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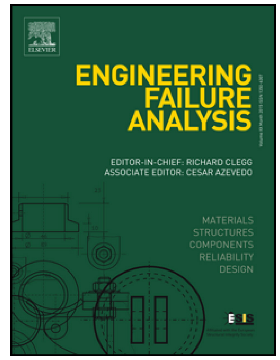

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PII: S1350-6307(16)30700-2
DOI: https://doi.org/10.1016/j.engfailanal.2017.12.014
Reference: EFA 3351

To appear in: *Engineering Failure Analysis*

Received date: 21 August 2016
Revised date: 25 January 2017
Accepted date: 19 December 2017

Please cite this article as: Ranjan Kumar, Vinayak Ranjan, Bipin Kumar , Finite element modelling and analysis of the burst margin of a gas turbine disc using an area weighted mean hoop stress method. The address for the corresponding author was captured as affiliation for all authors. Please check if appropriate. Efa(2017), https://doi.org/10.1016/j.engfailanal.2017.12.014

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Finite element modelling and analysis of the burst margin of a gas turbine disc using an area weighted mean hoop stress method

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Abstract

One of the main failure modes of the turbine disc is formation of yield zone at bore which leads to burst of the disc. Hence, disc burst is treated as a critical factor while designing the disc. The scope of present work is to carry-out the elastic – plastic analysis and to find the burst margin of a typical model of a gas turbine disc by means of the finite-element technique for different speed of rotation. The additional goal of the analysis is to compare the burst margin of turbine disc having variable thickness and uniform thickness profile of the disc. The burst margin is estimated using area weighted mean hoop stress (AWMHS) approach. For given burst margin greater than 122%, the variable thickness disc provides lower operating speed in comparison to uniform thickness disc. This helps in reducing hoop stress, which is highly desirable in aero-engine.

Key words: - Burst margin, Rotating disc, Stress analysis, Finite element method

1. Introduction

The function of the disc of a gas turbine is to hold the blades of the turbine in proper location and to transfer the torque from the shaft to the blades of the compressor to the turbine section [1]. The rotating discs with moving blades are stressed parts in an aeroengine due to high rotational speeds of blades and therefore disc experiences body forces and centrifugal forces due to blade attachment at circumference of the disc. The high temperature gradient existing between the bore and the rim of the disc, combined with centrifugal stresses, produce severe conditions of operation. At normal operating condition, the disc behaves elastically, but circumstances, such as unfavourable wind blow, may force pilot to exceed maximum operating speed. Over the maximum operating speed, the bore of the disc may experience plastic yielding, which weakens the disc structurally [2]. At higher speeds, this plastic yielding zone moves outward diametrically due to loss of material properties. This significantly enhances the plastic strain causing burst of the disc. During design of disc, no failure of disc up to 122% of maximum operating speed has to be ensured as per military specification standard (MIL-E-5007E) [3].The service life of a disc is estimated when full size disc is rotated in a spinning facility under stress and thermal conditions as experienced under actual working condition.

This test determines the cycle life of the disc to obtain the engineering crack of approximately 0.75 mm length at its surface when disc reaches cycle life, they are rejected from service without any inspection and further reuse is not advocated [4, 27]. This critical crack length of 0.75 mm on the surface also depends on geometry, material, loadings and other operating factors, therefore cycle life based upon the crack length criterion may not provide a constant safety of margin. However, the criterion based on crack length imposes rejection of large number of disc with considerable safe service life remaining, which further causes increase in life cycle cost [5].However, the disc may also fail without reaching the service life based on crack length criterion in unfavorable circumstances such as wind blow condition where the speed of disc goes beyond the maximum operating speed. This may cause burst of the disc. Thus the conventional life cycle method based on crack length criterion may not provide a constant safety factor for all working conditions. This motivates to introduce some efficient method for the estimation of burst speed of a rotating disc. Burst speed estimation of a turbine disc has been of interest to many researchers.

Very few works are being reported on burst speed investigation of turbine disc under complex loading condition. Induced strain and stress calculation of rotating turbine disc is important parameter in estimating the burst speed calculation. Robinson [6] in 1943 investigated that a disc would burst when the average tangential stress and the tensile strength of material became equal.

Arthur and Jenkins [7] analysed burst characteristics of solid disc of uniform thickness and proposed a solution for stress and strain on the basis of von Mises criterion and Hencky/. deformation theory of plasticity. Weiss and Prager [8] analyzed stress and strain distribution of hollow disc of uniform thickness using Tresca's yield criterion. Waldren [9], in 1963 carried out burst test of rotating disc analytically and experimentally for prediction strains causing instability based on plasticity theory. Percy et al. [24] presented experimental study for instability condition of rotating disc of uniform thickness with an objective

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