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The Gleeble® NEWSLETTER

Summer 2011

## Come See Us at the Shows

### Recap: Gleeble User Workshop India (GUWI)

The 3rd Gleeble User Workshop and National Conference on Thermo-Mechanical Simulation using Gleeble Systems was held September 16–18, 2011 at JSW Steel Ltd., Vidyanagar, Near Bellary, Karnatata State, India. Building on the success of the earlier two Gleeble User Workshop and Conferences that were held in 2008 and 2010, the conference featured well-known researchers and speakers from manufacturing, industry and research institutes.

Topics included:

- Continuous casting
- Rolling and forging
- Welding
- Strip annealing
- New applications and innovations
- Challenges in Gleeble testing and solutions

For additional information, please contact Mr. Suyash Nadkarni at ss_nadkararni@yahoo.com

### 1st Workshop on Gleeble Welding Process Simulation & Gleeble Welding Group Meeting

Gleeble Welding Group Workshop and Meeting will be held Feb. 27–28, 2012 in Graz, Austria. It will focus on the exchange of information about experiments related to welding processes carried out with any Gleeble machine.

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Gleeble Application Story

# *The Gleeble at the University of Wollongong and BlueScope Steel*

The BlueScope Steel Metallurgy Centre, University of Wollongong was established in 1995, consolidating a long history of collaboration between the University and BlueScope Steel. It undertakes strategic, basic and applied research that complements the in-house research capacity of BlueScope Steel and provides related undergraduate and postgraduate education. Operating funds are shared between UOW, BlueScope Steel and the Federal Government's Australian Research Council (ARC) through competitive research grants. BlueScope Steel is a global steel producer and the leading steel company in Australia and New Zealand.

The Centre focuses on research outcomes, development of research capacity, and the fostering of an awareness of steel research in the national and international arena. In this capacity it provides opportunities for academic staff to play a greater part in supporting the local steel industry and for technologists from industry to contribute to academic development. It also gives students access to industry, as well as giving them advanced educational opportunities in steel products and processes. Since 1997 the Centre has conducted research on numerous competitive grant projects with a total budget of nearly $10 million.

Research activities are conducted in several key areas focusing on the changing needs of BlueScope Steel as the company has responded to changes in its commercial environment. The Pyrometallurgy Research Group focuses on iron and steel making processes, and on sustainable

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*The busy Gleeble laboratory at the BlueScope Steel Metallurgy Centre, University of Wollongong.*

# Recent Gleeble Papers

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### The Mechanism of Brittle Fracture in a Microalloyed Steel: Part I. Inclusion-Induced Cleavage

*by D.P. Fairchild, D.G. Howden, and W.A.T. Clark*

The cleavage resistance of two microalloyed steels (steels A and B) was studied using several tests, including the instrumented precracked Charpy and Charpy V-notch (CVN) techniques. Ductile-to-brittle transition temperatures were measured for the base-metal and simulated heat-affected zone (HAZ) microstructures. Steel B showed inferior cleavage resistance to steel A, and this could not be explained by differences in gross microstructure. Scanning electron fractography revealed that TiN inclusions were responsible for cleavage initiation in steel B. These inclusions were well bonded to the ferritic matrix. It is believed that a strong inclusion-matrix bond is a key factor in why TiN inclusions are potent cleavage initiators in steel. Strong bonding allows high stresses in a crack/notch-tip plastic zone to act on the inclusions without debonding the interface. Once an inclusion cleaves, the strong bond allows for transfer of the TiN crack into the ferritic matrix. It was estimated that only 0.0016 wt pct Ti was tied up in the offending inclusion in steel B. This indicates that extended times at high temperatures during the casting of such steels could produce TiN-related toughness deterioration at even modest Ti contents.

