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Analysis of the Effect of Break Edge in Load and Lock Slot of Circumferential Dovetail Disk of Gas Turbine Compressor

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Abstract: ***Aviation gas turbine compressor disk assemblies are subjected to high thermo-mechanical loads due to rotation, radial loads of blades and thermal gradients. They contain highly stressed three dimensional features like load slot and lock slot. The centrifugal loads of the blades are transferred to the disk through disk dovetail interface. The sharp edges in the load and lock slot features in the hardware are removed by incorporating a blending with small radius. The study involves evaluation of the impact on stresses at critical locations by modeling the blending in finite element (FE) model of circumferential dovetail disks. The impact of this blending on the stresses at critical locations in the load and lock slot and at the disk and blade dovetail interface is analyzed using UG CAD package and the FE analysis package ANSYS. Including this feature in the FE model takes a lot of effort. Hence, the need for considering this blending in the FE model during the design and analysis has to be justified. The above study is conducted on parametric models of fictitious configurations resembling compressor disks to assess whether there is any substantial change in stresses by incorporating blending in the load and lock slot (LLS) features, as the feature sizes vary depending on the engine size and the stage of the disk in the compressor. By analysis comparison is drawn between with and without break edge and concluded that there is not of much variation in stresses by modeling break edge in LLS.***

Keywords: Break edge, Circumferential Dovetail Disk, gas turbine, Load slot, Lock slot, Finite Element Analysis, WOBE and WBE.

1. Introduction

A typical axial compressor used in aero-engines usually comprises of 6 to 14 stages. They consist of alternate stator and rotor stages. The rotors are composed of rotor disk with the blades attached to the disk rim using either axial or circumferential dovetail slots. Axial dovetails require axial retention to hold the blades. These types of dovetails are difficult to make in a multistage spool. In the aft portion of the compressor where the loading is lesser compared to forward stages, circumferential dovetail slots are used. Each of these disks typically consists of one load slot to load the blades into the circumferential dovetail slots and two lock slots to lock the blades in position using lock lugs. The rotors are generally manufactured by turning operation, once the rotors are manufactured by turning, 3D features are made in the rotor by milling operation, finally after manufacturing, the 3D features in rotors containing sharp corners are machined to obtained chamfers or fillets, making sharp edged corners into rounded fillet are called as break edge. The current study is to evaluate the impact on stresses at critical locations due to modeling the break edge (BE) in finite element (FE) model of circumferential dovetail disks of gas turbine compressor.

2. Problem Definition

Break edges are used to remove sharp edges in mechanical components. The available parametric models have to be simulated with and with-out break edges. The part is to be modeled using UNIGRAPHICS. The models of varying geometry, break edges are to be modeled in UNIGRAPHICS. These models have to be imported to ANSYS for the analysis. The important parameters which are considering for parametric study are Tangential width of load and lock slot (TW or CW), axial width of load and lock slot (AW), fillet radius of load and lock slot (r), break edge dimension (e). The simulation of these models with and with-out break edges (WOBE & WBE) has to be carried out using ANSYS.

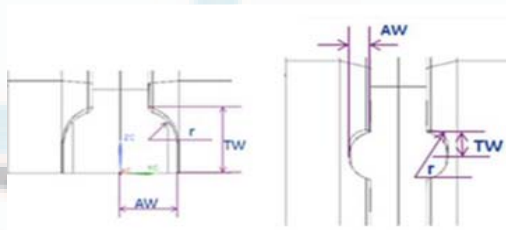

Figure 2.1: Dimensional terminology used

3. Methodology

A parametric circumferential dovetail disk with 48 blades is assumed, 4 bladed 30 degree sector models with different geometric configuration is used for analysis. A CAD package UNIGRAPHICS is used for modeling the parametric model. FE analysis package ANSYS is used for analyzing the effect of break edge. SOLID92, 10 node tetrahedral element in ANSYS is used for meshing. Boundary conditions and loads are applied; Blade load is applied as pressure on the pressure face. The problem is solved with PCG solver and the results are retrieved.

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4. Boundary Conditions, Loads

The model is constrained in the axial direction on the forward side and left free on the aft end. At the section 0 and section 1 planes reflective symmetry boundary condition is applied i.e. constraining in the θ direction (U_y =0). There are several loads acting on the rotor when the compressor is rotating at high speed of around 10000 rpm. Those are surface loads, body loads.

Surface load: blade load, gas load comes under surface loads because when the disk and blades are rotating about engine axis the blade is in contact with disk at the disk pressure faces they are in surface to surface contact. Here for the parametric model blade load is applied as the pressure load on the pressure face.

