Research Programs

CHT-*bf* - Computer-aided Heat Treatment Planning System for Batch Furnaces

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Research Team:
Dr. Quansheng (Charles) Lu
Dr. Jinwu Kang
Rohit Vaidya
Cheng Bai
Weiwei Wang
Prof. Yiming (Kevin) Rong, Advisor

Introduction

Heat treatment is a manufacturing process to control the mechanical properties of metallic components. The thermal history of each part and the temperature distribution in the whole load directly determined the final quality of parts. The thermal exposure a component undergoes depends on the design of the furnace load, location of the component within the load, furnace configuration, thermal schedule, and control strategy. As the part and furnace are given, part loading and thermal schedule are the main factors for temperature control the heat treatment process. In the heat treatment furnace heat transfer involves furnace control, combustion, convection, radiation and conduction.

Objectives

The objective of the proposed project was to develop an analytical tool to guide the designs of part loading and thermal schedule and improve furnace temperature control by the analysis of heat transfer during the heat treatment process.

The major tasks were defined for this project and all of them have been achieved:

- The development of knowledge-based CAD tool, which will provide a CAD user interface for the information input of the furnace, workpiece, and initial operation conditions that are used in the initial part load designing and thermal schedule designing. This is the input information of thermal analysis.
- The establishment of physics-mathematical models for the heat transfer process in the batch heat-treat furnace using thermodynamic theories, which will include a heating element model, a heat radiation model, a heat convection flow model, and a heat conduction model.
- The development of a numerical calculation method for estimating the temperature distributions in the furnace and workpiece by using FEA methods, under the specified furnace geometry, thermal schedule, part loading design, initial operation conditions, and performance requirements.

Methodology

An investigation was conducted on the state-of-the-art technology development and current practice in heat treatment industry. Then the problem was formulated based on the investigation and literature review. Through the thorough comparison of numerical simulation and analytical methods, finally, the technical

route of hybrid methods of numerical and analytical methods was set for the project. Mathematical models for furnace temperature control, combustion, convection, radiation and convection heat transfers were established.

Salient Results and Related Publications

An analytical tool -- Computerized Heat Treatment Planning System for Batch Furnaces (CHT-bf) was developed. When the part loading and thermal schedule are specified, the temperature distribution in furnace and parts can be calculated and predicted. Therefore, the part loading and thermal schedule can be optimized through several repetitions of heat transfer analysis. The system can be used for gas-fired furnaces (direct and indirect) and electric furnaces. The load pattern can be aligned or staggered. The system was evaluated by several case studies provided by CHTE focus group member companies.