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### Development of Ultrafine Grained AA5083 Using MAXStrain® Thermal Mechanical Simulator

*by W. Chen, D. Ferguson, H. Ferguson, R. Mishra and Z. Jin*

Ultrafine grain structures of metallic materials have become more and more attractive to academic and industry researchers due to their high strength and high toughness. Several techniques have been developed to produce the ultrafine grain structures primarily using a severe-plastic-deformation method, such as equal channel angular pressing (ECAP), 3D forging, torsion straining with or without applying axial pressure, and accumulative roll bonding (ARB) technique. Recently, a new multi-axis restraint deformation technique (MAXStrain®) was developed to study ultrafine-grained materials. This technique promised to easily produce much larger-size metals, compared to other methods developed. In this study, we adopted this multi-axis restraint deformation technique and developed the ultrafine grain structures of a commercial aluminum alloy AA5083 using the MAXStrain thermal-mechanical simulator. The grain structures of the deformed AA5083 were characterized using electronic microscopes as a function of strain. Mechanical properties were also evaluated and correlated with the resultant grain structures and the related processing parameters.

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### Effect of Boron on Hot Ductility of Low Carbon Low Alloyed Steel

*by H.-W. Luo, P. Zhao, Y. Zhang, and Z.-J. Dang*

The influence of boron on the hot ductility of C-Mn-Al-Cr steel has been investigated. At < 980°C M(CB) precipitated out and about half of the boron content was in solution in austenite at < 900°C. It was found that solute boron atoms segregate to austenite grain boundaries and occupy the vacancies induced by deformation. This prevents the formation and propagation of microcracks at boundaries and results in improved hot ductility and a reduced dynamic recrystallisation temperature.

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### Stressed Heat Affected Zone Simulations of AerMet® 100 Alloy

*by Joseph D. Puskar*

AerMet® 100 is a high strength, high fracture toughness alloy designed for use in aerospace applications. In previous work the welding behavior of this alloy has been evaluated, and it has been shown that a softened region in the heat-affected zone (HAZ) is a principal feature of the weld zone. A model of this softening, based on classical theories of precipitate coarsening and isothermal softening data, was developed and found to provide a reasonable description for weld thermal cycle simulation (Gleeble) experiments. Recent work has shown, however, that softening in real welds is not always well predicted by this model, so that additional effects, which are not captured in conventional Gleeble thermal cycle simulations must be addressed. In Particular, the stresses associated with real weld HAZ's may modify the softening kinetics. In the current work, Gleeble simulations in both stress-free and stressed conditions have been conducted and the kinetics compared. The accuracy of the thermal model predictions have also been considered regarding their impact on estimated hardness values.

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### Segregation of Phosphorus and Sulfur in Heat-Affected Zone Hot Cracking of Type 308 Stainless Steel

*by L. Li and R.W. Messler, Jr.*

The Auger microprobe analysis method was employed to indentify the presence and characterize the degree of interfacial segregation of P and S associated with weld heat-affected zone hot cracking in Type 308 austenitic stainless steel. Crack surface samples for Auger analysis were produced under a controlled evacuated and argon back-filled atmosphere on a Gleeble® thermomechanical simulator. Sulfur was found to strongly segregate to the intergranular fracture surface, while segregation of P, confirmed by earlier EDS analysis, was undetected by the Auger equipment employed. The relatively stronger tendency for S to segregate correlates well with this elements' higher diffusion rate compared to P and with cracking susceptibility test results, which showed S to be more detrimental that P to HAZ cracking.

# Using Type B Thermocouples

The use of type B thermocouples is becoming more popular among Gleeble operators because they have greater stability at high temperatures and are not affected by oxygen as are tungsten thermocouples. Before you use a type B thermocouple, however, there are some things you should know:

• Because of a double-valued performance curve and extremely low setback coefficient at low temperatures, the type B thermocouple is virtually useless below 50°C. It will not perform the same as other thermocouple types at room temperature.

• Accuracy for type B thermocouples is specified > 800°C (+/–0.5C). Below 800°C, the type B thermocouple is not specified for any accuracy. As a result, do not use type B thermocouples for important temperature measurements below 800°C.

