QUB - Mechanical and Aerospace Engineering PhD Project 2019-2020

Title: Battery Thermal Management and Algorithmic 3D Temperature Prediction

Project Background and Description:

The electrification of transport vehicles is the latest automotive mega trend, driven by the demand to reduce greenhouse gases and other harmful emissions (NOx, HC, CO, CO2). Vehicle electrification sees conventional IC engine replaced with an all-electric or hybrid electric powertrain, powered or partially powered by batteries.

Current battery technology in the form of lithium ion batteries, has an energy density in MJ / kg some 50 times less than gasoline and an energy density in a MJ / L some 14 times less than gasoline. In addition, current battery technology works in a very narrow range of temperature (-20 to +60 C) and has quite limited durability (typically about 3 to 6 years depending on type and operational use) especially when thermally stressed. Current battery management systems use exterior battery cell temperature as one of their main indicators for the control of the battery in terms of limiting its stress while in service. The battery cell temperatures that are measured are measured on the exterior of the battery cell or pack and are not representative of what's actually happening inside the battery itself, where the chemistry is occurring. Here the temperature can be extreme if it goes wrong, several hundred degrees it is thought, leading to thermal runaway. It is here within the battery itself that it is necessary to know and predict the temperature based on the performance demanded or provided by the battery. Battery thermal management is a significant problem, the resolution of which is part of the UK automotive Council, APC (Advanced, Propulsion Centre) and UK Faraday challenge roadmaps. This project is aligned to these initiatives

Aims and Objectives:

The overall aim of this project is to measure / map internal battery temperatures under real-life usage conditions and develop a predictive algorithm that reproduces these temperatures based on external battery sensor measurements. The objectives of the project are:

- To produce a Quality Assured (QA) process for non -intrusively instrumenting live prismatic or pouch battery cells under non oxygenated conditions (argon environment) following a process of magnetic resonance imaging (MRI) or scanning and Computer Aided Design (CAD) image replication by Computer Numerical Control (CNC) and robotic manipulation
- To develop the instrumentation process to provide an assured battery capable of automotive vehicle testing on or off road
- To provide an instrumentation process and sensory method that is chemically mute or neutral to the cell which will involve the application of novel chemical process and materials
- To map the internal temperature profile at specific locations inside the cell at normal road use and extreme damaging conditions on a chassis dyno and or on test track
- To analyse the data and produce a 3D internal mathematics heat flow map linked to the external cooling environment associated with individual and specific battery module positions in the vehicle pack.
- To produce a 3D numerical simulation and an associated numerical algorithm that predicts transient and static temperature profiles and point source within the battery at selected normal and extreme use operating conditions
- To develop an experimental software code in conjunction with a HORIBA Battery Management System (BMS) for process and algorithm validation

HORIBA is a global automotive and scientific instrumentation company with automotive development facilities near Nuneaton in Warwickshire.

This 3.5 year HORIBA sponsored EPSRC CASE studentship will provide a prestigious and privileged framework to acquire technical, commercial, societal and specialised industrial knowledge to enhance academic study. This work will be completed within the QUB Energy PRP (Pioneer Research Programme) within the Faculty of Engineering and Physical Sciences at Queens in the School of Mechanical and Aerospace Engineering. Through the PRP and the industrial partner HORIBA, the appointed student will be given the opportunity to work within a multi-disciplinary team of researchers and industrial practitioners. A combination of academic and industrially based training and experiential opportunities will be offered through

the completion of this project. Skill enhancements in addition to the core technical skill sets, will be in: systems thinking and multidisciplinary problem solving, sustainability and entrepreneurial understanding, communication and networking capabilities, team working and leadership. The student will spend regular periods on industrial placement (up to 6 months) for training and knowledge acquisition purposes. Specific periods of placement will be planned as required over the three years required to complete the work. A travel and bespoke training budget has been agreed with the industrial partner to cover the cost of training activities, software training, attendance at meetings with external suppliers and visits / meetings at company sites in the UK (and potentially worldwide) and at relevant academic conferences.

The student will be expected to manage the project and resources and engage with relevant experts in the field of automotive battery technology. The studentship will provide the necessary supportive context to complete a programme of academic PhD study and deliver outcomes from which HORIBA can benefit.

Key skills required for the post:
A minimum degree of 2:1 (or equivalent) in one of the following areas is required: Mechanical or Chemical Engineering or a closely related subject area. Candidates with other primary degree areas may be considered if they can demonstrate a high level of suitable relevance and experience to the scope of the project in their primary degree area. It would be desirable to have some understanding and knowledge of the automotive sector and battery technology. Solid computer skills are essential as the project will involve significant computer modelling, simulations and analyses.

Key transferable skills that will be developed during the PhD:
The key transferable skills that will be developed during this PhD project will be in the areas of significant mathematical modelling and simulation, industrial engagement and technology transfer, academic and industrial publication / presentation skills and experimental testing and analysis.

Lead supervisor:	Dr Stephen Glover, School of Mechanical & Aerospace Engineering s.glover@qub.ac.uk Tel:(+44) 02890975493
Other supervisor(s):	Dr Rob Watson & Dr Peter Nockemann in School of Mechanical and Aerospace Engineering and the School of Chemistry and Chemical Engineering respectfully.
Eligibility, Funding details including fees, stipend and top-up:	Normally, to be eligible for a full award of fees, stipend and top-up a student must have no restrictions on how long they can stay in the UK and have been ordinarily resident in the UK for at least 3 years prior to the start of the studentship (with some further constraint regarding residence for education). This will include a basic stipend plus a top-up of up to £5,000 per annum. The basic stipend for 2018/19 is £14,777. The successful candidate will be expected to be in post by October 2019.
Conditional top-up available:	The value of the top-up will depend on the candidate. The student will also be required to travel to at least 1 conference in North America & 1 in Europe.
Demonstrator hours:	PhD students may also have the opportunity to apply to be demonstrators on undergraduate modules. Compensation for this can amount to £1,200 per year.
Enquiries:	For informal inquiries, email s.glover@qub.ac.uk
Closing Date for Applications	28th February 2019

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.