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Study on the Influence Due To the Oscillation Frequency of the Blade of the Large Steam Turbine

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Abstract

The geometric structure of a steam turbine blade is a very complex. During its operation, the blade rotates with the rotor and carries loads that change with time. The load changes due to a lot of reasons, it can be a blockage in the steam transmission, flow breaks in the beveled sections of the nozzles at underload or some other cause can be sources of vibrations acting on the blades.

It has geometric complexities such as variation along blades that have a profile varying with radius, when machining has to be milled or planed according to a copy pattern, the labor cost to produce a long blade is greater than that of a wing with a constant profile with height. Blades usually do not have a belt at the tip to relieve stress. But the energy loss in the line at the tip of the blade will increase. In recent times, belts have been adopted in the longest blades by fabricating individual pieces of belts attached to the blades.

In order to improve the vibration characteristics of the long wings, a belt was used to link the neighboring wings together and the fixity of the blade also plays an important role because there is considerable variation in the frequencies of blades of newly assembled turbines and in frequencies in the starting stage. The tolerances of each blade will be caused the variation of its blade frequencies. This study will do some simulations with typical industrial turbine blades of a 300 MW steam turbine.

Keywords: *Steam turbine, Blades, Frequency, Simulations, Thermal power plant.*

1. Introduction

According to the structure of the blades of steam turbine, it is divided into many types: blades with profiles that change with height and blades with profiles that do not change. Usually, short blades have a constant profile while long blades have a profile that varies from base to tip. The blade is located on the turbine's rotor. In the blade's stages, the blades are incorporated into the rotor disc. On the rotor disc surface, there is a slot to install the tail of blade.

There are many causes of failure of the blades which are fatigue, the forces acting on the blades, its frequency. In this paper, the blade failures due to the frequency is discussed. The causes of vibration are many, it can be due to dynamic loads acting on the blades, or it can be appeared during ít operation. As the rotor blade passes through the nozzle of the stator, it experiences an oscillating lift and a repeating torque at the frequency passing through the nozzle. The blades are designed to avoid resonance at its steady operating speed of rotor, it is still resonant many times during turbine start-up and shutdown. This may result in downtime due to damaged blades. Vibration analysis of turbine blades has evolved from simple simulations analysis in this paper.

2. Theoretical Background

In the previous article, there are many different types of blades such as in the figure 1 in the steam turbine power plant [2]. This is the blade of the last stage mounted on the rotor it has parameters that change according to different positions and cross section of the blade such as aerofoil cross-section, camber, longitudinal taper and longitudinally varying thickness in figure 1 and figure 2.

It should also be noted that we chose this blade of the last stage because it has the most complex structure among the blades mounted on the rotor. These blades are longest and have a more complex structure than the others. So, there is a high possibility that it is very susceptible to oscillation when subjected to mechanical effects during turbine operation.

During its operation, the blade will be oscillated with different frequencies. Under certain conditions, if the natural frequency of the blade is equal to the frequency of the impacts, the blade will appear to have a resonance phenomenon and directly affect the endurance of the blade and possibly even destroying this blade.

Fig. 2 Steam turbine blade in a 300 MW steam turbine power plant

For more clearly, in the figure 2, The 3D model will be mentioned for an industrial steam turbine blade of a 300 MW steam turbine are highlighted, and this blade will be studied more deeply in materials, numerically simulated using finite elements methods

