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The Gleeble® NEWSLETTER

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Gleeble Application Profiles:

Optimizing Production through Physical Simulation— The Gleeble at Carpenter Technology Corporation

For Carpenter Technology Corporation, a Gleeble 1500 isn't simply an exotic piece of laboratory equipment or just a sophisticated thermal-mechanical physical simulation system, it's a critical tool that helps keep the company on the cutting edge of specialty steel production.

Carpenter Technology, or CarTech for short, produces more than 400 grades of steel and specialty alloys for a broad spectrum of industries: automotive, aerospace, tooling, electronics, consumer products, chemical processing, and more. "Just about any manufacturing sector you can think of uses at least one of our steels," says Edward Wanner, manager of Process R&D for CarTech, in Reading, PA.

And the Gleeble helps CarTech to deliver exactly what the customer wants, Wanner says. "It's standard operating procedure for us to use the Gleeble to determine the hot workability of these different steels."

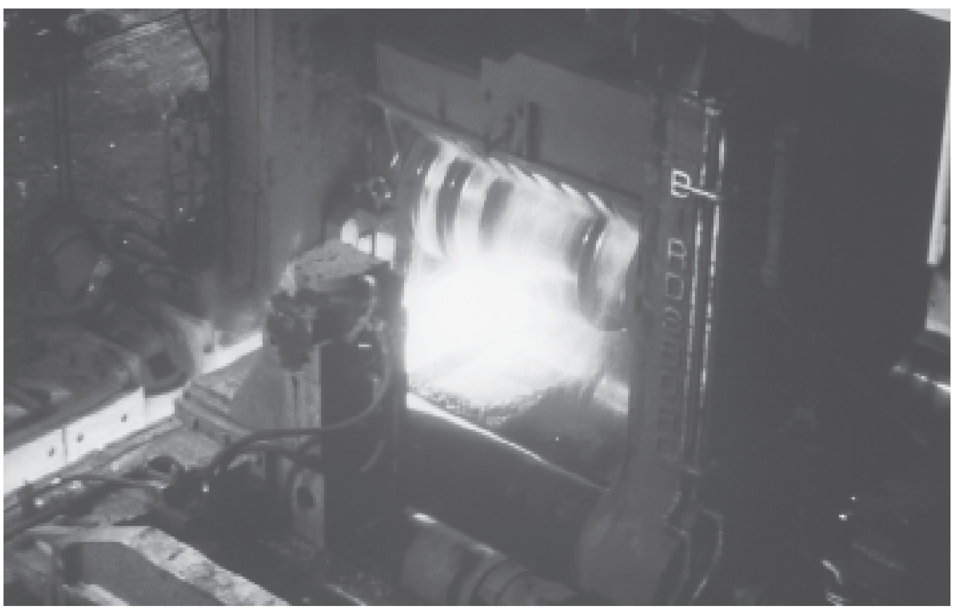
Mohamed Mohamdein, CarTech specialist in Process R&D, adds, "For a new alloy, we start by melting a sample of it as a prototype in a laboratory-scale heat. Before we prepare a full heat, we do Gleeble testing to determine its hot workability—for hot rolling, forging, and similar areas."

"That testing saves us a lot of trial and error in order to be able to hot work it successfully."

Mohamdein adds, "Typically, when starting with a new alloy, we take a laboratory ingot, cut Gleeble samples, do a series of tension tests, determine the range of hot workability, the optimum hot working temperature and how its behavior compares with our current materials."

"We've never found a sample that we

Continued on Page 4



Top: Robert Corell, Sr. Technical Specialist, operates the Gleeble 1500 at CarTech's Research and Development Center. Bottom: Experimental results produced by the Gleeble are used to help determine operating parameters for equipment such as this two-high reversing hot rolling mill.

