Dynamic Systems Inc.
Tel: 518 283-5350 Fax: 518 283-3160
Internet: www.gleeble.com
Email: info@gleeble.com

The Gleeble® NEWSLETTER

Fall 2005

See Us at the Shows

ICTP2005 Set for October 9–13, Verona, Italy

The 8th International Conference on Technology of Plasticity will be held October 9–13, 2005, in Verona, Italy. The Conference will be held at Palazzo della Gran Guardia in Verona.

For more information about ICTP2005, visit www.ictp2005.sistemacongressi.com.

THERMEC' 2006, July 4–8, 2006, Vancouver, Canada

THERMEC' 2006, International Conference on processing and manufacturing of advanced materials will be held July 4–8, 2006, at the Fairmont Hotel, Vancouver, British Columbia. The Conference will cover all aspects of processing, fabrication, structure/property evaluation and applications of both ferrous and non-ferrous materials, including hydrogen and fuel cell technologies, metallic glasses, thin films, ecomaterials, nanocrystalline materials, biomaterials and other advanced materials.

THERMEC' 2006 is built upon the proven concept and continues the tradition of its four predecessors, Japan (1988), Australia (1997), USA (2000) and THERMEC' 2003 in Spain.

For further information, visit http://thermec.uow.edu.au or contact:

Professor T. Chandra
Faculty of Engineering
University of Wollongong
Northfields Avenue
Wollongong NSW 2522, Australia
Email: tara@uow.edu.au
Fax: +61 2 4221 4921
Phone: +61 2 4221 3008

Gleeble Application Story

The Gleeble at ThyssenKrupp Stahl in Duisburg, Germany

ThyssenKrupp Stahl, a company of ThyssenKrupp Steel, is a flat steel producer that supplies hot strip, cold strip, coated product and heavy plate in a wide range of grades, from mild steel to high-strength steel. One of the main markets for the company is the automobile industry, to which it supplies carbon steels in standard and galvanized strips as well as tailored materials for auto bodies, truck frames, and so forth. The company also produces flat steel to meet the needs of the construction, electrical, and appliance industries.

Almost all research and development—including work with materials, production processes, and product and processing technology—is done at the Center of Materials Excellence at ThyssenKrupp Stahl's main location in Duisburg, Germany.

Dr. Hans Peter Schmitz, Manager at the Center of Materials Excellence says, "Our main goal is the development and optimization of products and processes. We use computer simulation to optimize material properties and use very modern lab equipment to develop and optimize new products."

He adds, "One of the machines we rely on is the Multi-Functional Simulation System from DSI. This includes a conventional Gleeble 3500 and the world's first HDS-V40, which stands for Hot Deformation System Vertical 40 tons."

"In our labs, we do physical simulation," he says, "We try to reproduce as precisely as possible what is going on in the actual production lines. If you do it very carefully, you can transfer the result into the production lines, and you can use the results for building up numerical models."

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Dr. Schmitz (right) and Mr. Tesh discuss test results from the HDS-V40.

Recent Gleeble Papers

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Dynamic Recovery and Dynamic Recrystallization of 7005 Aluminum Alloy During Hot Compression

by J. Shen, S.S. Xie, and J.H. Tang

Dynamic recovery and dynamic recrystallization behaviors of AA7005 aluminum alloy (Al-Zn-Mg) during hot compression are investigated by isothermal compression testing. The interdependence of flow stress, strain rate, true strain and deformation temperature for the alloy is analyzed by introducing Zener-Hollomon parameter. A steady-state flow of the 7005 alloy is confirmed to be a thermally activated process, which is governed by rate-controlling mechanisms of dislocations. A hyperbolic sine relationship can satisfactorily correlate temperature, strain rate with flow stress through an Arrhenius term that involves thermal activation parameters. The dynamic recovery mechanisms of the alloy are discussed. Cross-slip of jogged screw dislocations is the main dynamic recovery mechanism over the deformation temperatures and strain rates. Subgrains are highly developed in the originally elongated grains. The size of the subgrain increases with decrease of the natural logarithm of Zener-Hollomon parameter. Local dynamic recrystallization is operative when the alloy is deformed at temperature of 500°C and strain rate of $0.001s^{-1}$.

