Research Programs

Carburization Process Optimization

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Introduction

Gas carburizing is a widely adapted procedure used for surface hardening, yet it faces certain challenges in the performance reliability and the process control. Since the quality assurance criteria that carburized parts exhibit a set of mechanical properties required for a particular application and compliance with customer's tolerances and specification, it is necessary to be able to accurately predict carbon distribution in the case and to ensure satisfactory and reliable service life of the carburized parts.

The three stages of carbon transfer during the process are: 1) carbon transport from the atmosphere through the boundary layer, 2) chemical reaction at the steel surface, and 3) carbon diffusion into the bulk of the material. Total carbon transfer from the atmosphere to the steel is thus determined by the limiting process, which kinetically becomes the rate controlling stage of carburizing. Figure 1 schematically shows the mechanisms of carbon transfer during carburizing and the primary control parameters: the mass transfer coefficient (β) defining carbon atoms flux from the atmosphere to the steel surface and the coefficient of carbon diffusion in steel (D) at austenizing temperatures.

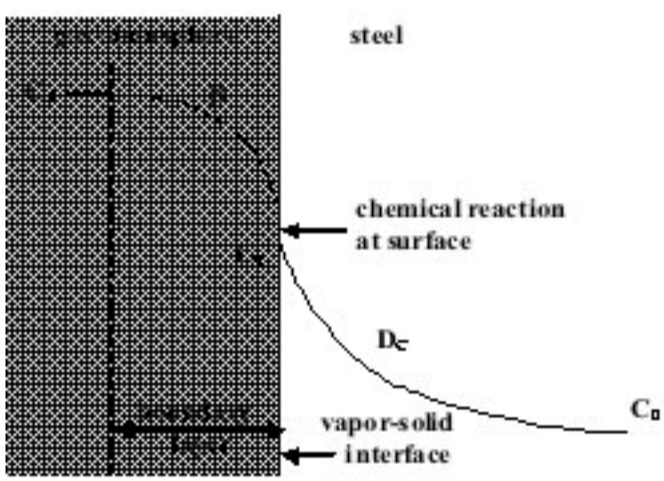

Figure 1: . Schematic representation of carbon transport in carburization process.

Considering the kinetics of the process, the maximum carburization rate is obtained when the carbon transfer from the atmosphere is equal or greater than the carbon diffusion rate in the solid state. Such diffusion controlled process has no deficiency of carbon supplied to the interface for its further transport into the solid; an assumption of constant surface carbon content may then be justified. In practice, however, the non-equilibrium carbon transfer from the atmosphere to the solid boundary including surface reaction is often reported to be the rate limiting factor [2,3] especially at the start of the carburizing process. After this initial stage, the process becomes mixed controlled [4-7] and should be modeled correspondingly.

Although carbon transport mechanism appears to be well understood, revealed experimental results have shown that for different carburizing atmospheres, the carbon concentration curves often deviate from those of the predicted ones. This suggests that knowledge of carbon potential and carburizing time are not sufficient for the process control, and require better understanding of β and D as a function of the process parameters for the successful control of gas carburizing process [8-9].

Objectives

The objectives of the project are to develop the information and a methodology (including process guidelines and process parameter control strategy) to optimize the carburization process to:

- Minimize case depth variability
- Minimize cycle time
- Minimize distortion (will not be the focus of this two year project)

Methodology

A predictive model is needed that uses the process parameters as inputs and the hardness and carbon concentration profile as outputs. A simple PC-based model will be developed at CHTE for carbon profile predictions. This model could be extended to hardness profiles.

In addition, DANTE and DEFORM software will be investigated for database needs/availability and applicability to this project's objectives. The accuracies of these models will be tested and confirmed by comparison with data from the CHTE members and the literature. These models will then be used for a process development effort (six sigma or DFSS etc.) to reduce the variability in the process and the cycle time. The steels to be investigated will be selected by the focus group. A series of experiments at CHTE member facilities will also be needed to fill in gaps in the data as well as test the predictive models.

References

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