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Effect of Material Behavior on Dynamic Characteristics Determination of Marine Propeller Blade Using Finite Element Analysis

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Abstract:

Natural frequency tuning is a vital problem in engineering. Every structure possesses its natural frequencies where vibrational loading at nearby frequencies excite the structure. This causes the structure to oscillate until energy is dissipated through friction or structural failure. A classical aspect of good structural design lies in optimising the stiffness to mass ratio through material, and shape. It may appear that natural frequencies can be manipulated as an afterthought. For more conventional structures, however, the roles of material, cross-section and boundary conditions are all comparatively small in allowing frequencies. This study of proposed work mainly focuses on the effect of material on the dynamic characteristics behaviour of marine propeller. Using appropriate finite element modelling desired simulation of the structure can be achieved to ensure a certain level of safety.

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Keywords: Finite element method;Modal analysis;Natural frequencies;Propeller blade.

1. Introduction

Accurate prediction of the natural frequency and mode shapes of marine propeller blade is of considerably important at the design stage. The blade geometry is quite complex and may have the pre twist, taper and asymmetry of the cross section and such blades are mounted on the periphery of rotating disc at stagger angle. The presence of

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taper in accordance with the effect of taper imposes maximum difficulties in determining the solution to the problem. Various researchers have derived solutions to the problem by considering individual aspects such as taper, pre twist, asymmetry of the cross section and centrifugal forces with making simplified assumptions about second order effects. The starting solution for a simple stationary blade is obtained from classical Euler-Bernoulli beam (1) with the cantilever boundary conditions for bending vibration and St Venants non-circular rod for torsion vibration(1,2).The solution of cantilever blade can be obtained by applying classical approach using simplified conditions for solving the differential equation of motion are Ward(3),Wrinch(4),Meyer(5) on tapered beams and Sutherland &Good man(6) on the effects of shear and rotary inertia. Power series of solution of blade natural frequencies have been obtained by Taylor[7] for the case of uniform and completely tapered beam.

Using the Galerkin method Rao (8) obtained the formula for the fundamental flexural frequency of a tapered cantilever beam with rectangular cross section. Considering the effect of pretwist on the blade Dunholter (9) considered the static displacements and natural frequencies of pre twisted beams. White (10) employed Greens functions to derive the conditions of orthogonally for a uniform pre twisted blade executing the bending vibrations. Diprima and Handle man (11) solved the equations of motion of a pre twisted cantilever blade by Rayleigh Ritz method to determine the frequencies and amplitude ratios. Carneige (12) described an experimental method to determine the centres of flexural and torsion of aerofoils cross sections. Houbolt &Brooks (13) derived the equation of motion for pre twisted a cantilever beam with asymmetrical aerofoils and suggested Rayleigh Ritz method for their solution.

Barten et al (14) used finite element method to study stationary thin blades. Ahamed et al (15) followed similar analysis for thick blades and this was extended to rotating blades by Bossak and Zeinkiwicz (16). The implementation of fiber reinforced composite materials to the application of blades continues to increase, since it is important to explore the potential benefits that can be designed into the physics of these materials. Vibration is often critical to the successful operation of engineering structures which are composed of composite materials for example propeller blades, helicopter rotor, wind turbine blades, automatic and aerospace panels. The first established work on pre twisted composite plates was carried out Qatu et al (17) to determine the natural frequencies of stationary plates using laminated shallow theory using Ritz method .Brig and Migliore (18) provided preliminary design method based on theory of Euler Bernoulli theory on layup structures and it was found that layup sequence which was obtained by this method did not meet the requirements of actual strength at the root area through analysing the finite element model. Ashwani Kumar (19) stated that Finite Element Analysis offers satisfactory results with additional ability to calculate regional mode and natural frequency with fracture locations during external loading condition. Free vibration analysis of laminated composite beams has been conducted by significant amount of research. Alejandro(20) proposed to analyse basic vibration mode of composite layup structure of wind turbine blades with the normal operating conditions by transforming complex geometric blade model into equivalent beam model using the VABS calculating program Liu Wang-yu (21) studied the influence of fiber angle of the layup blade on strength through the finite element model of the blade and combined the response surface methodology and results showed that when layup angle is near 45 it can get higher stability strength. Stacking sequence of a laminated cylindrical shell is optimized based on natural frequency by Shakeri et al (22). Yddorom & Koral (23)studied the out of plane free vibration problems of symmetric ply laminated beams using the transformation cross method Khedir &Reddy(24) have been studied free vibrations of cross ply laminated beams with arbitrary boundary conditions. Investigations on the natural frequency modes of graphite epoxy cantilever plate and shells was carried out by crawley(25) and the free vibrations of rotating composite plates was analysed by Wang(26) and Shaw(27). Most of these structural components can be approximated as laminated composite beams (28).

2. Material of the Blade

To evaluate the vibrational characteristics, the blade considered is varied with different materials both isotropic and orthotropic. The application of composite material as a replacement to isotropic lies in its potential for high strength to weight ratio and desirable properties can be achieved if these materials are tailored correctly in terms of its design parameters. In this paper alloy of aluminium, high tensile brass, composite materials of Carbon epoxy, and E-glass epoxy are investigated.