

Research Topic for the Arts et Métiers ParisTech - CSC PhD Program

A systematic approach for cracked rotating shaft analysis

Subfield: Applied solid mechanics, Structural analysis, nonlinear dynamics, vibrations, Finite Element Method, stability analysis

ParisTech School: Arts et Métiers ParisTech

Title: *A systematic approach for cracked rotating shaft analysis: breathing mechanism, dynamics and instability*

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Short description of possible research topics for a PhD:

Because of the increasing need of energy, the plants installed by electricity supply utilities throughout the world are becoming larger and more highly stressed. Thus, the risk of turbogenerator shaft cracking is increasing also. The development and propagation of a crack represents the most common and trivial beginning of integrity losses in engineering structures. For rotating shafts, a propagating fatigue crack can have detrimental effects on the reliability of a process or utility plant where these vital parts are subjected to very arduous working conditions in harsh environment. It is one of the most serious causes of accidents and, an early warning is essential to extend the durability and increase the reliability of these machines. The vibration analysis and modeling of the shaft and cracks are necessary for a reliable identification of the crack location and depth to avoid catastrophic failures. In fact, cracks can develop and propagate to relevant depths without affecting consistently the normal operating conditions of the shaft. Another feature related to the problem of modeling cracked rotating shafts is the consideration of the opening-closing phenomenon of the crack during the shaft rotation.

We recently have presented a systematic approach in dealing with the problem of modelling cracked rotating shafts. The breathing mechanism identification is the crucial step in the process and has been made with the greatest care. The approach presented is original and its implementation in industrial context is straight forward. To make this approach generic, we have opted for the identification of a dimensionless flexibility so that it can be used in similar configuration. We have presented a good polynomial approximation of the flexibility for the case of cracks with rectilinear tip. This will avoid further three-dimensional computations for scientists or engineers who will have adopted this comprehensive approach. Once the additional flexibility due to the crack identified, we have introduced it in a 2 dof dynamical system of a De Laval rotor with a breathing crack at midspan. All the known features related to cracked rotors have been observed. We have observed the superharmonic resonance phenomena when the machine is operated at an entire division of the first critical frequency. Also, we have found that the increase of the vibrational levels of the first and second superharmonics accompanied by the growth of static deflection is reliable indicators of a propagating crack.

Additional work is required for deeper exploration of the proposed model to examine more realistic cracking cases in industrial context. The objective, based on previous development we have recently proposed, is to build a finite element of cracked rotor to be use to explore the problem of multiple cracks affecting the same shaft and to suggest an analysis methodology.

Required background of the student: Solid Mechanics, Physics, Applied Mathematics,

2-3 representative publications of the group:

[1] S. El Arem, Q.S. Nguyen : Nonlinear dynamics of a rotating shaft with a breathing crack, Annals of Solid and Structural Mechanics, Volume 3, Issue 1-2, pp 1-14, June 2012.

