AN ADJOINT METHOD TO DETERMINE THE EFFECTIVE MATERIAL PROPERTIES OF AN ABLATOR

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The determination of the effective thermal properties of a material from thermocouple data has always been very labour intensive. Similarly determining the Arrhenius parameters for a decomposition model from thermo-gravimetric analysis is also very time-consuming. There is little formalisation of the procedures used to determine the material properties. Despite the fact that some effort has been devoted to this topic in the literature, it is not clear whether comparable effective material properties data would result if several groups used the same experimental data. The FGE Ablation code FABL has been written in an adjoint form and has successfully been used to efficiently determine the effective material properties from experimental data. The method provides a formalised procedure where the iterative aspect of this process has been automated.

The adjoint form of FABL calculates the partial differential of a cost function to many input variables in one pass of the code. The Jacobian (a matrix of the gradients) can be compiled in one calculation for n input variables, instead of from n+1 calculations which would be needed if it was calculated numerically. The Jacobian can then be used to optimise the input parameters and minimise the cost function. The cost function used in FABL is simply the sum of the absolute relative difference between the measured and predicted results. This can be the difference in thermocouple and/or surface temperatures or the variation of density with time, depending on the case being run. A simple steepest descent optimiser is currently the preferred optimisation method. The structure and flow of information in FABL Adjoint is shown in Fig. 1.

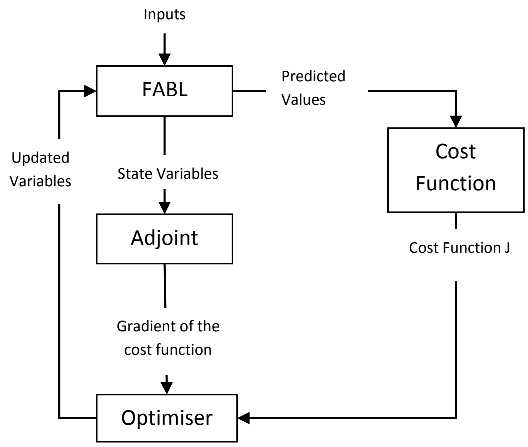

Figure 1: Overall Structure of the FABL Adjoint

The ability to calculate the Jacobian quickly and efficiently means that many material properties can be optimised in a relatively short amount of time without the need for large computations or many man hours. Many experimental data sets for the same material can be compared at once and material properties can be derived to best fit all the available experimental data. The data does not have to come from the same experimental campaign.

The adjoint has advantages when determining properties for a new material or supporting physics updates to the model. Effective material properties are only applicable for the experiment and model they are derived from. The adjoint allows the effective properties to be easily updated when the model is developed and extended or new experimental data becomes available.