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Design and Analysis on Dovetail Joint of an Aero Engine Compressor Disc and Blade with Different Skew Angle

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ABSTRACT

In an aero engine rotating disc and blades are the crucial components has their structural integrity is vital to the engine's service life. Design of attachment between compressor blades and disc is critical in order to transfer the large loads generated due to centrifugal action and other gas loads between these components. Several different methods have been adopted for establishing attachment between the blades and the discs such as welded, pin, dovetail and fir-tree joint etc., but in this study dovetail joint is considered, with straight and 10^0, 20^0 and 30^0 skew models.

This study is concerned about the effect of skew 10^0, 20^0 and 30^0 angle on compressor disc and blade assembly with different operational loads &Constant coefficient of friction. Finite element model was developed by using commercially available software, ANSYS Workbench to capture the stress concentration region. Comparative study is performed between straight and skew 10°, 20^0 and 30^0 angle of dovetail joint.

Keywords *- Aero engine, Compressor Disc, Blade, Dovetail Joint, Skew Angle*.

1. INTRODUCTION

A gas turbine is a device or rotary machine which works by utilizing the power of jet of gases and air by which energy transfer takes place between the working fluid and rotating element due to dynamic action. A gas turbine is most pleasing power rising unit surrounded by different means of producing mechanical power due to its incomparable dependability, freedom from vibration and capability to generate great powers from units of reasonably small size and weight. The jet engine plant mainly consists of compressor, combustion chamber and turbine.

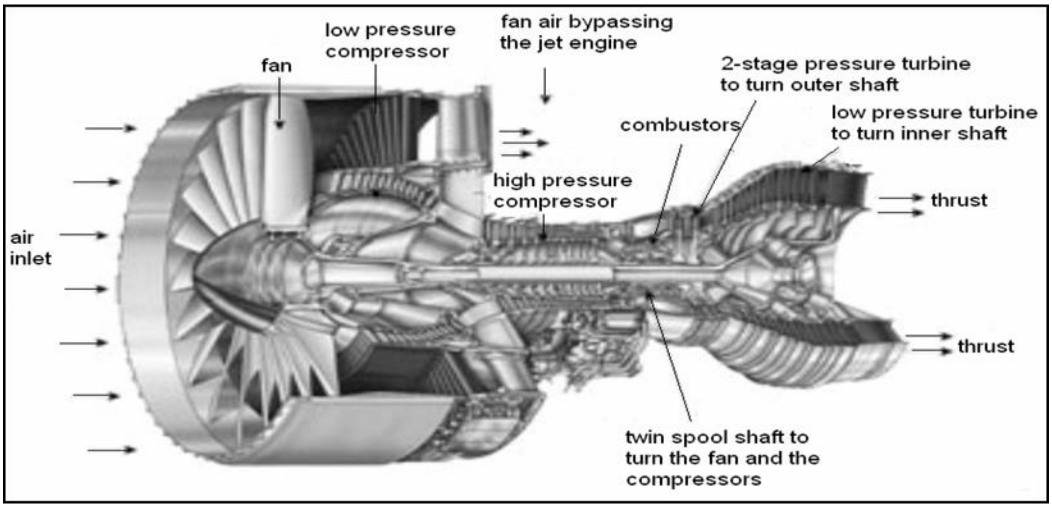


Fig 1: A Modern Jet Engine.

2. GEOMETRY AND FE MODEL

This chapter discusses the geometric creation and computer aided modeling of the disc and blade.

2.1 Geometry Modeling

Geometry is created as per drawing shown in the Fig 2 and Fig 3. Once the geometry modeling is completed disc and blades are assembled as shown in the below. Aero standard specification and dimensions are used to create disc-blade assembly, three dimensional model is shown in Fig 4 which is generated by suing modeling software called CATIA V5 R20 and this model is used for analysis.

