Modeling of Material Bend-Twist Coupling on Wind Turbine blades

Tohid. Bagherpour, X.M. Li, D.I. Manolas, V.A. Riziotis

PII: S0263-8223(17)33717-0
DOI: https://doi.org/10.1016/j.compstruct.2018.03.071
Reference: COST 9518

To appear in: *Composite Structures*

Received Date: 8 November 2017
Revised Date: 7 February 2018
Accepted Date: 20 March 2018

Modeling of Material Bend-Twist Coupling on Wind Turbine blades

Tohid. Bagherpour[a,*], X.M. Li[a], D. I. Manolas[b], V. A. Riziotis[b]

[a] *Huazhong University of Science & Technology, 1037 Luoyu Road, Hongshan District, Wuhan 430074,China*

[b] *School of Mechanical Engineering, National Technical University of Athens, 9 Heroon Polytechneiou Street, GR15780 Athens, Greece*

Abstract

Material bend-twist coupling (BTC) as a mean to passively alleviate wind turbine blade loads is assessed. It is accomplished by introducing an offset angle on the plies of the uni-directional material over the spar caps of the blade. At first, the ability of the multibody, FEM, aeroelastic tool hGAST to consistently predict deflections of BTC beam structures is proved through comparisons against existing measured data and numerical predictions. Next, the effect of the plies offset angle and the spanwise position wherefrom offset of the plies starts on maximum attainable tip torsion deflection is assessed. Bend-twist coupling coefficient distributions along the blade span are generated and associated with the corresponding ply offset angles. Finally, the potential of the material BTC method to alleviate blade loads is demonstrated through aeroelastic analyses based on IEC design load cases. Blade root flapwise bending fatigue (7-10%) and ultimate (6-8%) load reduction is possible by means of moderate ply offset angles of 9^o-12.5^o.

Keywords: wind turbine, material bend twist coupling, load alleviation, aeroelasticity

1. Introduction

Over the last 25 years, wind turbine (WT) blades have undergone a significant increase in size while at the same time levelized cost of energy (LCOE) produced by the wind has decreased. The technical barriers related with the up-scaling of commercial wind turbines from the size of 500 kW in the early 90's, to the size of 5-7 MW today are overcome through the continuous upgrading in manufacturing techniques, material technologies and simulations methods [1]. In particular, the development of advanced design and analysis tools helped a lot in elucidating several not well understood aerodynamic and dynamic phenomena [2] and thus served reduction of conservatism in newer and bigger designs. In recent years, the design and implementation of advanced control strategies [3] that actively control loading on the turbines (e.g individual pitch control for tower and blade loads mitigation) gave a great boost to the development of very large rotors (>5 MW) for offshore applications.

In order to achieve the vision of the 20 MW turbine that has been set as target by the scientific community through several research projects launched over the last few years [4], [5], technological breakthroughs and innovative turbine concepts will be needed that combine new advanced materials, hybrid manufacturing methods, new inner structure designs beyond the standard spar concept, new high performance thick airfoils and active or passive aeroelastic control techniques. Among the above, passive control methods have been proved very efficient in reducing loads [6], [7]. Such passive methods for controlling loads have been described by the wind scientific community through the term "Aeroelastic Tailoring (AT)". Aeroelastic Tailoring (AT) is a design technique through which geometric or stiffness properties of a structure are matched with its aerodynamic characteristics in such a way that overall structural loads are reduced. In wind turbines engineering AT appears as a passive control design option either based on Bend-Twist-Coupling (BTC) or Flap-Edge-Coupling (FEC). The term BTC describes the behavior of a structure which has been designed to undergo torsion deformation under the action of bending loads [8]. The resulting change in sectional angle will affect the aerodynamic loading through a change in the angle of attack. Modern approach to BTC is to twist the blade sections towards decreasing the angle of attack, which corresponds to the so-called twist-to-feather concept. This method has demonstrated significant fatigue damage reduction potential.

(*) corresponding author- t.bagherpour@uoz.ac.ir