Cylindrical co-ordinate system
Ux- Radial direction
Uy- tangential / circumferential direction
Uz- Axial direction (engine axis direction)

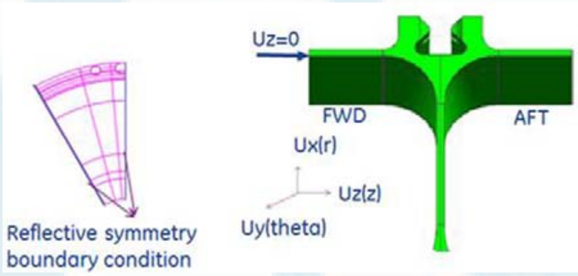


Figure 4.1: Reflective symmetry boundary conditions

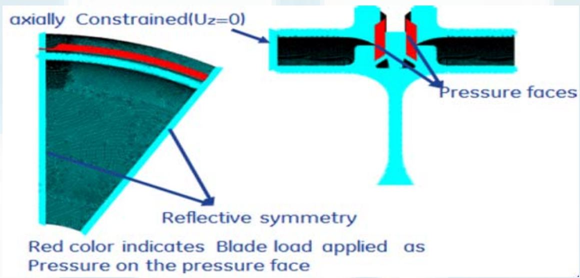


Figure 4.2: Model under blade load applied as pressure

5. Results

For the analysis, the material of the parametric model is considered as Inconel 718 which finds its applications in gas turbines, rocket motors, space crafts, nuclear reactors and pumps. The first four cases are analyzed by modeling only one slot i.e Load slot and analyzed at 15000 rpm and by applying 20000 psi blade load as pressure load on the pressure face. The last case is analyzed by modeling two slots both load and lock slot and analyzed by applying blade load as pressure on the disk pressure face where blade and disk are in contact.

Case I Stress contour plots for the parametric model with load slot basic dimensions CW/AW=1.25, r/H=0.51759

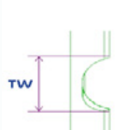
Stress analysis is carried out on the models without break edge and with break edge and is compared in terms of magnitude of normalized stress values.

case-1						
load slot stresses in ksi						
	Radial stress		Hoop stress		SEQV stress	
BE in mil	FWD	AFT	FWD	AFT	FWD	AFT
WOBE	1	1	1	1	1	1
WBE	1.04959	1.05097	1.0022	1.006	1.005	1.00586

Table 5.1: Results for Case-I

Case II Stress contour plots for the parametric model with the change in TW/AW to 1 from the basic dimension

The normalized CW/AW ratio of the slot is changed from 1.25 to 1, analysis is done.

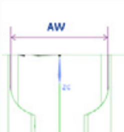


case-2						
load slot stresses in ksi						
	Radial stress		Hoop stress		SEQV stress	
BE in mil	FWD	AFT	FWD	AFT	FWD	AFT
WOBE	1	1	1	1	1	1
WBE	1.02156	1.01012	1.0044	1	0.998	1.00546

Table 5.2: Results for Case-II

Case III Stress contour plots for the parametric model with the change in CW/AW ratio to 1.66667 from the basic dimension

The normalized CW/AW of the slot is changed from 1.25 to 1.666 inch, analysis is done.

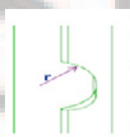


case-3						
load slot stresses in ksi						
	Radial stress		Hoop stress		SEQV stress	
BE in mil	FWD	AFT	FWD	AFT	FWD	AFT
WOBE	1	1	1	1	1	1
WBE	1.04871	1.08663	1.0004	1.007	1.011	1.00317
WBE	1.08414	1.13861	1.0003	1.014	1.005	1.00382

Table 5.3: Results for case-III

Case IV Stress contour plots for the parametric model with the change in r value from the basic dimension

The normalized (r/H) value of the slot is increased to 0.517, analysis is done.



case-4						
load slot stresses in ksi						
	Radial stress		Hoop stress		SEQV stress	
BE in mil	FWD	AFT	FWD	AFT	FWD	AFT
WOBE	1	1	1	1	1	1
WBE	1.02251	1.02191	1.0187	1.004	1.012	1.00759

Table 5.4: Results for case-IV

Case V Stress contour plots for the parametric model with both load and lock slot

In this fifth case the two slots are modeled in the disk, one for the load slot and other for lock slot, the results for both the slots are tabulated.

case-5						
load slot stresses in ksi						
	Radial stress		Hoop stress		SEQV stress	
BE in mil	FWD	AFT	FWD	AFT	FWD	AFT
WOBE	1	1	1	1	1	1
WBE	1.02278	1.03278	0.9981	1.002	1.001	0.99899
lockslot stresses in ksi						
	Radial stress		Hoop stress		SEQV stress	
BE in mil	FWD	AFT	FWD	AFT	FWD	AFT
WOBE	1	1	1	1	1	1
WBE	1.02791	1.01819	0.9952	0.993	1.001	1.00407

Table 5.5: Results for case-V

6. Summary and Conclusions

In the first case only one slot is modeled which is used as both load slot as well as lock slot and has drawn results from it. Then after considering two slots, modeling of circumferential disk is done for two slots and analysis is carried out similar to first case with one slot, finally through post processing results are retrieved. When comparison is drawn between without break edge and with break edge, stress values are appearing almost closer to each other there is not of much variation in stresses by modeling break edge in load lock slots. From this we can conclude that there is no need of modeling break edge in load lock slot.

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