The *Gleeble*®

NEWSLETTER

Spring 2000

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Come See Us at the Shows & Conferences

AeroMat 2000, Bellevue (Seattle), Washington, June 26–29, 2000

AeroMat is widely recognized as the premiere event for anyone interested in technology advances in aerospace materials, processes and designs. AeroMat 2000 will offer a broad spectrum of distinctive aerospace related symposia and will focus on the technology drivers that will influence the aerospace industry's performance and productivity in the 21st century. Stop by Booth 504 at the Meydenbauer Convention Center to speak with DSI applications engineers. For additional information about the conference, contact:

ASM International
9639 Kinsman Road
Materials Park, OH 44073-0002
Tel: 440-338-5151
Fax: 440-338-4634

Thermec 2000, Las Vegas, Nevada, December 4–8, 2000

DSI is proud to support the Thermec 2000 International Conference on Processing & Manufacturing of Advanced Materials. Thermec 2000 will focus on the recent advances in the overall field of science and technology of fabrication/manufacturing, structure/property and applications of

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Gleeble Application Profile

The Gleeble at Böhler Edelstahl

Böhler Edelstahl GmbH & Co KG produces high-speed steels, tool steels, corrosion resistant steels and special alloys in rolled and bright bar, forgings and ingots for German, European, and overseas markets.

Three years ago, a new group, responsible for physical and numerical simulation, was started within Böhler Edelstahl's Research and Development Department, beginning with the installation of a Gleeble 3800 system. The simulation group includes Mr. Herbert Emminger, electronic engineer, Gleeble tuning and Gleeble testing; Dr. Siegfried Kleber, metallurgist responsible for physical simulation on the Gleeble; Dr. Volker Wieser, mechanical engineer responsible for numerical simulation; and Dr. Christoph Wurm, metallurgist, responsible for automation and process control. Due to the early success of this team, expansion is planned for the near future.

The first goal of the researchers working with the Gleeble is to define the optimal processing routes and processing windows to obtain the best product quality. This goal has to be reached especially for new alloy compositions, alloys of high production costs and alloys of reduced hot workability. In co-operation with numerical process simulation, these investigations are performed to supply Böhler's production plants with the necessary process-relevant data to produce steels that meet the customers needs.

The second goal of the investigations is to measure application-relevant properties of steel grades and alloys. For example, it can be the creep resistance of a modified alloy in comparison to a standard alloy

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Dr. Kleber (left) and Mr. Emminger prepare for a simulation on the Gleeble 3800 at Böhler Edelstahl.

Recent Gleeble Papers

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Self-Propagating High-Temperature Synthesis as a Process for Joining Materials

by T.T. Orling and R.W. Messler, Jr.

Self-propagating high-temperature synthesis, or SHS, is a process that allows production of a wide variety of ceramic and intermetallic compounds by highly exothermic reactions. It has been successfully used for simultaneous netshape production, as well as joining, albeit the process of joining is in an embryonic state of understanding. In this study, the Gleeble was employed for the systematic evaluation of the effects of heating rate (0.5 to 2°C/s), processing temperature (500 to 1300°C), hold time (2 to 60 min), and applied pressure (8.8 to 82.7 MPa), as well as minor variations of reactant composition, on the degree of reaction, joining integrity, and filler metal density and homogeneity in a model system of 3Ni + Al > Ni_3 Al reacted *in situ* between Alloy 600 end elements. For all temperatures above the reaction ignition temperature (T_i), where a liquid phase is formed (639.9°C), joining integrity was good. The degree of reaction, as well as product homogeneity and density, were all increased most by increased processing temperatures, with more modest effects from longer hold times and higher applied pressures. Heating rate had no apparent effect, although the range was narrow. Composition around the perfect stoichiometric ratio had a modest effect on density.

