Dynamic Systems Inc.

The Gleeble® NEWSLETTER

Fall–Winter 1994

Bulletin Board

Welcome to the Fall 1994 edition of the Gleeble Newsletter. We continue to receive a wide variety of interesting papers describing work performed on Gleeble systems, and we are again publishing a selection of abstracts from them. A complete listing of Gleeble-related research papers is available upon request.

Thanks to everyone who visited our exhibit at the 1994 Materials Expo in Chicago. It was a great pleasure to visit with old friends and to make new acquaintances. Interest in physical simulation of thermal mechanical processes continues to grow, and we are seeing many new applications for Gleeble Systems.

In this issue, you'll also find a description of the Gleeble 2000, Model 20:10. This model is a new addition to the Gleeble Systems

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Gleeble® 2000 Model 20:10 Launched by DSI

The Gleeble 2000 Model 20:10, a new ultra-high-performance dynamic thermal-mechanical physical simulation system—designed with additional stiffness in the frame and compression components for superior performance in hot deformation simulations—is now available from Dynamic Systems Inc.

The new test system, based on the internationally renowned technology of the Gleeble 2000, features a maximum stroke rate of 2 meters/second and a maximum static force capacity of 20 tons in compression and 10 tons in tension. In

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Gleeble Application Profiles:

The Gleeble at the General Electric Research and Development Center

For Dr. Robert Sundell, Mechanical Engineer at GE's Research and Development Center in Schenectady, N.Y., the Gleeble is a highly practical research tool that has helped him and his colleagues solve some difficult processing problems.

"We purchased a Gleeble 1500 in 1985," Dr. Sundell says, "because GE's Aircraft Engine Group wanted to come up with a way to bond fan airfoils to forged hubs. These integrally bladed rotors, as they are called, are single-piece assemblies which eliminate the traditional dovetail fit in which a highly machined fan blade fits into a keyway in the hub. The integrally-bladed rotors save a lot of weight and are a more efficient configuration in terms of air flow in the jet engine."

The problem that faced the GE Research and Development team was to come up with a process to solid-state bond Titanium 6-4 fan airfoils to the hubs. They began looking at pressure welding (or upset welding) and evaluating the relationship of weld parameters, such as interface temperature, weld upset, upset rate, and post-weld cooldown rate, to the final weld properties. They were also interested in how each of these weld parameters affected the final weld microstructure.

Dr. Sundell says, "The Gleeble was ideal for doing this type of study. We tested subscale specimens with the correct bond geometry. We conducted large test matrices that were statistically designed to

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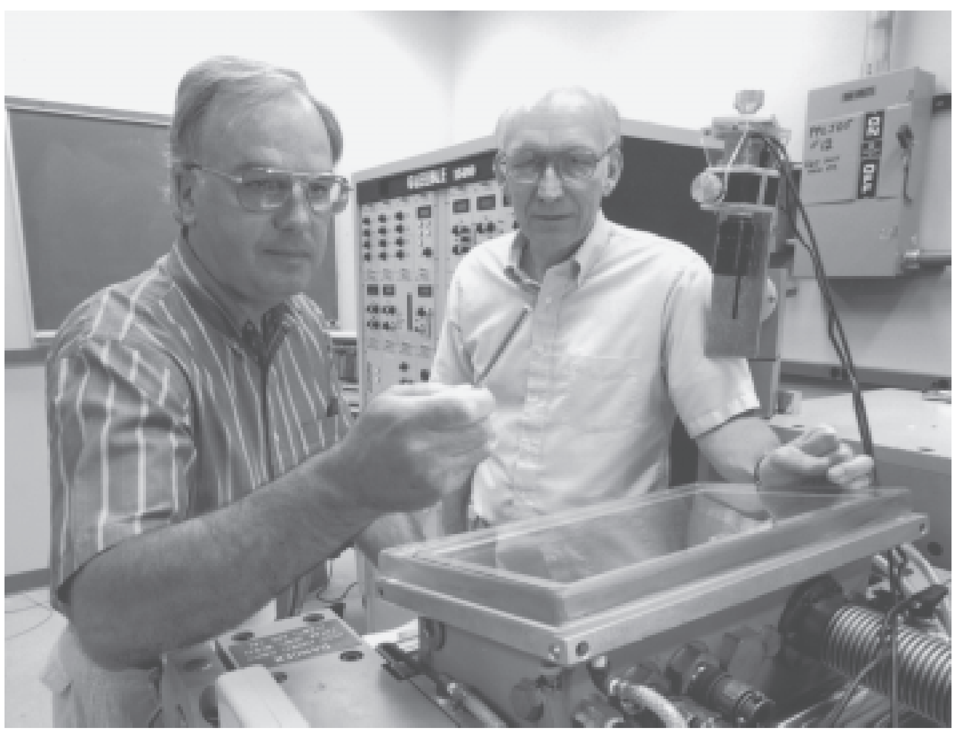