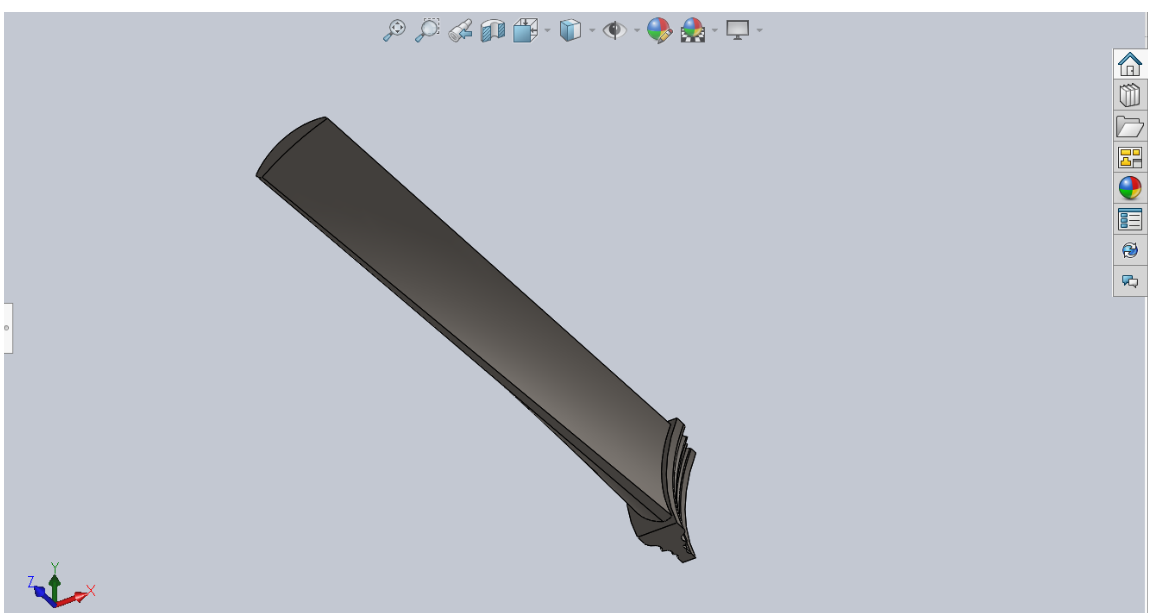


Fig. 2 Steam turbine blade in a 300 MW steam turbine power plant

The blades analysis for each low-pressure different stages [3] [4] [5] and a pair of eigenpairs were calculated for (i) a free-standing blade and (ii) blades with a lacing/string arrangement. The effect of running speed was estimated for different speed steps. The experimental values obtained for stationary cutting edges are compared with analytical values. The Southwell coefficient is inferred to predict the natural frequency at different running speeds from the calculated analytical values.
The Southwell coefficient is calculated from the equation bellow:

