Dynamic Systems Inc.

The Gleeble® eNEWSLETTER

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Standard Practice Devised to Measure Phase Transformation

The Bar and Rod Market Development Group of the American Iron and Steel Institute (AISI) announces 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.

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 nonstandard techniques that provided highly variable

New improvements and advances in technology

DSI Announces Industry-First Direct Rolling Simulator

For the first time ever, steel makers can explore the promise of continuous casting and direct rolling (CC-DR) on an affordable, reproducible laboratory scale.

Continuous casting followed by direct rolling (CC-DR) offers steel makers the opportunity for substantial energy savings and reduced capital expenditures, which in turn can reduce costs, sometimes by $40/ton or more. Development of continuous casting-semi-solid rolling offers even greater cost saving potential but widespread commercialization presents new technical challenges. The further adoption of CC-DR and/or semi-results. Accurate data 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.

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Highlights of the HDS-V40 CC-DR Simulator

In an industry first, Dynamic Systems Inc. (DSI) today announced the HDS-V40, the only commercially available laboratory system capable of simulating direct rolling, from the continuous caster to the end of the hot rolling process, all in one continuous sequence using a single specimen.

For the first time ever, steel makers can explore the promise of continuous casting and direct rolling (CC-DR) on an affordable, reproducible laboratory scale.

Applications of the HDS-V40 include:

- Direct rolling

solid rolling offer the following potential benefits:

- Enormous energy savings can be realized when compared to traditional casting and re-heating methods.
- New steels with exciting new properties and structures might be created.
- A radical reduction in the segregation of impurities may be possible with these production methods.
- A decrease in capital expense can be achieved since mills can be made smaller.
- Reduction in manufacturing time.

A New Technology for Process Development

Until now most developments in CC-DR and semi-solid rolling have been made using pilot mills or full size mills for experimental work. These methods are costly and instrumenting the process in a mill application is very difficult. The alternative method has been laboratory melting apparatus or traditional hot deformation machines. However these can only study one step of the process. In order to study the processes in greater detail than existing laboratory methods and at lower costs than mill trials, a new laboratory physical simulator, the model HDS-V40, has been developed by Dynamic Systems Inc. (DSI). This technology has been developed specifically to simulate continuous casting followed by hot rolling or semi-solid rolling in-situ and in the laboratory. The specimen size has been chosen to allow a suitable size cast volume and deformation area. The specimen section is 10 mm thick by 50 mm wide. Other specimen cross sections may be used. During melting, a zone approximately 75 mm in length is obtained by adjusting the thermal program. The mechanical system has a maximum force of 40 tons. For most work an anvil width of 15 mm is used with a length of 60 mm to span the 50 mm wide specimen. Other anvil sizes may be used within the maximum force limits of the machine.

Mechanical Systems

The mechanical configuration of the system is based on handling a large melt zone. Since the specimen has no strength while in the liquid state, a composite crucible is used to support the melt. The crucible has an open top with both sides and bottom of the specimen supported. The unique composite crucible permits cooling medium to be sprayed completely around the specimen, top, sides and bottom. The amount of cooling by this method is adjusted to provide the cooling and shell formation desired on the cast material. The ends of the specimen are retained in water-cooled grips, which provide adequate cooling on the specimen ends to prevent melting beyond the end of the crucible. The crucible is mounted under the specimen with two retractable arms that provide support for the crucible during the casting process.

- simulation
- Hot deformation
- Multi-stand rolling mill simulation
- Multi-hit forging simulation
- Stress relaxation
- Semi-solid rolling simulation

The HDS-V40 at a Glance

- Continuous Casting-Direct rolling, liquid metal core reduction, hot rolling and hot forging simulations
- Direct resistance heating for high speed thermal capability and precise control
- Two 40-ton hydraulic systems with exact control of strain and strain rate
- Deformation speeds from 1.7 meters/sec to 0.1 mm/sec
- Simulations can be run in air, vacuum or inert gas
- Quench in-situ at anytime during simulation with gas or water
- Eight channels of thermal and mechanical control
- Precise digital control system
- 16 channels of data acquisition at up to 50,000 samples/sec

For additional information, contact DSI or visit the DSI Web site at www.gleeble.com.

