Innovating Aero-Engine Dynamics: Numerical Modelling of Wave Propagation in Granular Crystals

Master's degree thesis to be conducted at Imperial College London in the Department of Mechanical Engineering

Suitable to engineering students. Preferably industrial sector, mechanical, aeronautics or mechatronics.

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Research Context

The aviation sector stands at a pivotal point, with the urgent need to design aero-engines that are not only lighter and more flexible but also environmentally sustainable to target Net Zero goals. Manufacturers such as General Electric and Rolls-Royce face the complex challenge of ensuring safety while reducing emissions, a task made daunting by the intricate vibrational behaviour of engine components. Predicting the engine dynamic behaviour is particularly complicated due to the complexity of the millions of components in contact. The different contact states introduce friction forces that can significantly affect the vibration amplitudes and induce a shift in resonant frequencies.

The goal of this Master Thesis Project is to develop a modelling solver to increase the understanding of friction in vibrating structures. The solver will model the propagation of solitary waves, which are mechanical waves that propagate in granular crystals. Solitary waves have been used for non-destructive evaluation (NDE) similarly to traditional ultrasonic waves. Although ultrasonic waves have also been used to monitor friction, solitary waves have never been used to this purpose. The goal of the newly developed solver is therefore to correlate for the first time changes in the solitary wave propagation to the friction properties of sliding contacts, thus developing a new modelling technique that could provide a breakthrough in the field of tribology and dynamics. By joining this project, you can make a tangible impact on the future of aviation, contributing to safer, cleaner, and more efficient air travel.

This research will be conducted at Imperial College London in the Tribology Group, which is one of the largest and most renowned tribology research groups in the world today. Its research is strongly supported by companies in Europe, the USA and the Far East (e.g. Rolls-Royce, Shell, SKF, Toyota, Bosch etc.) and it collaborates with many universities across the globe.

Expected timeline and costs

The start date of the research is flexible, and it can be set based on the student needs **(preferably to be started in March or April).** For students who have not yet made their home in London, the first month can be arranged remotely. The length of the research period is flexible, **from a minimum of 3 months to a maximum of 6 months**, depending on the results achieved by the student.

Funding is not provided but there will be no university costs to enrol as visiting student at Imperial.

Expected expenses:

- House rent in London is £500-£800/month for student standards.
- Food ~£500/month.
- Public transport: underground monthly pass £115/month, or you could buy a bike for ~£70 to move around.
- Phone sim ~£15/month.

Guidance will be provided in securing affordable accommodation and facilitating access to a wide array of university resources and networking opportunities. We encourage you to seek existing funding opportunities in Politecnico to afford the living expenses.

Project Outline

The objective of this thesis project is to develop a numerical solver that models the solitary wave propagation in solids and also includes the effects of friction. Experimental results will be provided as a benchmark to validate the numerical simulations. This research will be fully conducted at Imperial College London. The project will consist of the following:

- Study the existing literature on the topic (see e.g. [1 2])
- Develop a modelling tool in MATLAB using an existing proof of concept code developed in the Tribology Group.
- Use ABAQUS to generate finite element models of the investigated components.
- Link the MATLAB simulations to the FE simulations run in Abaqus.
- Validate numerical simulations with existing experimental data.
- Understand the numerical results and explain the physical origin of the observed results.

Professional Development and Future Opportunities

This thesis is more than a project; it is an exciting opportunity for those interested in numerical simulations, structural dynamics, wave propagation and tribology. It's also a gateway to unparalleled professional development in the renowned Tribology Group at Imperial College London. Engage with leading experts, access cutting-edge facilities, and open doors to future collaborations and career opportunities in academia and industry.

After the end of this Master Thesis Project, **there will be the opportunity to pursue a PhD in the Tribology Group at Imperial College as a continuation of this project**.

Your contribution could lead to a published paper, setting a strong foundation for an academic or professional career in a wide range of industries. Furthermore, the methods learned are applicable in a considerably wider range of industries, including the turbomachinery, automotive, maritime, space and energy industries among others.

Learning outcomes:

- Understand state of the art techniques to model nonlinear wave propagation, tribology and dynamics.
- Mastering state-of-the-art techniques in numerical modelling.
- Use MATLAB to develop scripts, post process data and learn how to best present complex information.
- Use commercial Finite Element codes and design new components.
- Interpret data to understand the physical phenomena behind them.
- Problem-solving, critical thinking, and cross-disciplinary communication

Requirements

The project would suit a student with a keen interest in structural dynamics, wave propagation, tribology, numerical simulations and turbine engines, and can form a basis for further computational research.

This project requires:

- Discrete knowledge of MATLAB to develop the code.
- Optional: basic knowledge of commercial Finite Element codes (Abaqus) to develop the FE models to be used in simulations. If not known, there are easy tutorials to learn from zero.

Don't miss this chance to be at the forefront of aero-engine innovation. To express your interest, contact Dr Alfredo Fantetti (a.fantetti@imperial.ac.uk), or talk to Prof. Zucca (stefano.zucca@polito.it) or Prof. Botto (daniele.botto@polito.it) from the Mechanical and Aerospace Engineering Department (DIMEAS).

The University

Imperial College London, located in the heart of London, is a global top-tier university that specializes in science, engineering, medicine, and business. With its cutting-edge research and innovation, Imperial offers a vibrant and intellectually stimulating environment for students from all over the world. The college boasts state-of-the-art facilities, a diverse and inclusive community, and strong connections with industry leaders, providing unparalleled opportunities for professional development and networking. Surrounded by the rich cultural and historical tapestry of London, students at Imperial enjoy a unique blend of academic excellence and a dynamic city life.

Recommended Literature

[1] J Yang et al. "Interaction of highly nonlinear solitary waves with thin plates" International Journal of Solids and Structures (2012).

[2] C Wang et al. "Wave transmission in 2D nonlinear granular-solid interfaces, including rotational and frictional effects" Granular Matter (2021).