CRANFIELD UNIVERSITY

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Friction in Landing Gear System

School of Aerospace, Transport and Manufacturing (SATM)
PhD. by Research

Research Progress Report

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Statement

Context:

The major role of a brake device is to slow down or bring to a complete stop a moving system or object. To perform this task a friction brake uses the friction force between two counter parts, normally a moving and a stationary part which are pressed together with an applied normal load. An ideal brake system would perform with a reasonably high and stable friction during its performance. This should be constant in variety of operating conditions such as environment, temperature, speed and applied pressure variations.

Although both the friction phenomena and usage of friction brakes represent an old science, our understanding of wear and friction behaviour of materials is limited, and considerable research and development efforts are being conducted in this area. This is mainly because, on the scientific level, we are only at the beginning of understanding the friction on the atomic scale and the chemo-mechanical mechanism occurring at the contact point of moving surfaces.

The design of any brake system depends on the mechanical properties of the friction materials which decides the sufficient strength, thermal properties allowing heat dissipation, adequate friction for effective braking performance and wear characteristics to improve the lifecycle of the system. Although all these parameters would be benchmarked by applying laboratory experimental tests, but it shall be noted that friction and wear are system properties, and it cannot be assumed that data obtained from simplified tests will be sufficient for material design.

In designing the brake systems, optimizations shall consider:

- Friction effectiveness (Coefficient of friction) of the contact materials
- Enhancement of durability
- Installations (applicable mechanical/physical design)
- Costs

The most recent trend in enhancement and development of friction brakes in aviation is to achieve a more efficient and cost effective friction system with reduction in weight and size of the entire brake system, increase the capacity to convert larger kinetic energy to heat, higher reliability and stability while reduction of maintenance and environmental friendliness are also important.

Advanced friction materials used in aviation and high performance applications are considered to perform more than generating friction. They play additional roles such as: controlling the vibration, heat dissipation, counterface cleaning, corrosion protection, wear reduction, etc.

Most recent materials used in aircraft brakes are Carbon/Carbon Composites, Powder Metallurgy friction linings and advanced Carbon/Silicon Carbide composites. C/SiC demonstrates significant advantages as high performance brake material such as: Excellent friction resistance, high strength, high temperature resistance, sufficient oxidation resistance, low density and low sensitivity to harsh environment.

The performance of materials in friction applications has until now typically been verified by empirical testing. The experimental methodologies are prone to be expensive, time consuming and only validated for a specific condition and material. Therefore, investigating the multi chemo-physical reactions and environmental factors effecting the tribologycal behaviour of friction materials through experimental tests, is a comprehensive task.

Aim:

This research seeks to develop and verify multi-physics modelling techniques to enable end-to-end performance based design of friction systems and reduce the dependency on physical testing. The physiochemical processes shall be captured at micro/nano scale using numerical simulations. Then a macroscale model of the brake wear would compare the previous experimental evidence.

Objectives and hypothesis:

This project would take an alternative approach, comparing to the earlier methodologies, as multi-scale modelling is proposed to complement the previous experimental data and enhance the existing knowledge on friction and wear of brakes. The initial interests of this work are to investigate the behaviour of advanced carbon based friction materials and identify the tribology properties of C-C disks. Recognising the capability of molecular dynamics simulations and debris modelling are the other fields of interest in this project. The micro scale modelling shall be utilized with Macro scale modelling of complex systems to investigate other potentials for improvement in end product.

Hypothesis to be tested during the research are identified as:

- Friction Mechanisms at the braking surface are dependent upon microstructural features.
- Microstructural features and consistency in thickness throughout a brake disc are a function of raw material selection and industrial process parameter control
- Multi-physics aspects of friction performance can be modelled
- A multi-fidelity approach to modelling for design and development purposes is feasible
- Modelling of the interdependence of friction performance to material characteristics is developable to a level of fidelity reducing or eliminating need for empirical product verification.
- Multi-physics modelling techniques of this nature could be developed and applied to similar empirically verified systems.

Methodology and quality assurance:

To give assurance to the conducted studies during this research, the Cranfield University code of practice shall be taken into consideration while the advantages of collaboration of London South Bank University in this project are significant.

The data management plan and risk assessment of the project would be updated during the work to make sure the methodologies used are suitable to handle every step of the project.

The literature review and history of tribological research are being studied with a meta-narrative methodology.

The nature of this PhD research is based on collecting and analysing numerical data. These data are mainly collected from simulations and experimental tests. Also there would be some data collected from existing studies, mainly from the industrial partner Airbus SAS.

In investigating the friction properties both the mechanical interactions and physio-chemical reactions are important, also wear of the material is due to abrasion and fatigue. Therefor the multiscale nature of the numerical modelling is considered as one of the challenges in this work.

Due to the multiscale nature of the physical processes such as oxidation, a dual approach to the modelling is proposed, where the micro/nano scale processes are captured using molecular dynamics simulations, while macroscale features are captured via a finite-element approach. A strong coupling between the two approaches will be ensured.

Initially the molecular dynamics simulations are proposed to investigate the influence of microstructure of the contact surfaces on friction and wear, the generated methodology shall be verified by existing experimental tests and previous studies. The external factors such as environment might be investigate through other recently developed methodologies such as quantum mechanics approaches. The created models might be carefully coupled with a macroscale model of the friction system using Finite Element Methods to captures other features of the system.

Collaboration with the industrial partner (Airbus SAS) would create a path to take steps of the project in the direction of market requirements and make sure the considered methodologies are either verified previously or feasible to be applied for current developments.

Potential impact:

Other motivations and potential impacts of the work can be referenced as:

- The wear performance of carbon friction materials has direct impacts on operation costs.
- Also braking performance improvement can significantly influence the carbon footprint of aircraft operations.
- Multiphysics modelling of complex empirically verified multi-dimensional engineering systems could contribute to a reduction in lead-time of creating solutions to product challenges throughout the aircraft lifecycle
- Performance of C-C Braking components is integral to overall performance of aircraft braking system
- Leadtime and Cost of development of brake materials is a significant contributor to the development lead-time of the aircraft design.

Keywords:

Friction, tribology, aircraft, brake material, molecular dynamics, simulation, Carbon reinforced carbon composites, ceramics,

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