The overall system has eight servo controlled axes. Five axes are servo hydraulic and three axes are thermal. The fragile liquid specimen with a thin shell requires that deformation be balanced, so the specimen does not move in the direction of deformation force while being deformed. Two vertical servo hydraulic rams are mounted with one in the top crosshead of the machine and the other in the bottom crosshead of the machine. These 40-ton capacity rams each travel toward the specimen, one from the top and the other from the bottom. The rams are synchronized to start and end deforming the specimen at the same time and velocity. Each ram has a maximum velocity of 850 mm/s. The opposing rams have a combined velocity of 1.7 m/s with a minimum pause time of 0.2 s. Each ram has an 80-ton capacity Hydrawedge to provide precise control of strain at high strain rates. Each Hydrawedge is also a servo hydraulic control axis. The two Hydrawedge axes are programmed as one, similar to the way the rams are programmed. Therefore, the operator only needs to program the amount of strain and the strain rate desired for each compression hit. The software provided with the machine calculates all the movements needed for the hydraulic rams and the Hydrawedge stops.

When the specimen mid-span melts, the level of liquid at the top of the specimen is depressed. The liquid level is brought back to the original height by reducing the length of the specimen. The space between the jaws is controlled by the fifth servo hydraulic system. The amount the grips are brought together to level up the liquid may be programmed either manually or automatically as part of the computer program. This returns the specimen to its original 10 mm thickness before solidification. During solidification the specimen is further reduced in length to accommodate the shrinkage, which occurs as the specimen cools.

Another feature of the new physical simulator is a mechanical system that permits moving the entire specimen and jaw system off the anvil centerline. Normally the specimen is deformed at the center of the mid-span, where the liquid thickness during solidification is the same on both sides of the anvil. However, as a means of more accurately simulating semi-solid rolling, the specimen can be moved to one side allowing deformation of the specimen where the thickness of the remaining liquid is greater on one side of the anvil than on the other.

Thermal Systems

Heating of the specimen is by self resistance to electric current flow. The thermal control circuit uses a thermocouple for temperature measurement and feedback. The output of the thermocouple is compared with the thermal program providing a difference signal. The electric heating current is continuously adjusted by the thermal servo control to minimize the difference signal and make the thermocouple value and program temperature match.

The compression anvils are moved away from the specimen at all times except during deformation. Deforming at very high temperatures causes an undesirable loss of heat from the specimen to the anvils when the anvils are cold. This new machine is equipped with two servo controlled

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.

anvil heating systems. The temperature of each anvil may be adjusted or programmed independently using the computer program. Using heated anvils limits thermal losses from the specimen during deformation and provides a more accurate simulation.

Measurement Systems

The HDS-V40 utilizes two computer systems. One computer system is used to store all of the programs and run the machine (the control computer). The second computer is used to create simulation programs, download programs to the control computer, gather all the data from the measuring systems on the machine and manipulate/print the data. The control computer is standalone and can run the machine independently from the second computer. This permits data analysis and plotting of prior tests while the next test is being performed on the machine. Alternatively, the machine may be run manually from the front panel controls on the control console.

The data acquisition system has 16 channels, which can simultaneously gather data at rates up to 50,000 data points per second on all channels. The physical simulation of real processes requires extensive data gathering if good analyses are to be possible. The unique data gathering system sets this simulator apart from pilot plants and other means of studying processes.

