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EFFECTS OF TRANSIENT LOAD ONGASTURBINE BLADE STRESS AND FATIGUE LIFE CHARACTERISTIC

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Abstract

The turbine blade is the most important component in the jet engine gas turbine. The common fatigue failures of the blade include the thermo-mechanical fatigue. Firstly, the finite element simulation of the blade is carried out in the working condition including the centrifugal load and mechanical load. The aim of this work was to develop and implement methods for the resource calculation of the jet turbine blade in which fatigue zone were detected during the load. The approach is based on a direct-step simulation of the load point based on the finite-element method (FEM).According to the simulation results of the thermos-mechanical load, the stress distribution of the blade body is reasonable in the working condition load; the stress level on the blade suction surface is higher than the pressure surface; in the blade body, the maximum Von Mises stress is 126 MPa, and the location of the minimum fatigue life is close to the blade shroud. Above simulation results is very useful for the structural design and fatigue experiment. Secondly, the stress and thermo-mechanical fatigue life characteristic are both analyzed with ANSYS software. Through the transient structure stress analysis, the stress-time history in the blade body is obtained; through the thermo-mechanical fatigue analysis, the fatigue zone of the blade first appears in the middle of the blade exhaust side. Based on these virtual results. These results are significant for the blade fatigue failure in the future.

Keywords: fatigue; FEM; thermal fatigue; life estimation; turbine blades; finite element simulation.

1. INTRODUCTION

The power generation efficiency of the heavy-duty gas turbine is very high, and the current maximum efficiency has been up to 60%. Furthermore, there are many advantages including compact size, rapid start-up, smooth operation, high reliability and low pollution emissions in the jet gas turbine. Therefore, it has become the main part in the power industry. In addition to the purposes of the transportation, the jet gas turbines as industrial facility also has great application prospects [1].The gas turbine blades are subjected to cyclic thermal stresses during transient operation like start-shut down or during load fluctuation. It is, of course, essential to know the magnitude of these stresses and the number of cycles to failure. The first stage rotor blade of a gas turbine has been analyzed for structural, thermal analysis using ANSYS software based on finite element method. The calculations are required to estimate blade life failure due to such cyclic loading. The first stage rotor blades are usually most critical in transient operation as they are under high thermos-mechanical stresses together with high centrifugal load. Specially at the trailing edge, the thermal stresses reach a maximum and under severe conditions, cracks can form at this area. Therefore, a first stage blade made from (nickel-base super-alloy) of a gas turbine was investigated.

1.1 FEM in ANSYS

The finite element method (FEM) is the most popular simulation method to predict the physical behaviour of systems and structures. Since analytical solutions are in general not available for most daily problems. A3D jet turbine blade was prepared for this analysis with height 0.082 m,chord 0.064 m and thickness 0.0195 m as shown in figure 1 below.

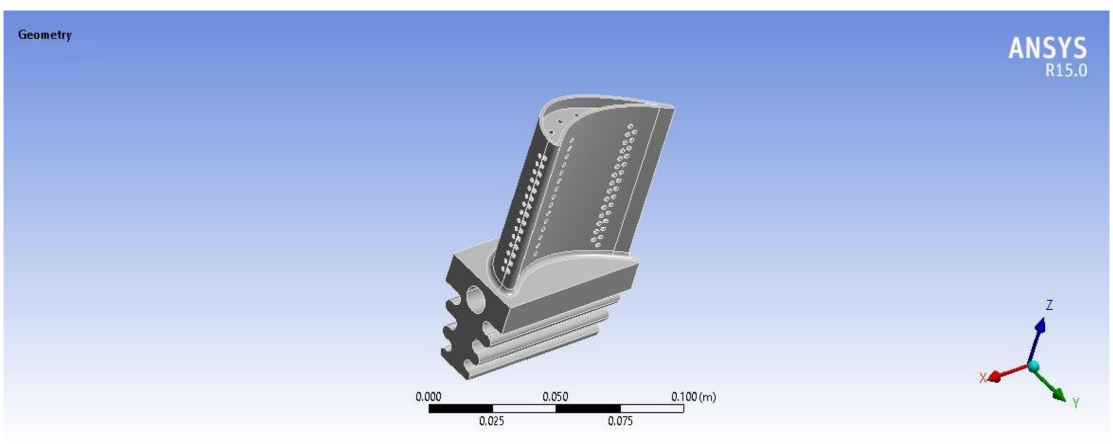

Fig. 1 Geometric model of gas turbine blade using workbench

in engineering sciences numerical methods have been evolved to find a solution for the governing equations of the individual problem. Although the finite element method was originally developed to find a solution for problems of structural mechanics it can nowadays be applied to a large number of engineering in which the physical description results in a mathematical formulation with some typical differential equations which can be solved numerically. Through workbench meshing process done to the 3D geometry with 39396 elements and 74279 no. of nodes. See the figure 2 below.

