ISSN: 2278 – 7798
International Journal of Science, Engineering and Technology Research (IJSETR)
Volume 5, Issue 4, April 2016

Effect of Geometrical Parameters on Fretting Fatigue of Dovetail Joint of Compressor Disc

Sunita Kumari[1], P V Srihari[2]

Abstract—**Aero engine compressor rotating disc and blade joint is critical component in the view of engine service life. Since this area transfer larger load in form of centrifugal force and gas load in cyclic mode fretting fatigue is most likely to occur. Fretting fatigue is responsible of critical failure across the aero engine parts due to small relative movements of the parts leading to degradation of the material in form of fatigue strength and corrosion. In this study Finite element analysis of aero engine dovetail joint has been done using CATIA V5R19 and ANSYS workbench 14.5 with different geometrical parameters i.e flank length and flank angle, to see the impact on fretting fatigue.**

Index terms—Dovetail, compressor disc/blade,Fretting,Fatigue

I. INTRODUCTION

Fretting fatigue is the phenomenon caused by a normal load between two surfaces having small relative movement i.e. up to 3-4 μm. As per ASM handbook of fatigue and fracture "A special wear process that occurs at the contact area between two materials under load and subject to minute relative motion by vibration or some other forces". Fretting is the wear and corrosion at the asperities level of two contact surfaces. Sliding between the contact surfaces causes mechanical wear and subsequent formation of oxide debris. Oxide of the material is harder then parent material and acts as abrasive agent. This process further accelerates the rate of fretting and wear. Factors which influenced the fretting fatigue most are temperature ,material in contact, cyclic frequency, Environmental condition, contact surfaces, coefficient of friction, hardness of material and contact pressure. Fretting fatigue can reduce surface strength of the material by half or one third. Fretting wear damage to the material caused by fretting phenomenon. Fretting corrosion refers to the combination of wear as well as corrosion. This basically refers to the corrosion damage occurred at the asperities level of the contact surfaces. Since dovetail joint is the weakest part of the aero engine compressor, contact surfaces between disc and blade is area of concern due to development of fretting fatigue.

Compressor disc and joint subjected to following forces : Centrifugal forces (Radial and hoop stress), Bending force, Body force, Thermal stresses. Due to cyclic loading and interaction between two surfaces, disc and blade joint is subjected to crack initiation and propagation.

II. LITERATURE SURVEY

Papanikos et al. [1] carried out 3D nonlinear finite element analysis of the dovetail region in aero engine compressor disc assembly using contact elements and validated using 3-Dimensional photoelastic stress freezing results. It was concluded that the maximum stress concentration at and just below the lower contact point between the blade and disc. In further analysis it was found that the flank angle, flank length, skew angle and coefficient of friction can significantly change the blade/disc interface stress distribution. Tigo de Oliveira vale et al. [2] used the different element (hexa 3mm, hexa 1mm and tetra) and comparative study carried out on normalized maximum stress by using FEA tool ANSYS 13.0. This revealed that stresses across thickness with frictionless condition were maximum with HexaMulti 1mm. It was also concluded that analysis of stresses along the interface using HexaMulti 3mm mesh presents a very high percentage difference of 29.71%. Gowda et al. [3] investigated the acute variation of displacement and maximum principal stress along the flank length and thickness for varying friction and rotational speed of the disc/blade interface. Witek [4] carried out nonlinear finite element analysis to determine the stress state of the disc/blade segment under operational and over speed condition. It was concluded that the fracture of the disc occurs at 14,500–16,000 rpm due to excessive stresses. Malay et al. [5] validated variation of stresses in dovetail joint of compressor disc in 2D and 3D FEA by using ANSYS tool. It was concluded that the equivalent and principle stress obtained at crack tip is very high than yield strength. It was observed that Stress Intensity Factor and crack growth rate increases with crack length. Witek [6] carried out maximum principle stress and von Mises stress distribution analysis in thermo mechanical load for fir-tree region and crack growth plots obtained for a crack propagated in different directions. Witek [7] carried out spin rig test which involves spinning a full scale disc assembled with dummy blades to simulate centrifugal loading in isothermal conditions to find the maximum principle stress and von Mises stress distribution. In this analysis, the stress and displacement contours of a turbine subjected to rotation at constant temperature were obtained and concluded that first critical area of a turbine is located on the corner of third lowest fir-tree slot of the disc, where the maximum stress was observed. Qiuwan et al. [8] done optimization of the turbine blades by 13 key dimensions and obtained a better structure reducing maximum equivalent stress by 22.52%. Anandavel et al. [9] presented the influence of preloading contact tractions, slip levels and stresses at the blade-disc interface of an aero-engine with finite element (FE) modeling and analysis. It was concluded that the preloading reduced the peak contact pressure (by 35%) as well as fretting. Dilip et al. [10] checked structural integrity of gas turbine blades for 2 cusp and 3 cusps fir-tree contacts using CATIA and Hypermesh. The analysis results obtained from ANSYS for 3 cusps fir tree contact showed improved results with less radial displacement and stresses compared to 2 cusps fir tree contacts. Kotresh [11] has analyzed aero engine dovetail blade disc joints by finite element simulation methods to investigate the fretting fatigue parameters for different geometrical models and for different thicknesses of disc and dovetail joint.