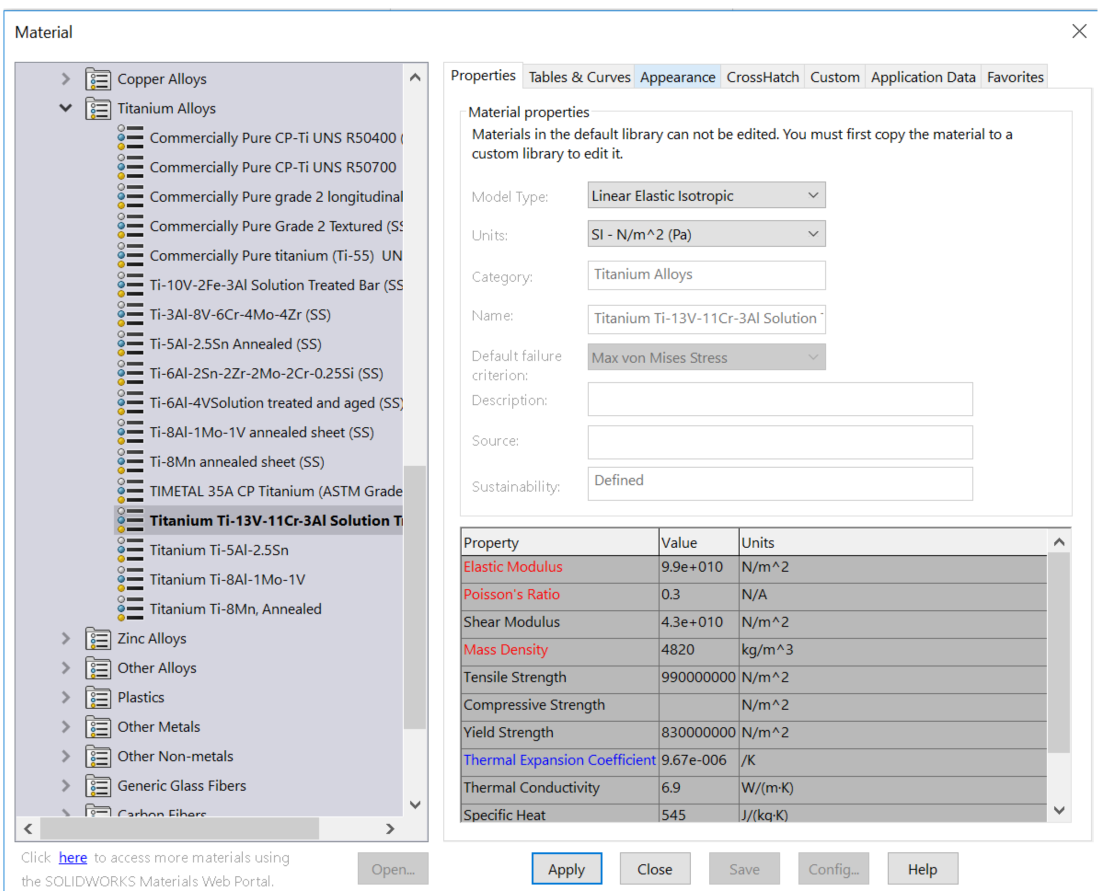
$$\omega^2 = \omega_0^2 + S\Omega^2$$

where ω is the natural frequency at the running speed,
ω_0 is the natural frequency at zero speed,
Ω is the running speed and S is the Southwell coefficient

3. Numerical simulation

3.1 Blade Material

The material properties of turbine blades are often overlooked in production, but they have a great influence on their performance as well as the durability of the blades during operation. The turbine's operating environment is resistant not only to high humidity and temperature, but also to the effects of forces as well as to the vibrations of the blades themselves. The similar blade material can be described as in Table 1 and this material Ti -13V-11 Cr – 3 Al will be studied for all numerical simulations in the paper.



Property	Value	Units
Elastic Modulus	9.9e+010	N/m^2
Poisson's Ratio	0.3	N/A
Shear Modulus	4.3e+010	N/m^2
Mass Density	4820	kg/m^3
Tensile Strength	990000000	N/m^2
Compressive Strength		N/m^2
Yield Strength	830000000	N/m^2
Thermal Expansion Coefficient	9.67e-006	/K
Thermal Conductivity	6.9	W/(m·K)
Specific Heat	545	J/(kg·K)

Tab. 1 The material of steam turbine blade in a 300 MW steam turbine power plant

The mesh is divided into 54392 nodes and 58695 block elements with engineering structural forms characterized, each of which is defined by a small number of reference points or nodes. Figure 3 represent the overall 3D finite element model of the blade.

