

# Fatigue and Fretting Studies of Gas Compressor Blade Roots

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**ABSTRACT:** Fretting Fatigue is the complex phenomenon which occurs at the contact regions. A typical dovetail blade and disc joints is the one in which the fretting fatigue failure takes place at their contact interference. There are so many parameters which depend on fretting fatigue failures, in this paper only the primary parametric characteristics for two different geometries like straight and 20° skew angle dovetail models were concentrated. By using Finite Element contact Analysis technique, those parameters are evaluated with suitable boundary and loading conditions. This study reveals that the maximum stresses occur at the lower contact regions of dovetail joints, fretting fatigue parameters for skew angle model shows higher stress values than the straight dovetail model.

**KEYWORDS:** Dovetail Blade Roots, Fretting-Fatigue, Finite Element, Contact analysis, Contact Pressure and Sliding Distance.

## I. INTRODUCTION

Fretting is a complex phenomenon that occur when two components are pressed into contact along with vibratory loading resulting in local slip, high stress, and surface damage. In many cases, this localized damage and high stress can result in cracking and ultimately lead to early failure of components. It depends on geometry and loading conditions, which are essential to the analyses of an actual blade-disk in a turbine engine jet. Examples of these are routinely seen damage in dovetail joints of turbine engine blades including their press-fit or interlocking connections to the disk, which are subjected to surface wear and fretting fatigue. Aero engine turbine discs basically have three critical regions on which attention should be focused: the dovetail-rim area (fir-tree slots, serration fitting), the assembly holes and the hub zone. The joint between the turbine blade and the disc usually represents the most critical area from the point of view of the static and fatigue approaches. The loads associated with these regions are mainly the centrifugal forces and thermal stresses. Very high edge-of-contact stresses coupled with fretting induced surface damage can lead to early fatigue crack formation and accelerated crack propagation in order to accommodate safe stresses value in this region, an adequate geometry has to be developed for the joint. Papanikos P et al. [1] have carried out 3D non-linear finite element analysis of the dovetail region in aero-engine compressor disc assemblies using contact elements. The main focus of the analysis was to study the effect of critical geometrical features, such as flank angle, fillet radii and skew angle upon the resulting stress field. Frictional conditions at the interface between the disc and the blade were also examined. Anandavel K et al. [2] have carried out the effect of three-dimensional loading on macroscopic fretting aspects of an aero-engine blade-disc dovetail interface for straight & a skew dove-tail & concluded that, the skew effect increases the peak contact pressure and slip by a factor of 2 compared to a straight dovetail slot. The blade airfoil loading combined with the skew effect further increases the contact pressure, slip and surface stresses. Golden PJ [3] used dovetail specimens with different contact angles shows a dovetail specimen with contact angle of 45° to study fretting fatigue life, and the results indicated that fretting fatigue life of a dovetail specimen will decrease with the increase of contact angle.

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## II. MODELLING AND FINITE ELEMET ANALYSIS

**GEOMETRICAL MODELLING:** In this study the dovetail blade-disc region geometry has referred from [1] and [2], with respect to those designs geometrical models were created in CATIA V5 R20 Cad software. For 20° skew angle dovetails slot axis was skewed with respect to the engine axis. The geometrical detail are shown in Figure 2.1, corresponding software models were as shown in Figure 2.2

