 450 alloy in chloride medium were derived and applied to the models. The results of this simulation were validated by comparing the depth of the simulated pits and the experimental results. The results are summarized as follows.

1. Stress concentration and stress interaction around the pits are the two mechanical reasons for the development of the pits towards each other. Under corrosion, the pits join together and form an equivalent pit.

2. The presence of the pits caused a stress increase of about 130 MPa compared to the blade without pits. The area between the two pits with stress of about 180 MPa showed the

interaction between the two pits in the operating conditions of the compressor blade.

3. The simulation was performed for 48 months on a compressor blade with pits. There was a good agreement between the simulation results and the results from the turbomachinery laboratory of the Texas A&M University.

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