Effect of Artificially Produced Pit-Like Defects on the Strength of AISI 410 Stainless Steel Compressor Blades

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Abstract

In the present paper, the effects of artificially produced pit-like defects on the strength of members made of AISI 410 Martensitic stainless steel were investigated. Compressor blades in power generation industries made of AISI 410 stainless steel commonly suffer from pitting corrosion. Well-defined pit-like defects were artificially produced on various specimen and strength tests were conducted. AISI 410 stainless steel microstructure shows a typical body-centered tetragonal (bct) structure. Strength tests analysis established yield strength of 547 MPa for case 1(max depth-max diameter) whereas a yield strength of 585 MPa for case 2(min depth-min diameter). In addition, strength and elongation of the artificially produced pitted tensile specimen gradually decrease with the increase of the area lost due to artificially produced pits.

Keywords. Stainless steel, compressor blades, pitting, strength

1 Introduction

Fatigue failure originating from pitting corrosion has been identified as one of the dominant life-limiting factors for gas turbine blades [1-4]. In power generation industries, compressor blades are subjected to corrosive environment from the incoming air during the operation [5]. In this respect, the effects of pitting corrosion on the structural strength and the integrity of the compressor blades need to be established. Nakai et al. [6] has concluded that the nominal tensile strength of pitted structural members decreases gradually while the total elongation decreases drastically with the increase of thickness loss due to pit-ting. Yoshino and Ikegaya [7] found that even small amount of H_2S have a significant detrimental effect on the resistance of the steels to the pitting corrosion in his study on 12Cr-Ni-Mo martensitic stainless steel in chloride and sulfide environments.

Geometric discontinuity due to a pit induces a large stress gradient with high magnitude of localized stress [8-10]. The time to nucleate a corrosion pit under surface straining was analyzed at the microscale [11]. A relationship between surface stress and pitting corrosion has been established [12]. The effect of pitting damage is to reduce the life of structural components [13-14]. Earlier research has already established pits geometry details [15].This research examines the strength response of AISI 410 martensitic stainless steel compressor blade material with different geometries of artificially produced pit-like defects. Several cases using same specimen geometry but different artificial pit geometries has been examined. The yield strength of the stainless steel sample coupons with and without artificial pit is compared.

2 Experimental Details

2.1 Material

The material investigated in this study is an AISI 410 martensitic stainless steel. The material was received in the form of circular plate with radius and thickness of 440 and 18mm, respectively. The chemical compositions and the mechanical properties are shown in Table 1 and 2, respectively.

Table 1: Chemical composition (in weight percent) of AISI 410 steel.

Material	C	Mn	P	S	Si	Cr	Ni	Mo	Al	V	Fe
AISI 410	0.2	0.5	0.02	0.002	0.35	14.20	0.39	0.01	0.003	0.03	Bal.

Table 2: Mechanical properties of AISI 410 steel at room temperature.

Material	Tensile Strength (MPa)	Yield Strength (MPa)	Elongation (pct.)	Maximum Load (kN)
AISI 410	656.04	620.17	30	21.27

2.2 Microstructure

For microstructural study, the specimens were finely grind, polished and etched in the etching solution (5 ml HCl + 2 gr Picric acid + 100 ml Ethyl alcohol) for 7 seconds and examined using optical microscope.

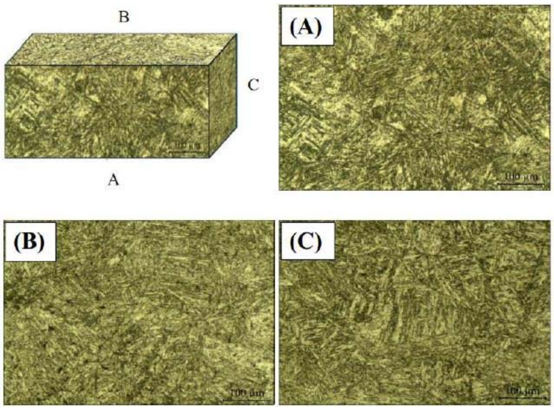

Figure 1: Microstructure observations for section A, B and C.

Fig. 1 shows typical microstructures of the AISI410 martensitic stainless steels at the three different orthogonal section planes. The microstructure shows a typical body-centered tetragonal (bct) structure. The darkarea represents martensitic phase while light area the ferrite phase. Since qualitatively identical microstructure is displayed for each section, the material is expected to behave inisotropic manner.

