Inverse Estimation of Heat Transfer Coefficients in Heat Treating Process

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Introduction

Heat treating is mainly used to improve the physical and mechanical properties of metals by controlled heating or cooling without changing the parts configuration. Although, steel quenching is one of the main heat treating processes that has been used for decades in many industrial applications, the quenching conditions are still obtained through intensive experimental work. This way of obtaining the quenching conditions does not provide detailed information about the microstructure and mechanical properties of the quenched part during the quenching process. This can lead to non-optimal material properties with associated financial consequences to the industry.

Therefore, the main objective of this study is to develop an online inverse algorithm that can be used to estimate and update the quenching conditions such as the convective heat transfer coefficient in real time to obtain the desired microstructure.

The online input estimation algorithm was developed by Tuan et al. [1] and has been successfully applied for many inverse heat conduction applications solving the thermal field only. In this work, the online input estimation algorithm has been modified for the coupled process of steel quenching.

Problem Formulation

The steel quenching process is a coupled problem where the thermal field is coupled to the microstructure field through the heat generation of phase transformation.

In the present study, the thermal field along with the heat transfer coefficient of the quenching process are estimated using the online input estimation algorithm given some transient temperature measurements. The obtained thermal field will be used in the microstructure model to calculate the volume fraction of the steel phases using the data from the TTT diagram [2].

The phase transformation during steel quenching can be classified into a diffusional transformation such as austenite to pearlite transformation and a diffusionless transformation such as austenite to martensite transformation. The former depends on the temperature and time while the latter depends on the temperature only.

The incubation and growth periods of diffusional transformation are calculated by the Scheil's additivity method and Johnson-Mehl-Avrami (JMA) equation respectively [2]. The diffusionless transformation is determined by the Koistinen-Marburger equation [2].

Results and Discussion

The online input estimation algorithm coupled with the steel microstructure model has been used to solve the quenching problem of a 1080 carbon steel cylinder of diameter 38.1 mm. The present results have been compared with the direct solution of the same problem solved by a fourth order Runge-Kutta method [2]. They are also compared with the experimental data reported in [3]. The cylinder is initially kept at the austenizing temperature of 850 ºC and then quenched in 22.5 ºC water.

Figure 1 displays a comparison between the exact and the reconstructed heat transfer coefficient by the online input estimation algorithm. The shape of the heat transfer coefficient is quite well reproduced by this method especially at the peak value of the early stage of the steel quenching process, thus providing confidence in the solution technique.

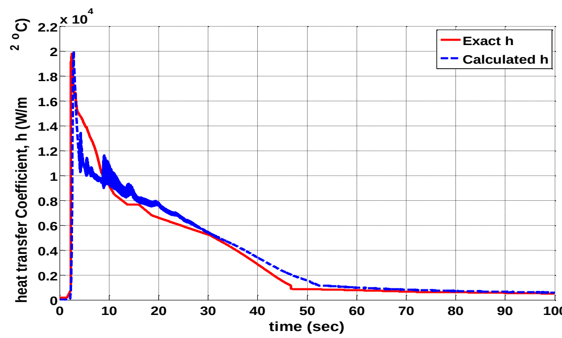

Figure 1 A comparison between the exact and the estimated convective heat transfer coefficient of steel quenching process.

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