III. MODELLING AND ANALYSIS

Solid model of disc and blade has been created in CATIA V5R19 as per the geometry given in Papanikos [1]. The material selected is Titanium alloy (Ti-6Al-4V). The blade and disc surface is modelled as contact surface with element CONTA174 and target element with TARGE170 using ANSYS Workbench 14.5. Augmented Lagrange has been used to represent non linear contact of two bodies. The model is meshed with tetrahedron element having 5mm mesh size. To obtain more accurate result contact region has been refined to 1mm mesh**.** In the view of symmetry one part of Blade/disk has been modelled to save computational time. In Finite element analysis of dovetail joint with different geometrical parameters following boundary conditions and assumptions has been taken into account as given in Kotresh [11]

a) Rotational velocity of 10000 rpm has been selected.

b) Blade mass inertia due to centrifugal force has been taken as 36000N

c) Normal displacement of side faces has constraint to zero.

d) Frictionless support at inner face of the disc to provide axis of rotation.

e) Bending and thermal stresses has not been considered.

f) Effect of vibration has not been considered.

IV. RESULTS AND DISCUSSION

Different model with variation in flank angle (64°,66°,68°,70°), flank length (9,11,12,13 mm) and coefficient of friction COF (0.1,0.15,0.2,0.25,0.3) has been analysed to see variation in fretting fatigue parameters like contact pressure and sliding distance.

A. Variation of sliding distance with respect to flank angle and coefficient of friction has been analysed and plotted in Figure 1, It shows significant decrease in sliding distance of joint with decrease in flank angle. This variation of sliding distance possibly due to decrease in force component along sliding direction..

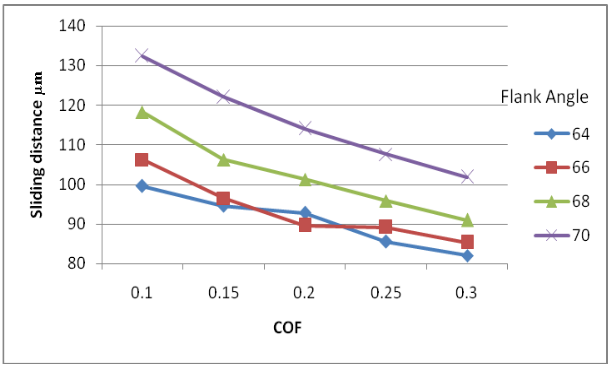

Figure 1 Variation of sliding distance with flank angle

B. Variation of contact pressure with different flank angle and coefficient of friction, as range stated above has been analysed and plotted in Figure 2. There is significant decrease in contact pressure value with decrease in flank angle.

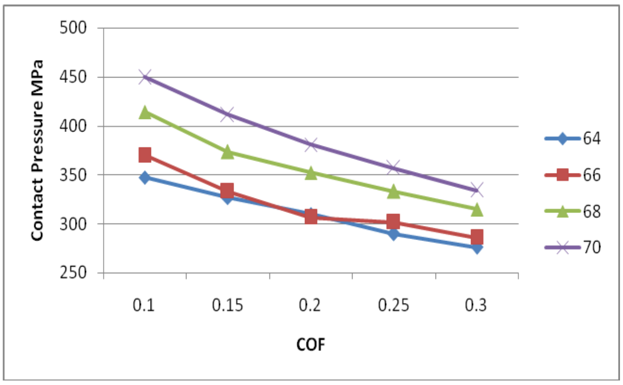

Figure 2 Variation of contact pressure with flank angle

C. Variation of sliding distance with flank length (considered variation in radii along with flank length) and coefficient of friction has been analysed and plotted in Figure 3, It shows significant decrease in sliding distance of joint with increase in flank length.