2.3 Test Specimen

The dog-bone shaped specimens are used for tensile tests. After wire-cut using EDM, the specimens were ground and polished with abrasive paper before being stress-relief annealed in high vacuum at 10-6 Pa (heating from room temperature to 600 °C in 1 hour, holding for 2 hours, cooling from 600 °C to 400 °C in 2 hours and to room temperature in ap-proximately 12 hours) to eliminate residual stresses [11].

To study the effect of different geometry pit-like defect of the strength of the material, artificial pit were generated in the gage length of the specimen. The maximum, minimum and nominal pit geometry details has been acquired from the earlier established research [15]. The artificial pits were generated using AG40L CNC Sinker EDM machine. The artificial pit geometry details and tensile test matrix are shown in Table 3 and 4, respectively.

Table 3: Artificial pit geometry details

	Pit Diameter	*Pit Depth*
Maximum	1.00 mm	0.75 mm
Minimum	0.30 mm	0.30 mm
Nominal	0.50 mm	0.50 mm

2.3 Tensile Test

These tests are performed on a ±100 kN servohydraulic materials equipped with on-line data acquisition system. Tensile tests to fracture were performed for 3 cases (max, min & Nominal). The displacement rate for the tests were set at 0.1 mm/min and 25 mm extensometer is used in all the tests. Fractographic analysis follows each test.

3 Results and Discussion

3.1 Tensile Test Results

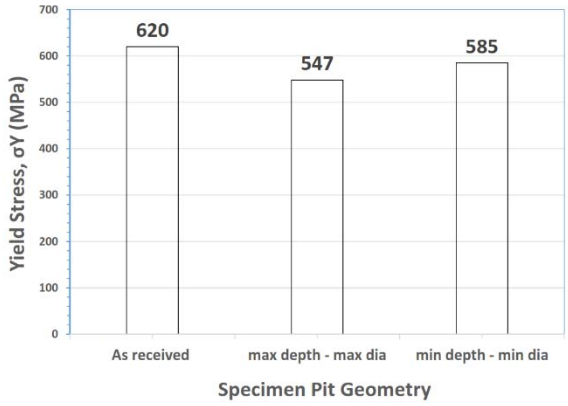

Figure 2: Yield stress values for artificially produced pitted specimen

The resulting load-displacement yield strength values for as-received (AR) and artificially produced pitted specimen is compared in Fig. 2. Results show that the apparent strength behavior of the pitted specimens is lower than that of the AR specimen. This translates into lower apparent yield strength. The observed behavior of lower load could be attributed to localized stress around the pits that leads to early failure of the material. Such localized failure manifests in the early and gradual degradation of stiffness of the pitted material, as shown in figure in Fig. 3.

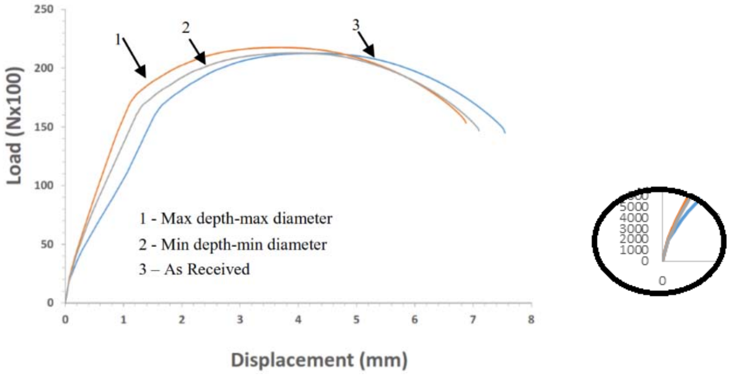

Figure 3: Tensile curves for (a) Original and artificially produced pitted specimen (b) enlarged view.

A decrease in total elongation of the pitted compared to AR specimens is noted. Since the artificially produced pit area was selective and limited to the surface only, the apparent loss for elongation at fracture is likely due to the same effect of localized stress at the pits, rather than degradation of ductility in the bulk section of the specimen.

4 Conclusions

Effects of different geometries of artificially produced pits on the apparent tensile behavior of AISI 410 martensitic stainless steel for compressor blades has been established. Major conclusions are as follows:

1. The strength of the material gradually decrease with the existence of the artificial pit.
2. The strength of the specimen with maximum diameter and depth of depth is lower than the strength of the specimen with other geometry of artificial pit.
3. Depth of the pit gives more effect on the strength of the material. The deeper the depth of the pit, the weaker the strength of the material.

5 Acknowledgement

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