Quenching – Understanding, Controlling and Optimizing the Process – II

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Objectives

Building on the work of the first two years of this project the proposed project will address "key" issues in the design, analysis, characterization and operation of a quenching system. These issues include

- the accurate prediction of the heat transfer coefficients on the quenched part surfaces as a function of
    - metal surface temperature,
    - part shape and orientation,
    - quench tank characteristics (i.e. agitation, temperature and location in the tank's flow patterns) as well as
    - the prediction of the quenched part's microstructure and deformation.

Strategy

The recently designed and tested CHTE quenching characterization system, the well proven and commercially available IVF quench probe, the Liscic-NANMAC three thermocouple quench probe and a newly designed CHTE four thermocouple plate probe will all be used to continue to populate the QUENCHPAD database with more quenching fluids including selected mineral oils, polymer solutions, water and gases as well as industrial quenching tanks.

The work will focus on quantifying the effects of fluid temperature and flow characteristics/agitation on heat transfer as well the effects of part geometry, orientation, material and surface condition on the effective heat transfer coefficients.

A model will be developed to predict the microstructure on the quenched part based on the alloy composition and part geometry. This project will work closely with test sites at some member companies to integrate their model for predicting deformation of the quenched part into the quench tank design, characterization, analysis and operation.

This project will also expand the alloys being quenched to include a variety of steels, nickel alloys, wrought and cast aluminum alloys and powder metallurgy parts. The CHTE quench probe systems will also be used to determine the causes of variation in the response of the probe including surface finish/condition and fluid physical properties and flow behavior.

This project will yield a greatly enhanced understanding of the relationship between the quenching response of the part to quench system design and operating parameters.

Current Status

CHTE probe system with probe tips made of different alloys and other commercial probes are currently being used to collect time-temperature data during quenching in various liquid based quenchants.

The CHTE quench probe system with 4140 steel and 304 steel probe tips were used in various oil based quenchants to study their performances. Probe tips of 1018 and 52100 steel have been fabricated. The preliminary experimental work is underway.

In addition a new probe immersion system has been designed and fabricated to insert and hold the two large probes, Liscic-NANMAC and CHTE Plate probes. This new immersion system will allow the control of the probes thermocouples orientation in the quench tank. Preliminary work is underway to test the new immersion system and large probes.

All the experimental data collected in this project are being entered in to the CHTE quenching database, QUENCHPAD. The database is written in Microsoft Access 2000. For the easy access of the data, the database has been made available to the CHTE member at the MPI website, http://www.wpi.edu/+mpi as a part of QuenchMiner, the web-based Decision Support System for Quenching.

Typical heat transfer coefficient curves for 4140 and 304 stainless steel probes as a function of temperature are shown in figure 1. 4140 steel probes are heated in argon prior to quenching while 304 probes are heated in air. 304 probes show the presence of Leidenfrost point or film boiling regime during quenching.

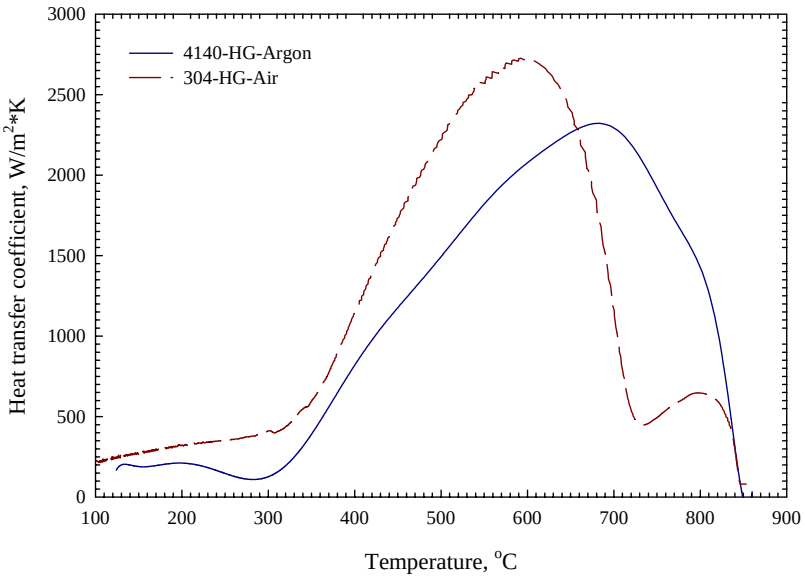

Figure 1: Heat transfer coefficients of 4140 steel probe heated in argon and 304 stainless steel probe heated in air prior to quenching in Houghton's Houghto G mineral based quench oil

CHTE Quenching Research Team at WPI has developed a Web-based bibliographic database QuenchBIB™. It serves as a central repository for information of quenching related publications that were used as references by CHTE Quenching Research Team and provides data sharing capability among members of CHTE through the use of the Internet. CHTE members are able to access to the database from any computers that have web browsers and Internet connections. QuenchBIB™ is at its beta version. Currently it has approximately 750 bibliographic records related to the quenching heat treatment process or relevant research areas and is continuously being updated as new citations are available. Figure 2 shows a typical search results web page.