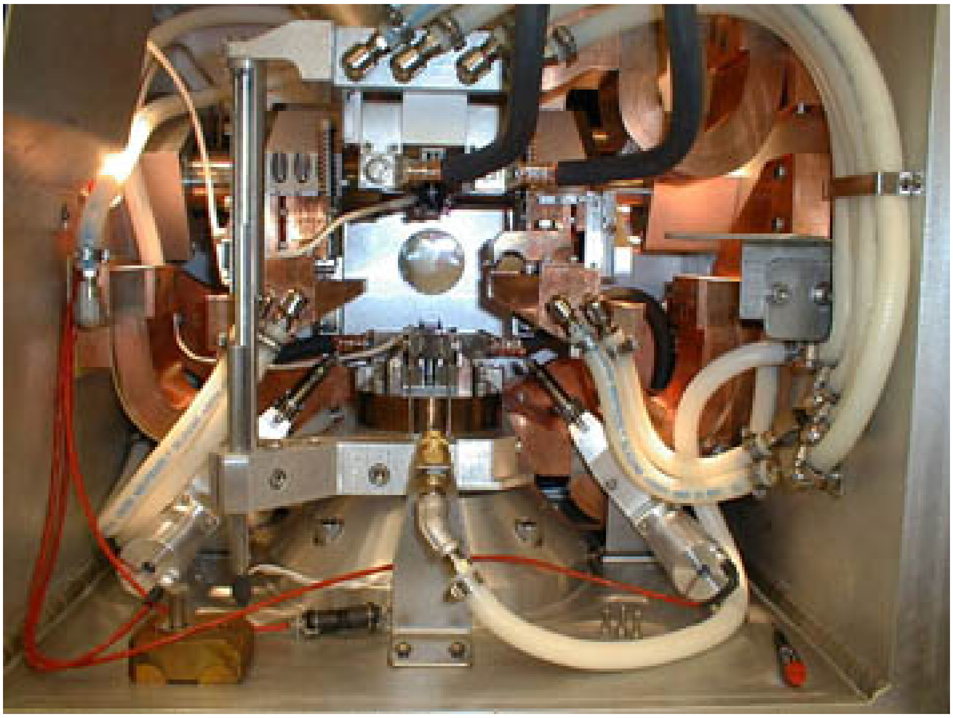
Application of the New Physical Simulator

This new machine accommodates a large specimen for in-situ casting and deformation during or after solidification. Complex procedures such as melting solidification, multi-state forming and multi-stage cooling in any combination can be carried out on the sample. During these procedures temperatures, strain, strain rates and forces can be controlled and measured precisely. The optional laser can be also used to measure the dilation of the specimen after deformation to obtain transformation information.

The specimen can be quenched at any time in-situ to study the effects of prior procedures.

The large cast specimen permits grain growth studies based on cooling rates with and without deformation. The dendritic growth direction and rate can be modified using forced cooling on different surfaces of the specimen.

This new simulator will significantly reduce development time for new materials, processes and products. The simulator will permit optimizing continuous casting and direct rolling in both semi solid and solid regimes to allow new developments to be made at lower costs. The technologies under study using this simulator offer potential for significant energy savings, new materials and new products. The first simulator of this design has been delivered to a German steel company where it has recently completed initial trials and is now in extensive use on various research projects. A second physical simulator of this design was commissioned in Europe in the summer of 2004.



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Recent Gleeble Papers

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Grain Refinement of Microalloyed Steel Through Heavy Hot Deformation and Controlled Cooling

by H.R. Hou, Q.Y. Liu, Q.A. Chen, and H. Dong

Heavy deformation and controlled cooling is one of the most effective ways for grain refinement in HSLA steels. In this paper, experimental specimens are prepared with a commercial linepipe steel grade X65 and the chemical compositions are (wt%): Fe-0.094C-1.42Mn-0.29Si-0.045Nb- 0.008Ti. After heavy deformation with 80% reduction in non-recrystallization range of austenite, and at controlled cooling rates from 2 K/s to 64 K/s, the grain sizes vary from 9.55 µm to 1.06 µm. It is shown by the results that a linear relationship still remains between the yield strength and reciprocal of square root of ferrite grain size as grain size is refined to 1 µm. The ultra-fine grains might be dynamically formed through the deformation-induced transformation when reduction is large enough. The grain sizes decrease when the cooling rates increase. When the cooling rates increase over 10 K/s, the grain sizes are rarely changed. The particles distribute on grain boundaries, sub-grain boundaries, deformed bands and within the ferrite grains.

