Applied Thermal Engineering 71 (2014) 433–444

Contents lists available at ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

# Non-uniform temperature distribution of turbine casing and its effect on turbine casing distortion

E. Poursaeidi, M. Taheri*, A. Farhangi

*Department of Mechanical Engineering, University of Zanjan, Zanjan, Iran*

ARTICLE INFO

*Article history:*
Received 25 January 2014
Accepted 7 July 2014
Available online 15 July 2014

*Keywords:*
Gas turbine casing
Thermal distribution
Thermal stress
Thermography

ABSTRACT

Stress analysis is essential for gaining an understanding of the factors affecting crack on turbine casing arising from temperature gradients. Hence, making determinations of temperature distribution on gas turbine casing is the first step in stress analysis. The next step is comparison of results with available thermography data related to the casing. In addition, stress and distortion distributions are presented for three test levels of working load on the casing. Comparison of stress concentrations at the eccentric pin hole and observed cracks in these locations validated evaluations for stress distribution.

© 2014 Elsevier Ltd. All rights reserved.

## 1. Introduction

Achievement of high thermal efficiency in gas turbine systems is strongly related to increased temperature at the turbine inlet, which is accompanied by excess thermal load in the hot components of a gas turbine. Thus, various cooling techniques [1–3] have been used to protect the main hot parts of gas turbines. If an unsuitable cooling method is used, local thermal crack and structural failure are yielded due to thermal stress and reduced material strength at high temperature. Therefore, failure analyses as well as thermal analyses for temperature, deformation and stress are required for effective thermal design and lifetime prediction of hot components. It is noted that failure analysis was investigated in other research only in terms of material, and rarely by thermal analysis [4–8]. Furthermore, temperature gradient in each hot component increases according to an increase of turbine inlet temperature and it generates thermal damage from high thermal stress. It is necessary to estimate temperature distributions in materials of the system in an appropriate thermal environment to predict the life and safety of hot components such as combustors, vanes, blades and casing. In recent years, several investigators [9–12] have attempted thermal analyses of hot components of gas turbines and made predictions of thermal damage. It has been shown that computed results are useful for inspecting the thermal environment of a gas turbine and to define factors that contribute to operational longevity. Many numerical studies have been done using CFD (computational fluid dynamics) codes [13,14], which are developed by solving Navier–Stokes equations using boundary layer modeling. Among them, TEXTAN [15] has been widely used in industry. With developing computer technology and turbulence models, CFD has become a powerful design tool. Many researchers have performed CFD predictions and compared results with test data obtained in the turbine. Brandts and Wesorick [16] pointed out that most cases of nozzle failure occurred because of thermal fatigue, whereas there is less impact at absolute high temperature. Moreover they show that conditions of maximum temperature and maximum gradient occurred at two different operating conditions. Analysis of the failure of a high-pressure nozzle of a 70 MW gas turbine reported a similar conclusion Mazur et al. [17]. The authors identified the origin of cracks in nozzles by numerical analysis and investigations of alterations to the metal grain. The critical region was identified as the inner part of the coolant holes, corresponding to the highest concentration of thermal stresses. Maintaining reliability is an important issue in thermal power plants as well as considerations of safety under operating conditions that include frequent startups and load changes. Unstable states arising during startup, shutdown, and load change give produce unsteady temperature distribution with respect to time in steam turbine components. Thermal stress is caused by a rapid increase in temperature that renders the components susceptible to failure and reduces their operational longevity. The internal stationary and rotating components of a turbine in a power plant are encased in massive steel-cast casings. These high- and intermediate-pressure casings are susceptible to frequent cracking due to thermo-

* Corresponding author. Tel.: +98 9109717821.
*E-mail address:* morteza_taheri88@yahoo.com (M. Taheri).

http://dx.doi.org/10.1016/j.applthermaleng.2014.07.019
1359-4311/© 2014 Elsevier Ltd. All rights reserved.

**Table 1**
Chemical analysis results of casing.

| Element | C | Si | Mn | Al | Cu | Ni | V | Cr | Mg | Ti | Co | Fe |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W% | 3.344 | 2.7 | 0.136 | 0.016 | 0.351 | 0.082 | 0.044 | 0.12 | 0.057 | 0.038 | 0.033 | Balance |

