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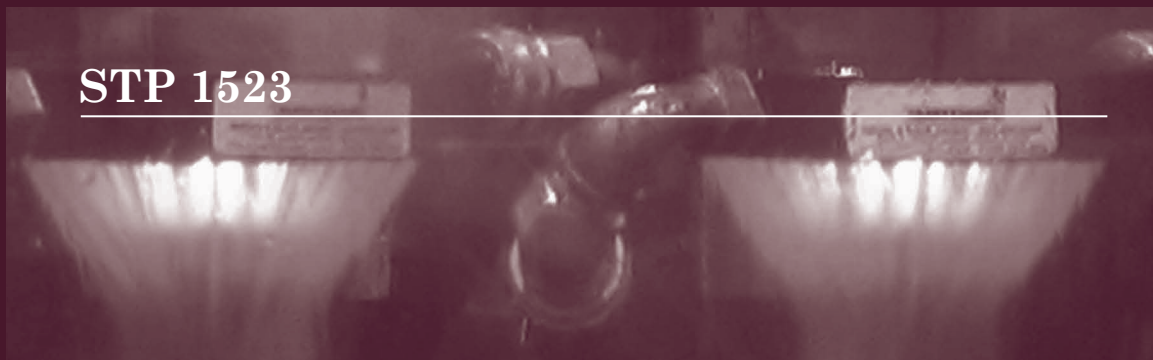

STP 1523

Quenching and Cooling, Residual Stress and Distortion Control

JAI Guest Editors:

Lauralice de C.F. Canale
Michiharu Narazaki

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Cover image illustrates a dual-spindle induction heating and quenching of steel shafts. Courtesy of Inductoheat Inc., An Inductotherm Group Company.

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Foreword

THIS COMPILATION OF THE *JOURNAL OF ASTM INTERNATIONAL (JAI)*, STP1523 on *Quenching and Cooling, Residual Stress and Distortion Control* contains papers published in JAI highlighting the impact of the quenching process on the heat treatment of metals. This STP is sponsored by ASTM Committee D-2 on Petroleum Products and Lubricants.

The JAI Guest Editors are Lauralice de C.F. Canale, EESC Universidade de São Paulo, Brazil, and Michiharu Narazaki, Utsunomiya University, Utsunomiya, Japan.

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Distortion and Residual Stresses

Property Predictions

Quenchants and Quenching

Gas Quenching

Hardenability

Cooling Curve Analysis Methodologies

Dilatometric Analysis

Overview

Quenching and distortion control continue to be of great concern to the metals processing industry since they exhibit tremendous effects on quality and profitability. Recently, many papers on topics directly and indirectly related to quenching and quenching processes have been published in the Journal of ASTM International (JAI). In view of the interest and importance of these topics to the thermal processing industry, a total of 59 JAI papers have been collected together into this ASTM Special Technical Publication (STP) and these papers have been organized into nine topical sections: Heat Transfer; Modeling and Simulation; Distortion and Residual Stresses; Property Predictions; Quenchants and Quenching; Gas Quenching; Hardenability; Cooling Curve Analysis Methodologies; and Dilatometric Analysis.

The Heat Transfer section includes papers describing experimental techniques for measurements of heat transfer distribution at the spray cooled surface and in gas quenching systems. Also included are mathematical models to promote accurate characterization of heat transfer throughout the quenching operation. There are also papers which review the characteristics of various quench media, effects of process parameters on quenching, mechanisms of thermal transport, and techniques for the estimation of heat transfer coefficients. Heat transfer studies for atomized water sprays, liquid media, and gas quenching system are discussed.

Modeling and Simulation are powerful tools in the design, optimization, and understanding of the quenching process and they are used increasingly in component manufacture. The development of simulation tools for quenching is critical for improving process performance by minimizing distortion and maximizing service life. Therefore, this section describes several examples utilizing FEM (Finite Element Methods), a combination of methods such as CFD (Computational Fluid Dynamics) and FEM-based thermal process models, to provide efficient and effective solutions applicable to quenching and tempering processes. Solid state transformations of ductile iron and new design steels are also discussed.

One section is focused on Distortion and Residual Stresses. Benefits associated with polymer quenching and uphill quenching for aluminum alloys are discussed. Carbonitriding and nitrocarburizing processes and their relationship with respect to size and shape distortion, retained austenite, and residual stresses are also discussed. Papers discussing tempering effects on as-quenched compressive residual stresses of carburized steel and the application of commercial codes including FLUENT, DANTE, CFD, ABAQUS, and Fortran subroutines to model and analyze residual strain, internal

stresses, and volumetric expansion due to phase transformation that occurs during steel heat treatment are included also.

In the Property Predictions section, an empirical equation is proposed to deduce the Vickers hardness of carburized and quenched components. Thermal and microstructure fields are predicted by numerical algorithms as well.

The Quenchants and Quenching section comprises of thirteen papers discussing a new ecofriendly starch-based quenchant and vegetable oil quenchants. Alumina-based nanofluids, hot alkaline bath, and bismuth bath are also described as cooling media. Accelerated quenching for steel plates is also addressed and the resultant microstructure and mechanical properties are analyzed. Intensive quenching and a timed quenching process are presented as alternatives to conventional heat treating. Spray quenching for induction hardening applications and comparative results of water and polymer quenchants for non-ferrous alloys are also covered.

Gas Quenching is considered a clean, non-toxic quenching medium that leaves no residues to be removed after processing. In this section, high pressure gas quenching processes exhibiting advantages including pure convective heat transfer are discussed, as is an upstream gas flow profile of the load as a key factor determining heat transfer distribution from the material. Finally, a simulation of the gas quenching processes is proposed as an efficient tool for investigation of mechanical properties, and their effects on quality are analyzed.

A shorter section on the classic topic of Hardenability includes two papers on the application of magnetic fields to enhance hardenability and an exploration of the effect of cooling rate on austenite decomposition in high strength sheet steels.

Quenching operations are a critical part of the heat treatment process. FEM simulations are used to optimize products and processes and are based on boundary conditions expressed as heat transfer coefficients, which are measured using cooling curves. Therefore, cooling curves are of great importance for the evaluation of quenchants and quenching processes and thus the section on Cooling Curve Analysis Methodologies is dedicated to this subject. A computational method for the prediction of cooling curves at the center of a steel bar based on a cylindrical silver probe is proposed. An experiment to detect dynamic cooling and steel transformation behavior upon direct quenching is also discussed. Test methods to characterize the cooling behavior of quenching media, which was introduced in China, are critically analyzed. Review on quench factor analysis and the Segerberg hardening power equation is also provided.

The final topic is Dilatometric Analysis. Its use as a powerful test for optimization of the age hardening parameters for aluminum alloys and for 17-4 PH stainless steel is discussed.

We believe that this Special Technical Publication of ASTM International on QUENCHING AND COOLING, RESIDUAL STRESSES AND DISTORTION CONTROL will provide an important contribution to the heat treatment industry worldwide.

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