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Modal Analysis of Gas Turbine Rotor Component using Finite Element Analysis

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***Abstract*— Structural integrity of the aero engine gas turbine blades are checked for 2 cusp and 3 cusp fir-tree contacts. Initially the 2 cusp and 3 cusp geometries are built using CATIA V5 software and later imported to Hypermesh for better quality mesh and results. Later entity sets are created to form contact pairs at the interface of the blade and disc arrangements. The contact elements are created using Ansys contact manager using Targe170 and contac174 elements based Eulerian algorithm. The analysis result shows higher displacement and higher radial, hoop, Von misses stress in the 2 cusp fir-tree arrangement for the given loads. Contact pressure variation shows 2 peaks at the cusp ends due to geometrical variation which creates the stress concentration in the joint. The 3 cusp fir tree arrangement shows improved results with less radial displacement and less stress. Even contact pressure is uniform indicating complete contact in the process. Contact pressure variation shows 3 peaks at cusps due to stress concentration. The analysis is carried out further to find the speed variation on the contact pressure and stress development along with radial displacement. The modal analysis results shows higher dynamic stability with 3 cusp attachment compared to the 2 cusp arrangement. All the results are represented with necessary pictorial plots.**

Keywords—fir-tree joint, gas turbine blade, hypermesh, contact analysis.

I. INTRODUCTION

The safety of gas turbine engines has always been the main concern of aircraft certification authorities. Economic pressure resulting from the reduced availability of strategic materials and the high cost of engine components and the continued demand, by the engine suppliers/users, for longer life and higher thrust to weight ratio continue to provide a stimulating challenge for engine designer developers. Tiago de Oliveria Vale et al. [1] in this study focused on the stresses arising from the centrifugal loadings in a fir-tree joint using a 3D Finite Element model in the commercial code ANSYS 13.0. The disc and blade assembly are forced to move with a certain rotational velocity. Contact connections are predicted on the common faces of the blade and on the disc at the root. Results can be compared with the mechanical properties of the adopted material. This conclude the importance of calculating the clearance between the teeth of the blade and the disc, for the calculation of thermal expansion of the bodies indicates the smallest possible value of clearance. The failure mode of a primary safety and service member in an engine, such as turbine disc assemblies, is usually catastrophic, often are constantly faced with the resulting in loss of Life and hardware.

II. LITERATURE SURVEY

G. D. Singh and S. Rawtani [2] discussed that in a blade root several parameters are involved and also the number of steps may vary. Hence the study of the effect of these parameters individually on the deformation pattern of the blade root was conducted. They studied a three step Fir Tree root individually for stiffness characteristics at the top and bottom neck for normal step load, tangential friction load due to contact between the blade and disc studs and the distributed centrifugal body force due to rotation.

Cheng-Hung Huang and Tao-Yen Hsiung [3] in their paper have discussed an inverse design problem is solved to determine the shape of complex coolant flow passages in internal cooled turbine blades by using the conjugate gradient method. The CGM together with the BEM was successfully applied for the solution of the inverse design problem to estimate the optimal shape of the internal cooling passages in turbine blades. Several test cases involving different design considerations were examined.

III. PROBLEM DEFINITION

Analyzing fir-tree type of turbine blade disc attachment for stress under inertia conditions. Since attachment is very important to keep the assembly intact, prior information of the nature of stress and deformations helps in better design. Aero engines are the most important in the space transportation and moves at very high speed. So inertia of this structure is very high and the resulting stresses are also high. So assemblies should have strong strength to take this load. Fir-tree, pin and dovetail are the three types of joints used for contacts between blades and rotor. In the present work, we are concentrating on the fir tree arrangements.

IV. METHODOLOGY

The material used was the same employed by Papanikos et al. [11] and Tiago de Vale et al. [1]. The properties of the materials used for modeling the blade and disc were that of titanium alloy Ti-6Al-4V. For this alloy material the values used were: Young's modulus E=114Gpa, Poisson's ratio υ=0.33 and density ρ=4492kg/m^3. The two proposed models were submitted to centrifugal loading with specific angular velocity, where ω is selected to be 1,000rpm. The model was imported to ANSYS R14.5 and the cyclic symmetry tool is used. It reduces computational time and gives accurate results.

The geometrical model prepared using Catia, a three dimensional modeling software. Meshing is done using three dimensional 8 noded brick elements. Application of material properties. Creating the contact pair using target and contact regions. Application of Rotational load of 1000 rpm. Comparing the problem under two and three cusps contact. Analysed results through static, contact and modal analysis.

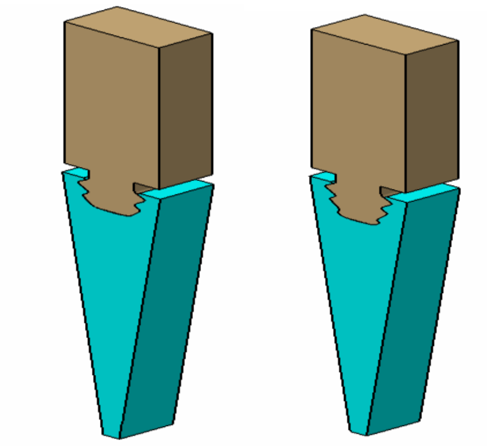


Fig 1: Isometric View of Proposed Models

The geometrical model in this study created is similar to that used in the works of Meguid et al. [9] and Tiago de Vale et al. [1]. The figure 1 shows two and three dimensional representations of the blade and disc with 3 cusp fir tree attachments. Initially the geometry is built using sketcher environment and later converted to part models in Catia. Draft copy of the model is obtained. Finally the members are assembled to form the fir-tree joint. It shows assembled blade and rotor disc for 3 cusp fir tree attachment in three dimensions. This part is designed in CATIA V5R18. The disc is represented for 10 degrees and overall 36 segments as referred from J.S. Rao [31] are required to form the complete assembly.