Figure 2: Search Results

QuenchMiner is a Web-based Decision Support System for the immersion quenching process that integrates the Quenchant Performance Analysis Database namely QuenchPAD, a Data Mining system, a Knowledge Base, and data visualization system. The list below summarizes the main objectives of QuenchMiner

- Compare experiments and find patterns from them.
- Experimentally determine the effects of particular parameters, their magnitudes, and the results when they are present in combinations.
- Integrate experiment database, handbook data, and expert knowledge in a single source.
- Incorporate model of material science and predict properties of quenched specimen based on time-temperature data from experiment.

A number of quenching experiments to characterize various quenchants have been performed and collected over the past few years in QuenchPAD database. The toughest challenge for QuenchMiner is how to apply or relate what we know and what we can predict about small probes quenched in laboratory environment in commercial quenching process,

where workpieces come in various shapes and sizes. *It is meant to be a quick reference and is not designed to run complicated simulations and numerical analysis.* Many quenching technologies other than immersion quench such as spray quench, press quench, and chute quench are used in production lines depending on the applications; however, this version of QuenchMiner currently only focuses on immersion quench using water, gas, oil, and polymer as cooling media.

Future Work

- Complete the 52100 test matrix
- Complete the 1018 test matrix
- Compare the results of 52100 and 1018 with the 4140 and 304 results.
- Design a complete test matrix for the Liscic-NANMAC probe and the CHTE Plate probe as a function of probe orientation and agitation.
- Conduct preliminary experiments of Liscic-NANMAC and CHTE 4-TC Plate probe as a function of orientation. The tests are to be performed at Bodycote's Worcester Heat Treatment Plant.
- Continue populating the databases: QuenchBIB, QuenchPAD.
- Continue work on the development of QuenchMiner

List of Publications

1. Md. Maniruzzaman, Marco Fontecchio and Richard D. Sisson, Jr., *Optimization of an Aluminum Alloy Quenching Process in Poly-Oxethylene Glycol Polymer Solutions using Taguchi Methods*, to be presented at the ASM 22nd Heat Treating Conference & Exposition , 15-18 September 2003, Indianapolis, Indiana.

2. Aparna S. Varde, Mohammed Maniruzzaman and Richard D. Sisson Jr., *The QuenchMiner Expert System for Quenching and Distortion Control*, to be presented at the ASM 22nd Heat Treating Conference & Exposition , 15-18 September 2003, Indianapolis, Indiana.

3. D. K. Rondeau, Md. Maniruzzaman and R. D. Sisson, Jr., *The Effects of Part Orientation on Heat Transfer during Quenching*, to be presented at the 22nd Heat Treating Conference & Exposition, 15-18 September 2003, Indianapolis, Indiana

4. Shuhui Ma, Aparna Varde, Makiko Takahashi, D. Rondeau, M. Maniruzzaman and R. D.

Sisson, Jr., *Quenching – Understanding, Controlling and Optimizing the Process*, to be presented at the 4th International Conference on Quenching and the Control of Distortion, 20~23 May 2003, Beijing, China.

5. Marco Fontecchio, Mohammed Maniruzzaman and Richard D. Sisson, Jr., *Quench Factor Analysis and Heat Transfer Coefficient Calculations for 6061 Aluminum Alloy Probes Quenched in Distilled Water*, submitted to the Journal of Materials Performance and Technology.

6. Aparna, S. Varde, Makiko Takahashi, Elke A. Rundensteiner, Matthew O. Ward, Mohammed Maniruzzaman and Richard D. Sisson Jr., *Knowledge Discovery and Data Visualization in Heat Treating of Materials*, to be presented at the 15th International Conference on Scientific and Statistical Database Management (SSDBM), July 9-11, 2003, Cambridge, Massachusetts, USA.

7. Richard D. Sisson, Jr., Md. Maniruzzaman and Shuhui Ma, *Strategies for Quenching Sensors and Control*, Presented at the 132nd TMS Annual Meeting, March 2-6, 2003, San Diego, CA.

8. M. Maniruzzaman and R.D. Sisson, Jr., *Heat Transfer Coefficients for Quenching Process Simulation*, Presented at the 2nd International Conference on Thermal Process Modelling and Computer Simulation, Société Française de Métallurgie et de Matériaux, Nancy, France, March 31st –April 2nd, 2003.

9. M. Fontecchio, M. Maniruzzaman and R.D. Sisson, 2002, *The Effect Of Bath Temperature And Agitation Rate On The Quench Severity Of 6061 Aluminum In Distilled Water*, Proceedings of the 13th Congress of the International Federation for Heat Treatment and Surface Engineering (IFHTSE) and ASM International Surface Engineering Congress, October 7-10, Columbus, Ohio.

10. A.S. Varde, M. Takahashi, M. Maniruzzaman and R.D. Sisson, 2002, *Web-Based Data Mining For Quenching Analysis*, Proceedings of the 13th Congress of the International Federation for Heat Treatment and Surface Engineering (IFHTSE) and ASM International Surface Engineering Congress, October 7-10, Columbus, Ohio.

11. M. Maniruzzaman, J.C. Chaves, C. McGee, S. Ma and R.D. Sisson, Jr., 2002, *CHTE quench probe system – a new quenchant characterization system*, Proceedings of the 5th International Conference on Frontiers of Design and Manufacturing (ICFDM 2002), Vol. 1, pp. 619-625, July 10-12, Dalian, China.

12. M. Maniruzzaman and R.D. Sisson, Jr., 2002, *Investigation of bubble nucleation site density during quenching heat treatment process using video imaging*, Presented at the TMS Annual Meeting 2002, Feb. 17-21, Seattle, WA.