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The Gleeble® NEWSLETTER

Spring 2001

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AeroMat Exposition 2001— Long Beach California Convention Center, June 11–14

Materials engineers have conquered the sound barrier and triumphed over the space barrier. But they still face the ultimate barrier: The bottom line. To help you meet your most pressing materials challenges, the AeroMat Exposition will cover advanced metals, materials and processes for structure and engine applications.

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Gleeble Application Profile

The Gleeble 3500 at the University of Wollongong

In the fall of 1997, a Gleeble 3500 thermomechanical simulator was commissioned at the University of Wollongong, made possible by an Australian Research Council grant supported by the Department of Materials Engineering, University of Wollongong (UOW), BHP Steel Company, CRC for Materials Welding and Joining, and ANSTO. The Gleeble system currently includes the general purpose Mobile Conversion Unit for axial tension and compression work and the Hydrawedge Mobile Conversion Unit for multi-hit compression work.

The Gleeble System has since been kept busy by several postdoctoral research fellows and doctoral candidates working within the UOW and BHP Institute for Steel Processing and Products (BHP-ISPP), and also by the engineers employed at BHP Steel, Port Kembla. The facility is under the overall supervision of Prof. Brendon Parker, Dean of Engineering, UOW with technical support from Dr. Priya Manohar, Research Fellow, BHP-ISPP and Mr. Robert (Bob) DeJong, Senior Technical Officer, Faculty of Engineering, UOW. The Gleeble 3500 facility is being used continually, and research is being conducted in several fields of study.

The Gleeble facility currently supports six doctoral research programs and three postdoctoral research projects. This meets the fundamental objectives of the university to provide high quality postgraduate training and to generate research of academic

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Dr. Priya Manohar, Research Fellow, BHP-ISPP, and Mr. Robert (Bob) DeJong, Senior Technical Officer, Faculty of Engineering, UOW, perform tests on the Gleeble.

The Gleeble at the University of Wollongong

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significance. The Materials Engineering Discipline at UOW has been acknowledged internationally for its contribution to research in thermomechanical processing of steels. The Gleeble facility is an integral part of the process research infrastructure that reinforces UOW's strong position in metallurgical research. Several projects of strategic and tactical interest to sponsoring organizations such as BHP Steel are being conducted using the Gleeble facility.

The availability of the Gleeble has promoted collaborative research between UOW and several other Australian research organizations such as ANSTO, CSIRO, other Australian Universities, Research Centres, and also the local manufacturing industries. UOW was named, for the second time in a row, as the joint winner of the Australian University of the Year Award for 1999–2000. Previously, UOW had been acknowledged as the Australian University of the Year for 1998–1999 for its outstanding research and development partnerships.

The Gleeble at UOW is being used to perform a variety of different tests on metallurgical specimens, including: plane strain compression to simulate industrial thermomechanical processes, hot ductility assessments including melting of specimens, high temperature mechanical properties of strip steels using tensile tests, continuous annealing simulations of cold rolled strips, Heat Affected Zone (HAZ) and weld simulations including melting, Nil Strength Temperature testing of Al-alloys, and Strain Induced Crack Opening (SICO) tests.

Materials being studied include Interstitial Free (IF) steels, several grades of microalloyed (MA) steels, low carbon peritectic grade steels, high purity Al-Si alloy, Mg-Al-Zn alloy (AZ92A), Austenitic Manganese Steel (Hadfield Steel), stainless steels, and metallurgical coke.

One of the investigations at UOW is near-net-shape process simulations for low carbon and peritectic grade steels. The team at UOW is also taking advantage of the Gleeble to perform thermomechanical process (TMP) simulations for IF steels, several microalloyed steels, and aluminum alloys to assess hot ductility of steels and Mg-alloys, and to study high temperature deformation behavior of several ferrous alloys. An example of the thermomechanical cycles employed for the hot ductility assessment of a peritectic grade steel is shown Figure 1. The samples were either directly heated to test temperature between 700–1100°C or remelted and cast *in situ*, subsequently cooled down to within the test temperature range given above. In a third thermomechanical cycle, samples were semi-solid processed during solidification and cooled to the same test temperature range. The results of low strain rate, high temperature tensile tests are presented in Figure 2.

