Queen's Doctoral Training Programme on
Secure Connected Intelligent Design and Manufacturing

Title: DTP: Machine tool design incorporating CFRP materials - understanding compliance and thermal deformations

This project is part of the Queen's Doctoral Training Programme in Secure Connected Intelligent Design and Manufacturing. Many of today's industrial approaches require transformative changes to ensure long term societal, economic and environmental resilience and sustainability. PhD projects in this programme explore the potential of emerging digital technologies, such as artificial intelligence, robotics, and the Internet of Things, to transform the way we design, manufacture and operate products and services.

Project description:
Machine tools create complicated parts to very high tolerances by shaping or forming workpiece material. Components produced by machine tools are used in a vast range of products. Machine tools themselves are generally designed to have components with high stiffness to achieve the required machining accuracy and process stability. However, to achieve efficient processes the mass of individual machine tool components is important to enable rapid shaping or forming operations. A further challenge, particularly for large machines is minimizing thermal deformations of a machine's components resulting from ambient temperature changes and local machine features such as motors, ball screws, bearings etc.. One potential approach to achieve low mass and stiff components is to use Carbon Fibre Reinforced Polymer (CFRP) materials for individual component construction. This approach has the additional benefit of CFRP material having a lower coefficient of thermal expansion compared with standard machine tool materials. Extensive work has been carried out to understand compliance and thermal deformation with traditional machine tool component materials, with demonstrated methods to measure, analytically model, regress and use empirical measured data and ultimately compensate for errors. However, there is much less research available considering CFRP materials in machine tool component design, and appropriate approaches to represent and manage deformations. A particular challenge for CFRP component design is the need to integrate local machine features which results in integrated hybrid structural and thermal systems with complicated geometry.

Aims and Objectives:
The aim of this project is thus to understand the challenges associated with CFRP material systems with respect to compliance and thermal deformation (proposing and demonstrating measurement and modelling methods; proposing and demonstrating compensation approaches; proposing and developing tools to support component design with CFRP materials).

- Review available measurement, modelling and compensation methods for machine tools.
- Based on the preceding review undertake an initial measurement campaign to characterise the current PKM-mini machine compliance and thermal deformation behaviour.
- Using available modelling technologies undertake a series of systematic modelling studies, focused on individual CFRP components of the PKM-mini machine, establishing and quantifying the key modelling challenges.
- Based on the initial measurement campaign and modelling outcomes select from the literature a measurement / compensation strategy for the PKM-mini machine and implement.
- Refine simulations to support the measurement / compensation strategy and assess the potential for modelling to support CFRP component design and optimization.
- Formulate design strategies to address the critical challenges associated with composite component design – proposing appropriate modelling strategies, measurement strategies, compensation strategies, quantifying the benefits / benchmarking against current state of the art, and the associated data requirements and computational costs.
- Write-up thesis and final journal papers.

Key skills required for the post:
A minimum 2.1 honours degree or equivalent in Engineering (Electrical and Electronics, Mechanical, Aerospace, Manufacturing) or Computer Science/Software Engineering, or other relevant discipline.

Key transferable skills that will be developed during the PhD:
The programme offers a bespoke research and training programme that aims to develop students into cross-disciplinary, industry-conscious thinkers and leaders who will influence the roadmaps of future advanced

manufacturing technologies and their applications. They will have a balanced understanding of ICT (security, communications and data analytics) in the context of their application to Advanced Manufacturing and High Value Design.	
Queen's University Belfast supervisor team:	Prof Adrian Murphy a.murphy@qub.ac.uk Dr Mien Van m.van@qub.ac.uk Dr Yan Jin y.jin@qub.ac.uk **i-AMS Centre** https://www.qub.ac.uk/sites/iams/ Colm Higgins c.j.higgins@qub.ac.uk **NITC** https://www.qub.ac.uk/sites/nitc/
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Guaranteed stipend:	This is a 3.5 year funded Queen's DfE DTPs studentship with Training Grant, to commence on 1 October 2020 (N.B. stipend for 20/21 is not yet known, but is likely to exceed £15,000). The studentship covers fees and maintenance and is available for UK residents (see full eligibility criteria - nationality, residency, and academic qualification at: http://go.qub.ac.uk/dfeterms). **When applying using the Queen's portal please ensure you include "DTP:" along with the project title.**
Conditional top-up available:	A top up may be available for an exceptional candidate, dependant on the recommendation of the interview panel and industrial sponsor.
PhD students in the School have the opportunity to apply to be demonstrators on undergraduate modules. Compensation for this can amount to in excess of £2,400 per year.	

Queens University Belfast is a diverse and international institution which is strongly committed to equality and diversity, and to selection on merit. Currently women are under-represented in research positions in the School and accordingly applications from women are particularly welcome.