# Phenomenological model for stability analysis of bladed rotor-to-stator contacts

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Long Abstract

## Introduction

The performances and operability of turbomachines are greatly improved by reducing the clearance between rotating blades and the casing; however, these improvements come along with an increase of the possible contacts between the rotating and stationary parts, which can cause unstable dynamic behavior. A better understanding of the outbreak of these unstable phenomena is of a great interest for aero-engine engineers. The present work focuses on the dynamic stability of a turbofan engine submitted to light contacts between the fan blade tips and the surrounding casing.

## 1. Methods

The approach is based on a hybrid model which introduces a simplified bladed wheel and a suspended casing to a rotor-shaft model (see Figure 1).

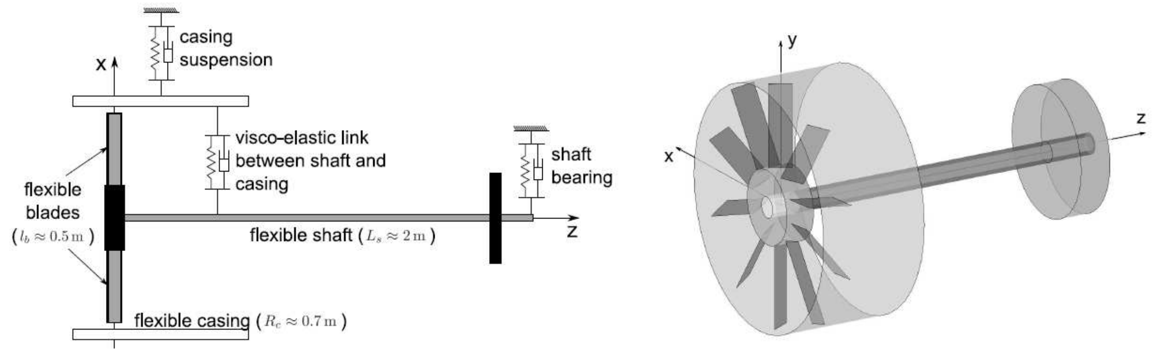


**Figure 1.** Model global architecture and 3D visualization

The bladed shaft formulation (based on the work of Sinha [1], Lesaffre [2] and Gruin [3]) introduces an inertial coupling between blades and shaft deflexion. The casing is modeled by an inextensible elastic ring (as in [2]). It also contains rigid body dofs contributed by its suspension. An elastic link between these suspension dofs and the facing shaft cross-section is introduced to describe the coupling brought by the fan frame struts and the first bearings of the turbofan engine. Thus, the phenomenological model, which contains less than 40 dofs, presents fully coupled modeshapes involving shaft, blades and casing.

In order to compensate the approximations brought by the phenomenological model, a 3D contact formulation was implemented to recover accuracy in the contact detection. As showed in Figure 2, this formulation introduces the geometry of the contact area by considering the leading and trailing edge 3D position at blade tip and the inclination of the inner surface of the casing. The clearance is then calculated taking into account the 3D kinematic of the model: disk and casing translations and rotations, casing normal deformation and blade deflexion.

The contact forces obtained with the penalty method are then integrated along the chord line to be projected onto the general coordinates. The friction force is introduced with Coulomb's law.

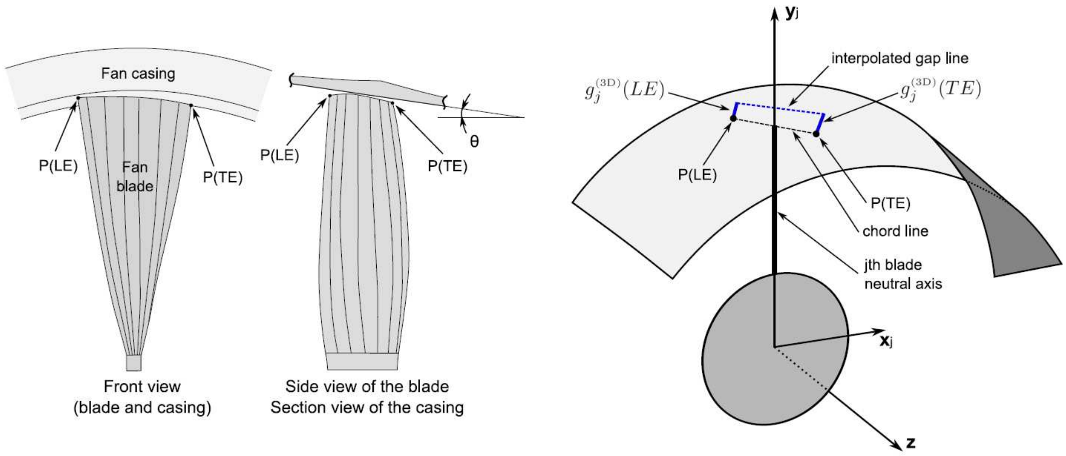


**Figure 2.** Geometry of the contact region and 3D view of the clearance values interpolated along the chord line

The unbalance response with blade-to-casing contact is analyzed through two approaches: the first one assumes permanent contacts and performs stability analysis on the static equilibria encountered in the rotating frame. The second one allows contact intermittence through transient analyses performed by the use of the explicit central differences scheme.

## 2. Results

The results highlight the relevance of the 3D contact formulation in predicting the stability of the system and the coupling influences in the trigger of unstable phenomena.
A good agreement is obtained between the "static" and transient results. The stability status obtained with the permanent contact approach, are confirmed by the transient simulations performed near the transition stable-unstable. More quantitative agreement is also observed: the unstable frequencies identified by the permanent contact approach confirm the spectral content of the transient signal obtained under the same conditions.
Finally, the transient simulations allow us to observe the trajectories of the disk and casing gravity center during the instability appearance. The trajectories are strongly affected by the shaft-casing elastic link and the blades and casing flexibility: leading to unusual orientations and even to an inversion of the directions during the transient simulation.

## References


[1] S.K. Sinha, Dynamic characteristics of a flexible bladed-rotor with coulomb damping due to tip-rub. *Journal of Sound and Vibration*, 273:875–919, 2004.

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[3] M. Gruin, F. Thouverez, L. Blanc. Nonlinear dynamics of a bladed dual shaft. *European Journal of Computational Mechanics*, 20:207-225, 2011