Semi-analytic solutions for the bending-bending-torsion coupled forced vibrations of a rotating wind turbine blade by means of Green's functions

X. Zhao[*], X. Jiang[*], Y.H. Li [**], W.D. Zhu[***]

[*]*School of Civil Engineering and Architecture, Southwest Petroleum University, Chengdu,Sichuan, PR China*

[**]*School of Mechanics and Engineering, Southwest Jiaotong University, Chengdu,Sichuan, PR China*

[***]*Department of Mechanical Engineering, University of Maryland, Baltimore County, Baltimore, USA*

Abstract. In recent years, wind power has received continuous attention as a renewable energy source in the context of carbon neutrality. A blade in wind turbine with an elongated structure are susceptible to damage due to aeroelastic instability. The basic solution of the system is derived by Laplace transformation and Green's function method, and then the system of second category of Fredholm integral equations about steady-state forced vibration of the blade can be derived according to the principle of superposition. The second type of Fredholm integral equation system is discretized numerically, and finally a semi-analytical solution of the coupled forced vibration of rotating wind turbine blades is obtained. By comparing the solution in this paper with the solution of the finite element method, the effectiveness of the solutions is verified. The results show that the inflow ratio at the hub has a great influence on the blade's flag displacement.

Introduction

Blades are the main force-bearing parts and the most vulnerable components, so studying the multi-modal coupling vibration of blades has practical engineering significance. Based on the finite element method, Park et al.[1] studied the modal characteristics of rotating blades and proposed a calculation algorithm for solving the modal characteristics. Luczak et al.[2] updated his finite element model through experimental data, and the new model obtained can effectively calculate the vibration characteristics of the blade. As an effective tool, various forced vibration problems are studied through Green's function. Zhao et al.[3] studied the bend-torsional coupling forced vibration of the piezoelectric energy harvester , and derived the closed solution of the piezoelectric energy harvester subjected to the fluid vortex by the Green's function.

Although previous works have given some important results in engineering applications, most of the previous research methods are finite element method, and compared with analysis methods, the main disadvantage of finite element method is that parametric analysis is inconvenient and inaccurate. The Green's function of a linear vibration system represents the fundamental solution of the system, and through the principle of superposition, we can derive the solution of the system under arbitrary external loads.

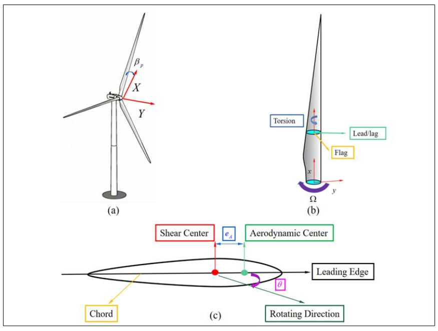

Figure 1: Schematic diagrams of (a) wind turbine, (b) blade and (c) blade section.

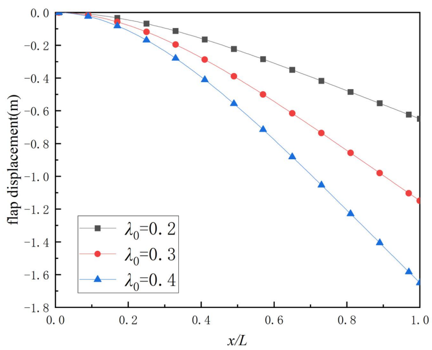

Figure 2: Effect of the inflow ratio at hub.

Results and discussion

Figure 1 shows the vibration of a rotating wind turbine blade in three directions (flap vibration, lead/lag vibration and torsional vibration) and a schematic diagram of the blade cross-section.In this paper, the semi-analytical solution of the coupled forced vibration of rotating wind turbine blades is obtained by using the Green function method, and some meaningful results are obtained.

It can be seen from Figure 2 that the inflow ratio size can change the flag displacement of blade, therefore, the inflow ratio at the hub is an important parameter to study the dynamic response of a rotating wind turbine blade.

References

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