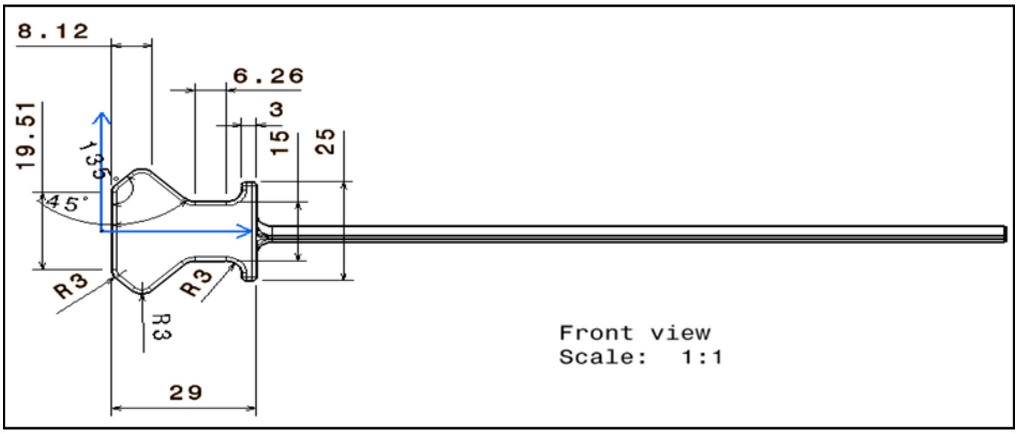
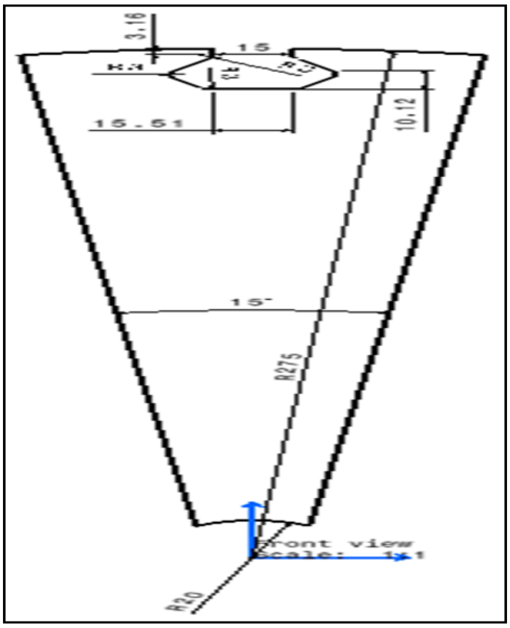


Fig 2: Geometric Details of Blade.



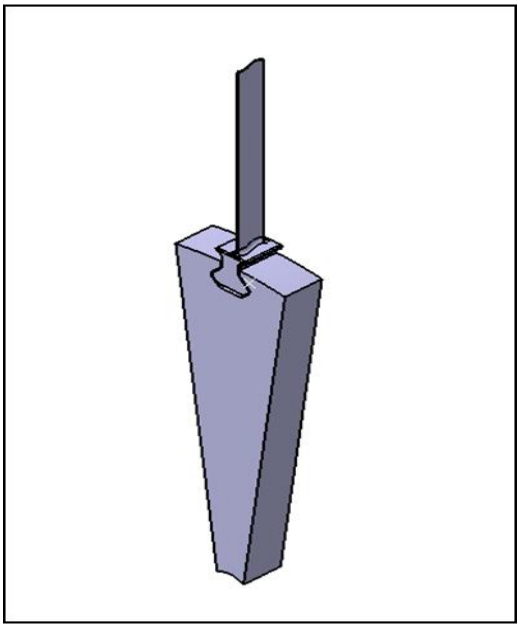


Fig 3: Geometric Details of Dovetail Joint. Fig 4: Isometric Model of Disc with Blade.

2.2 Material Properties

Table 1 shows the material properties considered for the analysis (Titanium Ti-64Al-4V). Engine components usually work under high temperature and pressure especially disc and blade need to sustain high thermal shock at different intervals. Hence, these components need high strength materials which can take this kind of loads. Titanium alloys have very high tensile strength and toughness even at very high temperature. Such alloys have good corrosion resistance, very light weight and high working temperature.

Properties	Ti-64Al-4V
Mass Density (Kg/m3)	4430
Young's Modules (GPa)	113.8
Poisson's ratio(NU)	0.342
Yield strength (MPa)	880
Ultimate strength (MPa)	950

Table 1: Material Properties of Titanium Ti-64Al-4V.

2.3 FE Model

A finite element model (FE model) comprises a system of points called nodes. Connected to these nodes are the elements themselves which form the finite element mesh. The density of the finite element mesh may vary throughout the geometry, depending on the shape of the geometry and change in stress levels of a particular area. Regions that experience high changes in stress usually require a higher mesh density than those that experience little or no stress variation. Points of interest may include fracture points of previously tested material, fillets, corners, complex detail, and high-stress areas. By using the proper element size, the mesh has been created for blade and disc. For meshing the complex geometry and for getting the high accuracy, 8 node hexahedral elements and 6 node penta elements are used.