Harold Jenkins (left), specialist, and Dr. Robert Sundell, mechanical engineer, perform tests with a Gleeble 1500 at GE's Research and Development Center in Schenectady, N.Y.

Recent Gleeble Papers

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Substructural Evolution of Ferrite in a Low-Carbon Steel During Hot Deformation in (F+A) Two-Phase Range

by Wang Rizhi and T. C. Lei

The dynamic recovery and recrystallization of metals and alloys have been intensively investigated in the past two decades. It is believed that in most cases subgrains develop in the strain hardening regime during hot working and reach an equilibrium size which can be maintained during steady state flow. However, most of the previous studies have concentrated on the microstructural characteristics in the steady state regime and their relations to macroscopic flow stress and hot deformation parameters, while the evolution of microstructures, especially at the initial stage of deformation, is far from fully understood. In a previous work, the authors have investigated the development of substructure in pure iron during hot rolling. In this paper, the microstructural evolution of ferrite is studied on a low-carbon steel compressed in the ferrite-austenite two-phase temperature range. The selection of two-phase structure is mainly due to the fact that the study on coarse two-phase structures is much less, compared with that on single-phase metals, and in many cases the controlled rolling processes of low carbon steels are prolonged to (F+A) two-phase temperature range.

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Role of Interface in Nucleation of Dynamic Recrystallization of Austenite

by R.Z. Wang and T.C. Lei

It is generally recognized that grain boundary plays an important role in the dynamic recrystallization (DRX) of single-phase metals, and the bulging of original grain boundaries is the most common nucleation mechanism of DRX. But in two-phase alloys, such as α - γ stainless, α - β brass and low-carbon steels in austenite-ferrite (F+A) temperature range, where the grain boundaries of one phase are partially or fully occupied by another phase, the nucleation mechanism of DRX is still unknown. In this paper, single-phase austenite and different morphologies of (F+A) two-phase structures were obtained in low carbon steels for the purpose of investigating the role of interface in the nucleation mechanism of DRX of austenite.

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Monte Carlo Simulation of Grain Growth in the Weld Heat-Affected Zone

by Y. Shen, B. Radhakrishnan, and R. G. Thompson

In the subsolidus portion of the weld heat-affected zone (HAZ), grain growth and precipitate dissolution occur simultaneously during the heating portion of the thermal cycle. A quantitative treatment of the above microstructural changes is vital to a better understanding of the extent of grain boundary liquation produced by constitutional liquation. The paper describes the use of Monte Carlo technique for simulating grain growth during continuous heating in the presence of dissolving precipitates. The results indicate that depending upon the alloy system, a considerable fraction of the initial grain boundary precipitates can be lost by both dissolution and by grain boundaries breaking away from the partially dissolved precipitates, before the liquation temperature is reached. Thus only a fraction of the original precipitate population contributes to liquation.

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Impact Toughness and Cleavage Fracture Strength of an Ultra-Low Carbon Steel

