Carbonitriding – fundamentals, modeling and process optimization

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Introduction

The carbonitriding process, which involves the diffusion of both carbon and nitrogen into the base steel, can be carried out in a salt bath or in a furnace gas atmosphere.[1] It is a modified carburizing process but is mostly done at a lower temperature and for shorter time than carburizing. This process is one of the widely used heat treatments for surface hardening. Nonetheless, there are challenges associated with the process performance and reliability.

In industry, numerical modeling is always an efficient approach with lower cost and less time to help study and optimize the process parameters. For surface hardening, case depth is a very important quality assessment index and is a function of processing temperature, time and the furnace atmosphere. Based on the experimental results, many empirical prediction functions for case depth prediction during carburizing process were developed and improved from 1930s.[2-6] J. I. Goldstein and A. E. Moren[7] developed a diffusion model for carburizing process with temperature dependent carbon diffusivity and various process parameters, but did not consider the effect of carbon concentration on carbon diffusivity. Olga Karabelchtchikova and Richard D. Sisson, Jr.[8] studied the carbon diffusion in steels with thermodynamics and kinetics methods during carburizing process, and calculated carbon diffusivity from experiment results. For the carbonitriding process, J. Slycke and T. Ericsson[9][10] studied reactions occurring during that process and diffusion of carbon and nitrogen in steel with a series of experiments. The interaction between carbon and nitrogen during diffusion in steels was studied and the diffusivities for carbon and nitrogen in austenite were calculated.

The objective of this project is to model the carbonitrding process and determine the boundary conditions for carbon and nitrogen absorption as well as the diffusion coefficients of carbon and nitrogen in steel during the process.

Methodology

The project focused on three tasks:

Task 1: Develop a fundamental understanding of the carbonitriding process.

Task 2: Modify the Carbtool to create Carbonitridetool by adding the nitrogen uptake and diffusion into austenite with concomitant carbon uptake and diffusion.

Task 3: Verify the Carbonitridetool in comparison with experimental results. The verification will initially be conducted by comparing with results in the literature and results from CHTE member companies. Selected experiments will also be conducted to test the model's accuracy and capabilities.

Salient Results

In this work, a series of experiments for AISI 1018 and AISI 8620 have been completed to investigate the effect of various ammonia additions into the furnace atmosphere on the kinetics of mass transfer during gas carbonitriding process and on the overall carbonitriding performance. The principal results of this work are:

The boundary conditions for carbon and nitrogen absorption during carbonitriding process were determined experimentally; and diffusivities of carbon and nitrogen in austenite were calculated and determined by comparing with the DICTRA results.

CarboNitrideTool© was developed to simulate gas carbonitriding process based on the experiment results and thermodynamic calculation results. The simulation results agree with the experimental results well.

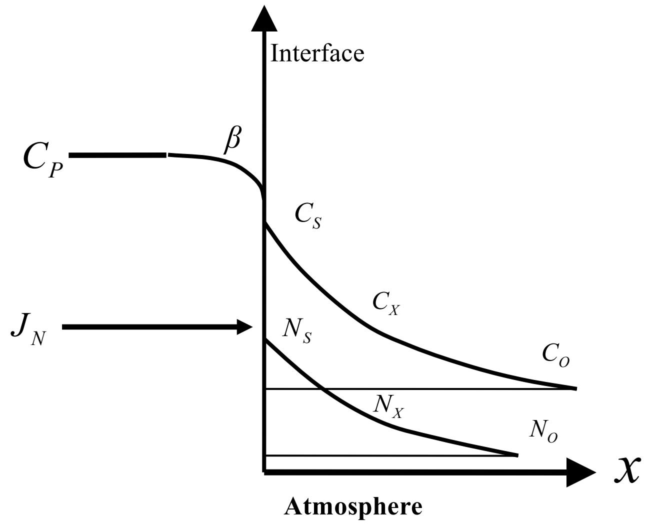
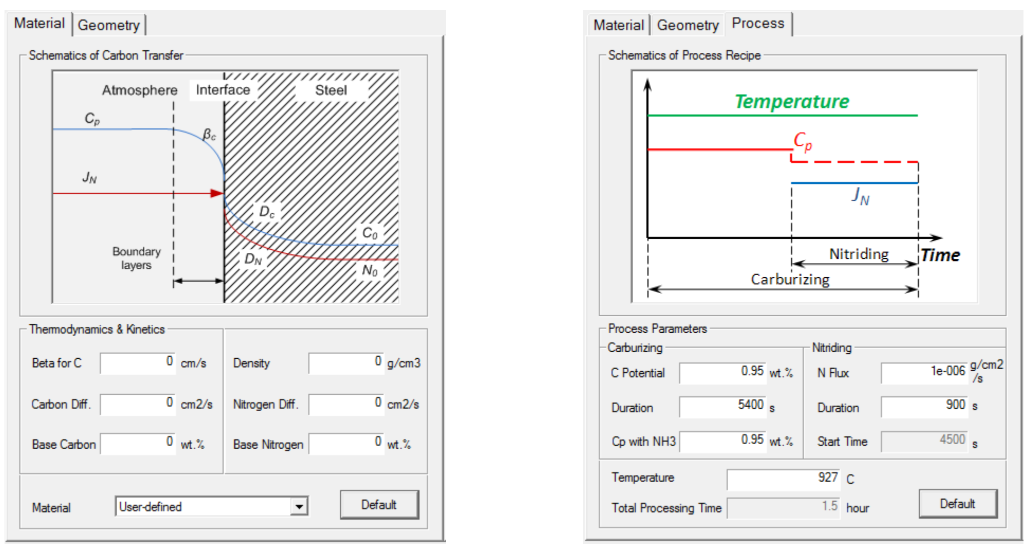


