Giving Thanks — Falling into Winter

The lives most of us live rarely afford us the time to stop and reflect on one's life and the many things we can take for granted. So, on this Thanksgiving holiday, we would like to take a moment to share what we are all thankful for; as a company and as individuals.

- **DANTE Solutions**: We all would like to thank our wonderful customers for their continued support in our efforts to bring simulation to the heat treat industry. Without you, we could not do what we do! We would also like to extend a warm thank you to all of our vendors who perform heat treatment processes on our behalf, usually very different from the recipes they are familiar with in production, and to all those who complete the variety of material testing required to accurately simulate the heat treatment process. Finally, we would like to thank all those we have collaborated with on projects aimed to advance heat treatment technology; your ideas and contagious enthusiasm propel us onward to new heights.

- **Eddy Lee**: I am thankful for the new friends I have made at this new job. Working here has helped me learn so much more about heat treatment, modeling, simulation, and computer programming.

- **Jason Meyer**: I am thankful for my health and a place I call home, with friends, family, and laughter to fill it.

- **Stefan Habean**: I am thankful for homemade cranberry sauce!

- **Justin Sims**: I am thankful for 15 years of sobriety, that all my senses still function reasonably well and am still mobile. I am thankful for the friends and family that have cared for me and that I have cared for. And I am thankful I live in a place that allows me to go after each and every dream and aspiration that I may have an inkling to strive for.

- **Charlie Li:** Thanks to all DANTE customers and friends. We can't be here without you!

- **Lynn Ferguson**: I am thankful that I work with thoughtful and hard working colleagues and that the work we do helps an important and necessary industry, heat treating. Besides my immediate colleagues, I have benefitted from the teaching and mentoring of many fine people. My home life has been great – what more could I want? Oh, I am thankful that I never bought season tickets to the Browns.

We all wish you and your family a safe and joyous Holiday season!

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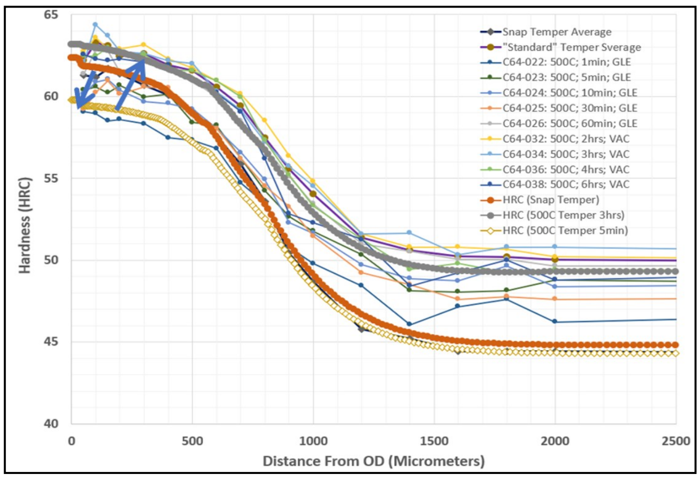
Software Highlights

Gearing up for DANTE 6.0

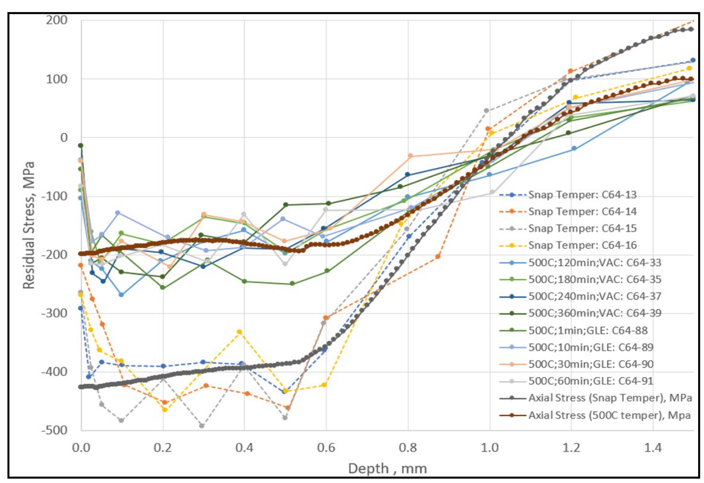
Tempering Models: Beyond time and temperature

Many tempering models, including DANTE's current commercial release, simply use time and temperature to determine the change in hardness and residual stress. While this model is generally sufficient to predict the reduction of hardness and residual stress for lower alloy steels, the model fails to accurately capture the hardness increase and residual stress reduction witnessed during secondary hardening of higher alloy steels. DANTE 6.0 introduces a precipitation model (described in the last newsletter) that can be used to model any type of precipitation in metals; including aluminum, Ni-based alloys, precipitation hardening steels, and many more. For steel alloys, the precipitation model in DANTE uses rate-based kinetics to first, simulate the precipitation of iron carbides from the martensitic microstructure, creating tempered martensite, and second, to simulate the dissociation of iron carbides and the formation of alloy carbides, leading to an increase in hardness from the as-quenched condition.