by M. G. Vassilaros and J. F. Knott

The impact toughness and cleavage fracture toughness of an ultra-low carbon bainitic (ULCB) controlled-rolled steel was investigated. The steel had 0.02%C-Mn-B and 0.02% Ti. The as-received microstructure of the steel was composed of fine grained (≈ 5µm) ferrite which possessed a yield strength of 500 MPa (72 ksi), and a Charpy impact 50% fracture appearance transition temperature (FATT) of –85°C (–120°F). The cleavage fracture strength of the steel was found to be 2050 MPa (≈ 300 ksi). Charpy impact toughness tests were performed on specimens subjected to simulated heat-affected-zone (HAZ) thermal cycles using a “Gleeble” thermal simulator. The tests were performed at –50°C and the results revealed a drastic reduction in impact toughness. Scanning electron microscope (SEM) analysis of the fracture surface indicated that the cleavage initiation site was a cuboid titanium-nitride (TiN) inclusion. An additional series of Charpy and notched four-point bend bars were performed on ULCB steel that had been heat-treated to develop a microstructure that was similar in appearance to the “Gleebled” specimens. Test results indicated a 50% FATT near room temperature and a cleavage fracture strength of 1650 MPa (≈ 240 ksi). SEM analysis of fracture surfaces of these specimens revealed initiation sites coincident with large (1-2 µm) TiN cuboid inclusions, just as the TiN inclusions appeared to have been the nucleation site for the large grains in the HAZ-simulated microstructure. These large TiN cubes are stable up to the melting temperature of steel, and therefore were present in both the fine-grained and coarse-grained (HAZ) steel. However, the cuboid TiN inclusions were cleavage crack initiation sites only in the large-grained material. The mechanism by which the large TiN inclusions interact with the cleavage fracture process are clear but their presence appears to be a necessary but not sufficient condition for low cleavage fracture strength. The fine-grained microstructure appears to mitigate the deleterious effects of the large TiN cubes.

The new Gleeble 2000, Model 20:10, shown here with optional Hydrawedge, offers maximum static force capacity of 20 tons in compression and 10 tons in tension.

Gleeble 2000 Model 20:10 Debuts

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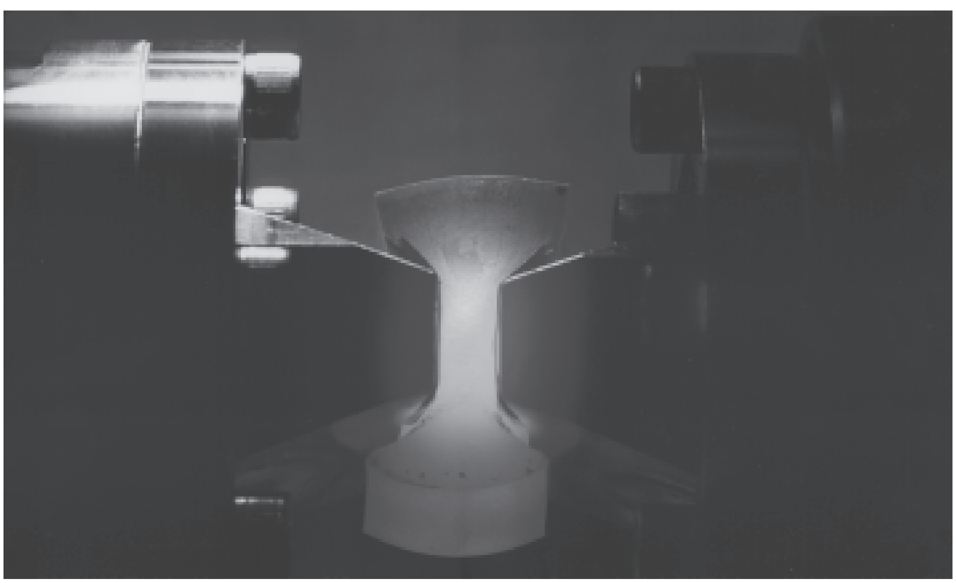
addition, it is capable of heating specimens at rates of 10,000°C per second. In keeping with the Gleeble concept of multi-functionality, this machine can be reconfigured to perform hot tensile tests, melting and solidification tests, and a variety of other thermal-mechanical simulation and test applications.

For hot deformation work, the Gleeble 2000 Model 20:10 can be equipped with a Hydrawedge system for precise control of strain and strain rate. The Hydrawedge option offers the unique capability to control the strain and strain rate independently during deformation. Through the use of two opposing hydraulic systems, one controlling strain, the other controlling strain rate, a Gleeble 2000 Model 20:10 with a Hydrawedge can be used to simulate high speed deformation processes, including multi-stand rolling mills and multi-hit forging operations.

The short cycle times and rapid thermal changes necessary for physical simulation of these processes are possible because all heating, cooling, quenching, and deformation are done on the specimen *in situ*.

