Title of the project :
Rotating bladed disk vibratory reduction with piezoelectric elements

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1 Contexte

The society is currently facing the paradox of an ever more interconnecting world and its need to decrease the pollution to protect the environment. In this context, European authorities have defined specific goals for aeronautical companies. In the short-term planning, they must decrease carbon emission and noise pollution. The proposed work is in line with the ecological goals and aims to be a pioneer for the 2050 target, which is carbon neutrality. These formidable challenges require a new vision of designing airplanes engines.

Engines vibrations are one of the main cause for noise pollution and system failure. Understanding and mitigating these vibrations allows decreasing the consumption of primary resources. Several strategies have been developed throughout the years to decrease the vibration level. For bladed disk systems, a mechanical passive approach is usually employed: small mechanical parts (underplatform dampers or friction rings for instance) are inserted into the main system to decrease the energy by friction. These approaches are cheap and barely invasive. However, they may be inefficient for some mode shapes of the structure: some modes may create a relative displacement at the contact interface which is more or less prone to dissipation. Besides, predicting the vibration reduction requires complex nonlinear static and dynamic computation.

An interesting alternative approach consists in using piezoelectric patches to convert mechanical energy into electric one. By connecting the system to a well-designed electrical circuits (shunt), the vibratory energy can be dissipated. This approach is becoming widely used in the scientific community and is often used to create metamaterials whose properties can not be realized currently with standard mechanical systems.

2 Description of the project

2.1 Goals

The main purpose of this work is to reduce the vibration levels of a rotating bladed disk system through piezoelectric patches and thus to create a highly damped metarotor. Piezoelectric patches can be connected to synthetic impedances to virtually realize any electrical circuits or mechanical components. Three approaches will be investigated during this project. Each one of them presents orginal features and can be subject to journal publications.

1. First a shunt approach will be investigated. A synthetic impedance mimicking an electrical circuit targeting a specific mode will be implemented. This strategy is well known but has never been realized on a rotating bladed disk system.

2. A second approach consisting of virtual acoustic black hole will be investigated. While the shunt strategy targets specific modes, the acoustic black hole is efficient starting from a cut-on frequency. Its reduction capacities is thus very interesting. However, its experimental implementation remains challenging and instabilities may arise.

3. Bladed disk structures are usually modeled as cyclic symmetric systems. However, this mathematical property breaks when mistuning (blades may be slightly different from one another due to manufacture tolerance or wear) is taken into account. Mistuning usually has the negative impact of increasing the vibration level due to the localization phenomena. The third proposed approach consists in implementing into the piezoelectric elements a control pattern to retune the structure and thus to optimize its vibration level.

This project will use the three main components of any scientific approach: theoretical (20%), numerical (40%), and experimental (40%).

2.2 State of the art

The shunt approach was initially proposed by Hagood and Flotow [1]. Since then, it has been widely used [2, 3]. One of the main challenges of such a strategy is the high inductance values required to target low frequency modes. To remedy this issue, Flemming et al. [4] proposed the idea of a synthetic impedance: the electrodes of the piezoelectric patches are connected to a digital circuit modeling any control law. This strategy offers countless of possibilities [5, 6, 7], such as nonlinear digital vibrations absorbers [8] or rainbow trapping devices [9].

For the shunt approach, different works have managed vibration reduction for a non-rotating structure [10] numerically, and [11] experimentally. Virtual acoustic black holes have already been implemented for the beam case [12]. For these first two approaches, the strategy to define the control law has already been defined.

3 Associated research team

The candidate will join the Complex Systems Dynamics team (DYSCO) at Ecole Centrale de Lyon. The person will be supervised by Samuel Quaegebeur (junior professor at Ecole Centrale de Lyon) and by Fabrice Thouverez (full professor at Ecole Centrale de Lyon).

4 Skills

- Mechanical Engineering
- Control theory
- Matlab, Simulink software
- English

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