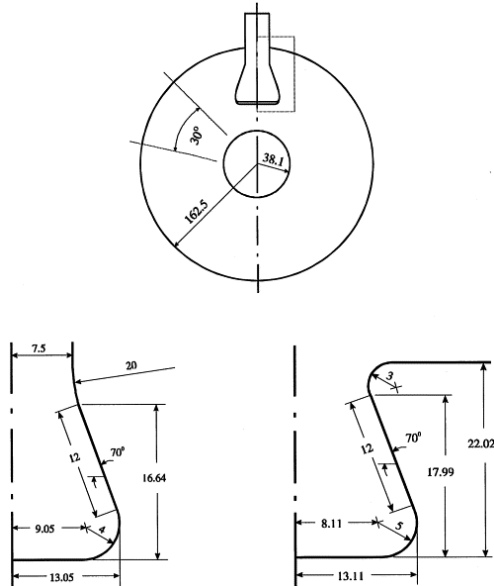


Figure 2.1 Geometrical details

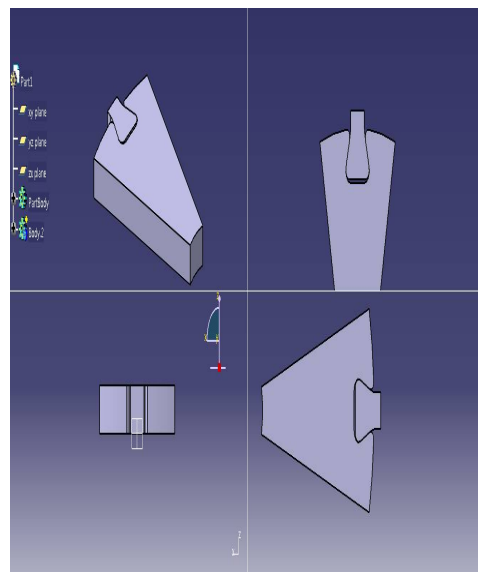


Figure 2.2.CATIA software model

### FINITE ELEMENT ANALYSIS:

Contact analysis was carried out in ANSYS 14.5 Work Bench Finite Element software package, in this software geometrical model was imported from cad software in the form of STEP file.

The later analysis steps will be as follows:

### MATERIAL SELECTION:

The material selected is Titanium alloy Ti 6-Al-4V, also known as Grade 5. This alloy is an alpha-beta type alloy and is the mainstay in the aircraft industry. It is significantly stronger than commercially pure titanium while having the same stiffness, and has a significant advantage over other alloys as it can be heat treated easily. The material composition of alloy is as shown in Table 2.1. For contact analysis the material property of alloy is as shown in Table 2.2

Component	Wt.%
Al	6
Fe	Max 0.25
O	Max 0.2
Ti	90
V	4

Table 2.1 Composition of Ti-6Al-4V

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Material Properties	
Young's modulus	110Gpa
Poisson's ratio	0.3
Density	4500Kg/m <sup>3</sup>

Table2.2 Material property of Ti-6Al-4V

### CONTACT PAIR GENERATION:

On importing the geometric model the software will select the contact faces automatically, co-efficient of friction values are given at specific intervals, all other parameters was taken care by the FE software.

### MESH GENERATION:

The model was meshed using tetrahedron elements with elemental size of 3mm. Fine mesh was required around the contact regions in order to improve solution accuracy for that 1mm mesh refinement was done. Coarse mesh was done to the rest of the model. The meshed pattern of the model is as shown in Figure 2.5.

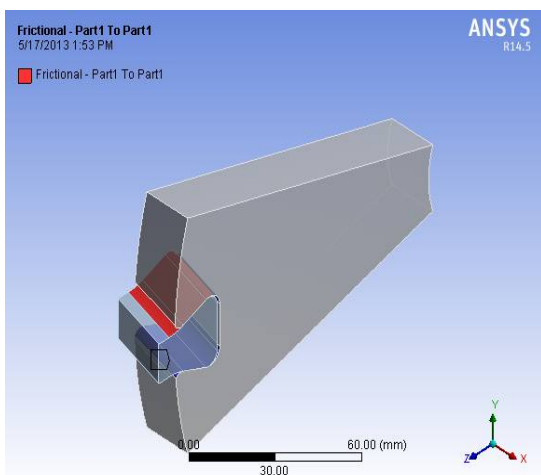


Figure 2.3 Contact generation

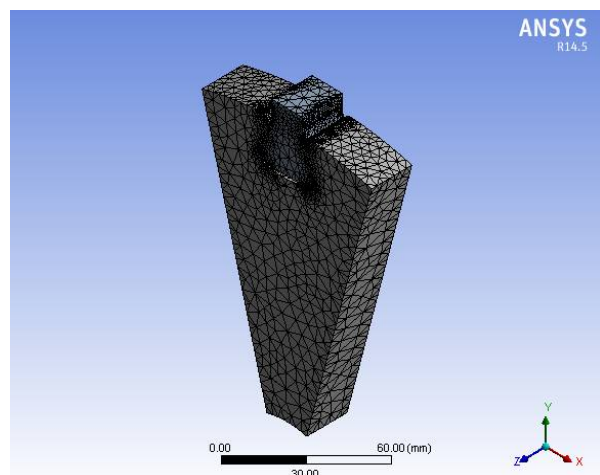


Figure 2.5 Meshed model

### BOUNDARY CONDITIONS:

The bottom surface of the disc was axially constrained (UZ). Since in this study it was considered only the root of the blade for FE analysis, the remaining mass of the blade was applied on the top surface of the blade using equation  $F=m\omega^2 r$ , where  $m$ =mass of the blade(Kg),  $\omega$ =angular velocity(rps),  $r$ =radius between the CG & axis of rotation(mm), force was found to be 20000N, the angular velocity of 1050rps was applied to both blade-disc rotating about origin.

