MODELLING OF STEAM CONDENSATION USING INVERSE HEAT TRANSFER TECHNIQUE

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INTRODUCTION

Inverse heat transfer is a stream of heat transfer which involves the estimation of system characteristics, e.g. boundary conditions, initial conditions, thermos-physical properties, etc. of the domain from the knowledge of temperature distribution at one or more point inside the domain. Since inverse problem deals with the determination of unknown boundary condition from known temperature distribution, they are ill posed in nature which makes their solution difficult to obtain and hence, special algorithms are required for their solution. In the present study, numerical simulations for inverse heat transfer problems have been successfully performed and inverse heat transfer technique (IHT) has been applied to simulated temperature measurements to check the validity of numerical codes for practical applications. The inverse method described here can be used for the determination of local heat flux during steam condensation on nuclear containment walls. Unlike conventional heat flux measurement methods, this method is non-intrusive and hence will not disturb condensation occurring on the containment walls.

MATHEMATICAL MODELLING

1-D heat transfer Governing equation:
\[
\frac{\partial^2 T}{\partial x^2} = \frac{1}{\alpha} \frac{\partial T}{\partial t}
\]

3-D heat transfer Governing equation:
\[
\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} = \frac{1}{\alpha} \frac{\partial T}{\partial t}
\]

Initial condition: At \( t = 0 \), \( T = T_i \)

Suitable boundary conditions are applied to the slab for simulation of 1-D and 3-D heat transfer.

![1-D heat transfer problem geometry](image1)
![3-D heat transfer problem geometry](image2)

Figure 1: Boundary conditions applied to 1-D heat transfer geometry and 3-D heat transfer geometry in ANSYS FLUENT

SIMULATION

Simulations for 1-D and 3-D heat conduction has been performed in FLUENT for various applied heat flux. A steel slab is made with temperature monitors placed inside it at known locations to obtain temperature distribution. Since simulated measurements are error free, white Gaussian noise (SNR = 50) is added to the
simulated measurements in order to check the applicability and stability of the inverse algorithm under practical conditions.

RESULTS AND DISCUSSION

The results of IHT code applied to simulated measurements are shown below:

Figure 2: Comparison of estimated heat flux using IHT with applied heat flux for 1-D heat transfer problem
Figure 3: Comparison of estimated heat flux using IHT with applied heat flux for 3-D heat transfer problem

Figures 2a and 3a represent estimation of heat flux during constant steam supply, and Figures 2b and 3b represent estimation of heat flux during intermittent steam supply. IHT numerical codes gives reasonable results for both cases. A sudden jump at start and end point for the case of periodically varying heat flux is observed. It is from the fact that finite terms of general Fourier series has been used to estimate the applied boundary condition, which is not capable to exactly represent a square wave. Further, experiments are needed to validate the obtained results.