Hardness

As carbon is released from the as-quenched martensitic structure, converting it from a BCT structure to a BCC structure, it combines with iron atoms to create iron carbides; shown as the "snap temper" condition of Ferrium C64 in the figure to the left. The iron carbides quickly begin to coarsen, reducing the hardness within a few minutes. For lower alloy steels, the coarsening continues and the hardness is subsequently reduced. For higher alloy steels, which can undergo secondary hardening, such as C64, the iron carbides dissolve and the carbon atoms are combined with alloy elements to form alloy carbides. With the formation of alloy carbides, the hardness is increased. If the temperature is lower than optimum, the formation of alloy carbides is reduced and longer times are required to achieve equivalent hardness; if the temperature is too low, alloy carbides will fail to form altogether. If the temperature is higher than optimum, the alloy carbides can coarsen rapidly, reducing the hardness even further.



Residual Stress:

With any steel tempering process, a reduction in the residual stress magnitude is realized. For carburized components, this is generally a reduction in the near-surface compressive stresses. This phenomenon is attributed to the relaxation of the iron matrix, from thermal effects, from the BCT to BCC structure change, and from the coarsening of iron carbides in lower alloy steel and alloy carbides in higher alloy steel. The figure to the right shows the stress reduction in a carburized C64 coupon. The "snap temper" condition already has relaxation of stress due to the rejection of carbon at lower temperatures (~130° C). The compression in the case is then reduced by 50% from the formation and slight coarsening of the alloy carbides.

Project Highlights

Hardness and Stress Evolution during High-Temperature Tempering

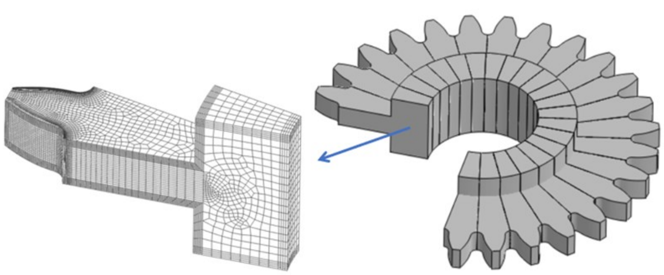
High temperature resistant alloys are becoming common place in aerospace powertrain applications. These alloys undergo precipitation hardening during high temperature tempering, forming alloy carbides which generally increase hardness. DANTE now models the precipitation kinetics and the following case study is provided as an example. The component is an aerospace test gear made from Ferrium C64 and is subjected to its standard LPC/HPGQ process, followed by a high temperature tempering process.

Model Description

- Single tooth modeled (cyclic symmetry assumed)
- Material: Ferrium C64
- Diameter: 100 mm
- Number of teeth: 28

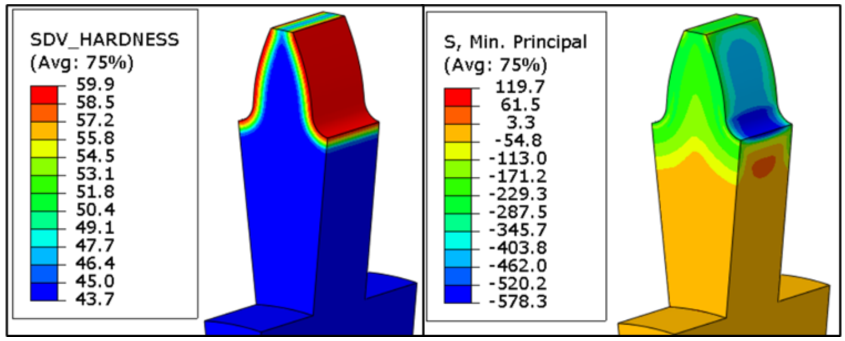
Process Description

- Austenitize and low pressure carburize at 1000° C
- HPGQ with 2 bar nitrogen
- Deep freeze
- High temperature tempering at 500° C

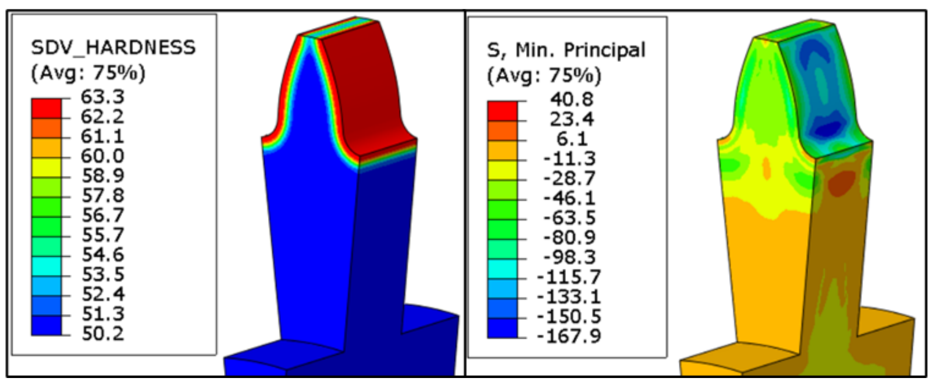


Results

- Predicted hardness and minimum principal stress after quench hardening shown below.
- Surface hardness is 60 HRC, with 578 MPa compression in the root fillet.



- Predicted hardness and minimum principal stress after tempering shown below.
- Surface hardness increases to 63 HRC and the surface stress in the root fillet is reduced to 60 MPa compression.



Conclusions

- Hardness from precipitation hardening can now be accurately predicted by DANTE
- The reduction in residual stress from the high temperature tempering process can now be considered in loading simulations