The features of CHT-bf are:
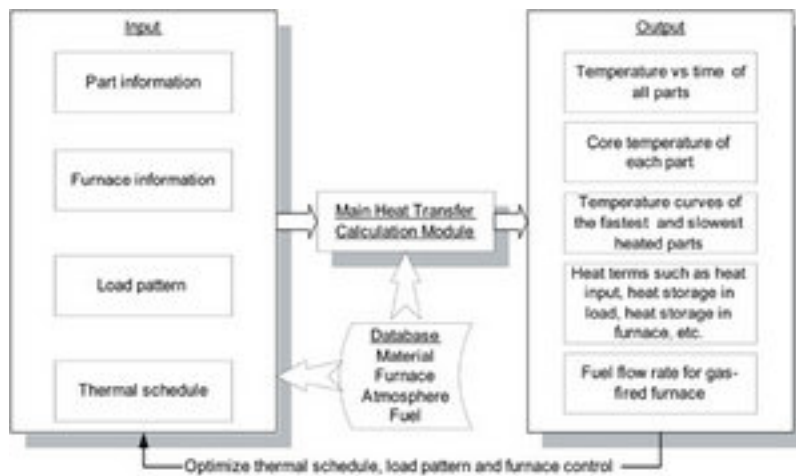
1. Accurate temperature profile prediction in furnace
   o   Prediction of the temperature profile of every part in furnace.
   o   Ability to determine surface & core temperatures, especially for large parts.
   o   Capable of handling multiple parts / layers / fixtures in 3-D.
   o   Simulation under vacuum and different atmospheres.
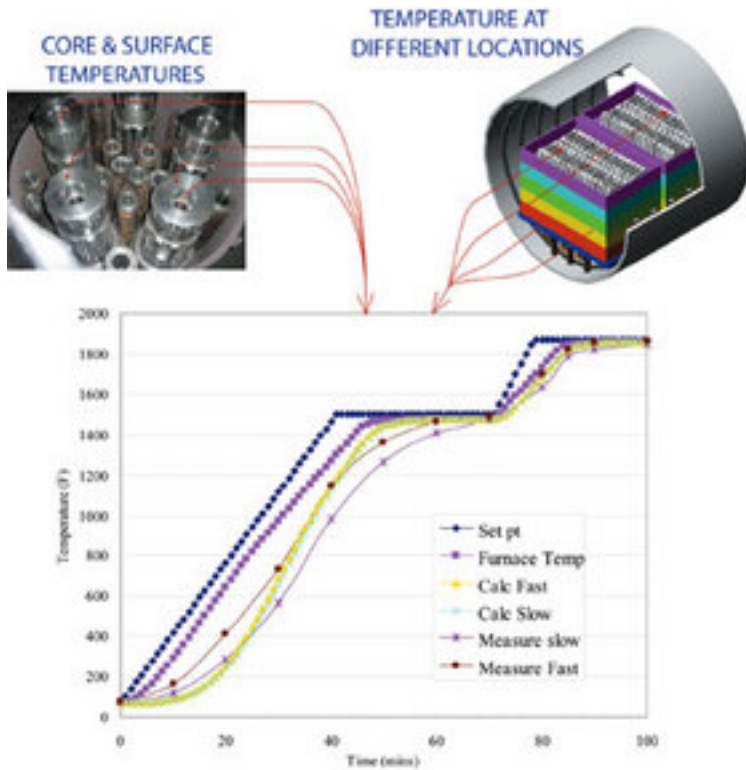
2. Ability to simulate various load patterns including complex random loads
   o Both arranged and random load patterns.
   o Ability to simulate the effects by varying the load pattern, thermal schedule and PID control.
   o Determination of the temperature profiles of the slowest and the fastest heating parts for a given load pattern.
3. Ability to calculate important heat treat terms
   o Prediction of the heat required for the load under different conditions.
   o Plot of the heat stored in the furnace and the load as a function of time.
   o Calculation of the different heat losses from the furnace.
   o Capability to simulate the effect of using different fixtures.

3. Prediction of fuel flow rate
   o Determination of the fuel required as a function of time, for better control of furnace performance.
4. Comprehensive Database
   o A comprehensive database system with more than 500 materials and several widely used furnaces enable the user to utilize CHT-bf quickly.
   o Also a separate Database Management feature assists users to add new data into the database seamlessly.

Publications

1. L. He, J. Kang, T. Huang and Y. Rong, "The Integrated Technique for the Heat Treatment of Aluminum Alloy Castings: a Review", Heat Treatment of Metals, Vol. 31, No. 3, 2004, pp. 69-72.
2. J. Kang, Y. Rong, W. Wang, "Numerical simulation of heat transfer in loaded heat treatment furnaces", Journal of Physics, Vol. 4, France, No. 120, 2004, pp. 545-553.

3. Q. Lu, R. Vader, J. Kang and Y. Rong, M. Hoetzl, "Development of A Computer-Aided Heat Treatment Planning System", Heat Treatment of Metals, March 2002, pp. 65-70
4. R. Purushothaman, J. Kang, L. Zhang, and Y. Rong, "Application of CHT-bf and CHT-cf in Heat Treatment Process Operation Design", ASM Materials Science and Technology Conference and Exhibition, Sep. 25-28, 2005, Pittsburgh, PA
5. J. Kang, T. Huang, Y. Rong, "Modeling and Simulation of Heat Transfer in Loaded Heat Treatment furnace", The Third Sino-Korean Conference on Advanced Manufacturing Technology, Xi'an, China, June 10~13, 2004
6. J. Kang, R. Purushothaman, Y. Rong, "Industrial Applications of CHT-bf and CHT-cf", the 23rd ASM Heat Treating Society Conference and Exposition, September 26-28, 2005 in Pittsburgh, PA.
7. J. Kang, R. Vaidya and Y. Rong, "A Computer Aided Heat Treating Planning System," ASM 22nd Heat Treating Conference & 2nd International Surface Engineering Congress, Indianapolis, IN, September 15-18, 2003
8. J. Kang, Y. Rong and W. Wang, "Numerical Simulation of Heat Transfer In Loaded Heat Treatment Furnaces", 2nd International Conference on Thermal Process Modeling and Computer Simulation, (ICTPMCS), March 31 - April 2, 2003, Nancy, France, pp. 545-553
9. J. Kang and Y. Rong, "Modeling And Simulation of Heat Transfer In Loaded Heat Treatment Furnaces", The 13th International Federation for Heat Treatment and Surface Engineering Congress, Columbus, OH October 7-10, 2002