Faculty of Science and Engineering

2020 Australian Government Research Training Program Scholarships

Strategic Project Profile

PROJECT TITLE: Diagnostic modelling and prediction of the failure of medical implants with machine learning

FIELD OF RESEARCH CODE: 0912

PROJECT SYNOPSIS: Currently, in Australia, the raw data of medical implant revisions are registered under a national data collection system. However, this data collection does not account for the root cause of most failures, namely corrosion. The Department of Medical Imaging and Physics within the Royal Perth Hospital (RPH) has taken the initiative by extensively recording and evaluating corrosion in modular junctions in a descriptive, though a rather qualitative perspective. In particular, RPH has investigated corrosion in the hip (head-stem and modular stem junctions), as well as the knee (revision arthroplasties).

Most of the investigations at RPH have been driven by a need to identify clinical solutions concerning the comparative performance of implants, or combinations of implants that are better for the surgeons to use in arthroplasty patients. However, to enhance the longevity of implants, it is vital to identify the mechanisms leading to corrosion and wear, including factors related to implant design and material specification, as well as the biomedical profile of the patient, the surgeon and operational procedures, etc., that can give rise to corrosive degradation of implants.

Tribocorrosion of biomedical implant materials used in, e.g., modular hip arthroplasty is a commonly encountered problem. Several laboratory and clinical studies have been undertaken to understand the underlying reasons leading to early rejection, accelerated metal ion release, corrosion, and implant fracture. However, the complexities of the process have resulted in conflicting hypotheses and proposed mechanisms. Although extensive in vitro laboratory simulation and clinical studies are being carried out globally to find remedies for the failure of implants, improvement to date has been modest at best.

The RPH has a unique library of more than 11000 retrieved implants, together with the patients' histories. This unique database contains potentially valuable information not attainable from any in vitro study. A thorough metallurgical characterisation of the retrieved implants, assessing their design combined with the patient's history could potentially uncover critical insights into the key factors leading to revision surgery. Also, in the majority of cases where implants cause inflammation, this can be related to the presence of corrosion products, wear debris, or both.

In this study, the data contained in the RPH database will be mined by building diagnostic models to predict the longevity of implants. Different complementary approaches would be possible. For example, to gain insight into the mechanisms and potential causes of failure, the cases will be clustered based on severity and longevity. Models designed to classify the cases could then be interrogated by a number of means to statistically determine the most important factors giving rise to the specific clusters. Established algorithms in the group would be used for this purpose. At this stage, these algorithms make use of random forests and multilayer perceptrons, but where justified, deep learning models would also be constructed and interrogated by model agnostic methods.

If needed, equipment in CME's tribocorrosion laboratory can be used to study dynamic crevice tribocorrosion in conditions that could simulate scenarios encountered in total hip joint replacements. The custom-made ring-on-plate tribo-electrochemical test rig can monitor intermittent micro-movements and associated passive film breakdown and repair. The proposed experimental approach could elucidate the effects of interrupted micro-movements on the stabilisation of pitting and crevice corrosion, following wear using a uniquely designed test rig. The results could then be compared with the retrieved implants available in the RPH database and the patient's history, e.g. inflammation, patient's activity, weight, etc. These results could also be used to validate or further develop some of the models, where needed.

In summary, the objective of the study would be two-fold. First, the models would provide insight into the factors leading to the failure of implants. The better understanding of the failure mechanisms would allow the design of better implants, surgical procedures, or both that would lead to better outcomes concerning the longevity of implants. Second, as the models would also be predictive, they would be able to flag patients at high risk of experiencing early failure of implants. In principle, it would then be possible to mitigate the problem by customising implants or surgical procedures to specific patients.

FEASIBILITY AND RESOURCING – DESCRIPTION OF THE SUPPORT THIS PROJECT WILL RECEIVE:

Dr Salasi and Prof. Iannuzzi have extensive experience in mechanically assisted corrosion, crucial to understanding the degradation of biomedical devices. The Curtin Corrosion Centre has world-class facilities to support the laboratory work required to validate the models and to generate data to augment the models. The RPH is the custodian of the data that would be pivotal to the project. Additionally, the primary supervisor has more than two decades of experience in the development of machine learning models. Curtin's computational facilities fully support large scale analytical projects such as this. The student will be further supported by a team of students with expertise in deep learning, artificial intelligence, and corrosion.

WHAT MINIMAL ATTRIBUTES AND SKILLS EXPECTED BY THE CANDIDATE BE COMPETITIVE:

- Background in material science, chemical engineering, metallurgical engineering, chemistry or equivalent;
- Background in computer science, artificial intelligence or machine learning; or
- Background in biology, biomedical engineering or medicine.

THE SIGNIFICANCE OF THE PROJECT/ PROGRAM FOR THE ENROLLING SCHOOL OR INSTITUTION:

Corrosion engineering is a strategic area of research within the WASM-MECE. The Curtin Corrosion Centre (CCC) has 32 years' experience in high-quality corrosion and materials research, mainly focused on the oil & gas industries.

This research initiates a unique materials research collaboration with the health sector, hence diversifying the research capabilities of CCC beyond the resource industry. This project will, therefore, contribute to the establishment of a local hub for biomedical materials research serving Western Australia, as well as the country. In addition, this would be a high profile project with potentially significant socio-economic impact nationally and internationally.

Students are advised to contact the Project Lead listed below prior to submission of their scholarship application to discuss their suitability to be involved in this strategic project.

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