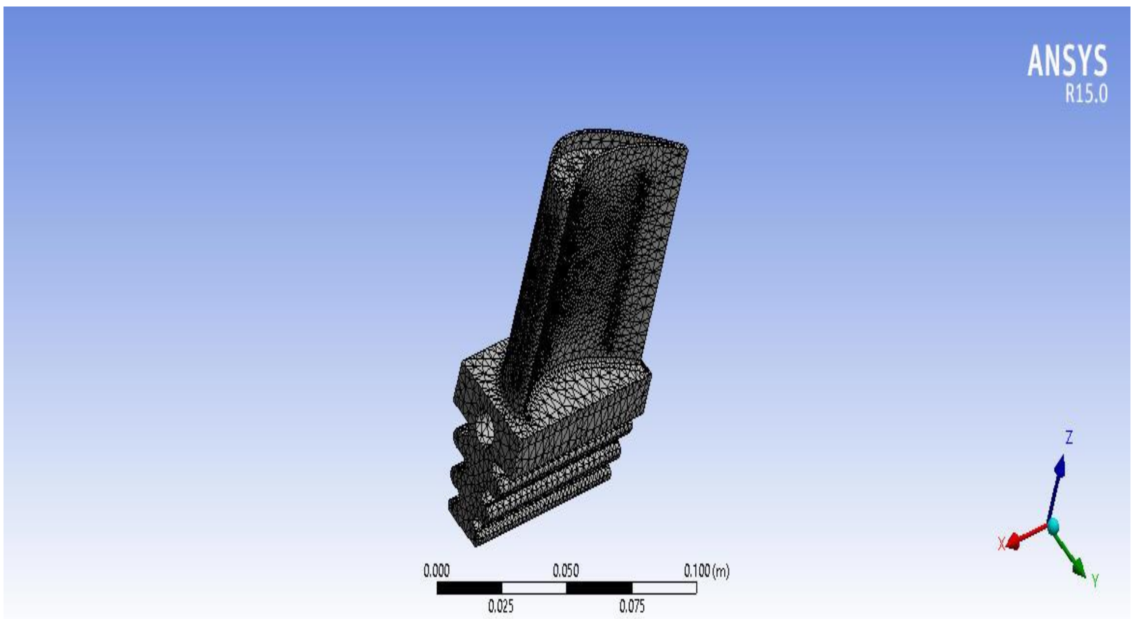

Fig.2 Meshing process of 3D geometry

1.2. Transient analysis

Transient analysis is used to calculate the effects of unsteady loading conducting on a structure, while inertia and damping effects concerned, such as those caused by time varying loads. Transient analysis is to determine displacements, stresses, strains and forces in structures or components caused by loads that include significant inertia and damping effects[2].

Table 1 Operation parameter of gas turbine

Parameter	Value
Turbine pressure inlet	8.5 Bar
Turbine Temperature inlet	1150C°

2. MATHEMATICAL ANALYSIS

The centripetal force is the external force required to make a body follow a curved path. Any force (gravitational, electromagnetic, etc.) or combination of forces canasta provide centripetal force. This force is directed inwards, towards the centre of curvature of the path. A simplified figure of the blades under discussion is shown in Figure 1.

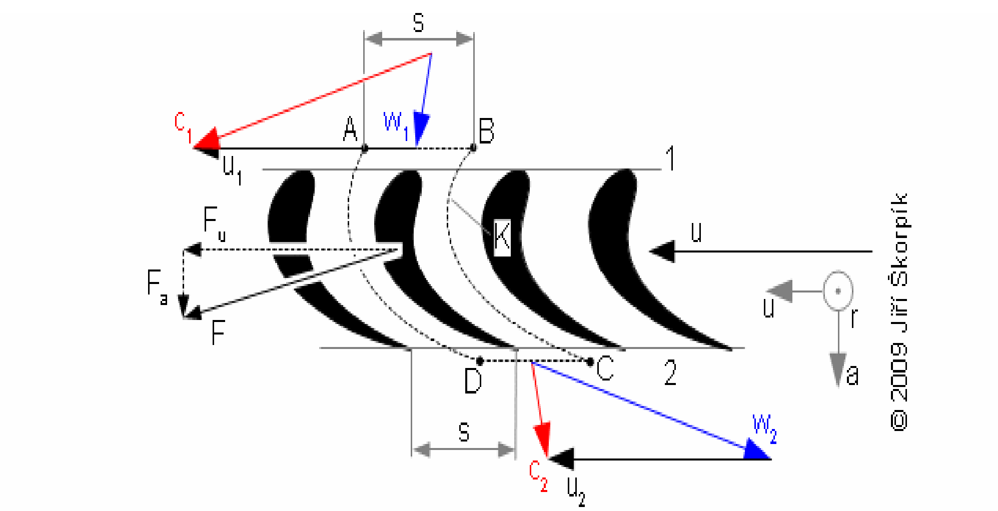

Fig. 3The force on the blade of the axial turbine stage

The development of improved phenomenological models of inelastic deformation, improvement of methods of computational mechanics and computer technology advances make it possible to implement solutions to complex, on-linear, boundary value problems arising with the modelling of crack prediction in turbine blades. In some cases, a direct mathematical modelling of crack growth eliminates costly and time-consuming experiments to confirm the state of the blades.

