

GA-based Heat Input Estimation Technique for Simulation of Shell Forming by Line-Heating

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ABSTRACT

The temperature of the gas adjacent to the plate T_G and local heat transfer coefficient α can be considered to remain nearly unchanged with time during spot and line heating. A generic algorithms (GA)-based direct identification technique for T_G and α is proposed. T_G and α during a spot heating test is identified by the proposed technique, and T_G for this spot heating test is measured by laser induced fluorescence technique. The validity of the proposed GA-based technique is investigated by comparing the identified and measured T_G , and comparing the measured T_B and that calculated by giving the identified T_G and α as thermal boundary conditions. As results, the followings are found.

- 1) Distributions of T_G and α during a spot heating test can be directly identified by proposed GA-based technique. The identified T_G is close to the one measured by a LIF system.
- 2) The plate back surface temperature during the spot heating test calculated from the identified T_G and α is comparable to the one measured. The results obtained demonstrate the accuracy of the identified heat input parameters and the validity of the proposed GA-based identification technique.
- 3) The proposed GA-based identification technique is valid for the high power heating case for which the conventional IHC-based techniques are not applicable.

KEY WORDS: Generic algorithms, Heat flux, Heat transfer, Inverse heat conduction analysis, Laser induced fluorescence technique, Temperature estimation, Line heating.

INTRODUCTION

Flame line heating is an effective method for forming flat steel plates into three-dimensional shapes for ships and other structures. However, this technique requires skilled workers who are now in short supply. Hence the urgent need to automate this process.

The problem of flame forming of metal plate can be separated into two

sub-problems: the heat transmission problem and the elasto-plastic deformation problem. In fact, the solution of the first problem is a prerequisite to approaching the second one.

Some reports on the heat transmission problem during line heating have been published to date (e.g., Moshaiov and Latorre (1985), Tsuji and Okumura (1988), Terasaki et al. (1999), Jang et al. (1997), Yu et al. (2001)). In these studies, the heat flux distribution around the torch is assumed to remain unchanged with time. This approximation is not sufficient for very slow torch speed and repetitive heating cases. In these cases, the plate face temperature immediately below the torch rises substantially over time, and the heat flux changes with time.

Tomita et al. (2001) measured in detail the transient 3-dimensional gas temperature field within the combustion flame during spot heating tests by a high performance laser induced fluorescence (LIF) measurement system. They found that the thermal-flow field of the heating gas becomes stable in an extremely short time, and remains unchanged during spot heating. This means that the temperature of the gas adjacent to the plate T_G and local heat transfer coefficient α can be considered to remain nearly unchanged with time. This leads to a linear relationship between flux q and heating face temperature T_S .

Time histories of plate back surface temperature T_B can be measured during a spot heating test. Time histories of flux and heating face temperature, q and T_S can be estimated by inverse heat conduction (IHC) analysis from the measured T_B . T_G and α can be identified by a linear regression analysis on the relation between q and T_S .

The authors (Osawa et al. (2004a), Osawa et al. (2004b)) proposed finite difference method-based IHC techniques for the estimation of q and T_S . However, we frequently failed to estimate the flux because the IHC problem is extremely sensitive to measurement errors. The robustness of the IHC analysis was improved by developing a function specification method (Osawa et al. (2007)), but it remained difficult to identify the heat flux when measured T_B has a certain degree of error. This problem can be overcome estimating time-independent T_G and α directly instead of the flux. In this study, a generic algorithms (GA)-based direct identification technique for T_G and α is proposed. T_G and α during a spot heating test is identified by the proposed technique,