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Vibration in Turbine Blades: Review of Techniques

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Abstract

In the present work a review on the vibrational analysis of turbine blades is present so that different techniques of blade vibration analysis may be compared. The value of natural frequency for any steam and turbine blade increases with the bending mode. At the root, blade is fixed, so the value of natural frequency at the root is low. As it proceeds from root to tip value, natural frequency increases. From the discussion presented in this work, it can be concluded that the variational method is a simple method, which yields good vibration characteristics. The results obtained by the variational approach are found very encouraging and this method can further be applied to more complex vibratory problems. Method of variational makes the base to find the natural frequency of beam vibrating in bending-bending mode. Further it is also observed that the values only for single value of breadth taper and depth taper. Researchers can observe the effect of breadth taper on natural frequency while keeping the depth taper constant. In the similar manner the effect of depth taper on natural frequency while keeping the breadth taper constant can be observed.

Keywords: blade, natural frequency, beam, vibration

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INTRODUCTION

Blades are vital part of the turbo machine either steam or gas turbine. Even the failure of a single blade may shut down the whole power generation plant and it, thus, may leads to a big economic loss in terms of power generation. [1–3] The cost of turbine based projects runs into millions of rupees and needs many months for completion even if expert labour is available. Any process that can reduce this expenditure of time, money and man hours is very much needed and it may be adoption of computational efforts also. [4–6] Thus, it has become essential to perform vibration analysis of the gas or steam turbine blade theoretically or computationally. Accurate prediction of the natural frequency of tapered blade is of considerable importance at the design stage of turbo machines to avoid any resonant conditions leading to the consequent failure of the blade due to fatigue while during their operation. [7–9]

Condition of resonance is due to matching in the blade natural frequency and excitation frequency. If these both the frequencies are resonating then their amplitude will increase. This leads to turbine blade failure. [10–13] The accurate prediction of natural frequency for the blade is helpful in calculating the conditions of its failure.[14–17] In the present work the mathematical models available in literature are discussed which are helpful in evaluation turbine blade natural frequency.

METHODS OF INVESTIGATION

The turbo machine blade geometry is quite complex which makes an exact investigation of the blade characteristics somewhat difficult. [18] It acts like a solid shaft and excitation from external source generates vibrations. It is the blade stiffness which acts against fluid kinetic energy.

Recent investigations indicate that the variational method has certain distinct advantages over the classical approaches of potential or complementary energy. In many papers, the variational method is successfully used to determine the vibration characteristics of cantilever blade. Cantilever structure is the simplest structural form of the blade. [19] The effects of shear deformation and rotary inertia have been included in many previous works. The variational method is found to be very novel theoretical process for evaluation natural frequencies. Ritz method is used to extremise the dynamic variational functional. Functional is the combination of many functions. [20] This method is simple and straightforward and has the distinct advantage that the all boundary conditions need not be satisfied.

The Variational Method has given good results for practically all problems treated computationally. It has also observed that there is no undue difficulty in handling the shear and rotary inertia effects in the variational method.[21] The blades were assumed to be standstill and the natural frequencies were obtained. In many works after developing the variational function Ritz method has been applied. Resulting equations are in the form of matrix. This matrix is solved with the help of computer program, which has been developed in the language FORTRAN. At present a lot of different softwares such as MATLAB are also available for expediting useful information from matrices. Differential equations of variational problem can be integrated only in exceptional cases. [21] It is therefore essential to find another method for solution of these problems. The idea underlying the so called direct method is to consider the variational problem as a limit problem for some problem of extreme of a function of finite number of variables. [22] This problem of extreme of a function of a finite number of variables is solved by usual methods, and then by a kind of limiting process the solution of the original variational problem is obtained.

Equation obtained after removing the effects other than flexure has been solved by assuming the shape functions of Subrahmanyam and the equation for the flexure has been solved by taking the shape function derived. For solving the equations Ritz method was used. The Eigen value problem defined is solved by developing a computer program in FORTRAN language and the natural frequencies of the first three modes of vibration for the Eigen value problem have been obtained.

The Program determines the value of determinant $|A+P^2 B|$, for an initial trial value of P. The value of the frequency is then incremented successively till a sign change occurs in the determinant. The actual natural frequency is then obtained by repeating the above procedure with halved intervals between the two limits, where the sign change initially occurred. In the program, the initial trial value is taken as the lower natural frequency available in the literature for the first mode of the pre-twisted blade and the accuracy in the natural frequency is set to 0.0001 times of the value.

Once a natural frequency is determined, the above procedure is repeated for the next higher mode natural frequency with the starting value of P as 1.01 times of the previous natural frequency. The following numerical data may use for checking the analysis, β=0.2, δ=p.4, $b_0=t_0=$ 6.35 mm; L=254 mm; ρ=7.8576×10–6 kg/mm^3, E=2.0685×1011 GPa. Results were obtained from the computer program for first three bending modes.

CONCLUSIONS

These results are presented almost in all literature in the graphical form as well as tabular form. These are concerned with blade natural frequencies. The first bending mode present method gives results 0.04% lesser than the Subrahmanyam’s results. For the second and third bending modes results are decreased by 0.00133% and 0.00789%, respectively. The value of natural frequency increases with the bending mode. At the root, blade is fixed, so the value of natural frequency at the root is low. As it proceed from root to tip value of natural frequency increases. In the graphs available in literature the values are plotted only for first three bending modes. Researchers can calculate values for higher modes also. Results obtained by two methods are discussed above. They are very close to each other. Secondly results obtained by variational method are less than the obtained by Subrahmanyam’s method. Though the results have been obtained only for first three bending modes, they can be obtained for higher modes also. Along with this, values can be represented in the graphical form by taking the different values of breadth taper and depth taper

Results are converged using computer program and compared with the available results. From the present discussion, it can be concluded that the variational method is a simple method, which yields good vibration characteristics. The results obtained by the Variational approach are found very encouraging and this method can further be applied to more complex vibratory problems.

Method of variational makes the base to find the natural frequency of beam vibrating in bending-bending mode. Further it is also observed that the values only for single value of breadth taper and depth taper. Researchers can observe the effect of breadth taper on natural frequency while keeping the depth taper constant. In the similar manner the effect of depth taper on natural frequency while keeping the breadth taper constant can be observed. These effects can be plotted in the form of graph for different modes.

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