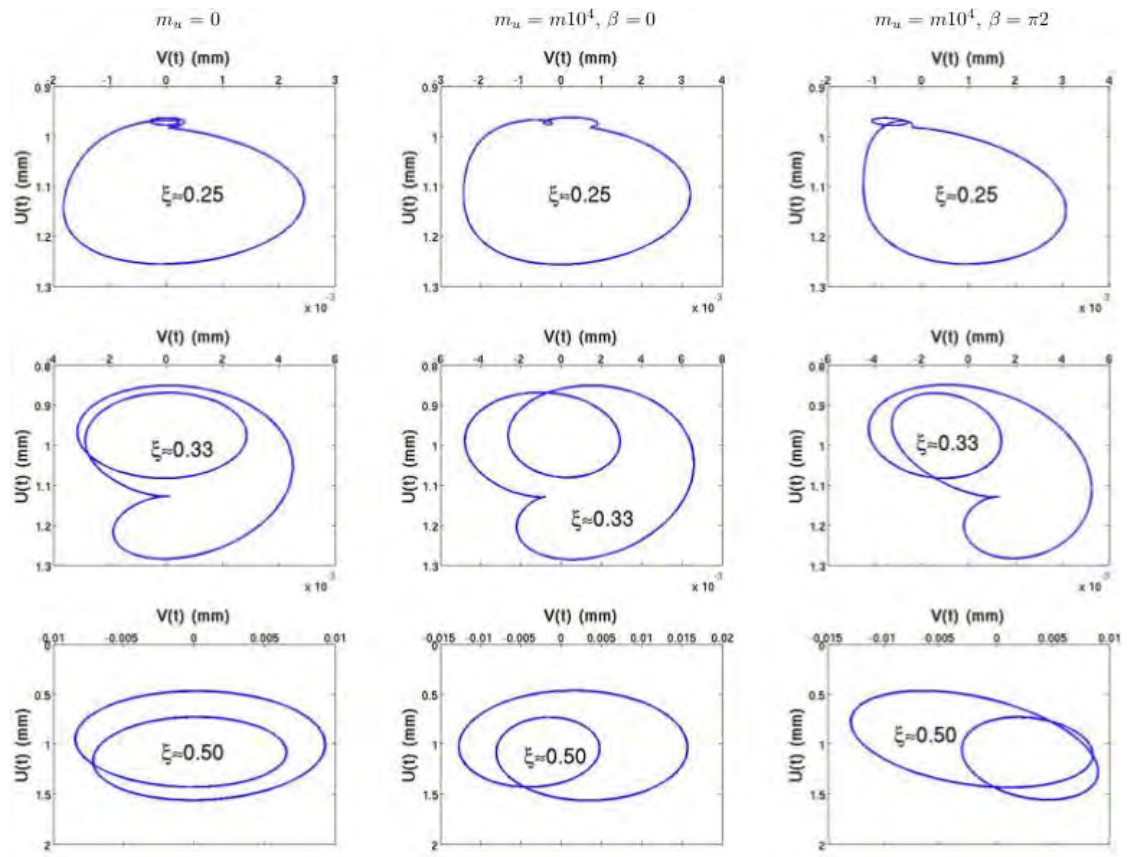
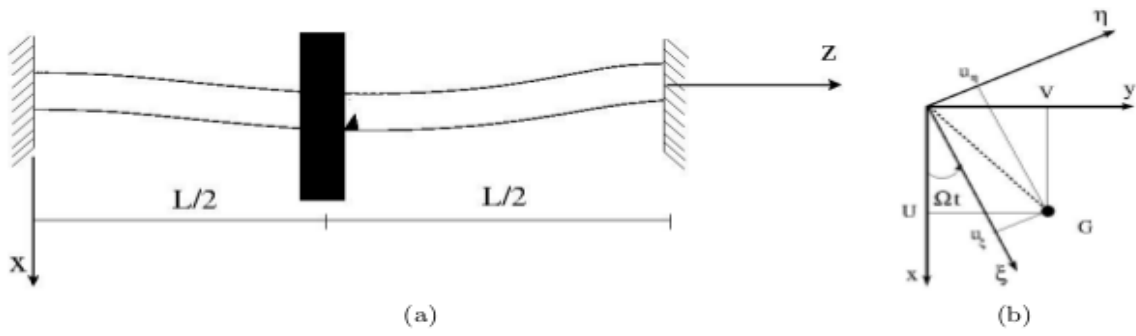
[2] S. El Arem : "Shearing effects on the breathing mechanism of a cracked beam section in bi-axial flexure", European Journal of Mechanics/Solids, Vol. 28, P. 1079-1087, 2009.

[3] S. El Arem, H. Maitournam : "A new cracked beam finite element : application to rotating shaft dynamics and stability analysis", Journal of Mechanics of Materials and Structures, Vol. 3, No. 5, P. 893-910, 2008.

[4] S. El Arem, H. Maitournam : "A cracked beam finite element : application to rotors dynamics", European Journal of Computational Mechanics, Vol. 16, No. 5, P. 643-663, 2007.

FOR APPLICATION, PLEASE CONTACT ADVISOR(S) BY EMAIL WITH COPY TO:

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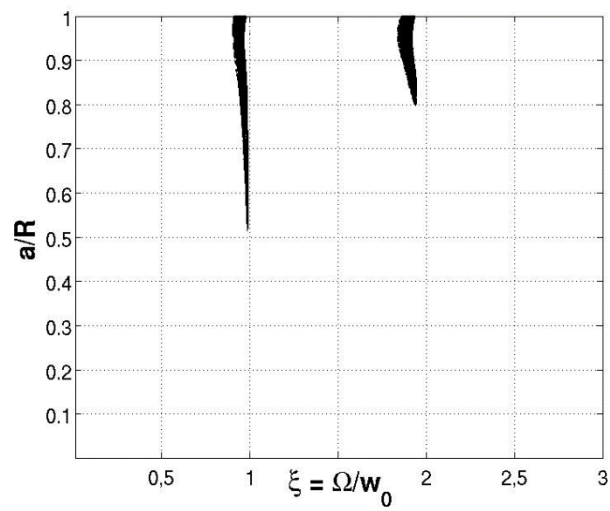


Figure: System, Orbits, stability