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Formation of Surface Heat Crack in Low Carbon Steels During Hot Rolling

by J.L. Lee, Y.T. Pan, and Y.S. Hwang

The formation of surface heat cracks in low carbon steels during hot rolling was investigated. Analysis of mill specimens indicated that these defects were closely related to the pile-up of sulfur. Hot ductility test revealed that the low carbon steels studied were relatively brittle at temperature range from 1100 to 900°C. Hot ductility was improved by prolonging the holding time before test. The loss of hot ductility was mainly attributed to intergranular decohesion caused by sulfur segregation at austenite grain boundaries, while the improvement of ductility was attributed to the formation and coarsening of MnS precipitates. Soluble sulfur was found to be the key factor determining the hot ductility and heat crack susceptibility of steels. During hot rolling, steels having soluble content of over 55 ppm were highly susceptible to heat crack. Decreasing sulfur content of steel and heating temperature of slab or increasing manganese content of steel were effective in improving hot ductility and thus alleviating heat crack.

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Thermomechanical History of Steel Strip During Hot Rolling—A Comparison of Conventional Cold-Charge Rolling and Hot-Direct Rolling of Thin Slabs

by C.A. Muojekwu, D.Q. Jin, I.V. Samarasekera, and J.K. Brimacombe

A thermomechanical model has been employed to simulate strip rolling in Compact Strip Production (CSP) and the conventional hot-strip mill. The model is based on an integrated finite-difference scheme that utilizes the uniform, through-thickness strain assumption to predict the thermal and microstructural evolution, and an Eulerian finite-element flow formulation scheme to predict the through-thickness strain and strain rate as well as the roll force. To generate data for the quantification of microstructural changes in the model, the deformation resistance, recrystallization kinetics and grain growth of the plain carbon steel, A36, were measured on a Gleeble 1500 thermomechanical simulator. The temperatures and strain rates chosen span the conditions encountered in a conventional hot-strip mill as well as the finishing train of the CSP process. Model predictions of temperature and roll force have been compared with mill data, and good agreement was established. It was found that the effect of through-thickness strain and strain rate variations on austenite grain size evolution were more prominent in CSP rolling than in conventional rolling. The final austenite grain size resulting from CSP rolling was found to be finer than the corresponding conventionally rolled strip despite the initial retardation of recrystallization from the coarse as-cast grain size. The finer grain size in the CSP process is attributed to the strain-induced grain refinement triggered by the high reduction per pass, particularly at the last two stands.

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Effect of Cooling and Deformation on the Austenite Decomposition Kinetics

by R. Pandi, M. Militzer, E.B. Hawbolt, and T.R. Meadowcroft

Controlled rolling on the finishing mill, followed by accelerated cooling on the run-out table of a hot strip mill are the final processing steps before coiling. Each has been found to significantly influence the final microstructure and thus, mechanical properties. The austenite decomposition kinetics in two low carbon, plain carbon steels and an HSLA-Nb microalloyed steel were investigated using a Gleeble 1500 themomechanical testing machine. This equipment can simulate the deformation conditions on the finishing mill and the subsequent accelerated cooling on the run-out table of the hot strip mill, while continuously monitoring the thermal/mechanical parameters involved. The effect of cooling rate, initial austenite grain size and retained strain on the austenite decomposition kinetics and the subsequent ferrite grain size are quantified. A semi-empirical and a more fundamental interpretive model are discussed.

Multi-Axis Hot Deformation System Can Produce Extreme Strain

DSI Announces MAXStrain® System for Ultra-fine Grain Materials Development

An innovative physical simulation system specifically designed for ultra-fine grain materials studies in steel, aluminum and titanium alloys is now available from DSI.

The MAXStrain multi-axis hot deformation system is capable of producing strain as high as 15 and beyond. To do so, it restrains up to a 25 mm square × 185 mm long specimen lengthwise while allowing deformation in the other two dimensions. The flexibility of the MAXStrain system allows trials involving many different parameters to be examined. As a result, ultra-fine grain materials can be produced under well-controlled thermal and mechanical conditions. The sample material produced is large enough to be subjected to other properties tests after processing.

