An Intelligent Approach to Inverse Heat Transfer Analysis of Irradiative Enclosures

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Abstract

This is a thesis by publication for a PhD degree of engineering in the university of Adelaide. The current dissertation comprises five published/submitted journal articles. Three of these journal papers have already been published in the journal of "International Communications in Heat and Mass Transfer" and one has been accepted by the editorial board of "Chemical Engineering Communications". This study, based on research undertaken in the area of Inverse Heat Transfer Problems (IHTP), aims at analyzing the applicability of Intelligent Techniques (ITs) to solve sequential (real-time) heat flux estimation class of IHTPs, especially those involving in the most complicated form of heat transfer , radiation. Currently, several optimization based methods have been developed and applied to solve heat flux estimation problems. These methods normally require detailed and accurate information regarding physical properties. Often, the measurement of such physical properties is extremely difficult, if not impossible. Moreover, all optimization-based methods require that the direct problem must be solved first. This constraint of the need for iterated direct problem solutions can produce significant computing errors and calculations may be excessively time-consuming. This thesis offers new inverse models to estimate heat flux based on a sequence of measured temperatures. The offered models developed by ITs, in accordance with the achievement of this research, only requires a series of temperature-input heat data for a few minutes of operation; the dimensions and thermophysical properties are not needed. As another significant advantage, the estimation stage by the trained ITs only includes a small number of simple calculations excluding any recursive computation; this means the method is very fast-paced in comparison with classical avenues of numerical heat transfer for similar problems.

At the outset, the most general form of ITs in engineering applications, Artificial Neural Networks (ANNs), employed to formulate an inverse model in the studied furnace/dryer (see chapter 4). The promising results confirmed that ITs are sound candidates to create inverse models. In that study, some deficiencies in ANNs such as finding the relevant parameters by trial and errors motivated the authors to check GA-ANNs and ANFIS as the possible alternatives for ANNs. The comparison study between aforementioned methods (see chapter 5) provided good outlines to find the best method in different situation. As the ANNs

optimized by Genetic Algorithms (GA) discovered as the best method in the chapter 5, different types of ANNs were compared to find the best one (see chapter 6) in terms of accuracy and computation time. The results demonstrated that Multilayer Perceptron (MLP) optimized by GA can perform the best among all studied ANNs.

Since the literatures lack of a practical comparison between the proposed and optimization based methods, as the next phase of study, these two method were compared (see chapter 7) to reconfirm the superiority of inverse models developed by ITs. In the last stage (chapter 8), a two -input/ two-output problem defined to check the capability of the proposed method in the problems more closer to the real-world industrial applications.

In short, a series of very accurate methods for inverse heat transfer problems is proposed and successfully tested using experimental data.

Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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Preface

This thesis is submitted as a portfolio of publications according to the "*PhD Rules & Specifications for thesis*" of the University of Adelaide. The journals in which the papers were published or submitted are closely related to the research field of this work. The citation is listed and the journals are ranked in the order of the impact factor in reference to their scientific significance (Journal Citation Report 2007, Thomson ISI).

The main structure of this thesis is based on the following three published, one accepted and one submitted papers:

1. **Mirsepahi, A**., M. Mohammadzaheri, L. Chen, and B. O'Neill, "An artificial intelligence approach to inverse heat transfer modeling of an irradiative dryer". International Communications in Heat and Mass Transfer, 2012. 39(1): p. 40-45. Copyright of this paper belongs to Elsevier Ltd. (Chapter 4).
2. **Mirsepahi, A**., L. Chen and B. O'Neill, "A comparative artificial intelligence approach to inverse heat transfer modeling of an irradiative dryer". International Communications in Heat and Mass Transfer, 2013. 41: p. 19-27. Copyright of this paper belongs to Elsevier Ltd. (Chapter 5).
3. **Mirsepahi, A.,** L. Chen and B. O'Neill, "A comparative approach of inverse modelling applied to an irradiative batch dryer employing several artificial neural networks". International Communications in Heat and Mass Transfer, 2014. 53: p. 164-173.Copyright of this paper belongs to Elsevier Ltd. (Chapter 6).

Accepted:

1. **Mirsepahi, A**., L. Chen and B. O'Neill, " An artificial intelligence solution for heat flux estimation using temperature history: a two-input/two-output problem". Submitted to Chemical Engineering Communications. Copyright of this paper belongs to Elsevier Ltd. (Chapter 6).

2. **Mirsepahi, A.,** Mehdizadeh, A., L. Chen and B. O'Neill, " Comparison of Inverse Modelling and Optimization-Based Methods in the Heat Flux Estimation Problem of an Irradiative Dryer/Furnace". Submitted to Journal of Computational Science. Copyright of this paper belongs to Elsevier Ltd (Chapter 7).

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