Fig.1 Schematic representation of the boundary conditions for carbon & nitrogen transportation in CarboNitrideTool©



(a) (b)

Fig. 2 User Interfaces of CarboNitrideTool© for Material properties (a) Process parameters (b)

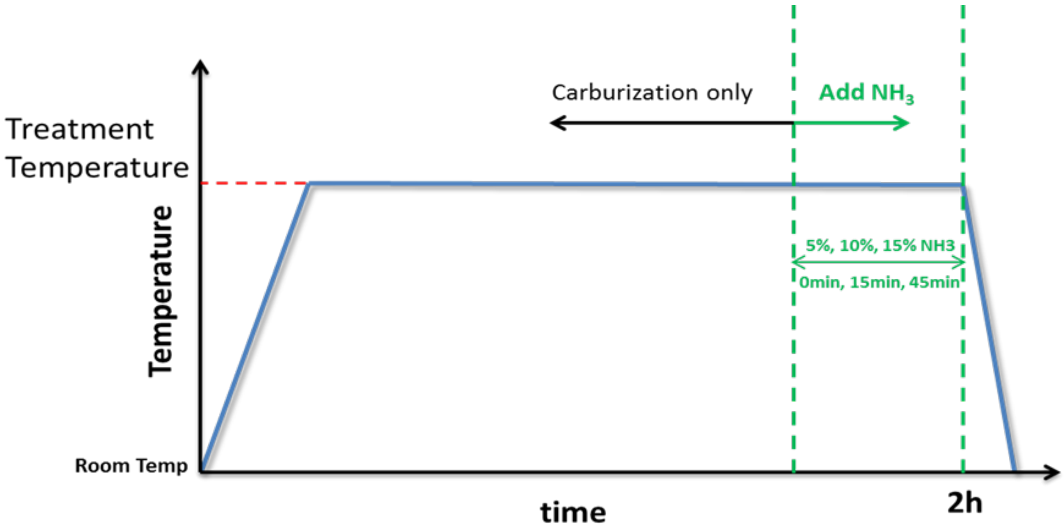


Fig.3 Schematic experimental processes

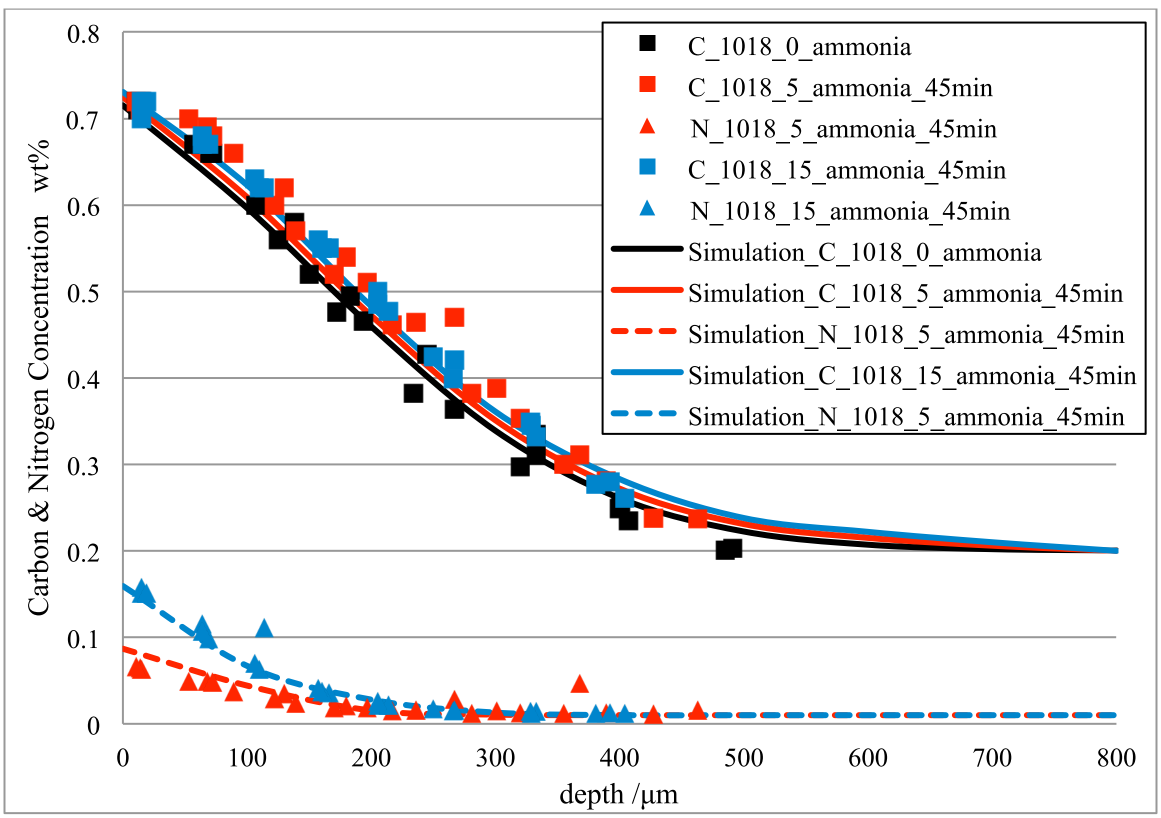


Fig. 4 Comparison between experiment result and simulation result

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