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Short communication

Microstructural change and impact toughness property of Inconel 738LC after 12years of service

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ABSTRACT

The Domestic and Foreign Object Damage (DOD & FOD) are knownas serious problems for many heavy duty (or high temperature) device such as compressor, different turbine sections of jet engines and gas turbine, therefore the impact resistance study plays an important role to prevent any catastrophic failures. In this study a V94.2 Siemens gas turbine blade was used, which has been exposed to hot gases, heating the material to a temperature of 800–900 °C in 105,120 operating hours. Initial metallographic investigation confirmed microstructural damage in the airfoil compared with the root of turbine blade.

Charpy V-Notch tests were made according to the specification ASTM-E23 in ambient and service temperature (900 °C). The *fracture surfaces* of the Charpy specimens were analyzed with the scanning electron microscopy,in order to identify the fracture mechanisms. The results showed that, with increasing the test temperature from 25 to 900 °C, the impact energy of the root in both temperatures were relatively equal and far from airfoil. The microstructural investigation confirmed that the microstructure of airfoil was damaged due to the long operation at high temperature. Also, rafting behavior is observed in airfoil section.

Fractographic investigations showed fracture mechanism of transgranular cleavage and dimples in the airfoil and root specimens in both temperatures.

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1. Introduction

Nickel-based superalloys are used at the higher fraction of melting temperature and therefore they are more suitable than cobalt-based and iron-nickel-based superalloys at service temperatures close to the melting temperature of the materials [1]. There are many application based on nickel-based superalloys for gas turbines, for instance the vanes and turbine blades mainly because of well-known oxidation effect and creep resistance and retained strength at high temperatures of alloy's. In addition the alloys are possible to strengthen in other different ways and they are in possession of high phase stability. Thus the dominating phases are the gamma matrix and the gamma prime. The strength of nickel-base superalloys is due to the presence of the coherent precipitates of γ'phase in γ matrix and primary carbides in the microstructure [1–2]. IN738L, due to its high-temperature strength, oxidation resistance and creep resistance, is applied to the hottest parts of the gas turbine. The mechanical properties of gas turbine components are influenced by the service condition. The service life is limited to creep behavior, fatigue, thermal shock, oxidation and wear [3]. The importance of the effect of some parameters such as type of processing, structure, and phases distribution on mechanical properties has been investigated by many researches in the past few decades such as elasticity, creep and fatigue [1–6]. During service of turbine at high temperatures, the components are imposed to the impact forces due to the

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hitting of surrounding objects. Turbine blade failures account for 25.5% of gas turbine failures. Turbine blade oxidation, corrosion and erosion are normally a longer time process along with losses of material slowly over a period of time. However, the damages resulting from impact by a foreign object are mainly very fast or sudden. The impact damage of the turbine blades will lead to changes in some parameter comparable with severe erosion or corrosion. Foreign Object Damage (FOD) is defined as material (nuts, bolts, ice, etc.) ingested into the engine from outside the engine envelope. Domestic Object Damage (DOD) is defined as objects from any other part of the engine itself [7–8]. For this reason, the high impact resistance in order to prevent catastrophic failures is investigated [4]. Most study has been focused on impact toughness of steels, titanium, magnesium and aluminum alloys including the amorphous alloys. However very few studies have been carried out about impact resistance and fracture characteristics of nickel based superalloys at high temperature [1–8]. Although there are some studies on the failure behavior and impact energy of the used super-alloy blades by other researchers [4,9] however it didn't link to the definitive result on the effect of microstructure on impact toughness.

In this study, the microstructure and impact toughness property of Inconel 738LC have been investigated on V94.2 Siemens gas turbine blade; here we present microstructural change and characterization result of a nickel base superalloys blade under their service after 12 years (105,120 h).

