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Review Article

DESIGN AND ANALYSIS OF TURBINE BLADE OF ENGINE - A REVIEW

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This paper involves various failure mechanisms and the general practices followed by a blade designer for deciding a blade configuration were also described. Although some significant advances have been made during past some decades in the design technology of the blade from vibration point of view. First the designing of the blade geometry completed with CAD software and analysis with the analysis software. Blade failures still continue to take place, and hence efforts are still on to understand in totality the blade dynamics which has caused in large number of technical papers. Some of important are presented here. In this review stress is placed on paper dealing with general structural analysis of blade by analytical modeling, blade excitation and fatigue life estimation of turbine blade.

Keywords: Review, Design, Turbine blade, Failures

INTRODUCTION

The turbine is a rotary mechanical device that extracts energy from a fluid flow and converts into useful work and purpose of turbine technology are to extract the maximum quantity of energy from the working fluid to convert it into useful work with maximum reliability, minimum cost, minimum supervision and minimum starting time.

CFX-Blade Genis an advanced, interactive blade design tool for turbo machinery modeling developed by AEA Technology Engineering Software Inc. Blade Gen incorporates year softurbo-machinery designand analysis expertise into aneasy to use graphical environment utilizing terminology familiar to engineers involved in the design of rotating machinery. With Blade Gen, the user can re-design existing blades to achieve new design objectives or create completely new blade designs from scratch.

Blade Gen represents a pivot all ink between blade design, advanced fluid analysis and manufacturing. Used in combination with the CFX-Blade Gen plus Analysis Module, users can rapidly evaluate the performance ofa component. Alternately,

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the geometry can be exported through CFX-Turbo Gridto CFX-TASC flow to provide amorerigorous analysis.

It also produces blade geometry files that can be exported to CAD design in package such as CATIA and AutoCAD. This enables the user to efficiently transition from preliminary blade design, to full3D viscous flow analysis, and finally to a CAD environment.

BENFITS USING BLADEGEN

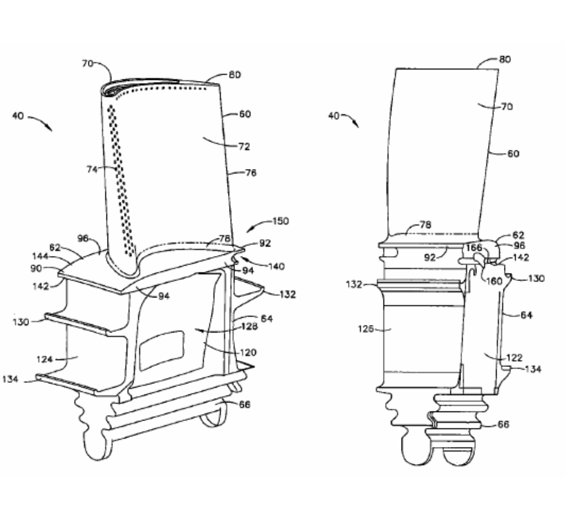
- Users should first describe the meridional profile earlier defining the Angle / Thickness or Pressure / Suction views, since these views stay dependent on the path length of the meridional profile's layers.
- The Angle, Thickness, and Pressure/ Suction Views define parameters on a layer. The first layer must be the hub and the second must be the shroud, with additional layers inserted at a user-specified fraction of the span. If only one layer is defined, it applies to the entire span between hub and shroud.
- All views display the same layer and blade. If a view doesn't have a definition for a particular layer that is being displayed, the calculated values at that layer are displayed.

FAILURES

Losses on the turbine consist of the mechanical loss; tip clearance loss, secondary flow loss and blade profile loss etc. More than 60% of total losses on the turbine is generated by the two latter loss mechanisms. These losses are directly related with the reduction of turbine efficiency. In order to provide a new design methodology for reducing losses and increasing turbine efficiency, a three-dimensional axial-type turbine blade shape will be designed by using CAD software like ProE or CATIA and optimization of design will be perform by analyzing different parameters using ANSYS workbench software.

Turbine efficiency is the most important factor on the performance of heavy duty gas turbines for power plants, air turbines, or turbo expanders etc. This efficiency is related very closely with losses in the passage. Losses on the turbine consist of mechanical losses due to the friction of rotating parts or bearings, tip clearance losses due to the flow leakage through tip gap, secondary flow losses due to curved passages, and profile losses due to the blade shape. So, it needs to develop a new design technology for providing an optimum turbine blade profile with either same or different material.

Figure 1: Blade Geometry of Turbine (Source Patent No. US6984112B2)



The break down and failures of turbo machineries have been influencing such as consequential damages andmost importantly the cost to repairs. To avoid these, it is obvious that the blading of turbo machinery must be made structurally stronger, that means not in dimensions and/or use of materials of construction, but keeping the operating stresses well within the limits.

Turbo machinery blades are classified into two categories depending on their manner of operation as either impulse or reaction blades. Impulse blades function by redirecting the passing fluid (steam or gas) flow, through a specified angle.

Reaction blades function as airfoils by developing a gas dynamic lift from the pressure difference, which the airfoil causes, between the blades upper and lower surfaces. High-pressure stages are generally impulse stages and low- pressure stages are reaction stages. Thus, a single free standing blade can be considered as pre-twisted continuous beam with an asymmetric airfoil cross-section mounted at a stagger angle on a rotating disc.Reasons for failure of bladed disc are Excessive stresses, Resonance due to vibration, operating environmental effects.