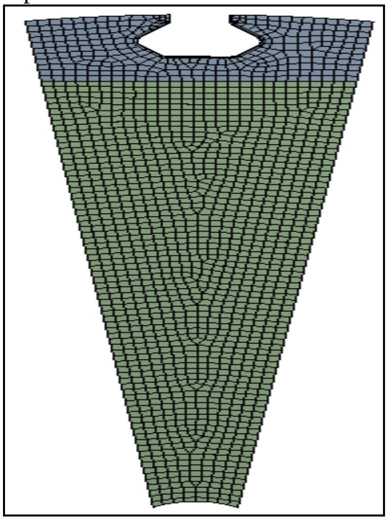


Fig 5: FE model of Disc

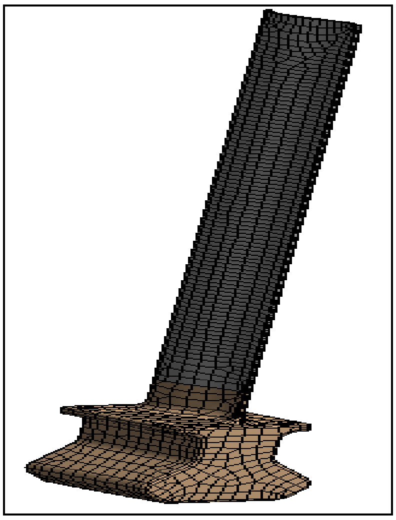


Fig 6: FE Model of Blade.

It is ideal to have hexahedral model throughout the model, but due to geometric configuration and to meet convergence criteria, penta elements are included while generating finite element model.

2.4 Mesh Statics

Total no. of elements	4432
Total no. of nodes	6604
Total no. of Hex elements	4336
Total no. of Penta elements	96

Table 2: Mesh Statics.

2.5 Boundary Condition

Below Fig shows the boundary conditions applied on the low pressure compressor assembly of Finite Element Model.

- On either cross sectional side faces of disk sector i.e. **C** shown in above Fig 7, were applied with cyclic symmetric boundary conditions by selecting edge of the disc.
- Axially constrained at the bottom edge of the disc sector i.e. **B** (inner radius of the disc) as shown in the Fig 7.
- Inertia force is applied i.e. **A** to the model as shown in the above Fig 7.

- The dove tail blades base root face is in contact with the dove tail disk root face.

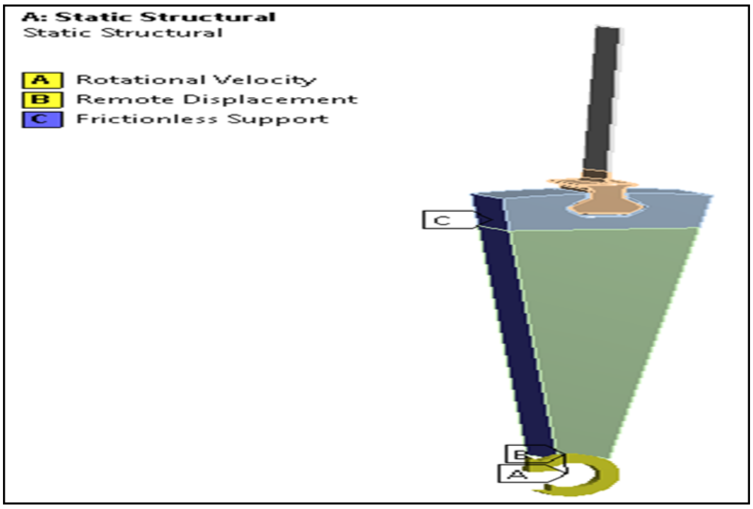


Fig 7: Boundary Condition of Blade and Disc.

The angular velocity of 10000 rad/s (100%) is applied. The Inertia Loads are usually much greater than the gas forces and often a limiting factor in design and in this analysis the gas forces are not considered.

3. RESULTS AND DISCUSSION

Within the scope of our investigation static analysis is carried on compressor disc/blade assembly of Skew dovetail joint. Further in the report it can be observed the plots are concentrated only on the dovetail region, as our study concern more on that.