In tests at DSI, plain carbon steel (AISI 1018) was studied using the MAXStrain system. One-micron grain size was achieved. The ultimate tensile strength was double that of the same steel that had been conventionally hot rolled. The MAXStrain system is also being used on aluminum and titanium alloys.

Based on the proven technology of the Gleeble Series 3 physical simulation systems, the MAXStrain system offers:

- high speed multi-axis deformation
- extreme compression strain (until material failure)
- high speed heating and cooling
- separate yet synchronized control of three hydraulic systems
- plane strain deformation geometry when lengthwise restrained
- large volume specimens for subsequent mechanical properties testing

The MAXStrain system can also be used for hot rolling and forging process simulation as well as for the development of ultra-fine grain steel, aluminum and titanium.

The MAXStrain features the DSI Series 3 Digital Control and incorporates closed-loop thermal and mechanical systems. Windows-based computer software, combined with an array of powerful digital processors, provides an extremely user-friendly interface to prepare test programs, to provide digital closed-loop control of the thermal and mechanical systems, and to collect data.

The MAXStrain system is the latest in a long line of standard-setting metallurgical test and physical simulation systems developed by DSI. Founded over 40 years ago, DSI has pioneered the development and manufacturing of dynamic thermal/mechanical systems for materials research, including the Gleeble 3800, Gleeble 3500, Gleeble 2000, Gleeble 1500, and the Gleeble HAZ 1000.

Gleeble systems are used for process simulation, materials characterization, and basic research in technical institutes, industrial laboratories, and universities throughout the world. To obtain a copy of the technical paper "Multi-Axis Deformation Methods to Achieve Extremely Large Strain and Ultra-fine Grains," written by Wayne Chen, David Ferguson and Hugo Ferguson, contact DSI.

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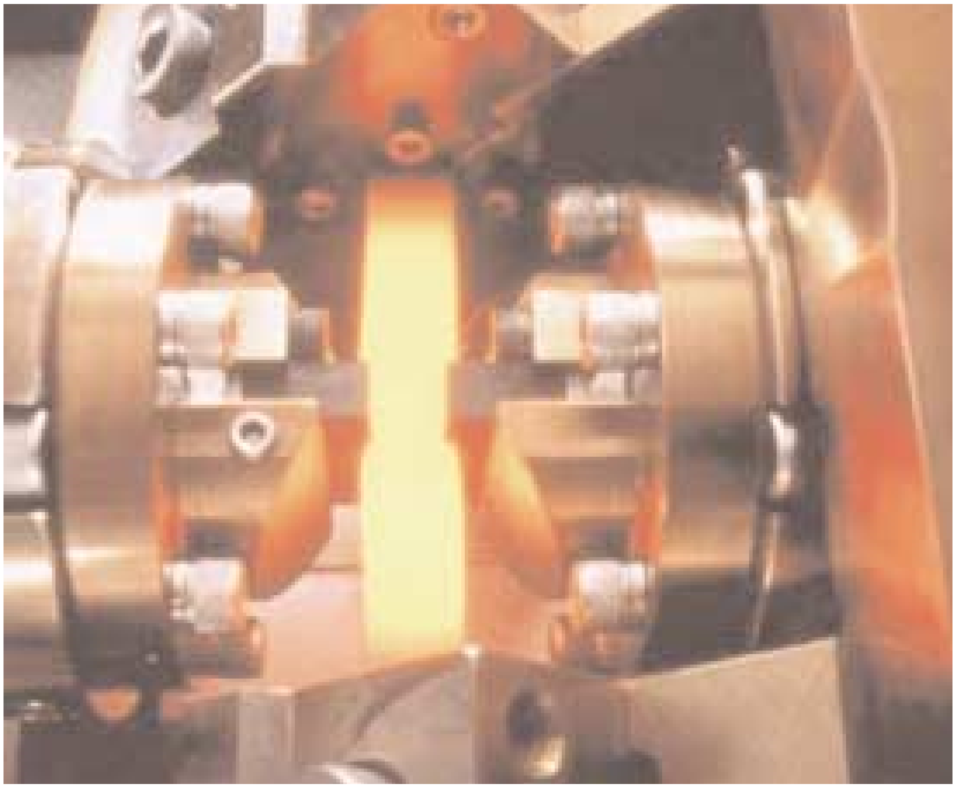