mechanical, low-cycle fatigue (LCF) at the nozzle fit corner radius or other stress concentration shapes. The non-uniform temperature field contributes to a high stress gradient appearing in the turbine casing. High temperature reduces strength of the casing material. Failure analysis for turbine engine components has received the attention of several investigations [18–24]. Choi et al. [25] defined thermal stress concentration factors for inner surfaces of the casing and valve to account for geometric variations using three-dimensional, finite element analysis. In addition, total strain range was obtained to assess the low-cycle fatigue life according to life assessment procedures conducted in Korea. The model can be used to obtain maximum thermal stress level and strain values related to creep and fatigue damage. Using this model, more accurate data on life consumption can be obtained by using steam turbine inner casings as an input for the Korean simple life assessment procedure without the need for complex time-consuming calculations. Witek et al. [26] described the fracture problem of turbine casing for a helicopter engine. Visual inspection of the defected component was incomplete because the fracture was repaired by welding during a technical inspection of the engine. Authors of this work tried to explain the causes of damage to the turbine casing by application of numerical stress analysis. A geometrically complicated numerical model was created to solve the problem. The finite element method (FEM) was used in computations. Stress and deformation contours were generated from results of nonlinear static analyses performed for both mechanical and thermal loads occurring during operating conditions. High thermal stress gradients were found at the region of casing where cracks were detected in engine operation. Cheong and Karstensen [27] reviews a recent structural integrity assessment carried out on a high-pressure turbine inner casing that had suffered from temper brittleness. The assessment was made to demonstrate that the casing can be safely returned to service based on revised operating conditions with particular emphasis on temperature control of ramp rates during start-up and shutdown events. A retirement for-cause philosophy was adopted to account for some operational flexibility that is required prior to replacing the casing at the next planned outage. Descriptions of the open cycle gas turbine operation, the operational background and the problem of failure at the Putrajaya Power Station in Malaysia were reported by Rashid et al. [28]. According to the report, the main concerns were repeated findings of several obvious surface-crack spots on the weld joint zone of a plenum barrier plate of the gas turbine frame.

**Table 2**
Shows mechanical properties of the ASTM A395 ductile cast iron.

| Hardness (Brinell) | Tensile strength, ultimate (MPa) | Tensile strength, yield (MPa) | Modulus of elasticity (GPa) | Poisson's ratio |
|---|---|---|---|---|
| 167 | 461 | 329 | 165 | 0.29 |


**Fig. 1.** Thermography image of the outer side of the casing in the first row of the turbine.

## 2. Turbine casing and its performances

The most important role of a gas turbine casing is taking turbine rotor with an axial symmetry and inhibition of elements such as nozzles and shroud segments in its fixed position with a total high weight. In addition, turbine casing has an important structural role. Besides its own weight, it tolerates the moment arising from components such as the exhaust chamber, the combustion chamber and compressor weights. Turbine casing operation is similar to that of pressure vessels that tolerate hot gas pressure caused by products of combustion. Another vital role of gas turbine casing,

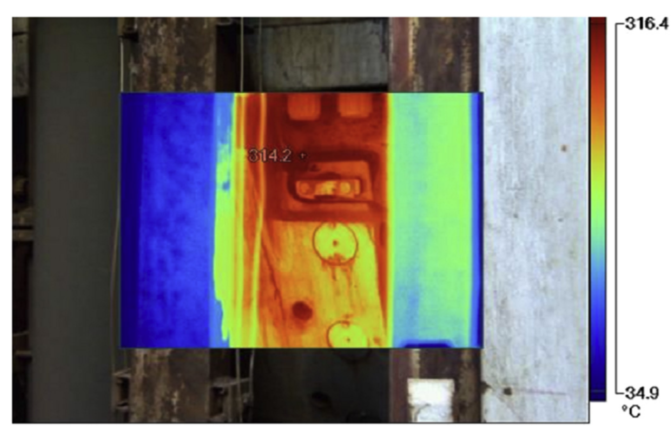


**Fig. 2.** Thermography image of middle part of bottom half casing near the horizontal turbine casing flange.

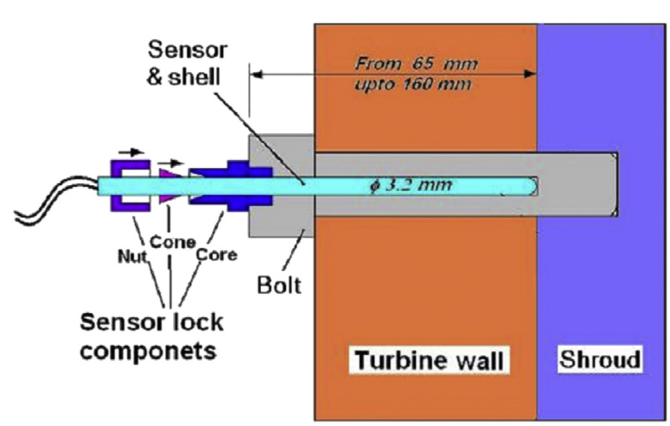


**Fig. 3.** Installation of thermocouples inside the turbine casing.

Download English Version:

https://daneshyari.com/en/article/646122

Download Persian Version:

https://daneshyari.com/article/646122

Daneshyari.com