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On the feasibility of determining the Heat Transfer Coefficient in casting simulations by Genetic Algorithms

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Abstract

A genetic algorithm (GA) to determine the correct value of the Heat Transfer Coefficient (HTC) between mould and casting is suggested. The GA stochastically feeds different HTC values on a casting simulation program, until an acceptably low difference between the real and simulation of temperature evolution curves is reached. A numerical casting experiment was conducted assuming specific HTC to obtain the temperature versus time curve for particular points. The GA did succeed in finding the HTC values originally employed in all cases examined and the influence of its parameters on accuracy and speed was explored.

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Keywords: Metal casting; numerical simulation; heat ransfer coefficient; genetic algorithms

1. Introduction

Smarter factories may be achieved by the virtual manufacturing paradigm, involving accurate simulation of manufacturing processes in order to design tooling and select process parameters ‘right first time’. In metal casting simulation, the Heat Transfer Coefficient (HTC) between the casting and the mould is not known, despite its

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influence on the accuracy and credibility of results [1]. Temperature distribution, phase changes and mechanical properties as well as defects may appear significantly different than in reality depending on the HTC employed in the simulation [2]. Furthermore, the HTC may differ from region to region, mainly due to the local casting modulus, i.e. the ratio of volume to surface of the different bodies that may comprise the casting [3]. Thus, typical HTC values are adopted in simulation, as commonly suggested by the software's developers. In order to improve on this situation, in this paper it is suggested to use an intelligent search methodology based on a genetic algorithm (GA) that can determine the correct value of HTC or indeed the different HTCs applicable in different regions of the casting. Although it has been suggested that GAs do not possess regularisation properties [4], they are certainly one of the possible classes of solutions to the unstable ill-posed inverse problem of determining HTCs [5], [6], In commercially available casting simulation software inverse methods are functional only for 2D geometry. Trial-and-error, on the other hand, are reliable, but very cumbersome since they are manual methods [1], [7].

Genetic Algorithms (GAs) have been applied to casting part and feeding system optimisation and selection of casting parameters [8] but not concerning the much more fundamental issue of HTC determination [9], [10]. A GA was employed in [11] to determine the mean HTCs along a 2D cross-section of the casting to achieve uniform and in [12] to determine HTC in simple shape continuous casting given temperature measurements. HTC between casting and mould was identified in [13] by a neural network trained with numerical simulation data and experimental cooling curves.

The GA suggested tries different HTC values on the simulation software stochastically, until a stopping criterion is reached. The latter consists of an acceptably low difference between the reference and simulation curves of temperature versus time at one or more points of the casting. In order to test the suggested methodology, numerical casting experiments were conducted using two casting shapes. The numerical casting experiments were conducted on Procast^{TM} assuming specific HTC values and, as a result, the cooling curve for particular points of the casting were obtained. Then, the GA was setup and the HTC search methodology was implemented. investigating the influence of the most important GA parameters on the accuracy and speed of reaching the desired HTC values.

2. Casting simulation and HTC

2.1. Simulation setup

The commercial casting simulation software ProCAST® was used, supporting coupled heat transfer, fluid flow and stress analysis. Two simplified casting shapes were examined, see Fig. 1, namely Case 1 being a parallelepiped of uniform section and thus a single casting modulus and Case 2, being a stepped section prism and corresponding to two different casting moduli, namely 3.33 and 6.67. Therefore, it was assumed that the first part can be assigned one HTC, whereas the second part should be assigned two different HTCs. Gravity casting of Al is assumed with a steel mould (H13). Melt of initial temperature of 700^{o}C, is poured from above at a rate of 1kg/s and heat is rejected to the environment (ambient temperature 20^{o}C) with a convection coefficient of 10W/m^{2}K. At the free surface of the melt radiation emissivity coefficient of 0.3 is assumed. To simplify matters, there was no feeding system as such.

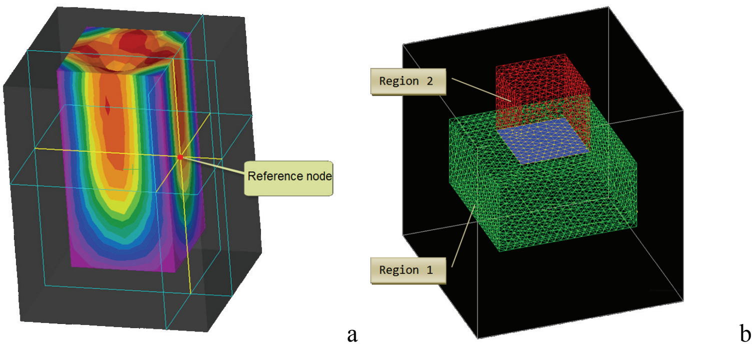

Fig. 1 Casting geometry in the numerical experiment (a) uniform HTC (b) discrete HTC