Recent Gleeble Papers

277

A Mechanical Method for Determining Precipitation in an Ultra-Low Carbon Bainitic Steel

by Dang Zijiou, Zhang Yan, Wu Na, Ke Jun, He Xinlai, and Yang Shanwu

Stress relaxation was chosen as the best method for monitoring the precipitation process. Tests were carried out on an ultra-low carbon bainitic steel containing Mn, Nb and B over the temperature range 800 to 950°C. Specimens were solution treated at 1250°C for a certain holding period. A prestrain of 20% was applied at a strain rate of 10^{-1}/s. The test results are displayed by a set of stress vs. log (time) curves which are different from the typical stress relaxation curves. There are two singularities which form a stress plateau on the stress vs. log(time) curves when precipitates could be observed. Suppose the first one is the beginning of precipitation (P_s), and the second represents the finish of precipitation (P_f). As a result, Precipitation-Time-Temperature relationship is described as c-shaped curves based on two points. This mechanical method is suitable and precise for measuring precipitates in microalloyed steels during hot working.

258

Grain Boundary Segregation of Phosphorus on Quenching Crack Type Cold Cracking in Weld HAZ of Medium/High-Carbon Low-Alloy Steels

by H.S. Park and F. Matsuda

As well known, one of the serious problems in welded HAZ of medium/high carbon low alloy steels is very high susceptible to quenching crack type cold cracking. From our results of the simulated cold cracking test and Auger electron microscopic (AES) analysis with vacuum induction melted JIS SNCM447 containing low (about 0.001 wt.%) and high level (about 0.030 wt.%) of phosphorus and sulfur, it was cleared that phosphorus is one of the main influence factors to enhance the crack susceptibility of the quenching crack type cold cracking because of the grain boundary segregation. Phosphorus enhances intergranular embrittlement and greatly reduces fracture stress. On the other hand, sulfur did not show the detrimental effect. The AES results clearly indicated that phosphorus was segregated at grain boundaries. Carbon was also found to be segregated at the grain boundaries. The phosphorus segregation to grain boundaries is fairly increased by grain boundary liquation and decreased with increasing in cooling time. These tendencies were closely correlated with those of the fracture stress and the fraction of intergranular fracture surface. The decrease of phosphorus segregation in relation to increasing cooling time occurred at the temperature region below Ms during cooling. However, the tendency of phosphorus segregation was inconsistent with general tendency of equilibrium segregation described in Fe-P binary alloy. Generally, for most cases of grain boundary segregation with thermal cycling during heat treatment, the experimental results are analyzed either quantitatively or semi-quantitatively from theoretical formulae for equilibrium segregation devised by McLean. By contrast there are no cases of analysis for transient conditions during, for example, the weld thermal cycle. Consideration of this type of cracking, which is prone to develop at the grain boundaries following liquation, requires the analysis to take account of the transient effects. For this reason, grain boundary liquation due to heating and subsequent segregation of phosphorus at the grain boundaries during cooling were analyzed theoretically based upon a concept of equilibrium segregation and a liquation model. It is thought that, using the above technique, the various factors which comprise the weld thermal cycle can be investigated under wide range of conditions. Furthermore, valuable information can be determined concerning the selection of welding, pre/post-heating conditions. Thus, in this report, the variation of phosphorus concentration at grain boundary in the weld thermal cycle was examined by calculation in consideration of the following effects: grain boundary liquation at peak temperature; solidification at the grain boundary liquation zone; homogenization following solidification; and variation of phosphorus concentration at grain boundaries due to equilibrium segregation which develops simultaneously with the homogenization described above. In addition, attention was given to carbon segregation at the grain boundaries noted in the previous report. The carbon segregation at the grain boundaries and the subsequent decline of the concentration of phosphorus segregation at the grain boundaries were also investigated.

284

Microstructural Evolution on Billet Heating Practices of 6xxx Aluminum Simulating the Extrusion Process

by T.J. King, W.Z. Misiolek, and R.N. Wright

The effects of billet heating process parameters on the microstructural evolution of a common 6xxx alloy have been studied. Thermal cycles throughout the extrusion process promote the growth or dissolution of magnesium silicide (Mg_2Si) precipitates which are responsible for the mechanical properties of the Al-Mg-Si alloys. The Gleeble 1500 thermo-mechanical machine can perform these thermal cycles. In this study, the process parameters focused on have been reheat rate, holding time and temperature, and ambient exposure time to simulate transferring the billet from the furnace to the press. Optical and scanning electron techniques have been used to analyze the specimen. A line intercept method has been used to quantify the microstructure. A discussion on the application of this model is presented.