We recommend power control for the initial heating of the specimen. As starting place for power control when transitioning to thermocouple control using a type B thermocouples with a 10 mm steel specimen, try the following:

• Set power angle to 40°
• Wait tcl > 400°C
• Ramp tcl to 1200°C in 100 sec.

For more information about the specifications and performance of type B thermocouples, consult:

http://www.omega.com/temperature/z/pdf/z036-040.pdf

http://www.omega.com/temperature/z/pdf/z212-213.pdf

# High Temperature MCU Introduced

A special MCU (Mobile Conversion Unit) designed for tensile and thermal testing at sustained operating temperatures up to 3,000°C is now available for use on Gleeble 3500 or 3800 systems.

The new MCU features modified water cooling circuits to protect jaws, grips, load cell and other MCU components when operating at high temperatures and also has special heat shielding of extensometers. A special two-color high temperature pyrometer is used for thermal control.

The high temperature MCU includes an atmosphere control tank for testing in gas or vacuum and can be retrofitted to existing Gleeble 3500 and 3800 systems.

For more information about the high temperature MCU, please contact us here at DSI.

# 9th International Trends in Welding Research Conference

The 9th International Trends in Welding Research Conference, to be held June 4–8, 2012 in Chicago, features five days of technically-intensive programming focusing on both fundamental and applied topics related to welding and joining.

Top researchers and colleagues from around the world from industry, government and academia will present the latest in experimental and modeling developments in the following areas:

• Friction Stir Welding
• Microstructure
• Phase Transformations
• Properties and Structural Integrity of Weldments
• Residual Stress and Distortion
• Sensing, Control and Automation
• Solidification
• Transport Phenomena
• Weldability
• Welding Processes, Procedures and Consumables
• Other Experimental/Modeling Investigations

For further information on the 9th International Trends in Welding Research event, contact ASM at:

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## Come See Us at the Shows

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Topics will include:

• Welding processes: conventional arc welding, resistance (spot) welding, solid state welding such as friction stir welding, etc.
• Metallic materials: steels, aluminium, titanium, magnesium, nickel, etc.
• Similar and dissimilar joining
• Discussion about problems and solutions of Gleeble experiments

Registration deadline and fees:

• Presentation (title and short abstract) — Dec. 17, 2011
– Workshop and dinner (1st day)
– Gleeble Welding Group Meeting (2nd day)
• Participation — Jan. 30, 2012
– 1st day (fee 50€)
– 2nd day (fee 50€)
– Ph.D. students (50% discount)

Please register via email or fax stating first and family name, address, telephone number, email address, and send it to:

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### European Gleeble Users Group Meeting

European Gleeble Users Group meeting—to be held in Delft, Netherlands, Spring, 2012. Watch for more information about this event.

# Gleeble at Univ. of Wollongong and BlueScope Steel

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smelting technologies for low greenhouse gas emissions. The Physical Metallurgy Group concentrates on thin strip continuous casting technology, thermo-mechanical processing, steel product development and physical metallurgy of welding. The casting part of this program contributed to the development of the recently commercialised thin strip casting process, Castrip®.

Practically, this means there are constantly multiple large joint research projects running, which currently involve five Ph.D. students and a number of undergraduate projects. In general, BlueScope Steel makes a sizeable contribution towards purchasing analytical equipment, while the university operates and maintains it and provides support staff. Project costs are then usually split. A very positive side-effect of this arrangement is that it ensures the university graduates are highly skilled in those fields that are relevant to BlueScope Steel.

The BlueScope Steel company specializes in the production of premium metallic coated and painted steel building products and supplies customers in Australia, New Zealand, Asia, the US, Europe, the Middle East, the Pacific and elsewhere.

BlueScope employs 21,000 people in 17 countries, with over 100 manufacturing facilities worldwide. The steelworks at Port Kembla in New South Wales is the largest steel production facility in Australia and one of the world's lowest-cost producers of steel products. BlueScope Steel is widely recognised for fostering the development of innovative steel solutions through its own research and through strategic alliances with world-leading technical partners.

