Université Gustave Eiffel

MSME

LABORATOIRE MODÉLISATION ET SIMULATION MULTI ÉCHELLE

Sous la co-tutelle de :
CNRS
UNIVERSITÉ GUSTAVE EIFFEL
UPEC • UNIVERSITÉ PARIS-EST CRÉTEIL

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COMPUTATIONAL NONLINEAR DYNAMICS AND MACHINE LEARNING IN THE FIELD OF NEW ENGINE TECHNOLOGIES FOR PLANE PROPELLERS.

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Doctoral School: Paris-Est Sup, ED SIE Sciences Ingénierie et Environnement
https://www.paris-est-sup.fr

Conditions: 3 years CDD. Thesis from October 2023 until September 2026. Doctoral contract (3 years contract from 2100 euros brut in 1st year until 2300 euros brut in 3rd year) + teaching possibilities

General context: The laboratory has a recognized expertise concerning several aspects related to the dynamical behavior or turbine bladed-disks, whether it be at the level of geometrical nonlinearities modelling [1], justified by new technologies involving slender blades with smaller and smaller section; or at the level of the mistuning modelling [2,1] justified by the uncontrolled deviations at the geometric and material level; or at the level of detuning optimization [3,4] that allows for inhibiting the existing amplifications induced by the mistuning phenomenon.

Sustainable development and reduction of environmental impacts requires lighter structures and optimization of multi-layer composite materials to optimize performances. Not only geometrical nonlinearities have to be considered but also the nonlinear aspects of viscoelastic with memory materials must be integrated in the models. There is a solid background in the team about the subject and the proposed Phd thesis is in line with this research.

Program of the thesis: The objective of the thesis is to propose a computational methodology and a new computational tool for analyzing and optimizing the nonlinear behavior of mistuned rotating turbine bladed disks that are made with viscoelastic with memory materials (see [5] for the general theory and [6] for its implementation in a linear context).

The program will focus on the following.
The first step consists in appropriating the physical aspects related to the turbomachinery context and the necessary numerical tools that allows for analyzing its dynamical behavior.
In a second step, a numerical model will be developed based on the existing theory. This will be devoted to the construction of a nominal reduced-order model (NL-ROM) issued from the full nonlinear boundary value problem of a deterministic detuned rotating structure made up with a nonlinear viscoelastic with memory material and that undergoes finite displacements. Such NL-ROM will be formulated in the time domain and in the context of the forced response analysis. The numerical developments allowing for the construction of the time dependent reduced operators will be constructed with the finite element method in a 3D context and will be integrated in an existing code in MATLAB. In addition, algorithmic extensions will be necessary to solve the nonlinear equations regarding the dependence of the operators to the preceding time steps. Existing finite element codes (MSC NASTRAN) will be used to validate these new extensions.
A third step will concern the validation of those developments by using a representative industrial numerical model, which will have to be numerically optimized regarding the dimension of its reduced-order model, the random aspects related to the mistuning that will be suitable for intensive numerical simulation in the goal to obtain several detuning configurations that will be considered as a training set. Comparisons will be established to analyze the effects of the viscoelastic with memory material.

The last step of the PhD concerns the formulation of the inverse problem of detuning optimization. Its resolution will require the use of machine learning tools [7] to find the best detuning configuration in a feasible numerical context.

Profile and skills required:

University-level college with competitive entrance examinations, University Master 2 in computational mechanics or in numerical analysis.
The proposed PhD is computational and requires advanced numerical modelling skills.
Skills required in numerical analysis including big data, finite element modeling, computational mechanics. A good knowledge of MATLAB is also required. A strong taste for modelling and intensive numerical simulation is also asked.

References:

[1] Capiez-Lernout, E., Soize, C. and Mbaye, M., *Mistuning analysis and uncertainty quantification of an industrial bladed disk with geometrical nonlinearity*, Journal of Sound and Vibration, 356, 124-143, 2015.

[2] Soize, C. *A nonparametric model of random uncertainties for reduced matrix models in structural dynamics,* Probabilistic Engineering Mechanics, Elsevier, 2000, 15 (3), pp.277-294. ⟨10.1016/S0266-8920(99)00028-4⟩

[3] Picou, A., Capiez-Lernout, E., Soize, C. and Mbaye, M., *Robust dynamic analysis of detuned-mistuned rotating bladed disks with geometric nonlinearities*, Computational Mechanics, Springer Verlag, 2020, 65 (3), pp.711-730, DOI 10.1007/s00466-019-01790-4.

[4] Capiez-Lernout, E., and Soize, C., *Nonlinear stochastic dynamics of detuned bladed disks with uncertain mistuning and detuning optimization using a probabilistic machine learning tool*, International Journal of Nonlinear Mechanics, 143 (2022).

[5] Capillon, R. and Desceliers, C. and Soize, C., *Uncertainty quantification in computational linear structural dynamics for viscoelastic composite structures,* Computer Methods in Applied Mechanics and Engineering, Elsevier, 2016, 305, pp.154-172.

[6] Desceliers, C. and Soize, C., *Non-linear viscoelastodynamic equations of three-dimensional rotating structures in finite displacement and finite element discretization*, International Journal of Non-Linear Mechanics, Elsevier, 2004, 39 (3), pp.343-368.

[7] Soize, C. and Ghanem, R. *Probabilistic learning on manifolds (PLoM) with partition*, International Journal for Numerical Methods in Engineering, doi: 10.1002/nme.6856, 123(1), 268-290 (2022).

Practical informations

The statutory working time is 35 hours per week, 5 days works, 7 hours per day.
5 weeks of vacations per year

Concerning the lodging for the international residence, the link is the following.
https://www.uxco.com/fr/logement-etudiant/champs-sur-marne/
There is also another residence on the campus
https://campus.youfirst.co/fr/residences/residence-etudiante-paris-cite-descartes
The cost is about 630-640 euros per month. Is included in the price the electricity, the heating, the wi-fi

A PhD student has a student status at the University, it means that there are about 470 euros of fees per year.

The University offers an academic sport formation which means that there is a consequent sport equipment that is accessible for free to every student of the campus.