Review on Fir-Tree Joint of Turbine Disc In Aero Engine

Vijay A. Gaikwad, Pravin Lohote
1Lecturer, Department of Mechanical Engg. ICOER, PUNE. MH-India, vijay19920822@gmail.com
2Lecturer, Department of Mechanical Engg. ICOER, PUNE. MH-India.

Abstract—Now a day’s the fir-tree joint is very much evident from the literature that not much work carried out on effect of cooling passage of fir-tree root joint of turbine disk. The method of attaching the blades to the turbine disk is of considerable important, since the stress in the disk around the fixing or in the blade root has an important bearing on the limiting rim speed. On earlier days, whittle engine were attached by the dovetail fixing but this design was soon superseded by the fir-tree fixing that is now used in majority of gas turbine engines. The fir-tree fixing type involves very accurate machining to ensure that the loading is shared by all the serrations. When the turbine is stationary, then the blade is free in the serrations and is stiffened in the root by centrifugal loading when the turbine is rotating. This paper proposed the work on the development of geometric model of disc and blades for turbine.

Index Terms—Fir tree joint, Turbine disk.

I. INTRODUCTION

The Gas turbine engine design is the most highly advanced design. A good design is one which provides all the strength and rigidity to meet all its design requirements. The structural components of the gas turbine engine consist of compressor, combustor, turbine, exhaust system and a convergent-divergent nozzle. The sectional view of the gas turbine engine as shown in Figure 1.

![Figure 1. Sectional view of gas turbine engine](http://www.ijrmee.org)

The thermodynamic process requires a supply of air under pressure. The purpose of the compressor is to raise the pressure of the air besides a small rise after air intake. A compressor includes a rotor (mobile blades) which imparts motion to a mass of air and a stator (stationary vanes) which transforms the velocity into pressure. In the mobile blades the velocity of the flow increases because of the motion imparted to the air and the pressure increases because of the configuration of the blades (divergence). In the stationary vanes the velocity is transformed into pressure because of the divergent air path, and the flow is straightened. The combustion chamber receives air from the compressor and it mixes with fuel sprayed from nozzles in the front of the chamber. The mixture is burned at high temperatures to generate the maximum possible heat energy. The process of burning is initiated by igniter plugs, it is isolated after start-up, and continues until the fuel supply is shut off. In a gas turbine engine, the output of the turbine is used to turn the compressor (which may also have an associated propeller or a fan). The hot air flow leaving the turbine is then accelerated into the atmosphere through an exhaust nozzle to provide thrust or propulsion power. The exhaust system passes the turbine discharge gases at some velocity to atmosphere, and in the required direction, to provide the resultant thrust.

II. LITERATURE SURVEY

Wenbin Song et al [1] has carried out automation and optimization of the design of a turbine blade fir-tree root by incorporating a knowledge based intelligent computer-aided design system (ICAD_) and finite element analysis. The fir-tree joint used to hold a blade in place in a turbine structure is usually identified as a critical component which is subject to high mechanical loads. Most often the attachment is a multi-lobe construction used to transfer loads from blade to disk. The loading on the root is mainly due to centrifugal load which is dependent on the mass of the whole blade. The design of the fir-tree root involves an iterative process of controlling the blade mass, which incorporates the root mass. Also some key features, such as the fillet radius, play very important roles in the stress distribution in notch regions. H. D. Conway et al, [2] developed a numerical method for finding the distributions of contact stresses between two and three-dimensional elastic bodies which were pressed together, the area of contact either being free from or subjected to frictional forces. The method was first applied to the plane stress problem of a strip which was compressed by a rigid, axially-loaded, flat-ended indenter where the contact surfaces were either free to slide over one another (zero friction coefficient) or locked together (large friction coefficient). Numerical values of the contact stresses and displacements were computed in each case of several indenter width vs strip depth ratios.