High cycle fatigue plays a significant role in many turbine blade failures. During operation, periodic fluctuations in the steam force occur at frequencies, corresponding to the operating speed and harmonics and cause the bladed disk to vibrate. The amplitude of these vibrations depends in part of the natural frequencies of the bladed disk to the forcing frequency. Large amplitude vibration can occur when the forcing frequency approaches or becomes resonant with the natural frequency of the blades. Steam turbine manufacturers typically design and manufacture blades with adequate margins between the forcing frequencies and the fundamental natural frequencies to avoid resonance.

FAILURESIN STEAM TURBINE BLADES

In the following paragraphs various failure modes of the turbine blade are discussed along with different kinds of stresses in the blade and the nature of aerodynamic excitation. A brief discussion of each of the above failure mechanisms follows in order to understand their significance.

Excessive Stress

The total stress at any location of the blade is sum of the centrifugal tension, centrifugal bending, steady steam bending and the alternating bending. The amplitude of alternating bending depends on the dynamic bending force, damping factor and the resonant frequency. Each of these is briefly discussed below to high light their importance.

Centrifugal Stress

In steam turbine, centrifugal stress is never the main cause of a blade failure, except in the rare cases of turbine run-away or due to low cycle fatigue caused by frequent start ups/shutdowns. However, centrifugal stress is an important contributing factor with fatigue failure, corrosion fatigue failure and stress corrosion failures. The level of centrifugal stress is kept at such a level so as to have enough margins for alternating stress. The blade configuration is designed so as to keep the center of gravity of shroud, airfoil and root attachments, on common radial axis. This prevents centrifugal induced torsion stresses.

ANALYTICAL MODELING

There has been a continuing improvement in the analytical modeling for the determination of natural frequencies of the system comprising of a set of blades mounted on the bladed disk. The early attempts to model the blade as a beam element have gradually led to a more detailed finite element representation. This finite element representation of real blade profile becomes necessary especially when plate or shell type of vibratory modes is induced.

Le-Chung Shaiu and Teng-Yuan Wa (1997), studied the free vibration behavior of buckled composite plates by using finite element method. Unlike beams or columns, plates can carry a much-increased load after buckling without failure. Here triangular plate element is taken for finite element analysis. This element is developed based on a simplified high order plate theory and large deformation assumptions. The nonlinear governing equationsofmotion forplates is linear zed into two sets of equations by assuming small amplitude vibration of the laminates about its buckled static equilibrium profile. In the post buckling region, the buckled plate may shift from are buckling mode to another. Due to this buckle pattern change, plate is also suddenly changed which in turn makes the natural frequencies of the plate to have sudden jump. The buckling mode of plates shifted from first to second. Then the stiffness of the plate is increased which makes a sudden increase in natural frequencies.

Hu X X and Tsuigi T (1999), had done free vibration analysis on curved and twisted cylindrical thin panels. Blades are part of turbomachinery rotating at high speed, so it is important to ensure safety while rotating. A turbomachinery blade is treated as a cylindrical thin panel twist, chordwise and spanwise curvatures along lengthwise direction. The non-linear strain-displacement relations of the model are derived based on the general thin shell theory and a numericalmethod for analyzing the free vibrations of curved and twisted cylindrical thin panels is presented by means of the principle of virtual work for the free vibration using Raleigh-Ritz method. It is shown that the method is effective for analyzing the free vibrations of the turbomachinery blades, and can provide accurate results when the proper number of integrating points and terms of displacement functions are adopted. The effects of curvature and twist on the vibrations are studied. This method is adequate for evaluating the vibration characteristics even if the models have large curvatures and large twists.

Rao J S (1974), made a two-dimensional analysis of free vibrations in the tangential direction. The first step is to develop the potential and kinetic energies for the tangential motion of the blades and shrouds. Second, Hamilton's principle is applied to derive the differential equation of motion and the boundary conditions.

Tsuiji and Sueoka (1990), deal with the free vibration of cylindrical panels by using Raleigh-Ritz method. Blades of turbo machinery are twisted in axial direction and cambered in the chord wise direction. The blade has been idealized to a twisted cantilevered cylindrical panel and numerical methods have investigated its vibratory characteristics. The convergence of frequency parameters is studied with the increase of number of strip and of terms in assumed solution functions. To demonstrate the usefulness of the method, the frequency parameters obtained. The frequency parameters and the modes of vibration are analyzed for typical twisted cylindrical panels and the effect of pre twist on them is investigated.

Leissa, MacBain and Kielb (1984), made a comprehensive study of the numerous previous investigations on the free vibration of twisted cantilever plates of rectangular platform which are results of a joint industry, government and university effort.Theoretical results received from different FEM programs utilizing shell theory and beam theory were compared with two independent sets of data obtained from experiments.Reasonable agreement among the theoretical results was found but it was recommended that further improvement in analysis method is necessary for increased dependability.

Sagar P Kauthalkar and Devendra S Shikarwar, had investigated the deformations and stresses induced in blade geometry they have found out the maximum elongations and temperatures are observed at the blade tip section and minimum elongation and temperature variations at the root of the blade. Temperature distribution is almost uniform at the maximum curvature region along blade profile. Temperature is linearly decreasing from the tip of the blade to the root of the blade section. Maximum stress induced is within safe limit. (Michel Arnal, 2007).

Avinash V Sarlashkar, Girish A Modgil, Mark L Redding summarizes the architecture and capabilities of Blade Pro, an ANSYS based turbine blade analysis system with extensive automation for solid model and F.E. model generation, boundary condition application, file handling and job submission tasks for a variety of complex analyses.

CONCLUSION

In this paper, analyzed previous generals and designs of the gas turbine blade to do further optimization, Finite element results for free standing blades give a complete image of structural characteristics, which can utilized for the improvement in the design and the operating conditions. From the review it can be noted that there are various factors like blade angle, blade geometry, number of perforated holes and the material of the blade can affect structural as well as thermal stresses.

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