The GLENIS Software Package for Simulation of Time-Temperature Characteristics in Gleeble Specimens

Researchers in the Department of Materials Engineering at the University of Wales, Swansea, have developed a three-dimensional computer program for the prediction of temperatures and cooling rates within specimens heated by the Joule effect in a Gleeble simulator. The software is based on the successful "MAVIS" software which has been widely adopted in the UK foundry industry for the simulation of heat transfer and solidification in castings.

Called "GLENIS," the new PC-based software package can be used to model a variety of specimen material and jaw types commonly used in the Gleeble. The software consists of a number of sub-programs. The first, a "solid modeller," is employed to input the geometry of the specimen-jaw configuration, and to specify the location of the electrical contact surfaces. The user is then prompted for the electrical resistivities, thermal conductivities, specific heat capacities and densities of the specimen and jaw materials.

All of the properties can be specified to vary as a function of temperature, which is especially critical in the case of ferrous materials, in which, for example, the resistivity of steel can change by an order of magnitude on heating. Where heating above the solidus is performed, the latent heat of fusion can be specified together with the relevant fraction solid versus temperature data.

After indicating the temperature-time program to be followed at the central control thermocouple location, the main part of the software is used to predict the evolution of temperature with time throughout the specimen and jaws. The applied voltage is adjusted at regular intervals according to the difference between the program temperature and the predicted temperature at the location corresponding to the control thermocouple. The applied voltage is used to predict the distribution of current densities throughout the specimen and jaws. A powerful finite difference algorithm then calculates the temperatures that result from the I^2R effect and the conduction of heat along temperature gradients in three dimensions. The loss of heat from surfaces and the transfer of heat across the specimen-jaw interface is dealt with by two separate heat transfer coefficients specified by the user.

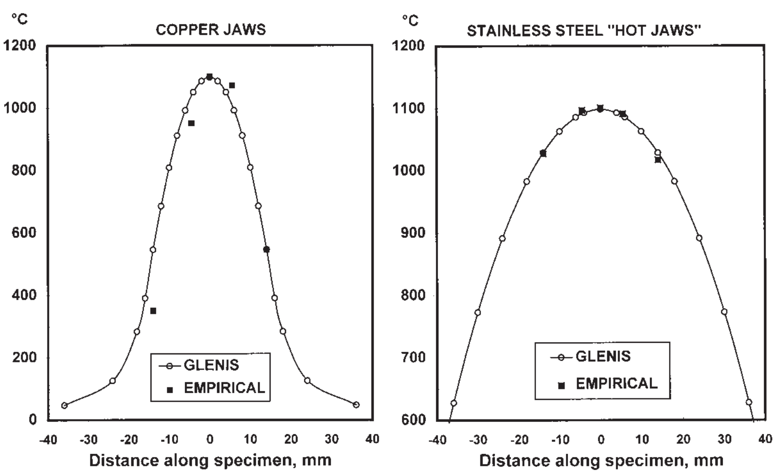
As the simulation proceeds, a file is created of the temperatures recorded as a function of time at several user-defined locations in the specimen and jaws. The applied voltage employed at each time step is also recorded to provide an indication of relative power consumption. In addition, a graphical post processor facility enables the user to view contour maps of voltage, current density, temperature and fraction solid.

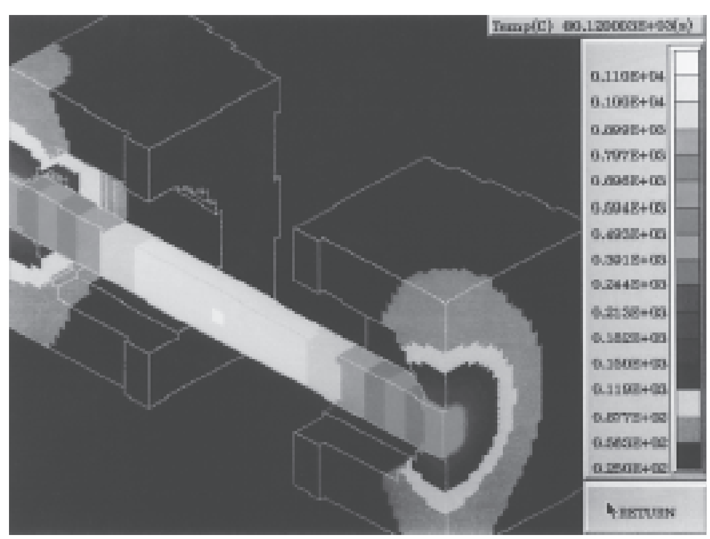
The package can thus be used for:

- predicting the distribution of temperatures within a specimen,
- determining the length of the "work zone" or region of the specimen within a specified temperature limit,
- predicting temperature gradients,
- predicting the cooling rates attainable for a given specimen size,
- comparing the use of different jaw types, e.g., copper jaws, stainless steel jaws, hot jaws, etc., and
- taking account of melting/freezing during specimen heating/cooling.

GLENIS requires a Pentium PC with 32 MB RAM.

For further details, please contact:
Mr. Cliff Jobson, Alphacast Software Ltd,
2 Kimble Close, East Hunsbury,
Northampton, NN40RF, England.
Telephone and fax: 01604 674 716.





Top: Temperature distributions obtained from 0.2% C steel 10 mm diameter specimen after heating to 1100°C in 110 seconds and holding for 15 seconds. Bottom: Temperature map for 0.2% C steel 10 mm diameter specimen heated with stainless steel "Hot Jaws" to 1100°C in 110 seconds and held for 10 seconds.

The Gleeble at Carpenter Technology Corporation

Continued from Page 1

couldn't work, but we certainly have been warned by the Gleeble tests that some steels were going to be difficult. As a result, we were able to go into the process with our eyes open and prepared to make the necessary adjustments."

"Before we purchased the Gleeble," Wanner says, "we had developed two other tests for determining hot workability. Unfortunately, these tests were not capable of providing the level of temperature control and strain rate control required to successfully predict an alloy's hot working behavior in our various manufacturing operations."

Mohamdein says, "Before we got our own Gleeble, we evaluated samples on the Gleeble at Rensselaer Polytechnic Institute. As part of a program to improve the hot workability of a high-temperature aerospace alloy, we did a three-way cross check using the Rensselaer Gleeble and the two CarTech-developed tests. The Gleeble gave us results that were usable, while the other tests did not."

He adds, "We now have our own Gleeble—a Gleeble 1500—which we installed in 1991. And we are seeing much better agreement between the Gleeble results and what happens in the mill."

"We now use the Gleeble as a routine screening test for forgeability. Through the use of this test, we have been able to substantially improve the quality and properties of our product. We have improved the forgeability of our steels over the years."

There have been some other interesting benefits from the Gleeble as well. Wanner says, "We've used it to fine-tune production practices. With the Gleeble, we can really determine the optimum working temperature for an alloy."

"Using the Gleeble, we have been able to identify and assess the severity of the damage done by overheating steel in the furnace, even though the actual hot working was performed in the proper temperature range."

"The Gleeble has also helped us in working with customers. We have assisted customers who perform additional hot working operations on our products in defining the correct temperature ranges in order to have a sound end product."

"We have also used the Gleeble to develop flow stress data for various customers. This is not an everyday occurrence, but it is fairly common. Flow stress data that we have developed has been used for our own finite element analysis simulation programs."

Mohamdein points out that the data produced by the Gleeble pays off handsomely because CarTech makes sure that their furnace controls and rolling line are well-instrumented, so they can be certain that there is good correlation between the data produced by the Gleeble and actual conditions on the production line. This makes transfer of Gleeble data between the lab and the production line fast and efficient.

The Gleeble at CarTech is extremely busy testing hot workability. In addition, CarTech has begun experimenting with using the Gleeble for continuous casting simulation and simulation of annealing and quenching cycles. It's not yet clear where these explorations will lead.

Both Wanner and Mohamdein are emphatic in their conclusion regarding the Gleeble: "It's an absolutely essential part of our business."

Gleeble Newsletter

The Gleeble Newsletter is intended to be a forum for Gleeble users worldwide to exchange ideas and information. We welcome your comments and suggestions. Letters, comments, and articles for the newsletter may be addressed to David Ferguson at Dynamic Systems Inc., faxed to us at (518) 283-3160, or e-mailed via the Internet: info@gleeble.com.

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