3.1 Stress Analysis of Compressor Disc and Blade

Static structural analysis is carried out on compressor disc/blade assembly. The equivalent stresses, deformation and Max principal stresses are noted down for the angular velocity of 1,000 to 10,000 rad/s applied incrementally by 1,000 rad/s with co-efficient of 0.1µ on the compressor blade disc assembly.

3.1.1. Von-Mises Stress Analysis of Skew Fit Compressor Disc/Blade

The von-Mises stress distribution in the skew fit of compressor disc/blade assembly for different skew angle such as 00, 100, 200, and 300 are shown in Fig 8, 9, 10 and 11. It is observed that, the maximum value of radial stress at the dovetail root region of compressor disc is approximately 314.79 MPa.

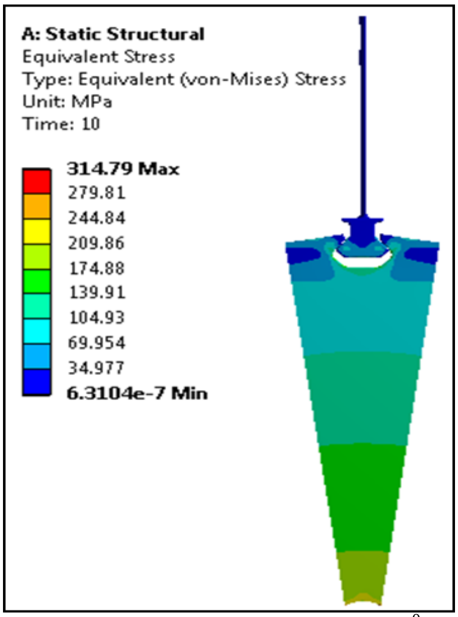


Fig 8: von-misses stress plot for 0^0.

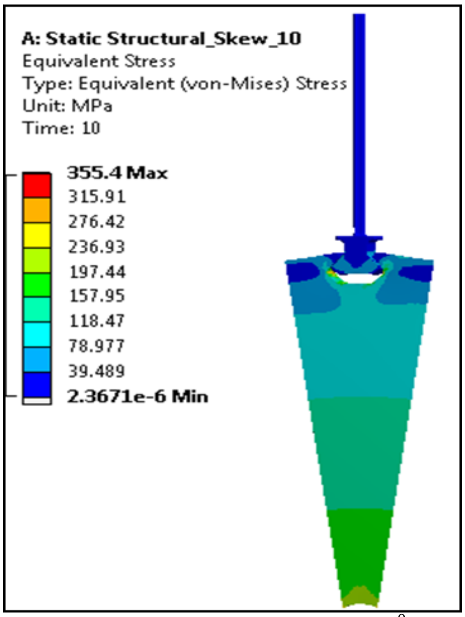


Fig 9: von-misses stress plot for 10^0.

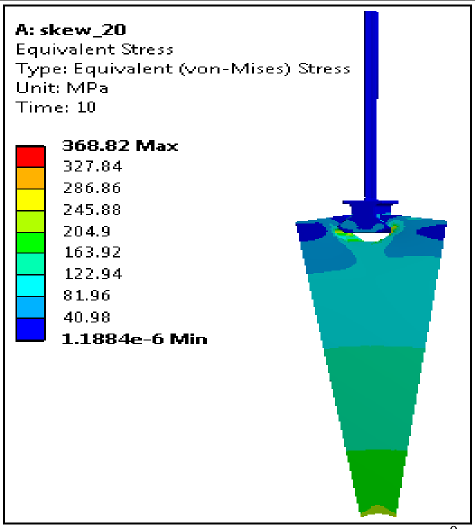


Fig 10: von-Mises Stress Plot for 20^0.

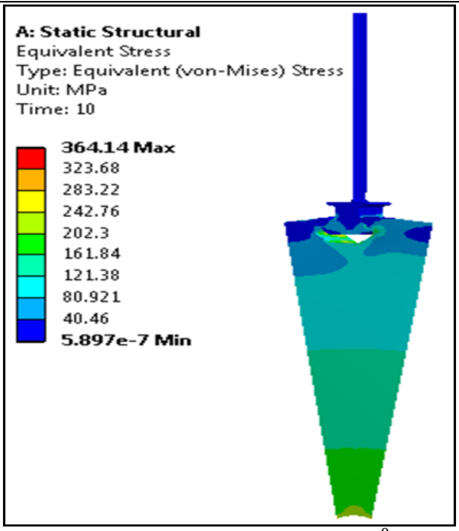


Fig 11: von-Mises Stress Plot for 30^0.

