Strong Bar Competition

Washkewicz College of Engineering

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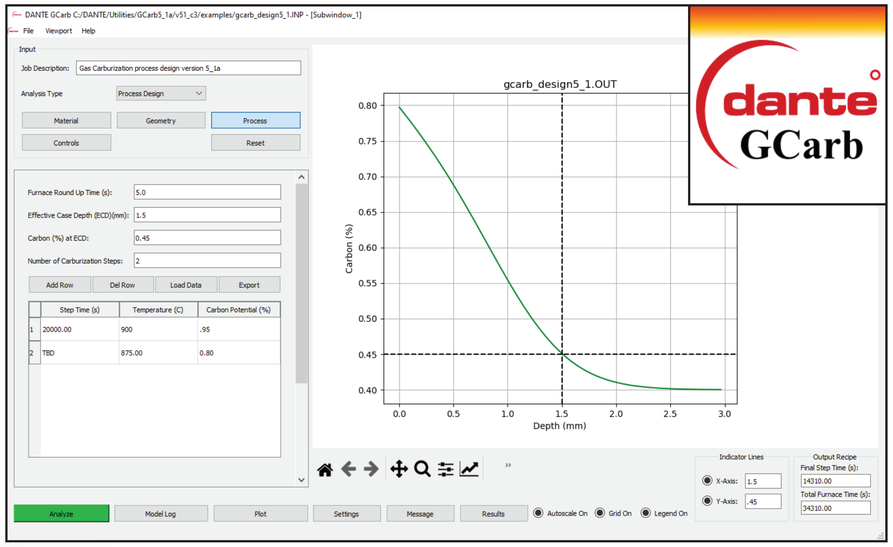
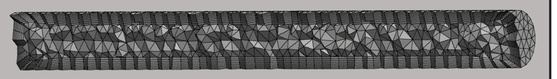


The full bar geometry was designed in Ansys SpaceClaim and meshed with finer elements near the surface to capture steep thermal and carbon gradients.

Mesh consists of:
15, 960 Nodes
35,431 Elements



Several preliminary models were executed to determine the best heat treatment process. The decision was made to include a carburization step to the process to take advantage of the increased material properties that a higher carbon level could provide in bending.

A case depth of 1.5mm (0.060") was chosen, as 0.5mm (0.0197") was to be machined off of the bar, circumferentially.

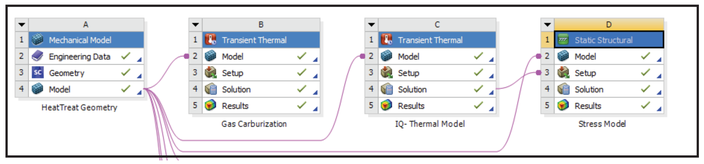
A carburization schedule was designed using DANTE GCarb, and the carburization times and potentials were added to the simulation.

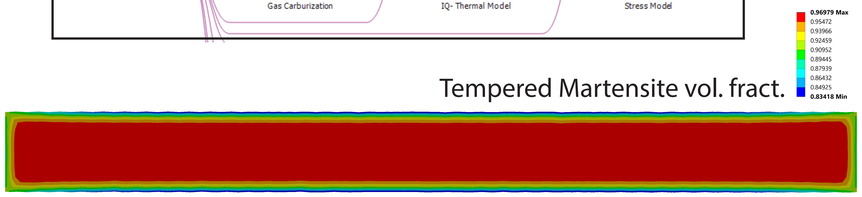
Unfortunately, Cleveland State University does not have carburization capabilities, nor an atmosphere-controlled furnace. The decision was made to reach out to a local heat treatment company to execute the process described below:

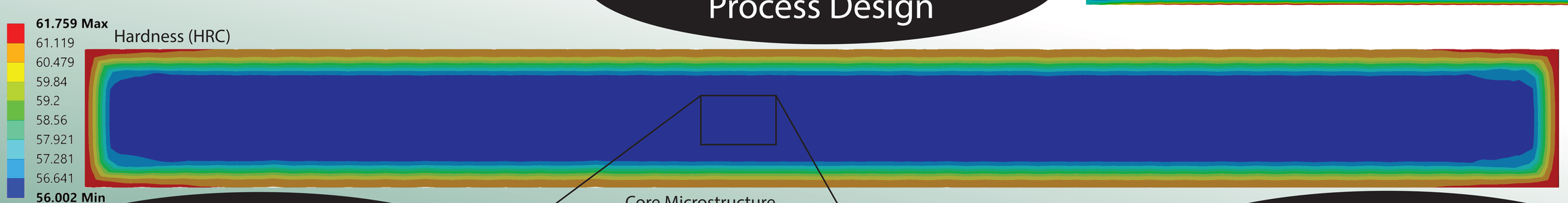
- Gas carburization to the targeted case depth (1.5mm, 0.060")
- Normalize in a vacuum furnace after carburization
- Reaustenitize in a salt pot at 850°C (1560°F)
- Intensive water quench
- Immediate temper at 165°C (330 °F)

These process steps were applied to the Ansys Transient Thermal and Static Structural (Stress) models. The models were executed with the DANTE subroutine and with the carbon profile generated previously. The resulting contours for carbon weight fraction, Martensite, retained Austenite, tempered Martensite and Hardness (HRC) can be viewed to the left, right, and below, respectively.

