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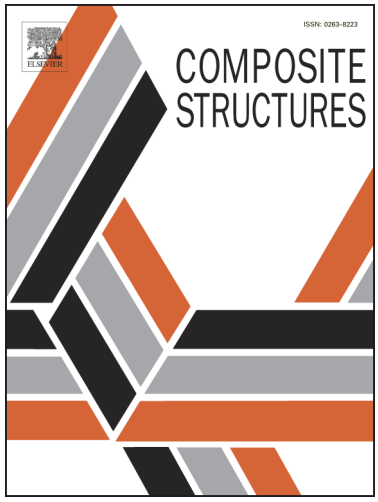


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PII: S0263-8223(17)30332-X
DOI: http://dx.doi.org/10.1016/j.compstruct.2017.01.078
Reference: COST 8212

To appear in: *Composite Structures*

Received Date: 24 July 2014
Revised Date: 28 January 2017
Accepted Date: 30 January 2017

Please cite this article as: De Paula Mendonça, W.R., De Medeiros, E.C., Pereira, A.L.R., Mathias, M.H., The dynamic analysis of rotors mounted on composite shafts with internal damping, *Composite Structures* (2017), doi: http://dx.doi.org/10.1016/j.compstruct.2017.01.078

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# The dynamic analysis of rotors mounted on composite shafts with internal damping

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**ABSTRACT**

*This paper presents a study on the dynamic analysis of rotors mounted on composite shafts. The dynamic analysis of these rotors differs from conventional analysis due to the existence of internal damping in the shaft. The shafts are made of composite materials, which exhibit viscoelastic behavior. The equations of motion for these rotors represent the influence of internal damping on the dynamic behavior of the rotor system. Composite materials can be manufactured using different layups. This study reviews the methodology that can be used to predict the equivalent mechanical properties of composite shafts. Several finite element simulations are presented to show the influence of the composite shaft layup on the dynamic behavior of the rotor. The simulation results are used to present the influence of the layup on Campbell diagrams, critical speeds, instability thresholds and frequency response functions.*

**Keywords:** critical speed; finite element; loss factor; viscoelastic; damping; classical laminate theory

## 1. Introduction

Recent decades have seen the increasing use of composite materials in engineering applications. Among these materials, carbon fiber composites have been used in the naval, military, aerospace and automotive industries [1, 2]. This increase is due to their excellent mechanical properties, such as high strength-to-weight ratios, very high ratios of the modulus of elasticity to weight, high fatigue strength [3], light weight, good corrosion resistance and very low coefficients of thermal expansion. Some of these properties are highly relevant to the development of rotating machinery, especially for rotor shafts under fatigue and high torque [3]. Several studies have used composite materials to improve the efficiency of rotating machinery [4, 5]. Some current applications include drive shafts in helicopters, ships and cars [6-8].

The design of rotor axes or other structures, such as helicopters blades and wind turbine rotors, need to be carefully design because to high levels of oscillatory loads [9]. The designer can optimize the structure by adjusting the mechanical properties of the composite material through the choice of an appropriate layup. These properties affect the dynamic behavior of the rotor by changing the natural frequency and, consequently, the critical speed and instability threshold [10].

Carbon fiber composites are classified as viscoelastic materials, which have high internal damping compared to metallic materials. The existence of this damping, turns the prediction of natural frequencies difficult instead of using static stiffness [11]. In a rotor system, the presence of damping from an external source, such as certain types of bearings, is beneficial because damping promotes stability [12]. The opposite situation occurs when the damping occurs in the rotor shaft. Although shaft damping may reduce the vibration amplitude at subcritical speeds, instability often occurs in the rotor

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