3.1.2 Maximum Principle Stress Analysis of Skew Fit Compressor Disc/Blade

The Maximum principle stress distribution in the skew fit of compressor disc/blade assembly is as shown in Fig 13. It is observed that, the maximum value of principle stress at the dovetail root region of compressor disc is approximately 353.93 MPa.

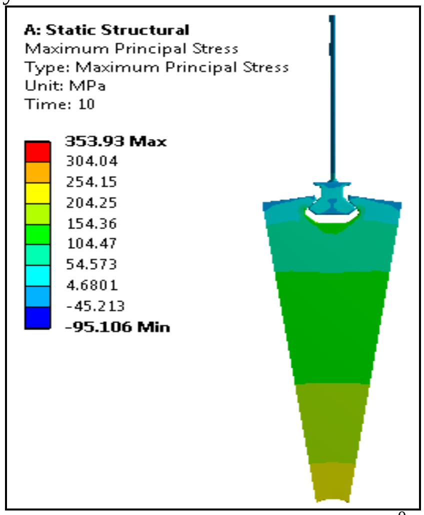


Fig 12: von-Mises Stress Plot for 0^0.

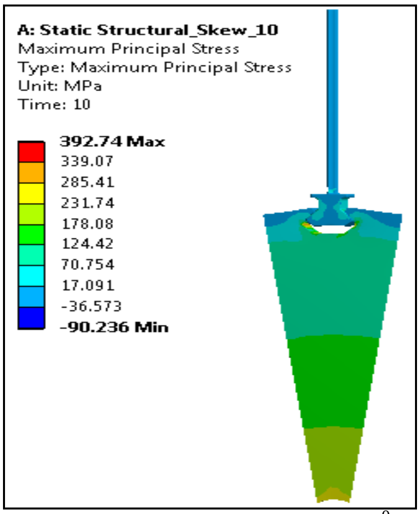


Fig 13: von-Mises Stress Plot for 10^0.

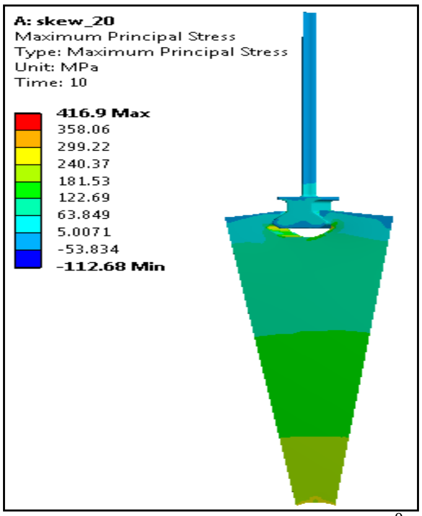


Fig 14: von-Mises Stress Plot for 20^0.

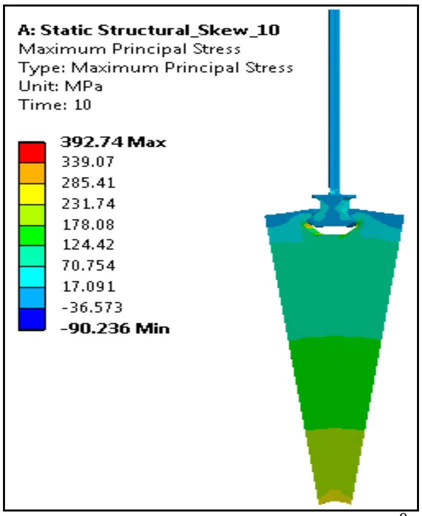


Fig 15: von-Mises Stress Plot for 30^0.

3.1.3 The Displacement Contour in Skew Fit Compressor Disc/Blade Assembly

The displacement plot in skew fit compressor disc/blade assembly is as shown in Fig 15, 16, 17 and 18. The maximum displacement observed is 0.3268 mm at the tip of the blade, because the displacement accumulated at the free edge of the blade. The displacement is uniformly increases from bottom of the compressor disc to tip of blade. The displacement observed here is very small which is considered to be having minimal effect on the system.