**III. RESULT AND DISCUSSION**

3D Straight dovetail model results		
Co-efficient of friction	Contact Pressure (MPa)	Sliding Distance ( $\mu\text{m}$ )
0	496.97	186.59
0.3	295.75	118.63
0.5	241.99	99.71
0.7	209.38	89.25
1.0	173.38	76.68

Table 3.1 Straight dovetail results

3D 20° Skew dovetail model results		
Co-efficient of friction	Contact Pressure (MPa)	Sliding Distance ( $\mu\text{m}$ )
0	1759.44	489.05
0.3	1308.43	251.91
0.5	1214.67	166.56
0.7	1178.26	136.68
1.0	1175.73	

Table 3.2 20° Skew dovetail results

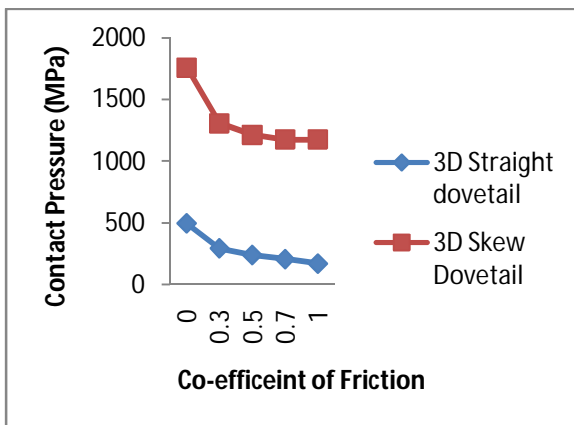


Fig 3.1 contact pressure v/s Co-efficient of friction

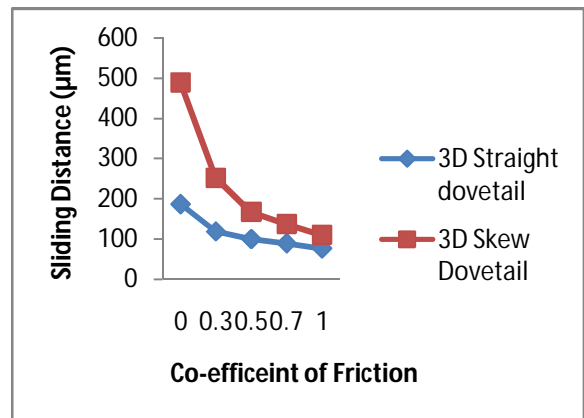


Fig 3.2 Sliding distance v/s co-efficient of friction

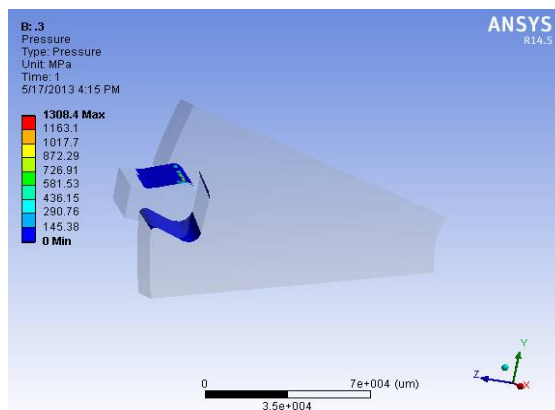


Fig 3.3 FE result of Contact pressure for 0.3 co-efficient of friction

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## IV. CONCLUSION

The present study investigated fretting fatigue parameters using finite element contact analysis from the obtained results one can conclude that,

- ❖ The Contact pressure & sliding distance at the contact region decreases with an increase in co-efficient of friction.
- ❖ The maximum stresses are induced at the bottom region of the blade disc joints.
- ❖ Skew model shows higher contact pressure & higher sliding distance than the straight dovetail model.

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