Improving rotor stability through direct piezoelectric effect

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Abstract. The aeroelastic instability known as whirl-flutter becomes very relevant to development of the next generation of propeller-driven aircraft, influencing specially the design of wings, nacelle and rotor. Although this instability is classically treated as linear, all aeronautical structures may present a certain level of nonlinearity that can be predicted in the project or can arise during operational life, affecting the aircraft's performance and reliability directly. Thus, the development of techniques to increase stability margins in the presence of some type of nonlinearity becomes important in the current aeronautical scenario. So, the present research sought the application of piezoelectris passively, together with a structural cubic hardening nonlinearity in the mounting of a rotor system. Possible results includes extension of useful speed range and limited amplitude oscillations after the instability speed, with direct influence of piezoelectric effects in amplitude reduction.

Introduction

The optimal relationship between performance and safety in aircraft is fundamental when aeroelastic solutions are sought. Although nonlinearities are neglected in several problems, the system's behavior may be highly affected when they arise in aeronautical structures leading to dangerous situation. Corrective solutions to mitigate undesirable nonlinear effects and understanding how they affect system's behavior becomes important [1]. In addition, apparently overcome problems arise in the present due to modern air mobility. The whirl-flutter, which is characterized as a divergent elliptic precession movement that occurs in the rotor due to non-stationary forces and moments [2], can be harmful and influence the design of the new generation of propeller aircraft, and therefore, needs special attention.

Although, techniques to control this instability are explored, the piezoelectric investigation to this propose and energy harvesting remains underinvestigated, specially when structural nonlinearities are considered.

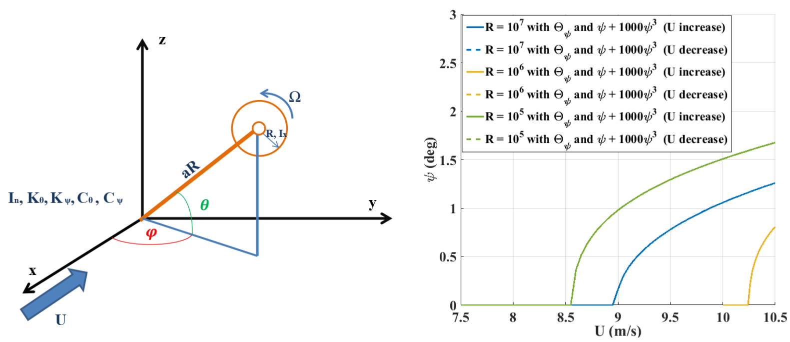

Figure 1: (a) At the left, rotor-nacelle system representation submitted to whirl-flutter. (b) At the right, yaw response for different load resistances.

Results and Discussion

In order to observe nonlinear-piezo-aeroelastic model's behavior submitted to whirl-flutter, a two degree-of-freedom rotor-nacelle model, considering a quasi-stationary aerodynamics [3], shown in Fig. 1a, was modified including both piezoelectric approach described by [4] and the structural hardening nonlinearity. Preliminary results have shown that the nonlinearity in the yaw degree of freedom provides a limit cycle oscillation (LCO) in the post-flutter regime. The presence of an *unimorph* configuration piezoelectric in yaw postponed the critical speed, meaning that the Hopf bifurcation occurred at different speeds with a subcritical behavior depending on the load resistance, as depict Fig. 1b. In the final paper, both configurations, *unimorph* and *bimorph* will be considered in pitch and yaw degrees of freedom.

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