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Development of Constitute Equations for Ti-6Al-4V Alloy Under Hot Working Condition

by L.X. Li and D.S. Peng

The deformation behavior of Ti-6Al-4V alloy under hot working condition has been studied by compression testing in the temperature range 750–950°C and strain rate range $0.05–15s^{-1}$. The flow stress decreases with the increase of temperature and with the decrease of strain rate. After a steep initial strain hardening, a flow softening occurs. This softening is mainly ascribed to the temperature rise and dynamic recrystallization. By a simple extension, a classical sinushyperbolic constitutive equation can be used to describe the flow behavior of Ti-6Al-4V alloy. The flow stress is described as a function of strain, strain rate, and temperature. The parameters Q, n and a are the same at different deformation conditions, and A is a function of strain.

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Effect of Copper and Boron Content on Strain-Induced Nb (C,N) Precipitation in ULCB Steels at Hot Deformation Temperature

by G. Zhou, M. Wen, P. Li, and X. He

The stress relaxation curves of Ultra-Low Carbon Bainitic (ULCB) steels with different Cu and B contents were measured by using Gleeble 1500 dynamic thermal-mechanical simulator. The results show that Cu and B added can accelerate the strain-induced precipitation reaction, and the effect of Cu and B is even more obvious with Cu and B combined addition or Cu content increased. The TEM analysis of precipitate engendered at the temperature of 850°C indicates that Nb (C,N) precipitate nucleates dominantly on the dislocation line, and grows with holding time extended while the precipitate particle size increases from 5 nm to 17 nm.

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Hot Deformation Characteristics and Microstructure Development of Ti-6Al-4V Bar Under Forging Conditions

by J.N. Aoh and Z.H. Lin

The uniformity of microstructure distribution across the transverse section of a Ti-6Al-4V bar after stepwise radial forging process is a relevant index to the quality of the forged bar. In this work, hot deformation characteristics of Ti-6Al-4V bar in the stepwise radial forging process were investigated in the $\alpha + \beta$ and β range between 940°C and 1000°C. Various flow curves and microstructures were obtained by using Gleeble simulation. The deformation process of a bar from initial diameter to a desired reduction in cross section was simulated by using a FEM code ABAQUS combined with the constitutive models obtained from physical simulation. Heat conduction model was coupled to the computation. The principal stresses and final strain distribution of the bar after forging were predicted by the contours obtained from FEM analysis. Together with the results obtained from Gleeble simulation, a map of microstructure distribution on the cross section of the forged bar was constructed. According to the map, recrystallized zone in the center region of the bar was predicted to be approximately 50 to 65% of the total cross section area.

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Joining of Ni_3Al by Pressurized Combustion Synthesis Using Gleeble 1500 Test Simulator

by W.P. Liu, F.X. Zhai and C.H. Ding

In this investigation, the Gleeble 1500 test simulator was used for carrying out experiments of joining by the pressurized combustion synthesis (PCS). The intermetallic compound Ni_3Al was bonded by using the exothermic synthesis reaction of a mixture of elemental Ni and Al powders pre-compacted as the interlayer material. Effects of the key process parameters, such as the heating rate and joining temperature, as well as the hold time, on the joint formation and microstructural homogeneity were studied. The feasibility of the addition of Al_2O_3 particles in the joint interlayer for producing intermetallic-matrix composite joints was also explored. Results show that the microstructural homogeneity in the synthesized joint interlayer was significantly influenced by the joining process parameters. The fully synthesized Ni_3Al joints exhibited an average tensile strength of 486MPa at R. T. With the addition of Al_2O_3 ceramic particles in the reactants, joints with reinforced Ni_3Al-matrix composite interlayer were obtained.

New Developments in CCT Measurements

Until the establishment of ASTM A1033-04, data on the transformation of steel properties resulting from thermal treatment had been collected by a variety of techniques that created variability in the results.