G. D. Singh and S. Rawtani [3] 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. Used the stiffness of a fir-tree joint to characterize that load sharing. Deformations of the root for different values of applied load were determined based on a simplified finite element model. Subsequently, a
regression analysis was employed to characterize the stiffness of the different teeth. Cheng-Hung Huang and Tao-Yen Hsiung [4] 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. RELATED WORK

A fir-tree joint may be used in turbine structures to attach a blade to the rotating disk. Mechanical loads are transferred through the joint from the blade to the disk. The overall aim of fir-tree structure optimization program is to enable the designer to explore different candidate geometries at the preliminary stage, ranging from relatively simple designs to rather complex ones, at a reduced cost compared to using previous manual methods (such costs have often prevented the exploration of more complex profiles and different size and shape teeth). This process involves the use of feature-based parametric geometry construction tools such as CATIA and large-scale structural finite analysis packages, along with an optimization program implementing various search strategies. Although this problem is basically a structural analysis problem, the strategy employed here is rather different. The use of the CATIA system and finite element analysis software together gives it the capability to model the variations parametrically both for dimensions and in the topology used, and to analyze the effect of geometric features on the stress distribution based on the finite element analysis results. Further-more, the above process may be incorporated into a search loop to automatically find the best solution against predefined constraints. As considered here, this is a 2D problem nested in the overall 3D blade/disc optimization procedure and uses well established 2D criteria modified from 3D analysis. The overall architecture of the CATIA based design optimization used is illustrated in Fig. 2. In this structure, CATIA is used to generate the model definition based on rules which may be stored in a knowledge database. The model is defined in a descriptive form using the CATIA design language which is a derivation of and extension to common LISP, aimed at geometric modeling capabilities. This model is used to produce geometry and related information. The geometry is passed to the analysis code along with any geometry dependent properties to evaluate the design performance. The optimizer is used to find the best solution for a particular set of design parameters. Parallel processing can be achieved by using facilities provided by the OPTIONS search systems.

IV. SYSTEM DESIGN

The work carried out in this paper is to development of geometric model of Disc and Blade for turbine. Geometric modeling will be carried out by using Catia tool. Further Geometric model will be converted into FE model using commercially available tool Ansys workbench. Figure 2 shows structural view of turbine disc. The major function of the turbine is to extract energy from the hot gas flow to drive the compressor and the accessory gearbox. Gas turbine disc works mostly at high temperature gradients and are subjected to high rotational velocity. High speed results in large centrifugal forces in discs and simultaneous high temperature reduces disc material strength. 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. The turbine discs basically have three critical regions for which lifetime certification is necessary: the fir-tree rim region, the assembly holes or weld areas and the hub region. Fig. 2 shows these areas along with their associated loads.

In this study, attention is devoted to examining the effect of the critical geometric parameters upon the contact stress distribution and load sharing between the different teeth of a fir-tree joint. These features, include the number of fir-tree teeth ni, flank length l, contact angle a, and flank angles P and y which define the tooth pitch. In addition, interface conditions in the fir-tree region will be studied by varying the coefficient of dry elastic Coulomb friction p.
Different Methods Adopted In Fastening Blades to Discs

The different methods adopted in fastening blades to discs are pin joint, dovetail and fir-tree. Dove-tail joints are commonly used for the disc blade attachments in compressors whereas fir trees are used for the turbine disc blade attachments. Fir-tree fasteners have ken commonly implemented in turbines because they provide adequate multiple areas of contact over which large centrifugal stresses can be accommodated.

CONCLUSION

The following conclusions can be drawn from the results obtained:
1. The maximum stress occurs at the fillet location on the blade due to more load is accumulated at the location.
2. The displacements of hollow blade and fir tree root of hollow blade are comparatively little bit lesser than solid blade and fir tree root of solid blade respectively.
3. The stress distribution of hollow blade is greater than solid blade and both stresses are lie within the limiting stress.
4. As hollow blade will have less mass compared to solid blade with not more rise in the stress as we are observed in the results obtained, so as the mass is reduced the efficiency is increased in the turbine.

FUTURE WORK

As turbine blade flank length & depth is very imported dimension in the turbine rotor. The optimized dimension should be made to have minimum stress & displacement at the root of the blade & disc. As turbine blade require cooling to reduce the thermal stresses, the size of the cooling passage is very important. The optimized size should be made to have maximum cooling of the blades but there should not be over cooling as it affects the thermal efficiency. The pseudo-elements are used to decrease the analysis time. The pseudo-elements are dead elements so that we can easily increase or decreases the size of the blade’s hole there by reduces the time for re-meshing of the whole blade.

REFERENCES