EXPERIMENTAL VALIDATION OF AN INVERSE HEAT CONDUCTION BASED NON-INTRUSIVE THERMAL SENSOR

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INTRODUCTION

Conventional sensors, disturb the very phenomena they are measuring especially the ones which depend on surface characteristics. Thus, a non-conventional inverse heat conduction based sensor (patented at IIT Kanpur) is being developed \cite{1, 2}. The main advantage of the sensor is that, it can determine transient temperature, heat flux and heat transfer coefficient all at one time and that too using a single sensor. In the present study, experimental validation of the sensor for the prediction of heat transfer during steam condensation is carried out; a small scale experimental mimic of the steam condensation over the containment walls during a severe accident conditions. A schematic of the experimental set-up is shown in Fig. 1.

![Figure 1: Schematic of the experimental set-up](image)

The set-up consists a Stainless Steel (SS)-304 test plate of $96 \times 80 \times 20$ mm$^3$, bolted on a Teflon block of $252 \times 202 \times 24$ mm$^3$. It is then mounted on a cooling chamber made of $252 \times 202 \times 50$ mm$^3$ using SS-304 and the test plate is cooled using a recirculating water bath (Julabo F34). The other side of the plate is exposed to steam supply coming from steam generator through a pipe of 4.2 mm diameter. Two needle valves are incorporated in the steam line namely valve 1 and valve 2, to maintain the quantity of steam passed, and for closing and opening of steam supply.

As soon as valve 2 is opened, steam flows over the test plate and gets condensed. The resulting temperature distribution at specified location within the plate is measured from the thermocouples (T1, T2, T3, T4, T5, T6, and T7). Using Fourier law of heat conduction, heat flux is estimated from temperature gradient. The measurements taken from the thermocouple T1, are inverted using Levenberg-Marquardt algorithm (Figure 2) \cite{3} to estimate heat flux transferred through the plate.

![Figure 2: Flowchart of Levenberg-Marquardt algorithm](image)
RESULTS AND DISCUSSIONS

Figure 3: Comparison of estimated heat flux using IHT technique with the heat flux calculated from two fixed thermocouples using 100, 200 and 400 seconds temperature data

Figure 3 shows the comparison of heat flux estimated using IHT technique and Fourier law of heat conduction for two cooling water temperature conditions i.e. 15°C and 25°C. It is found that IHT technique overestimates the heat flux by 30% (approx.). Over-prediction at the start of steam condensation is mainly due to lag in temperature response with respect to heat flux excitation at the test surface. This lag is more pronounced for the thermocouple located deep beneath the test surface. It is also seen here that thermocouple T1 data gives better estimation of the heat flux than the thermocouple T4 data.

REFERENCES