Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 157 (2016) 82 – 88

Procedia Engineering

www.elsevier.com/locate/procedia

IX International Conference on Computational Heat and Mass Transfer, ICCHMT2016

The solution of a two-dimensional inverse heat transfer problem using the Trefftz method

B. Maciejewska[a]*, K. Strąk[b], M. Piasecka[c]

[a]*Faculty of Management and Computer Modelling*
[b,c]*Faculty of Mechatronics and Mechanical Engineering*
Kielce University of Technology, Al. 1000-lecia P.P. 7, 25-314 Kielce, Poland

Abstract

This paper deals with a two-dimensional inverse heat transfer problem solved by means of the Trefftz method. The aim of the calculations was to determine the flow boiling heat transfer coefficient from the temperature measured by infrared thermography. The experiments concerning flow boiling heat transfer were conducted for two parallel asymmetrically heated rectangular minichannels. The element heating Fluorinert (FC-72) flowing in the minichannels was a thin foil, smooth on both sides in one channel and with enhanced surface on the side in contact with the fluid in the other channel. The enhanced surface was produced with iron powder deposited by soldering. The results are presented as infrared thermographs and plots of the heat transfer coefficient against the distance from the minichannel inlet. The values of the heat transfer coefficient were calculated using the Trefftz method. In the subcooled boiling region, the values of the heat transfer coefficient were relatively low, while in the saturated boiling region, they were very high. The local values of the heat transfer coefficient reported for the surface enhanced by soldering iron powder were only slightly higher.

Peer-review under responsibility of the organizing committee of ICCHMT2016

*Keywords:*inverse heat transfer, Trefftz method, flow boiling, minichannel, infrared thermography

1. Introduction

Recently there have been many studies into flow boiling heat transfer in minichannels with different geometries because of the rapid development of high-performance integrated systems consuming large amounts of energy and generating large amounts of heat. Highly efficient small size cooling systems for new generation compact devices are thus in great demand. The great number of experimental and theoretical analyses reflects the importance of the

* Corresponding author. Tel.:+48-41-34-24-444; fax: +48-41-34-24-404.
*E-mail address:*beatam@tu.kielce.pl

Peer-review under responsibility of the organizing committee of ICCHMT2016
doi:10.1016/j.proeng.2016.08.341

research into the boiling phenomena in minichannels. Currently, the investigations focus on heat transfer on enhanced surfaces because of their theoretical potential to improve the heat transfer process. An overview of the relevant literature on heat transfer in minichannels can be found in [1-17].

In flow boiling heat transfer, which occurs at the interface between the minichannel wall and the fluid, the heat transfer coefficient can only be identified when the wall temperature, the temperature gradient and the fluid temperature are known. In a two-dimensional calculation model, these quantities can be determined by solving the inverse heat conduction problem [18].

Inverse problems can be dealt with using the method proposed in 1926 by E. Trefftz [19]. The unknown solution of a differential equation is approximated using a linear combination of functions that exactly satisfy the differential equation. Such functions are known as the Trefftz functions. The next step involves adjusting the approximate function to satisfy the boundary conditions, and, in the case of unsteady state problems, also the initial conditions. Details of the method based on the Trefftz functions can be found in [20-26].

Nomenclature

A	surface area, m^2
α_i	coefficient of the linear combination
I	current supplied to the heated foil, A
J	functional
P	number of measurements
q	heat flux density, W/m^2
q_{loss}	loss of heat to the surroundings, W/m^2
q_V	volumetric heat flux, W/m^3
T	temperature, K
u	particular solution of the differential equation
$v_i(x,y)$	Trefftz functions
x, y	spatial coordinates
Greek symbols	
α	heat transfer coefficient, $W/(m^2 K)$
ΔU	in voltage along the foil, V
δ	thickness, m
λ	thermal conductivity, W/(m K)
σ	relative difference
Ω	two-dimensional domain
Subscripts	
f	fluid
l	liquid
P	last measurement point
p	measurement point
sat	saturation

2. Experiment

The most important element of the main loop is the test module with two parallel vertically oriented rectangular minichannels, each 1.7 mm in depth, 16 mm in width and 180 mm in length. The heated element in contact with the fluid flowing in the minichannels is a 0.1 mm thick Haynes-230 alloy foil. The properties of the Haynes-230 alloy was discussed in [27, 28].

In one minichannel, both surfaces of the foil are smooth, while in the other, the surface in contact with the fluid is enhanced. The surface enhancement was achieved by soldering iron particles to the Haynes-230 alloy foil.