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Special Issue on Advances in Methods, Quenchants, and Equipment for Hardening Steel

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Overview

Special Issue on Advances in Methods, Quenchants, and Equipment for Hardening Steel

The continuing development of new quenchants and understanding their behavior is vitally important to assure global competitiveness into the future. This ongoing effort also includes quench process design. Quenching processes conducted in increasingly modern heat treating facilities has evolved from simply dropping or dunking a heated part into a tank containing unagitated water as a traditional blacksmith would have done in the past. Today, renewable liquid quenchants or perhaps high pressure gasses might be used depending on the process and component design requirements. To achieve these requirements, the appropriate quenchant must be selected. Various computational simulations to develop the best materials and process designs to meet these requirements are increasingly being routinely performed. This Special Issue of the ASTM journal *Materials Performance and Characterization (MPC)* entitled*: Advances in Methods, Quenchants, and Equipment for Hardening Steel* contains a series of selected and peer reviewed papers targeting a range of topics which capture advances in the state-of-the-art of quenchant development and approaches to process design improvements in use today.

The first paper in this Special Issue of MPC provides an overview of the ongoing activities currently underway at the newly formed (2010) and globally important Quenching Research Center (QRC), which is located in Zagreb, Croatia. Some of these activities include: research into the mechanisms and process designs for quenching in vaporizable liquids and salt baths or cooling by high pressure gases. Other projects include: process parameter development, ultrasonic agitation system development, and development of new quenchants, such as: water, oil, aqueous polymers, vegetable oils and nanofluids. Research is currently underway utilizing the unique high-pressure gas quenching facilities available at the QRC to provide hardware for controllable heat extraction processes. The QRC was one of the initiators and an active participant in the Global Database Development Project on quantifying the cooling intensities of liquid quenchants commercially available worldwide. This project is coordinated and conducted by the International Federation for Heat Treatment and Surface Engineering (IFHTSE).

There are three papers exemplifying ongoing efforts to further the understanding of metallurgy of quenching. Topics include a review on super-strengthening of steel which occurs during intensive quenching, the effect of partial decarburizing on the amount of retained austenite formed during quenching, and the effect of carbide precipitation on mechanical properties during quenching and tempering. Also in this section is a discussion of the effect of quenchant selection on the hardness of nanobainitic steel.

In another section of this Special Issue is a review of surface temperature pulsations or localized thermal shocks which occur during nucleate boiling and their potential impact on the quenching process. Also, in this section is another paper on the possible use of the noise that accompanies film and nucleate boiling in the development of a quench process control system based on monitoring these noises throughout the quenching process.

One of the most critical roles of the quenching process is to provide the necessary distortion control and optimal residual stresses in the final component. This Special Issue contains three papers that are indicative of continuing research and applications work in this area. One paper discusses modeling of thermal distortions and residual stresses after transformation-free cooling. Another paper discusses modeling and experimental work to study the microstructural evolution and accompanying residual stresses that are formed when quenching large forgings. The third paper in this section discusses the development of new quenching processes to optimize component distortion, residual stresses, and mechanical properties.

Some of the first modern work on quenchants such as Le Chatelier's ground-breaking research on quenching behavior in 1904 was to identify useful parameters to quantify quench severity and quench process performance. This type of research is continuing over 100 years later. Recently developed quench process indicators are included in a section of this Special Issue entitled *Quench Severity Characterization*. Topics include the measurement and sensitivity of heat transfer coefficients, simulation of heat transfer using molecular dynamics involved when carbon nanotube (CNT) – based nanofluids are used as quenchants, development of parameters to characterize cooling during immersion and spray quenching, and the use of regression analysis and neural networks to parameterize quenching processes.

In the section entitled *Quenchant Characterization,* cooling performance of selected petroleum and aqueous polymer quenchants is discussed. Also discussed in this section is the effect of additive chemistry on quenching performance and possible methods to control the cooling stages exhibited by vacuum quenching oils. Although the use of vegetable oils as quenchants has been widely discussed, properties such as distortion and residual stress, especially compared to petroleum oil quenchants, has not been widely discussed until now. This topic is addressed in this section as well. Quenching process characteristics of nanofluids are discussed, as is the impact of the preparation method on nanofluid quenching behavior. Finally, an experimental and computational methodology is described which is used to establish the optimal process window for induction hardening processes.

Cooling curve analysis has long been considered the best method of characterizing quenching performance and many references detailing various cooling curve methodology have been published. However, in the *Quenchant Testing* section, there are three papers that discuss new aspects of cooling curve analysis including: use of a newly developed probe for direct estimation of cooling rates, heat flux and hardenability during quenching of hardenable steels and a new method for testing cooling power using a silver probe which includes the important development of a new reference quenching fluid. The use of a prototype of the rotary-arm test system, which utilizes a small spherical probe for cooling curve analysis, is discussed here. The last paper in this section discusses the development and operation of a stationary quenchant testing apparatus and its use to characterize the quenching behavior of fresh and used commercial petroleum oil for quenching AISI 1045 carbon steel.

The final section of this Special Issue addresses *Quenching Equipment and Fixtures*. The papers in this section discuss spray cooling devices for heat treatment of large steel forgings and the design and use of perforated plates to optimize gas quenching processes. The last paper in this section is a relatively rare but important review of press and fixture quenching for distortion control.

Taken together, the papers in this Special Issue do address the *Advances in Methods, Quenchants, and Equipment for Hardening Steel*. From this work, it is clear that the integration of the use of computational methods is exhibiting significant improvements in quenchant development and process characterization and design and this is likely to continue into the future.

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The high quality of the papers that appear in this publication is a tribute not only to the obvious efforts of the authors represented but to the unheralded, though essential, efforts of their reviewers. It is to the reviewers dedication to upholding the high standards of their profession that this note pays tribute. On behalf of ASTM International and the authors as well, we acknowledge with appreciation their important contribution to the success of this journal.

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