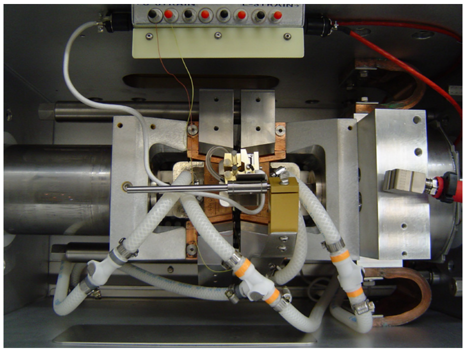
Recently, however, the Bar and Rod Market Development Group of the American Iron and Steel Institute (AISI) announced the successful conclusion of the QMST collaborative project, and the availability of ASTM Standard Practice A1033-04 for acquiring quantitative data on steel transformation. Data acquired and archived through this standard practice are crucial for process simulation models that can accurately predict residual stress, distortion, and microstructure evolution during manufacturing processes such as steelmaking, forging, and heat treating. For more information about the standard, contact Dave Anderson, American Iron and Steel Institute, 2000 Town Center Drive, Southfield, MI 48075; tel: 248 945-4777; fax: 248 352-1740; e-mail: andersn@autosteel.org; Web site: www.autosteel.org. Accurate data derived from physical simulation will enable reliable predictive computer modeling of structures and residual stresses. For example, design of automotive chassis and powertrain components will benefit from optimized processing of performance-critical automotive bar and rod steels.

DSI offers three key tools which meet the new standard to help researchers engaged in transformation studies.

CCT Dilatometer for Accurate Measurement of Transformations

The Model 39018 CCT Dilatometer is an LVDT-based dilatometer designed for accurate measurements of material transformations and can be used on Gleeble 3500 and 3800 systems and Gleeble 1500D systems using a Series 3 Digital Control. The transducer can also be used for measuring transformations after deformation on a variety of materials and specimen sizes.

The Dilatometer kit comes complete with heat shields, mounting brackets, signal conditioner, and spare parts. Built in heat shield and cooling ports allow the dilatometer to be used for high temperature tests up to 1,300°C. The cooling medium is typically air or inert gas. Since the cooling ports are tightly sealed from the outside, the fixture can be cooled without compromising the vacuum atmosphere so critical to accurate transformation measurements.



The model 39018 CCT Dilatometer features a slide mount bearing.

The fixture features precision machined roller bearings that provide smooth action for the dilatometer. These bearings allow the unit to be more sensitive and capture minute changes in diameter. The dilatometer mounting system also uses a precision machine slide bearing which ensures the dilatometer stays in the center of the specimen when the specimen is strained. Another advantage of the slide mount bearing is that it reduces the chance of side loading on the fixture which would compromise the data.

As with all Series 3 Digital Control extensometers, the 39018 CCT Dilatometer has its own signal conditioner that plugs directly into the front of the Gleeble console. A multi-colored LED on the front of the conditioner provides a quick status check for calibration.

The maximum deformation speed during compression testing is restricted to the speed at which the dilatometer can maintain adequate contact with the specimen. Generally, this means deformation rates up to 10/sec. Higher deformation speeds require careful planning and consideration of specimen geometry to make sure the transducer is not damaged and the measurements are not affected.

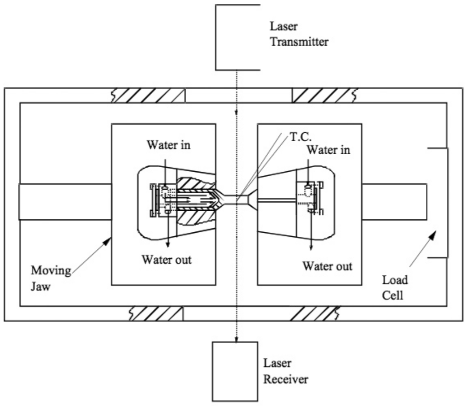


Figure 1. Schematic of the ISO-Q laser dilatometry system.

The kit also includes a carrying case for easy storage of the unit and its accessories.

38520 ISO-Q Quench Fixture

To meet the need for high cooling rates during transformation studies, DSI developed a special isothermal quench fixture (ISO-Q), as schematically shown in Figure 1. (An LVDT dilatometer transducer can also be used with the ISO-Q technique, although a laser dilatometry system is shown in the figure.) A reduced section bar specimen with a hole drilled at each end of the specimen is adopted for such testing, as shown in Figure 2. The diameter of the reduced section can be as small as 5 mm. Typical standard size is 6 mm diameter. With water quenching at both ends of the reduced section, an isothermal plane is maintained during high speed cooling in the midspan since heat loss is along the specimen axis. A cooling rate of 400°C/s has been reached from 800°C to 500°C with a 6 mm diameter reduced section plain carbon steel bar.

There is also an ISO-Q specimen design used for compression testing. As a result, dynamic CCT work can also be conducted using this ISO-Q technique when a high cooling rate is required.