$F_c = m \cdot w^2 \cdot R = \frac{V^2}{R}$ (1)

Where:

m: mass of the turbine blade;

w: Rotation speed of the rotor;

R: distance between the centroid of the turbine blade and the axis of rotation.

Blade tapers in thickness towards its tip; but, for simplicity, assuming the blade to have a constant cross-sectional area A (m^2) and material density ρ (kg/m^3), we can write:

$\delta m = \rho A \delta r$(2)

and equation (2) becomes:

$\delta F = \rho A \omega^2 \delta r$(3)

where r is root radius.

Once this force has been calculated, we can estimate the nominal stress σ on the blade root using the following relation:

$\sigma = \frac{F}{A_{root}}$ (4)

where A_{root} is the cross-sectional area of the blade root.

Factor of safety (FOS) is a term describing the structural capacity of a system beyond the applied loads or actual loads. A calculated ratio of strength (structural capacity) to actual applied load. This is a measure of the reliability of a particular design:

FOS=$\frac{Yield\ strength}{Von\ mises\ stress}$ (5)

Strain life approach is used to calculate the fatigue life cycle of blade material, we can use Muralidharan and Manson equation to calculate life of the turbine blade:

$\frac{\Delta\epsilon}{2} = 0.623(\frac{Su}{E})^{0.832}(2Nf)^{-0.09}+0.0196(\epsilon f)^{0.155}(\frac{Su}{E})^{-0.53}(2Nf)^{-0.56}$(6)

Identification of the critical state of the blade that causes its destruction (or maximum values of permissible stress that could be reached according to the strength standards and material characteristics [4][5].

Table 2 Physical properties of blade

Material	Nickel Super alloy material
Density	8500 kg/m^3
Modulus of elasticity	790 GPa
Poisson ratio	0.31
Thermal expansion coefficient	1.70e-5 k^{-1}
Heat capacity	360 j/kg.k
Thermal conductivity	90 w/m.k
Design temperature	1650

3. RESULTS

The simulation technique was implemented to find out the distribution of the gas pressure on the surface of the blade, as well as their dependence on time also solution to the problems of thermo-elasticity, and creep to determine the stress-strain state of the blades in the presence of full-load.

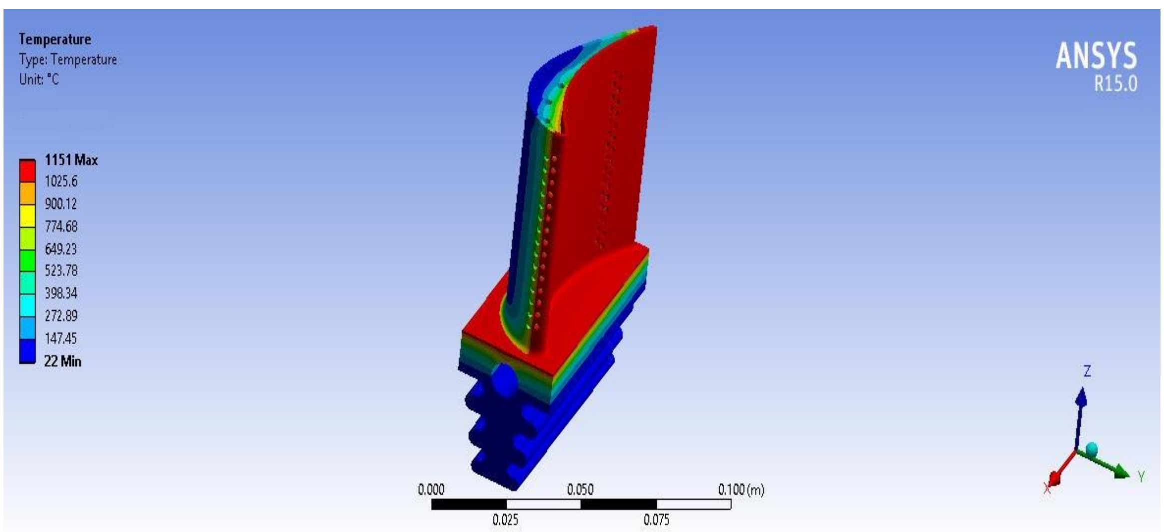

Fig.4 Temperature distribution ofnickel-base super-alloy blade

The stress analysis simulated the transient behaviour of the blade under service conditions where the centrifugal load, gas pressure load, and thermal expansion are present. The equivalent stresses and total deformation plots for a blade are shown in Figures 5 and 6, respectively. The peak stress of the blade occurred at the bottom fir tree, notate the top section of the blade and it can be future failure zone due to critical condition.