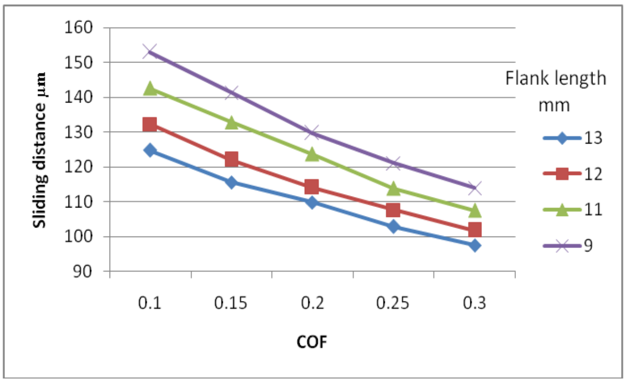

Figure 3 Variation of sliding distance with flank length

ISSN: 2278 – 7798
International Journal of Science, Engineering and Technology Research (IJSETR)
Volume 5, Issue 4, April 2016

This variation of sliding distance is possibly due to more surface contact with increasing contact length

D. Variation of contact pressure with different flank length and coefficient of friction is plotted in Figure 4. There is significant decrease in contact pressure value with increase in flank length. This variation is possibly due to increase in surface contact area between blade and disc.

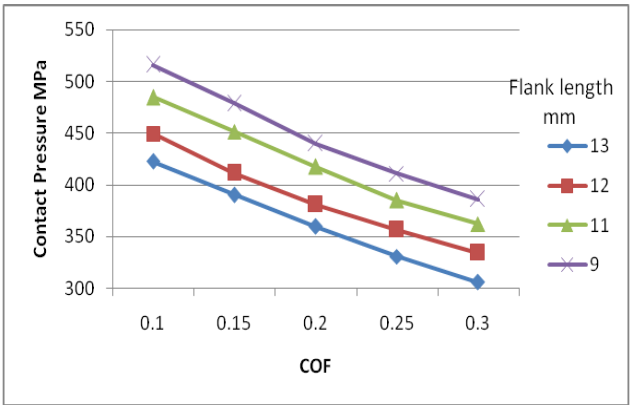

Figure 4 Variation of contact pressure with flank length

V. CONCLUSION

From the finite element analysis of the dovetail joint of compressor disc and blade with different geometry like flank angle and length, following conclusion has been drawn

- There is 19% and 20% decrease in contact pressure and sliding distance respectively with the change in flank angle from 70° to 64° at coefficient of friction value 0.25.Variation is maximum at the coefficient of friction value of 0.1.
- There is 19% and 15% decrease in contact pressure and sliding distance respectively with the change in flank length from 9 to 13 mm at coefficient of friction value 0.25.

VII. REFERENCES

[1] P. Papanikos, SA. Meguid, Z. Stjepanovic, "Three dimensional nonlinear finite element analysis of dovetail joints in aero engines disc," Finite Elements in Analysis and Design. Vol. 29, pp.173-186,1998.

[2] Tiago de Oliveira Vale, Gustavo da Costa Villar, "Joao Carlos Menezes," Methodology for structural integrity analysis of gas turbine blades, Journal of Aerospace Technology and Management. Vol. 4, pp. 51-59, 2012.

[3] B.M. Gowda, H.R. Yeshovanth, C. Siddaraju , "Investigation and Efficient Modeling of an Dovetail Attachment in Aero-engine," Procedia Materials Science. Vol. 5, pp. 1873 – 1879, 2014.

[4] L. Witek, "Failure analysis of turbine discs of aero engine, Engineering Failure Analysis,"Vol. 13, pp. 9-17, 2006.

[5] M. Kheto, NC. Mahendra Babu, J. Madan, "Fretting fatigue failure of dovetail joint of compressor through numerical simulation," SASTECH. Vol. 8,pp. 71-76, 2009.

[6] L. Witek, "Numerical simulation of fatigue fracture of the turbine disc, Fatigue of Aircraft Structures,"vol. 1, pp. 114-122, 2012.

[7] L. Witek, "Stress analysis of turbine components under spin rig thermomechanical condition," AVIATION.Vol. VIII, pp. 1648-7788, 2004.

[8] Qiuwan, M. Jiaobin, Q. Jing, D. Zhang, "Research on optimization for the mushroom-shaped root-rim structure of turbine blades," 5th International Conference on Civil Engineering and Transportation.pp. 1921-1924, 2015.

[9] K. Anandavel, R.V. Prakash, D. Antonio, "Effect of Preloading on the Contact Stress distribution of a Dovetail Interface," International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering. Vol. 4-10, pp. 1107-1112, 2010.

[10] A.B. Dilip, S. Zameer, "Structural Integrity Analysis of Gas Turbine Rotor Component using Finite Element Analysis," Indian Journal of Applied research. Vol. 4-7, pp. 177-178, 2014.

[11] M. Kotresh, P.V. Srihari, K. Ramachandra, Fretting fatigue studies of aero engine dovetail roots using contact analysis, International conference on Computer Aided Engineering CAE, pp. 93-98, 2013.

[1]M.Tech, Product Design & Manufacturing, Department of Mechanical engineering, RV College of Engineering, Bangalore, India, Sunita.shri45@gmail.com

[2]Associate Professor, Department of Mechanical engineering, RV College of Engineering, Bangalore, India, pvsrihari@gmail.com