Isothermal quenching can be conducted in either vacuum or inert gas environment. The quenching water/gas from the computer controlled quenching system will not affect the vacuum during the test. This is important especially when the laser dilatometry system is used.

When a higher cooling rate is required, thin tubular specimen can be used but with radial thermal gradients in the measurement zone when passing the cooling medium through the tube. The thermal gradient is dependent on the thermal conductivity of the specimen material and should be taken into account when observing the transformation measurements. A cooling rate of more than 3000°C/s has been obtained by passing water through a reduced section bar.

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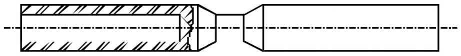

Figure 2. Reduced section bar specimen with a hole drilled at each end.

Dynamic Systems Inc.
P.O. Box 1234, 323 Route 355
Poestenkill, NY 12140 USA

The Gleeble at ThyssenKrupp Stahl, Duisberg, Germany

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Dr. Schmitz and his colleagues are using the Multi-Functional Simulation System to simulate casting, rolling and continuous casting/hot rolling. “The system can simulate continuous casting/hot rolling very well,” Dr. Schmitz says, adding “Thin slab casting offers a number of advantages including large energy savings, more homogeneous materials, and better precipitation behavior both during and after hot rolling.”

“We also use the Gleeble 3500 to simulate welding and continuous strip annealing,” Dr. Schmitz says.

Materials testing programs with the Multi-Functional Simulation System include hot deformation, hot compression, phase transformation, continuous cooling, and isothermal holding. “Our goal is to understand what is going on in the material,” Dr. Schmitz says.

In the area of material behavior, researchers of the Center of Materials Excellence are performing studies on work hardening, transformation behavior, and recrystallization behavior.

“The new Multi-Functional Simulation System has a number of advantages,” Dr. Schmitz says. “For example, it offers very high heating and cooling rates. We can achieve heating rates of 10,000 degrees K per second to do welding simulations, and we can achieve cooling rates higher than 1,000 degrees K per second to quench materials extremely fast for CCT work. In addition, the machine can do strain rates higher than 100 sec^{1}.”

Using the Multi-Functional Simulation System, the team of the Center of Materials Excellence has performed a number of important tests on the behavior of sheet materials in a press (stamping) shop. “People in press shops in Europe were thinking about heating up the sheets of steel before forming automotive parts to achieve better flow,” Dr. Schmitz says. “But some very important questions were raised: Are you changing anything in a detrimental way? What exactly is the effect of heating before stamping? With these machines, you can study such problems very precisely.”

For coating and annealing lines, ThyssenKrupp Stahl researchers studied the optimization of annealing multi-phase steels by heating into the gamma-alpha range, the intercritical region, with roughly 50% ferrite, 50% austenite.

Dr. Schmitz says, “This is a typical annealing cycle for cold rolled TRIP steels. By varying the time and temperature in the intercritical region, the cooling rate, the holding temperature and time in bainite, the production conditions for annealing and coating lines can be optimized because we can study the metallurgical behavior of the material during the whole process.”

He adds, “The Gleeble makes it possible to do that. It gives us a tremendous advantage in developing new materials and optimizing existing materials and processes.”

New Developments in CCT Measurements

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The typical diameter of the reduced section is 5 mm with a hole of 3 mm in diameter.

35530 CCT Software for Windows

DSI’s Model 35530 Continuous Cooling Transformation Curve Generation Software is a software package written for Windows that allows the user to generate CCT curves for up to 10 transformations from each of up to 45 acquired cooling curve files.

The CCT software speeds analysis by allowing it to be performed on the video display rather than paper. The keyboard or mouse is used to move a line along the dilation versus temperature curve and to visually select transformation points. When the transformation point is selected the time and temperature of the point can be stored for analysis. The data is automatically plotted and can be modified to take into account subsequent metallographic analysis.

To help the user determine the transformation points there are two computer software aids. One method is the use of a linear approximation to the dilation curve equation before and after transformation. As a second method, a numerical derivative technique is available to help the user determine the phase transformation points. The second derivative of the dilation to temperature can be plotted on the same Dilation vs. Temperature graph. The deviation points from and to a near constant line represent the start and finish points of phase transformation respectively.

For additional information about these CCT tools, contact DSI.