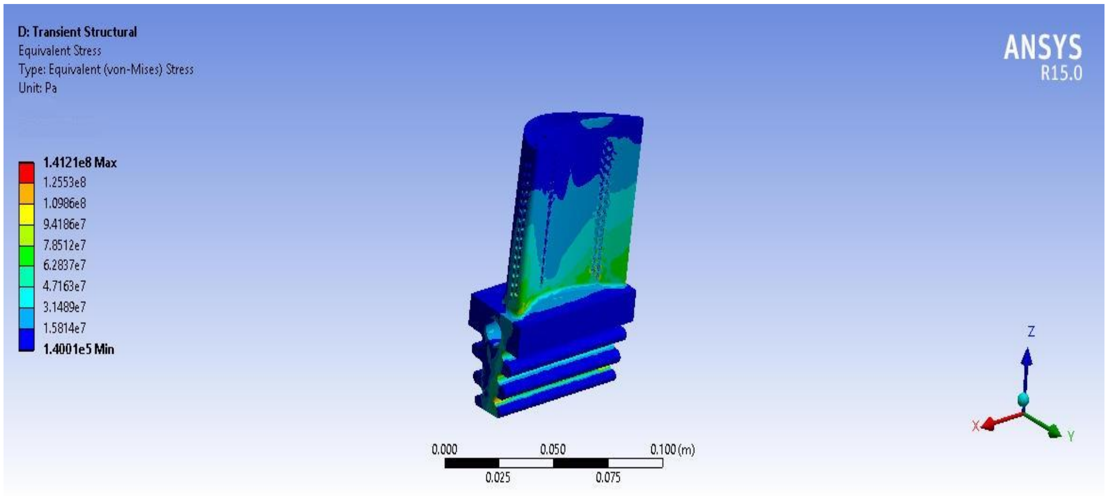

Fig. 5 Von-Mises Stress ofnickel-base super-alloy blade

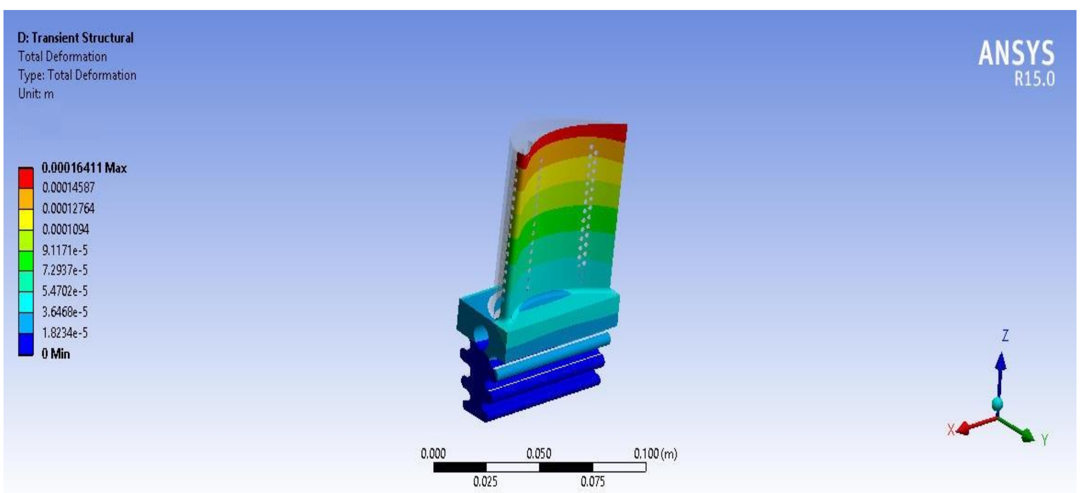

Fig 6. Deformation ofnickel-base super-alloy blade

According to the software results, the value of von-mises was 126 MPa, and maximum total deformation145×10^{-6} m.

4. CONCLUSIONS

1. The methods and computational algorithms for the simulation process of thermal fatigue zones detection in the blades were developed and verified jet rotor turbine blade. Finite-element calculations were performed using the ANSYS software.
2. The temperature distribution was analysed, and show significant effect on blade life.
3. The value of fatigue is allowable for this model and material.
4. The thermal load concentrate on blade base. It is, therefore, unlikely that blade failure could directly related to centrifugal and gas loading.

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