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Artificial Neural Networks—Modelling, Programming and Appliction in Material Hot Working

by H.T. Li, Y. Deng, and J.T. Niu

The developments of modern mathematics and computer science make artificial neural networks become most useful tools in a wide range of fields. Modeling methods of artificial neural networks are described in this paper. The programming technique by using Matlab neural networks toolbox is discussed. The application in Material Hot Working of neural networks is also introduced.

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Evolution of Microstructures and Hardness During Continuous Thermo-Mechanical Processing of 6201 Aluminum Alloy

by H. Zhang, Y. Liu, D. Peng, and C. Wang

Continuous thermo-mechanical processing (CTMP) of 6201 aluminum alloy was simulated on the Gleeble 1500. The deformed specimens were analyzed by the observation of TEM and the measurement of hardness. It was shown that rapid solid solution and aging treatment can be effectively combined in one procedure by the strain induced during CTMP. The deformation temperature is ranging from 540°C to 300°C, the hardness increases directly before the 6th pass followed by a slight drop, the amount of precipitates increases with the holding time after deformation. Uniformly distributed and stabilized Mg^2Si precipitates, as well as dislocation substructure can be observed on deformed specimens which have been subsequently held at 300°C for 60 seconds.

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Application of Gleeble 1500 on Superplasticity

by B.Z. Bai, X.J. Sun, and L.Y. Yang

The Gleeble 1500 thermo-mechanical simulation machine is considered to be the first grade equipment in materials research. However, it is seldom used in superplastic research. Perhaps this is because its specimen's heating method is not suitable to get large elongation. Elongation is an important parameter to evaluate superplasticity, but some other parameters such as the relationship between stress and strain rate are more important than elongation—it is an essential property to superplasticity. The stress-strain rate relationship can be very easily and very accurately got with Gleeble machine than with some other similar equipment, and the relationship between microstructure and superplastic deformation is more easily examined with Gleeble. Present authors have got some new achievement in anisotropy, heterogeneity of superplastic deformation, and first put forward the regulation of dynamic equilibrium in microstructural evolution during superplastic deformation. All of these have been concluded from the experimental results mainly through Gleeble as well as the microstructural examination. The research work has got the support of National Natural Science Foundation and some international cooperation. Some theoretic and experimental results have been used in the practice of superplastic forming. Obvious effect of reducing cost and improving quality of formed parts has been achieved.

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Prediction of Flow Stress of High-Speed Steel During Hot Deformation by Using BP Artificial Neural Network

by J. Liu, H. Chang, R. Wu, T. Hsu, and X. Ruan

The hot deformation behavior of T1 (18W-4Cr-1V) high-speed steel was investigated by means of continuous compression tests performed on Gleeble 1500 thermomechanical simulator in a wide range of temperatures (950°C-1150°C) with strain rates of $0.001s^{-1}$-$10s^{-1}$ and true strains of 0-0.7. The flow stress at the above hot deformation conditions is predicted by using BP artificial neural network. The architecture of network includes three input parameters: strain rate, temperature, and true strain, and just one output parameter, the flow stress. Two hidden layers are adopted, the first hidden layer includes 9 neurons and second layer includes 10 neurons. It has been verified that BP artificial neural network with 3-9-10-1 architecture can predict flow stress of high-speed steel during hot deformation very well. Compared with the prediction method of flow stress by using Zener-Hollomon parameter and hyperbolic sine stress function, the prediction method by using BP artificial neural network has high efficiency and accuracy.