The MAXStrain multi-axis hot deformation system is capable of producing strain as high as 15 and beyond. To do so, it restrains up to a 25 mm square × 185 mm long specimen lengthwise while allowing unlimited deformation in the other two dimensions.

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both ferrous and non-ferrous materials. Special sessions will be devoted to superplastic deformation, texturing, modeling, net shape forming, impact engineering, intelligent/smart materials/processes and coatings.

For more information visit the web site at: www.thermec2000.conf.au

Important Dates:

April 25, 2000—Notification of acceptance of abstracts

August 25, 2000—Manuscript due & authors registration mandatory

September 25, 2000—Early registration with discount

October 5, 2000—Hotel reservation

December 4–8, 2000—Thermec 2000 Meeting

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The Gleeble at Böhler Edelstahl

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under the complex working condition of an extrusion die. These investigations are a special service to Böhler's customers to propose the optimal alloy for their special application.

Toward that end, Dr. Kleber and his colleagues use the Gleeble 3800 to perform:

- Hot/warm tensile testing on a wide variety of steel grades and alloys.
- Hot ductility testing on special steel grades such as stainless chromium-nickel-steels or duplex steels for hot extrusion manufacturing.
- Thermal/mechanical fatigue testing on hot work tool steels.
- Hot/warm compression testing and single and multi-step plane strain compression as well as single and multi-step uniaxial compression on special steel grades and alloys with reduced hot workability.
- Melting and solidification testing on high-speed steel grades and alloys with reduced hot workability.

High-speed steels, hot work tool steels, valve steels, nickel-based alloys, cobalt-based alloys and stainless chromium-nickel steels have the highest priority for Gleeble investigations at Böhler Edelstahl. Next come cold work tool steels, plastic mould steels, creep-resisting steels, steels with special physical properties, stainless chromium steel, and heat resisting steels. These are followed by saw steels, case-hardening steels, heat treatable steels, nitriding steels, spring steels, anti-friction bearing steels, free cutting steels, and unalloyed tool steels.

Dr. Kleber says, "In general the Gleeble testing programs help to keep the quality of our products on a high level and to prevent production faults. It also helps us to reduce the time required for product development and gives us the capability to test unconventional process routes without having to run expensive experiments on the production line with a high risk level."

BÖHLER

He adds, "The Gleeble also gives us quick information about material workability and the properties of new alloys on a laboratory scale. The Gleeble 3800 was specially designed for the simulation of hot working processes for high alloyed steels and alloys of high temperature strength. The system allows experiments under conditions that are very close to those found in the real hot forging and rolling processes."

"We don't have to extrapolate to high strain rates, we control them!" he says.

Gleeble investigations were also involved in troubleshooting on the Böhler Edelstahl production lines. In their very first Gleeble project, the simulation team was faced with the challenge of the productivity of a high alloy heat and corrosion resistant steel grade. It showed sensitivity towards hot cracking during the first deformation steps of the ingots.

Dr. Kleber says, "We have learned a lot about the crack initiation mechanism, so we could optimize the process parameters, which helped us to reduce the production loss."

He concludes, "In further projects, the Gleeble will help to find out the correct process parameters for different steel grades to obtain an optimal microstructure. That guaranties the quality of our steels and alloys."

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., e-mailed to info@gleeble.com, or faxed to us at 518-283-3160.