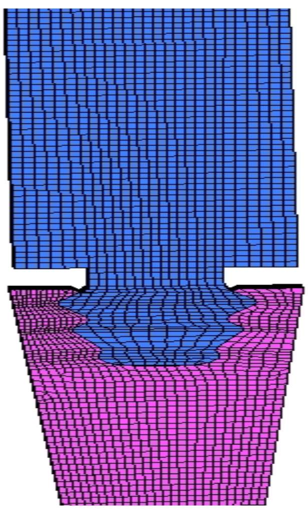


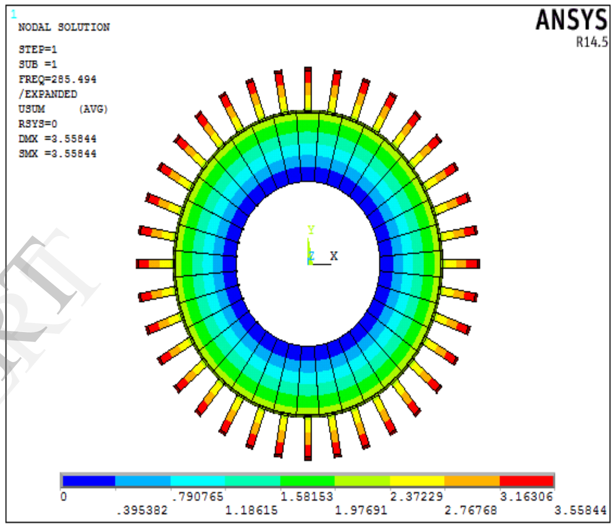
Fig 2: Meshed view of the Model

There are several methods for discretization available for the generation of finite element meshes in non-linear contact analysis. A map meshing routine is used due to obtain good results. The mesh is checked for aspect ratio =5, skew angle =15 degree, warpage =5 degree and jacobian =0.7 for better results.

V. RESULTS AND DISCUSSIONS

Modal analysis is very important for dynamic stability of the problems. Modal analysis is carried out to find the natural frequencies and mode shapes of the problem. The modal frequencies help identify the dynamic stability of the systems. Resonance is the most critical aspect of dynamic stability of the problems. Generally higher natural frequency is desirable for avoiding the resonance. Hence modal analysis is carried out to both the configurations.

Fig 3: Mode Shape for freque



ncy of 285.494 Hz– Model 1

Resonance takes place in the system when operational frequency matches with natural frequency of the system.

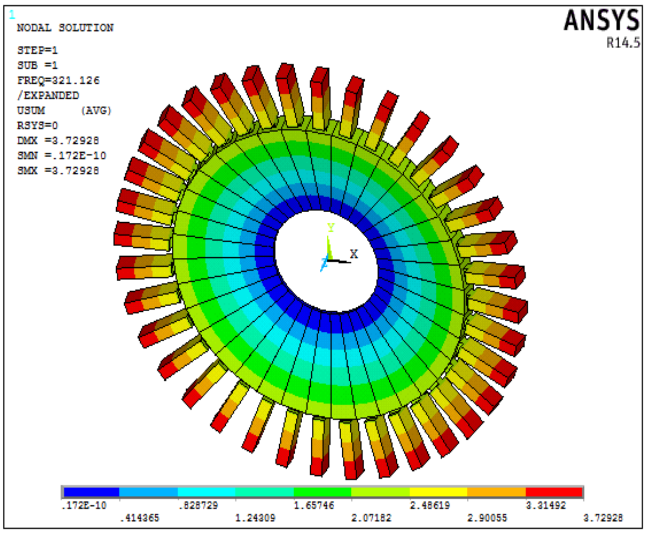


Fig 4: Mode Shape for frequency of 321.13 Hz– Model 2

The results show greater improvement of natural frequency with 3 cusp arrangement. At higher range this difference is still higher. So 3 cusp contact gives better static and dynamic stability compared to the 2 cusp contacts.

Table 5.1: Modal Comparison

Details	Frequency(Hz) 2 Cusps	Natural Frequency(Hz)- 3 Cusps
1	285.49	321.13

The table shows higher natural frequency for 3 cusp fir tree attachment compared to the 2 cusp fir tree attachment. Dynamic stability of the problems is defined by higher fundamental natural frequency. Hence, 3 cusp fir-tree arrangements in blade and disc are better than 2 cusp arrangement dynamically.

VI. CONCLUSIONS

- Initially the geometry is built in Catia, a three dimensional modeling software and drafting is represented for both 2 cusp and 3 cusp contact of blade and rotor configuration.
- The models are imported to Hypermesh in Step file format to obtain better quality mesh. The mesh is checked for aspect ratio, skew angle, warpage and jacobian for better results.
- Modal analysis is carried out to find the dynamic nature of the system. The results shows greater difference of natural frequency with three cusps compared to the two cusp contacts. So greater static and dynamic stability can be obtained by more contacts.
- All the results are represented with necessary graphical plots.

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