It is clear from Figure 2 that *in situ* melted as well as semi-solid processed samples exhibit lower hot ductility, especially below 900°C, compared to the direct heated samples. These results suggest that the test procedures that generate the as-cast microstructure in tensile samples are far more applicable in analysing industrial problems related to the hot cracking of continuously cast strands compared to the conventional hot ductility tests that involve direct heating of specimens to the test temperature.

Additions to the capability of the Gleeble

The Gleeble System provides a versatile platform that allows the user to modify the system for experiments. Over the past few years we have made the following modifications to the Gleeble since it was installed:

1. One of the important issues concerning the generation of high vacuum subsequent to the water quenching of samples in the Gleeble is how to prevent the water from getting into the vacuum system. The presence of water in the vacuum system drastically reduces the efficiency of vacuum generation and leads to a greater down time of the machine when oil in the roughing pump has to be changed regularly. While the standard vacuum system has a water trap it was desirable to enhance the pumping capabilities further. A liquid nitrogen trap was installed between the work chamber and the vacuum system. The liquid nitrogen trap was manufactured in-house to fit exactly within the existing setup.

2. Modular design of the Gleeble system has permitted us to develop special fixtures to conduct a variety of tests. For example, the use of water-cooled copper grips allowed a better control of cooling rate in HAZ simulations.

3. A new set of tooling was also developed to simulate equal channel angular extrusion of aluminium alloys using the plane strain compression (Hydrawedge) module.

Conclusion

The capabilities of the Gleeble make investigations at UOW easier in a number of ways. First, the flexibility afforded by The Gleeble's modular design allows for the testing of a large variety of samples geometries, and the table and GSL programming facilitates an accurate simulation of industrial processes. High temperature testing is not limited, due to resistive heating of the samples. In addition, cooling rates can be effectively controlled and water quenching of the samples is available, which is indispensable for the high temperature recrystallization studies. Finally, changeover between the modules is reasonably quick which assists in an efficient scheduling of work in a multi-user environment at UOW.

In all, the Gleeble is a powerful and useful tool for the research at UOW.

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.