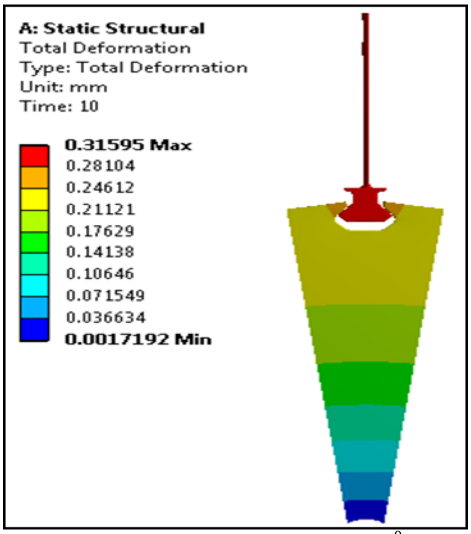


Fig 16: Total deformation plot for 0^0.

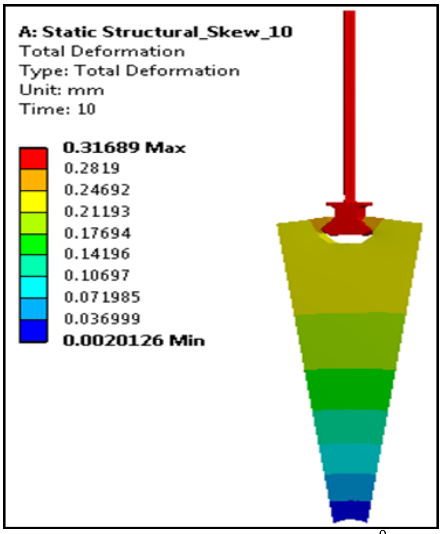


Fig 17: Total deformation plot for 10^0.

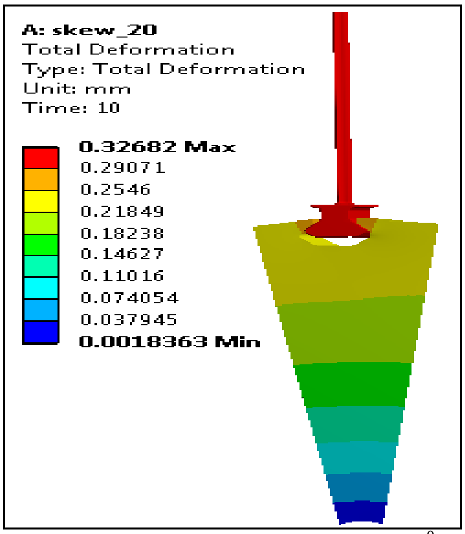


Fig 18: Total deformation Plot for 20^0.

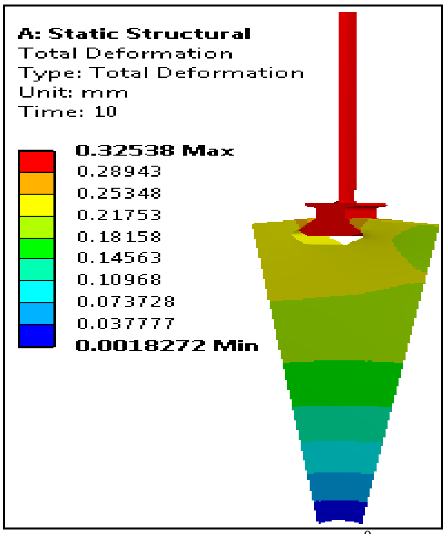


Fig 19: Total deformation Plot for 30^0.

4. CONCLUSIONS

From the analysis following conclusions can be made

- The skew angle can considerably change the blade/disc interface stress distribution.
- The contact edge stress distribution pattern over the interface plays important function in the fretting damage at the dovetail interface.
- The peak contact stresses are observed near the bottom and top contact edges of blade and disc.
- The results indicate the increase in interference fit will reduce the amplitude of cyclic loading stress at the top and bottom contact edge of interface.
- Von-misses stress is maximum for 20^0 skew angle i.e. 368MPa at 10000 rad/s and minimum for 0^0 skew angle i.e. 314MPa. The obtained stresses for both the skew angle is less than the yield stress of the material.
- The mathematical models developed for determining the von-Misses stress is very much valid for any variable within the scope of this investigation.

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