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Fast solution of direct and inverse design problems concerning furnace operation conditions in steel industry

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A B S T R A C T

In this paper a fast numerical simulation tool able to accurately predict steel products heating in an industrial furnace is developed. This prediction tool is set up in two steps: firstly, a complete finite element model of the furnace is built up, and then a surrogate model based on the information extracted from the results of the previous one (alternatively, results of experimental tests could also be used) is developed.

More precisely, the surrogate model developed in the second step is based on the computation of a numerical simulation database (using the finite element model) and the use of a High Order Singular Value Decomposition and interpolation techniques. Errors in the heating prediction provided by the surrogate model are comparable to the corresponding errors in the finite element model. Computation time instead is dramatically reduced: in the validation case presented in this paper (corresponding to a heat treatment furnace), computation time of the heating prediction in a desktop computer drops from around 2 h for the complete finite model to a few milliseconds for the surrogate model.

The developed fast prediction tool is then applied to solve some design problems. Among them, a problem concerning the design of operation conditions able to minimize a functional involving the quality of the workpiece heat treatment and the fuel consumption is solved.

1. Introduction

Heating of steel pieces inside continuous heat treatment or reheating furnaces has received a lot of attention from approximately ten years ago up to now due to the huge fuel consumptions involved and consequently enormous energy expenses. The importance of these energy costs, that can be up to 100 MW of power consumption, increased competition within the industry, and an increased environmental awareness has highlighted the importance of energy efficiency. Experience has shown that improving knowledge of the heating processes can achieve energy savings of around 10%. The workpiece heating process, that involves very complex phenomena, like thermal radiation, fluid flow and combustion, has to be somehow controlled to guarantee an acceptable temperature range. This heating process has to be well modeled not only in the initial furnace design steps, when a choice of furnace type and size and suitable burners has to be made, but also day after day in order to produce satisfactory steel discharge temperatures, avoiding over and under heating of the workpieces, with minimum energy use for variable production demands and steel qualities.

Furnace design and operation can be simulated using mathematical models that are particularly useful to obtain an approximation to furnaces measurements, safely and economically, avoiding stopping production. Other advantages of using numerical modeling techniques are the simplicity of evaluating a wide range of design options without the need for prototyping furnace and the assessment of considered modifications to existing furnaces. The complexity of the numerical models that have to analyze the fluid flow, the combustion characteristics and the radiative and convective heat transfer rates in complex geometries are only recently available. Among these recent works stand out the studies

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