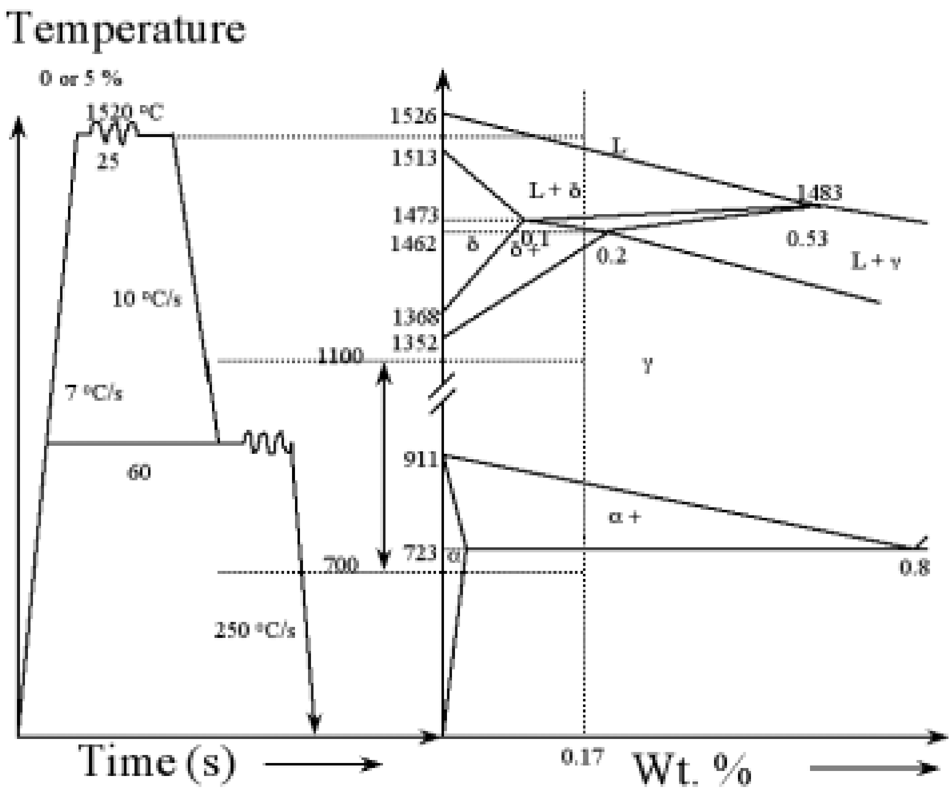

Figure 1. Experimental schedule for thermomechanical cycles and tensile testing.

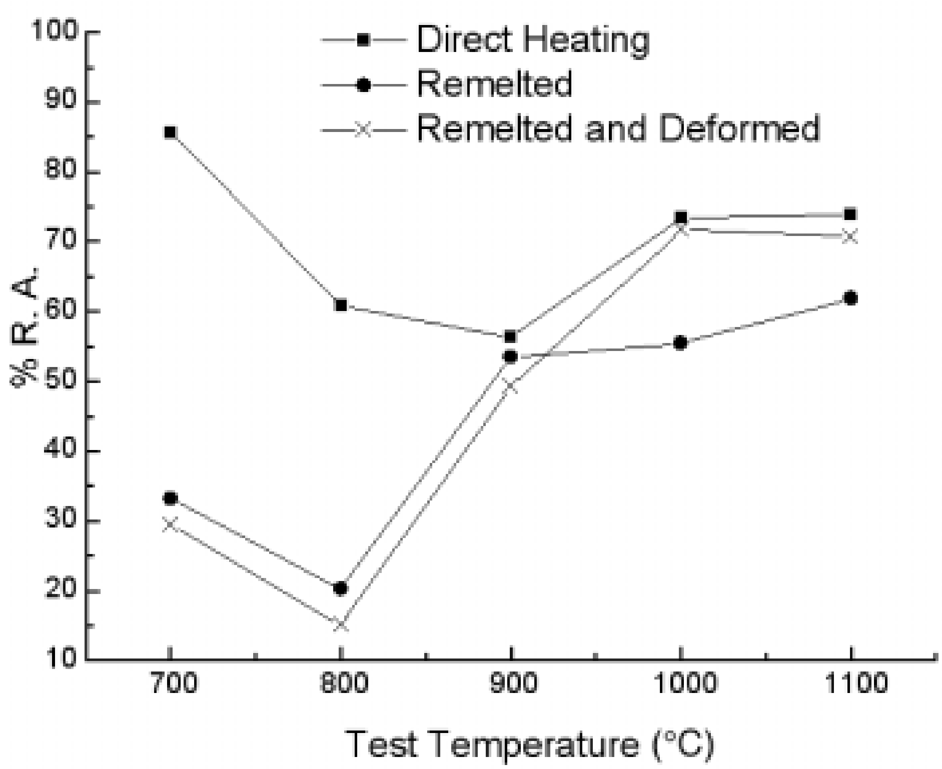

Figure 2. Influence of remelting and solidification processing on hot ductility.

DSI at the Shows

43rd Mechanical Working and Steel Processing Conference—Adams Mark Hotel, Charlotte, NC, October 28–31, 2001

Learn about the latest developments in bar products and forgings, flat products, process technology, roll technology, and more.

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For additional information about the conference, contact:

The Iron & Steel Society
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ASM Materials Solutions Exposition—ASM Heat Treat Show, Indianapolis Convention Center, November 6–8, 2001

This unique event provides opportunities for cross-networking, learning, and problem solving. Technical programs of the accompanying conference are organized by industry, including aerospace, automotive, energy, heavy equipment, machinery, and durable goods. DSI will be there to discuss physical simulation, process optimization, and materials characterization.

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Recent Publications Based on Work Using the Gleeble 3500

M. Syed, P.A. Manohar, and R.J. Dippenaar: "Influence of Composition on the Hot Ductility of Microalloyed Steels." To be presented at Engineering Materials 2001 conference, Melbourne, Sept. 23–26, 2001.