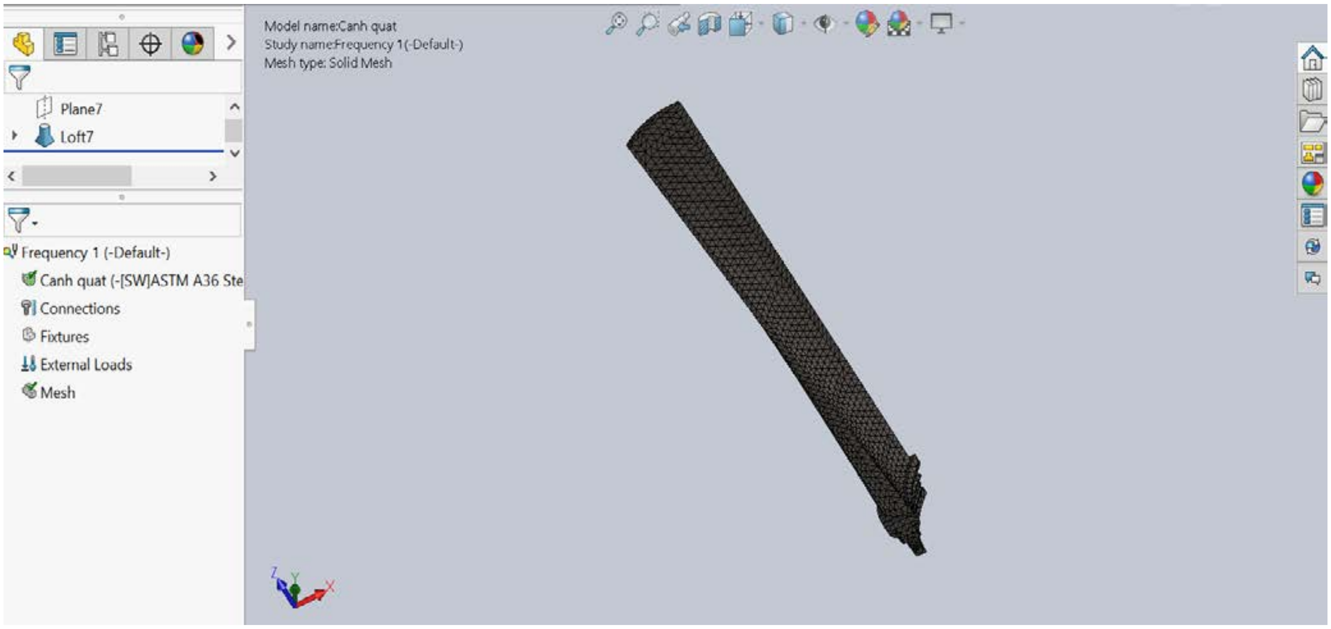


Fig. 3 The mesh of steam turbine blade in a 300 MW steam turbine power plant

For the geometric complexities, the condition of fixity at the end is not true in practice but the blade will be fixed which is connected to a flexible disc in the figure 4. The disc also contributes to the frequencies. The frequencies of the disc depend the geometry of the disc and the method of attachment to the drive shaft.

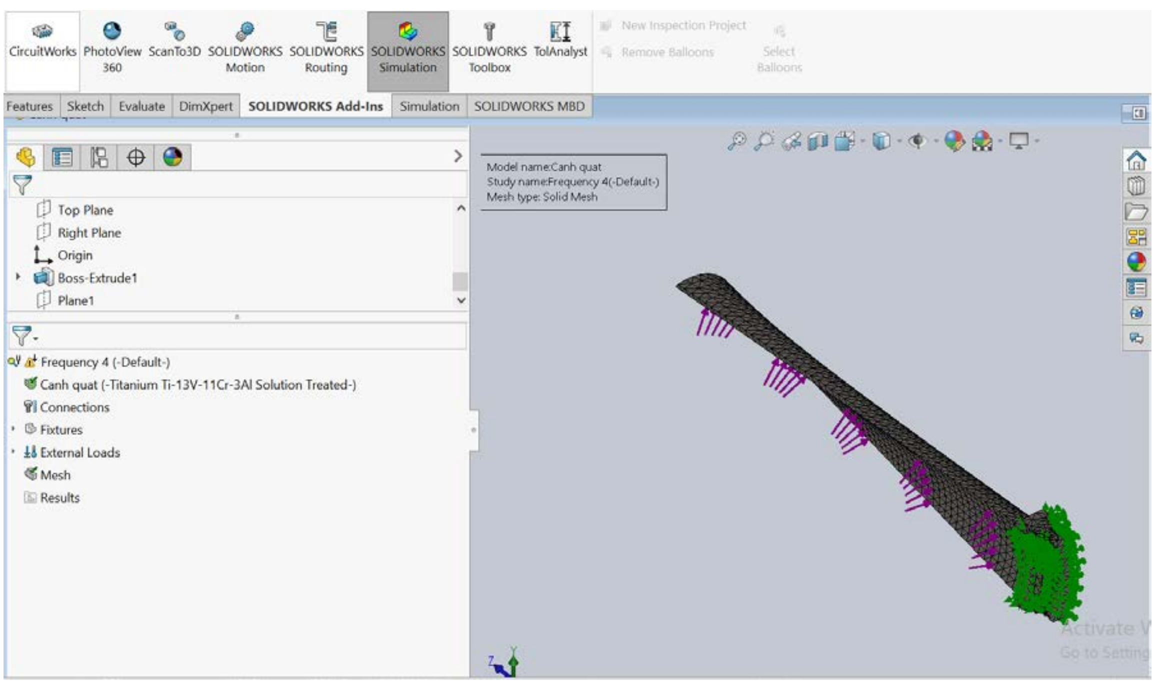


Fig. 4 The Steam turbine blade in a 300 MW steam turbine power plant

4. Results

The results show that the blade oscillates with a frequency that is not uniform across the entire blade surface, but depends on the position of the point on the wing. Analysis of resonant amplitude frequencies and corresponding eigenforms. The first eigenform corresponds to a frequency value of 47.832 Hz