Process Design





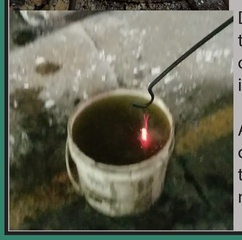


Heat Treatment

The actual heat treatment was performed at Akron Steel Treating (AST) with the approval of Joe and Steve Powell. Big thanks to the team at AST for helping with the hardening process described above that could not be performed at the lab at Cleveland State University.

The bars "rode along" with another job that AST had for the required 1.5mm (0.060") case depth. The actual carburization process was not disclosed, but we feel the predicted process from GCarb matches the actual process well due to the hardness measurements on the witness coupon provided by AST and the metallography performed in the lab at Cleveland State University. The bars were then normalized in the vacuum furnace and awaited one of our team to come down to AST for the reaustenitization, quench and temper.

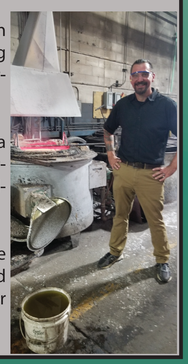
Reaustenitization was performed in the salt bath pictured to the left, and quenching was done in a polymer and water bucket with ice, as shown below.



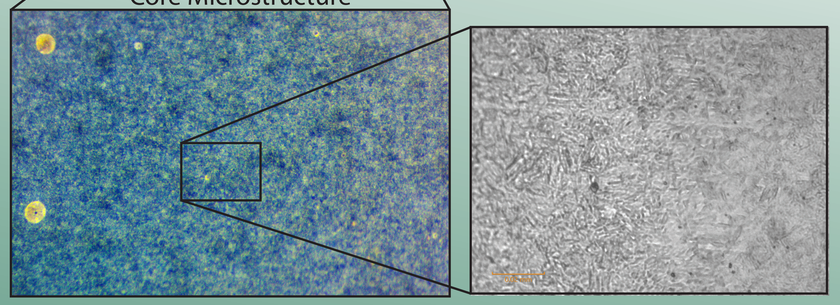
The samples were cool to the touch after ten (10) seconds of quenching and were placed in the tempering furnace for one hour.

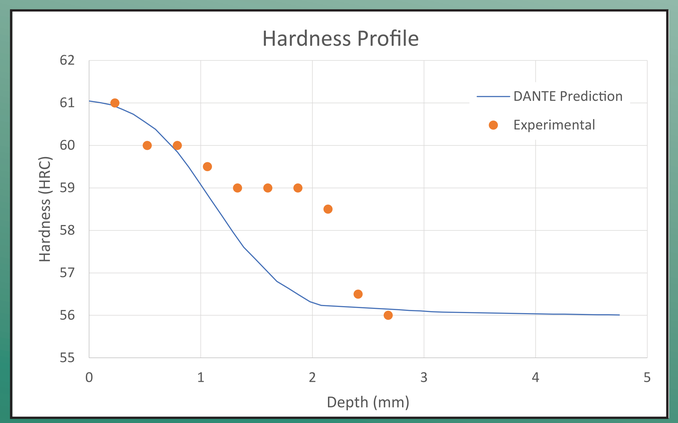
During the wait, Jason was given a tour of the facility at AST and was thoroughly impressed with all the capabilities they have to offer.

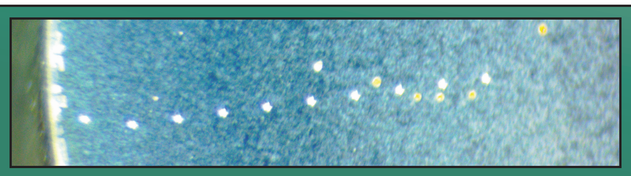
After tempering, the samples were cooled to room temperature and taken to the lab at Cleveland State for metallographic analysis.



Core Microstructure







Metallography

The metallography was performed in the lab at Cleveland State University. First, a bar was chosen to be cut cross-sectionally with the diamond disc cutter. After the section was cut, the sample was polished using increasing grit sandpaper and finally polished with 4µm diamond paste and a polishing pad.

After polishing, hardness measurements were taken using the Vickers hardness tester at CSU. Ten measurements were taken from surface to core, at approximately 0.3mm distance between each, providing the hardness profile to the left. The overall location of each measurement is pictured in black and white to the upper right and in color below the profile to the left.

The carbon case is clearly shown in the color micrograph to the bottom left. This darker color can be seen from the surface to just after the sixth hardness measurement, confirming the penetration depth is just over 1.5mm (0.060").

The stepped micrograph to the right shows increasing magnification from top to bottom of the surface microstructure. From the etched sample we can clearly see tempered Martensite (dark), small carbides (black) and retained Austenite (white) present at the surface of the bar.

The micrographs for the core section can be viewed to the top left. The core continues to show predominantly tempered Martensite (dark), retained Austenite (white) and some very small carbides or oxides (black).