P.A. Manohar, M. Ferry, and A. Hunter. "Direct Strip Casting of Steels: Historical Perspective and Future Direction," *Materials Forum*, Vol. 24, 2000, pp. 15–32.

K. Carpenter, P.A. Manohar, B.P. Parker, and C.R. Killmore: "Hot ductility of Nb and Nb-Ti Microalloyed Steels." Presented at the International Conference on Processing and Manufacturing of Advanced Materials—Thermec 2000, Las Vegas, Dec. 4–8, 2000.

Y. Huang, F.J. Humphreys, and M. Ferry: "The annealing behaviour of deformed cube-oriented aluminium single crystals," *Acta materialia*, Vol. 48, 2000, pp. 2543–2556.

P.A. Manohar, K. Kunishige, M. Ferry, and T. Chandra: "Continuous cooling transformation behaviour of Si-Mn and Al-Mn TRIP steels." Presented at the Workshop on Contemporary Research in Physical Metallurgy, Monash University, Melbourne, Australia, Feb. 8–9, 1999.

D. Yu, M. Ferry and T. Chandra: "Effect of finish deformation temperature on texture development of Ultra Low Carbon steel." Proceedings of the International Conference ICOTOM-12, ed. J.A. Szpunar, National Research Council of Canada, 1999, Vol. 2, p. 1003.

N. Stanford and M. Ferry: "Particle stimulated nucleation following deformation at high strain rate and temperature." Proceedings of the 4th International Conference on Recrystallization and Related Annealing Phenomena—ReX'99, Tsukuba Science City, Japan, 1999, p. 179.

C. Jones, H. Li, A. Croker, and D. Dunne: "Welding simulation of the heat affected zone (HAZ) of 2.25Cr1Mo pressure vessel steel." Presented at the WTIA 48th Annual Conference, Brisbane, Australia, Oct. 29, 1999.

A. Croker, H. Li, and C. Jones: "Life estimation of welded pressure equipment operating at elevated temperature." Proceedings of Operating Pressure Equipment V, Melbourne, April 19–21, 1999, p. 277.

M. Ferry, D. Muljono, and D.P. Dunne: "Influence of heating rate on recrystallization kinetics, grain size and texture in low and ultra low carbon steels." Proceedings of the International Conference ICOTOM-12, ed. J.A. Szpunar, National Research Council of Canada, 1999, Vol. 2, p. 873.

D. Muljono, M. Ferry, and D.P. Dunne: "Continuous annealing—modelling the kinetics of recrystallization." Proceedings of the 4th International Conference on Recrystallization and Related Annealing Phenomena—ReX'99, Tsukuba Science City, Japan, p. 67.

P.A. Manohar and M. Ferry: "The development of a technique for the determination of hot ductility of as-cast steel." Proceedings of the International Conference—Materials '98, July 6–8, 1998, ed. M. Ferry, The Inst. of Materials Engg., Australasia Ltd, Wollongong, Australia, p. 131.

D. Yu, M. Ferry, and T. Chandra: "Effect of finish deformation temperature on microstructural development of a cold rolled and annealed ultra low carbon steel." Proceedings of the International Conference—Materials '98, July 6–8, 1998, Wollongong, Australia, ed. M. Ferry, The Inst. of Materials Engg., Australasia Ltd, p. 179.

D. Muljono, M. Ferry, and D.P. Dunne: "High-rate annealing of cold rolled low carbon steel sheet." Proceedings of the 39th Mechanical Working and Steel Processing Conference, ISS, Indianapolis, USA, 1998, vol. 35, p. 667.

D. Muljono, M. Ferry, and D.P. Dunne: "Modelling the kinetics of recrystallization during continuous annealing." Proceedings of the International Conference—Materials '98, July 6–8, 1998, Wollongong, Australia, ed. M. Ferry, The Inst. of Materials Engg., Australasia Ltd, p. 191.

For more information about these publications or the Gleeble System at the University of Wollongong, please contact Dr. Priya Manohar, email Priya_Manohar@uow.edu.au.