Accurate physical simulation requires that the specimen undergo the same thermal and mechanical treatment as it would in the actual production process. The Gleeble 2000 system provides a valuable tool for accurate simulation work.

For additional information about the Gleeble 2000, contact us here at DSI.



This sample of carbon steel at 1150°C, under test in the Gleeble 2000 Model 20:10 equipped with Hydrawedge, shows moderate deformation after the first compression of a multi-stand rolling mill simulation.

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product line for 1995 and offers many enhancements to our previous Gleeble 2000, 20-ton system. A Gleeble 2000, Model 20:10 System is in operation at our factory and is available for demonstrations. This Gleeble System includes a hydrawedge and is equipped for high speed, multi-hit, hot deformation, and forging simulations.

In addition, if your application involves hot tensile testing, melting and solidification, or welding, we have Gleeble Systems available in our factory demonstration center to show you how a Gleeble system can be used to address your production problem or area of research. If you are interested in visiting the DSI factory demonstration center, please call us to make arrangements. We look forward to meeting with you.

Plans are under way for the next International Symposium on Physical Simulation (ISPS) to be held in the United States in the Spring of 1996. Topics will include welding, continuous casting, hot deformation, including hot rolling and forging, semi-solid processing, and advanced materials processing. The last ISPS, held in Delft, Netherlands, was a resounding success, with attendees from around the world. Watch upcoming editions of this newsletter for details on ISPS ’96.

As the holiday season approaches, all of us at Dynamic Systems wish to extend our thanks to everyone who has contributed to the success of our company. To our customers, research colleagues, representatives, suppliers, and supporters, our heartfelt thanks and best wishes for a Happy Holiday Season and a prosperous New Year.

It’s your turn. This column is intended to be a forum for Gleeble System users throughout the world. Information, replies, comments, or correspondence may be addressed to David Ferguson at Dynamic Systems Inc.

The Gleeble at GE's Research and Development Center

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evaluate the effect of the various parameters on weld properties. The team also developed a finite difference model of the pressure welding process, which gave deformation or upset/profiles for different temperature distributions and weld upsets. By comparing the Gleeble results with model predictions, we were able to verify the finite element model which could then be used to model the full-scale welds."

He adds, "In the end, we came up with a broad process window which gave weld properties equivalent to the parent material's properties. GE Aircraft Engines made up several fan/hub assemblies, and they were engine-tested successfully."

The Gleeble at the GE Research and Development Center was also utilized in defining the process for the superplastic forming of aircraft engine components. Superplastic forming is a near-net shape process for forming parts from alloys which exhibit exceptional ductility at particular stain rates and temperatures. The near-net shape part is usually blow-molded by pressurizing the inside of a pre-assembly which is contained in a die. A finite element model was again constructed for the forming process and super-plastic material properties for Titanium 6-4 were needed to get useful results from the model.

Dr. Sundell says, "What we needed was a constitutive equation which gave the flow stress of the titanium as a function of temperature and strain rate. We conducted a series of tensile tests with the Gleeble, deforming Titanium 6-4 at different temperatures and strain rates, to get information for the model. Eventually, a processing map was developed for an efficient and reliable process."

Dr. Sundell also reports that he and his colleagues have used the Gleeble to evaluate the tensile strength of braze alloys used in the manufacture of X-ray tubes at GE Medical Systems. Brazing is used in the joining of a molybdenum alloy to a nickel-based alloy.

"We made up tensile specimens from pins brazed together at different temperatures and with different braze alloys and then conducted tensile tests in the Gleeble to evaluate the joints. We've also used the Gleeble to measure the radiative emittance of various alloys. This data has been used in conjunction with an infrared instrument developed here at the Center to monitor the temperature of various metallurgical processes," Dr. Sundell says.

Other projects have included simulating temperature and strain cycles in a weld zone during post-weld heat treating and evaluating Titanium 6242, 6246, and 17 for pressure welding.

Dr. Sundell adds, "The Gleeble System is unique in allowing one to simulate process heating and cooling rates over several orders of magnitude. Also, tests can be conducted in vacuum as well as in other controlled atmospheres. Conducting similar tests in other facilities is much more complicated, if not impossible. No other equipment allows us to control cooldown rates. It's a dynamic machine for dynamic tests that simulate the real world."

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, or faxed to us at 518-283-3160.

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