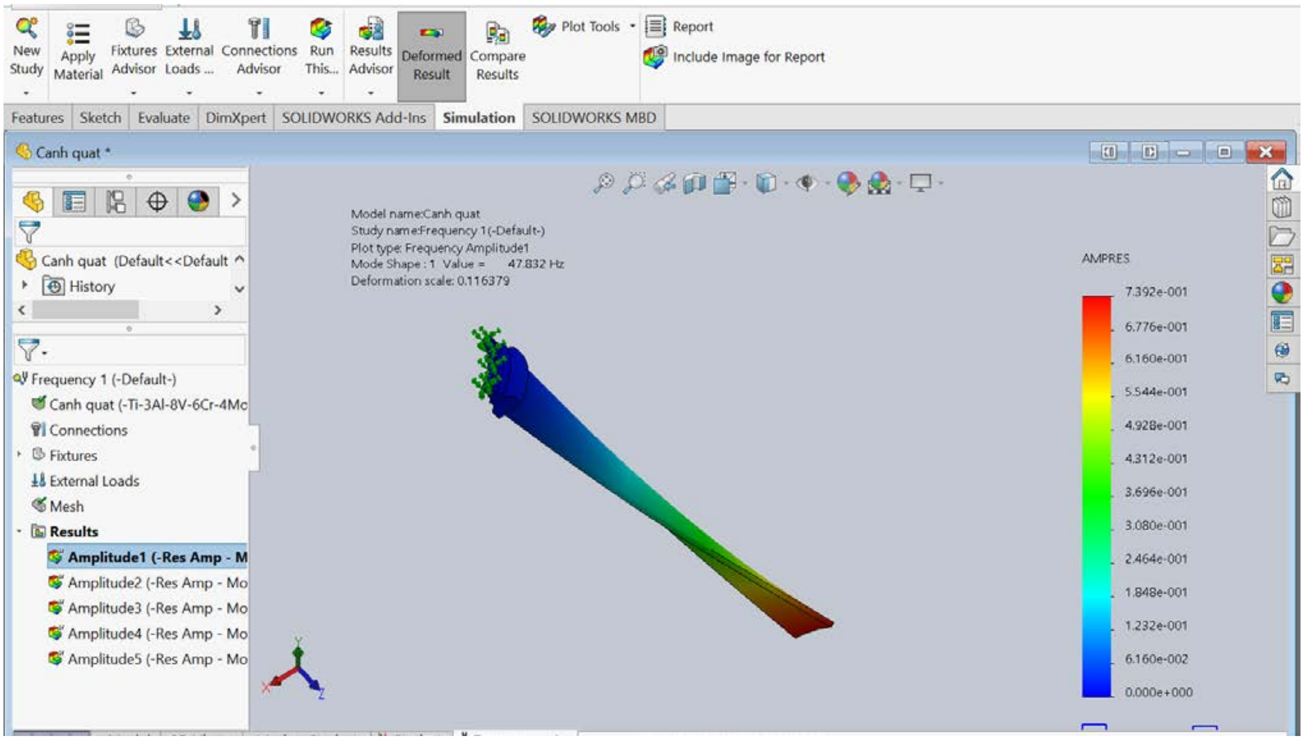


Fig. 5 The result of numerical simulation of the steam turbine blade in a 300 MW steam turbine power plant

5. Conclusions

The numerical simulation allows us to determine the natural frequency of the blade under the action of a given force. The natural frequencies of the blade–disc block at running speed is considerably reduced from the end to the top of blade. Low power amplitude at the root and maximum resonance capacity at the tip. The resonance amplitude is not the same over the entire blade surface but changes, the resonance amplitude gradually increases from the origin to the top of the blade. Based on the results of analysis of natural frequencies and resonances on the blades, it is possible to evaluate the durability of the current turbine blade material. If the resonance occurs on the entire blade, there is a risk of increasing the damage of the blade more thereby ensuring the uniformity of the material organization...Increasing the durability of the wing when in use.

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