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Technical Report

Effects of welding defects on reducing lifetimes of first stage nozzles of a 123 MW gas turbine made of FSX-414 alloy

M.R. Jahangiri *, A.A. Fallah

Metallurgy Department, Niroo Research Institute, Tehran 14686, Iran

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ABSTRACT

In this paper, premature failure of one set of first stage nozzles (stationary blades) in a 123 MW gas turbine has been analyzed. Metallurgical and mechanical experiments showed that the main mechanism for such unexpected cracks is thermal fatigue phenomenon accelerated by presence of welding defects in nozzles. Based on the results, it is recommended that repaired nozzles be thoroughly checked before being re-installed in turbines. Moreover, it is recommended; based on the results; to coat nozzles by corrosion/oxidation resistant coatings after their welding by low chromium filler metals such as L-605.

1. Introduction

One of the problems in frame nine gas turbines in Khoy power plant was premature cracks in one set of first stage nozzles (vanes) and insufficiency of their lifetimes. In order to evaluate the problem and detect causes of such cracks, various experiments were designed and conducted on nozzles. The experiments began with statistical and operational studies of nozzles followed by visual inspections, fracture surfaces analyses, metallographic investigations, mechanical properties testing and cyclic oxidation experiments. Based on the results, the role of welding defects was recognized as a major factor in reducing lifetimes of such nozzles.

During service, blades and nozzles of gas turbines are exposed to very high thermal and mechanical stresses, which can lead to cracking of these components. This makes necessary that damaged components are replaced or repaired. However, new blades or nozzles are expensive, and economic considerations generally persuade the repair of damaged components. Fusion welding is a usual repair method to increase the component lifetimes.

Cobalt-base superalloys are known as suitable materials in respect of welding procedures [1–3], but precipitation-strengthened nickel-base alloys, which are used in manufacturing of gas turbine blades, have a limited weldability because of their low resistance to heat-affected zone cracking during welding and subsequent postweld heat treatment [3–5]. Therefore various modern welding techniques such as microplasma arc welding [6] and laser welding have been developed for repairing [7] and manufacturing [8] of nickel-base superalloys. It has been reported that direct laser fabrication of abrasive turbine blade tips results in significant cost savings and improved performance over the currently employed production techniques [9].

In contrast to nickel-based superalloys, cobalt-based superalloys are usually welded by relatively low-cost well-known methods such as tungsten inert gas (TIG) welding using cobalt-base filler metals due to their superior weldability [1,3]. Moreover, cobalt-base superalloys are considered as corrosion resistant alloys [10,11] and components manufactured from these alloys are generally less sensitive to apply coatings on their surfaces for service in hot sections of gas turbines. Hence, the nozzles manufactured from cobalt-based superalloys such as FSX-414 alloy, are not generally coated in new or repaired conditions [11,12].

2. Experimental procedures

2.1. Statistical data regarding the real-life of first stage nozzles

Available documents published by turbine manufacturer shows that the nominal life of investigated nozzles must be equal to three times of the hot gas path inspections or minimum of 72,000 h [13]. Table 1 shows history of operating and repairing of these vanes in Khoy power plant from installation in turbines up to the date of 2006/3/21. As indicated, nozzles have been almost repaired after 20–30 trips in turbine operation conditions and this reveals that trip cycles have an important role in cracking of nozzles and their necessity to repair. Tables 2 and 3 show chemical composition of gas and gas oils used as fuels of turbines. As indicated, in the composition of used gas oils, there is about 1 wt% sulfur, which may cause corrosion problems in hot components.

* Corresponding author. Tel.: +98 21 88079401 6; fax: +98 21 88078296.
E-mail address: mjahangiri@nri.ac.ir (M.R. Jahangiri).

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