A wide variety of tests and physical simulations are performed on the Gleeble at the BlueScope Steel Metallurgy Centre. These include plane strain compression tests on high strength steels to simulate thermomechanical processing for alloy and process development, simulation of novel thin strip casting and hot rolling processes to assist in setting up the world's first Castrip® Plant, and hot tensile tests to measure ductility at elevated temperatures to simulate slab casting and thin strip casting.

Other studies encompass investigations of scale build-up under different atmospheres, for example to simulate conditions in hot and cold rolling, plane strain compression tests on very thin (1.6 mm) samples and ultra fast quenching to reveal prior austenite structure for steels with low hardenability, and welding simulations on a wide range of steel grades and conditions. Additional investigations focus on simulation of thin strip casting and hot rolling with complex programs including several rapid cooling and re-heating steps.

Tom Schambron, product development metallurgist at BlueScope, says, "Since world research and innovation are cornerstones of our business, the Gleeble is key to meeting the objectives of BlueScope. It assists in product development and improvement—such as trialling new steel grades, processing parameters, and so forth—and in tracking and solving of quality issues."

BLUESCOPE STEEL

For example, BlueScope has used the Gleeble for measuring critical processing parameters (Tgc, Tnr, Ar3) for new steel grades, which has enabled the company to adjust the composition and to design the processing schedule. In addition, the Gleeble was used to determine the temperature range of low ductility during slab and thin strip casting, vastly reducing the number of casting cracks. The Gleeble has also been instrumental in proof of concept work for patent applications.

Investigations conducted using the Gleeble assisted in the development of a new generation of high strength pipeline steels and provided valuable interaction and exchange between academics from the University of Wollongong and BlueScope Steel researchers. Further, results obtained from Gleeble experiments led to numerous peer-reviewed publications.

A unique experimental technique was developed at the University of Wollongong to simulate the extreme thermal and atmospheric conditions experienced during electric resistance welding (ERW) of steel pipe. The technique utilizes the Gleeble 3500 thermal-mechanical simulator in pocket jaw configuration. Specimens are rapidly heated from 25 to 1300°C in 0.5 seconds, then held at this temperature for various time periods. Tubular-shaped specimens are used and a dry or humid oxidizing gas was passed through the central bore during the heating cycle. After heating, the outside wall of the sample is cooled by water quenching. Oxidation on the inside wall of the specimens is then studied. The oxidation products are similar to that observed in standard ERW pipe. This experimental simulation will prove useful in the assessment of ERW steel weldability prior to the current (expensive) approach of conducting full-scale pipe mill production trials.

The development of this technique has been a collaborative effort between researchers at the University of Wollongong and Bluescope Steel. The concept for the technique was first proposed by Mr. Mark Reid (Research Fellow), and it was developed by Mr. Matthew Franklin (PhD Student) and Mr. Robert DeJong (Gleeble Manager). Valuable contributions were made by Dr. Frank Barbaro from Bluescope Steel, Professor Rian Dippenaar, and Professor John Norrish from the University.

Details of the experimental technique were presented by Mr. Matthew Franklin at the Materials and AustCeram 2009 conference, Gold Coast, Queensland, Australia, 1–3 July, 2009.

For three years, Dr. Ali Dehghan-Manshadi (Research Fellow) has been conducting a number of experiments on the Gleeble and the Hydrawedge. These include studies on: dynamic, static and meta-dynamic recrystallization of different grades of steel, deformation behavior of centerline precipitates in low Mn, low C pipeline steels, transformation-precipitation interaction in steel structures, and hot deformation and recrystallization in titanium alloys. He has also been investigating strain induced phase transformation in titanium alloys using the Gleeble's pocket jaws.

Schambron says, "The Gleeble makes our investigations easier through its ability to test outside the range of the capabilities of our production facilities. It allows us to systematically change individual process parameters, and it gives us quick set-up and turn-around time which translates into the ability to get results instantly and at low cost."