Title of the project :
New nonlinear design for cyclic symmetric structures

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1 Context

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.

In order to reduce fuel consumption, designers aim to increase the bypass ratio of the engines. Thanks to the developments of composite materials, fan systems have become larger while maintaining a slender profile. However, the intrinsic geometrical effects become more pronounced, leading to a nonlinear dynamic behavior. One of the main features of nonlinear system is that multiple stable solutions can coexist. This project thus aims to find these new solutions and design the system to make them advantageous in term of vibration attenuation.

Complex dynamic behaviors (internal resonances, subharmonic interaction, and so on) arise in nonlinear systems. Different kinds of solution may exist : stable/unstable, periodic, quasiperiodic, and chaotic. Bringing new insights into these behaviors will enable using these nonlinearities for energy transfer between the modes, and thus aiming for a global energy reduction.

2 Description of the project

2.1 Goals

This project aims to propose new design of cyclic symmetric structures using wisely the intrinsic nonlinearities to decrease the vibration levels. To achieve this, it is mandatory to compute all periodic solutions of the systems, to characterize them and follow their evolution. The outline of the project is the following

1. Carry out an extensive literature review of the different analytical and numerical methods and evaluate their respective efficiency.
2. Apply and adapt the most promising strategy to cyclic symmetric structures
3. Low dimension system will be initially investigated before large scale systems.
4. Find, on an experimental setup, the solutions (isolas, bifurcations, etc).

2.2 State of the art

When nonlinearities are taken into account, the system exhibit numerous stable and unstable solutions [1]. Continuation strategy and bifurcation tracking [2, 3] exist to compute these underlying solutions from the linear system. However, other solutions, called isolas, also exist and are detached from the main solution curve. These solutions come from modes coupling and have been observed numerically [4] and experimentally [5]. Many strategies have been proposed throughout the years to compute these solutions: Groebner basis [6], Melnikov principle [7], and so on. Cyclic symmetric structures are found in many engineering systems: engines, nuclear power plant, windmills, and so on. The nonlinear dynamics of these structures is extremely interesting as the mathematical properties of cyclic symmetry can be combined to the nonlinear features of the system. This research topic is largely studied [8, 9, 10, 11].

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). Depending on the results of the research, a partnership with Camille-Jordan institute might be considered.

4 Skills

- Nonlinear Dynamics
- Applied mathematics
- Programming software
- English

References

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