The 8th European Congress on Computational Methods in Applied Sciences and Engineering
ECCOMAS Congress 2022
5 – 9 June 2022, Oslo, Norway

Using Gaussian Process Regression with Coupled Multiphysics FEA Simulations to Enhance Sparse Experimental Data

Rh. Lewis*[1,2], Ll.M. Evans[1,2,] R. Otin[2], A.D.L Hancock[2]. A. Davis[2], P. Nithiarasu[1]

[1] College of Engineering, Swansea University,
Fabian Way, Swansea, SA1 8EN
https://www.swansea.ac.uk/engineering/
[2] UK Atomic Energy Authority,
Culham Science Centre, Oxford, OX14 3DB
https://ccfe.ukaea.uk/

Key Words: *Gaussian Process Regression, Inverse Modelling, Machine Learning,*

The Heating by Induction to Verify Extremes (HIVE) testing facility at the UK Atomic Energy Authority is a high heat flux experiment used to research and develop plasma-facing components for fusion energy devices. Induction heating delivers up to 20 MW/m^2 of surface power to a component while high-pressure coolant passes through it.

HIVE collects experimental data via thermocouples and an infrared camera. Due to experimental setup constraints the data collected from the infrared camera is limited to temperature distribution on certain surfaces. The thermocouple measurements are limited to a handful of point locations, which are either placed on surfaces or internally within holes drilled into the component. In the former scenario internal temperature values are estimated through interpolation, while in the latter they're measured directly but the component's temperature distribution is affected due to the thermal barrier introduced by the hole. Using a simulation informed machine learning model, the volumetric thermal profile for a component can be calculated from its surface thermocouple measurements.

Data is collected from a parallelised, fully automated multi-physics Finite Element Analysis (FEA) simulation of HIVE using a novel data sampling technique. A Gaussian Process Regression (GPR) model, which maps simulation parameters to thermocouple temperatures, is trained using this data. This model is then used by a constrainable inverse modelling framework to advise the simulation parameters that yield the thermocouple temperatures measured during the HIVE experiment. The constrainable nature of this framework enables ranges to be placed on inverse solutions, meaning that certain simulations parameters can be fixed while more uncertain parameters are given a range for a solution. Using the inversely informed simulation parameters a FEA simulation is performed, producing a volumetric thermal profile which is consistent with the measured thermocouple data.

Converting a small number of discrete surface temperature points into a volumetric thermal profile substantially increases the knowledge gained about a component's response to the loading conditions. Additional information, such as thermal expansion related stresses in the component, can also be calculated, providing even greater insight into the component’s suitability for fusion application.

Corresponding author: Rhydian Lewis, 930500@swansea.ac.uk