2. Materials and methods

The blade used in this investigation was Inconel 738LC of V94.2 Siemens gas turbine blade with service time 105,120 h and the composition (wt.%): Ni–17 Cr–8.7Co–1.9Mo–3.4 W–0.86Nb–3.2Ti–3.3Al–0.08C–0.04Zr–1.8Ta. Inconel 738LC is a nickel-based superalloy of a different classand mainly used in the hottest part of the turbine. The turbine blade consists of two parts: the airfoil which is exposed to the flow of heat gases, and the root section which attaches the blade to the turbine disk. The airfoil of the blade in the third turbine stage is exposed to hot gases which leads to heating the material to a temperature of up to 850 °C beside the temperature of the blade root which is in the range between 400–600 °C [1–2]. The investigations were carried out in both airfoil and root section. Metallographic samples and Charpy V Notch (CVN) specimens were prepared from airfoil and root. The different locations of the sample in blade are depicted in Fig. 1.

According to ASTM-E3 standard for scanning electron microscopy, the two-step polishing was performed on samples after grinding from 80 to 1200. The samples were etched in an Acetic Glyceregia solution with chemical composition of 10 mL HNO_3, 10 mL acetic acid, 15 mL HCl, 2–5 drops glycerol. Metallographic prepared sections were initially examined in an optical microscope and subsequently evaluated in a scanning electron microscope equipped with an EDS spectrometer. Both the ambient and 900 °C temperature Charpy V-Notch tests were made according to the specification ASTM-E23. The impact specimens were prepared with sub-size dimensions. Fracture surfaces of the Charpy specimens were analyzed by scanning electron microscopy (SEM) in order to identify the fracture mechanisms.

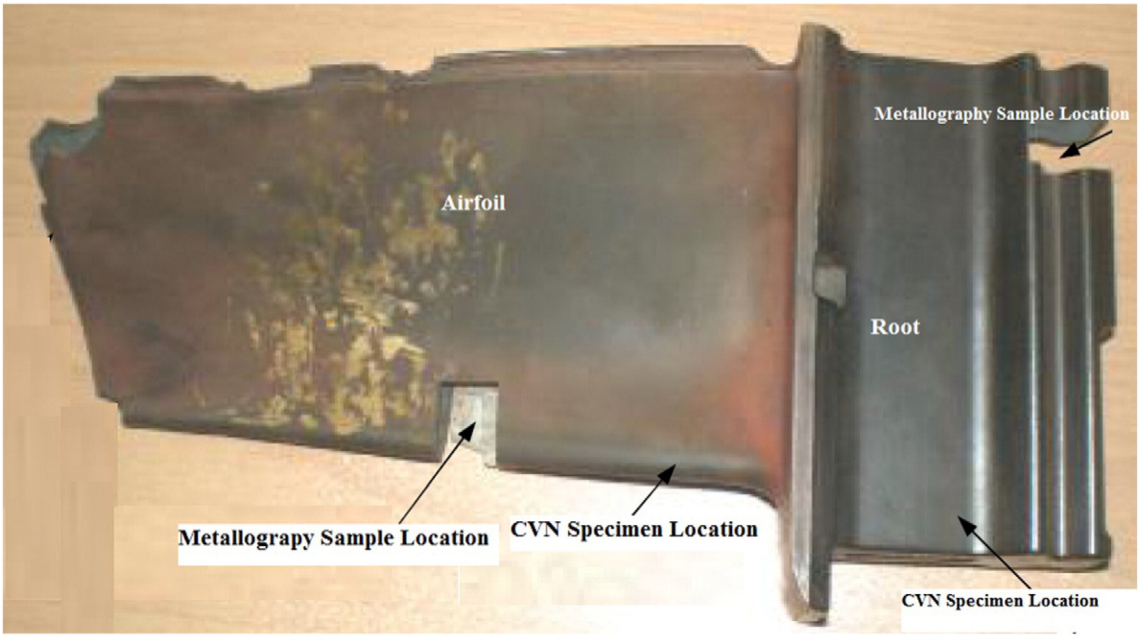

Fig. 1. Inconel 738LC of V94.2 Siemens gas turbine blade with service time 105,120 h.

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