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The Gleeble® NEWSLETTER

Fall 2000

Physical Simulation Used for Solid/Liquid Bimetallic Interface Characteristics

by Yoni Adonyi, Ph.D., Professor, Omer Blodgett Chair of Welding and Materials Joining Engineering, LeTourneau University

The interface morphology and properties of bonds between dissimilar metals is of great interest in a number of engineering applications. Centrifugal casting and electroslag weld overlaying are a few of the bimetallic applications in which only one of the materials is in molten state before bonding. The temperature gradient, cooling rate and intermix between the metals vary greatly at the interface.

A new approach was developed to reproduce these liquid/solid interfaces using the Gleeble 1500 thermal-mechanical simulator. Two concentric cylinders, one solid and one hollow (Figures 1 and 2), are electrically insulated and placed in the jaws of the Gleeble. Only the center solid rod (Metal 1) is resistively heated, while the outer hollow cylinder (Metal 2) is heated radiatively (Figure 3).

Typical Metal 1/Metal 2 combinations can be nodular iron/high chromium-carbon steel or martensitic stainless steel/carbon steel. A flux with oxidation retardants and wettability agents may be placed in the ~3 mm space between the two cylinders. The solidus/liquidus temperatures of the two metals have to

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Gleeble Application Profile

The Gleeble 1500 at LeTourneau University

LeTourneau University is a co-educational, inter-denominational Christian university that offers undergraduate, graduate, and continuing education with courses in engineering, technology, the liberal arts, business, aviation, education and the sciences. U.S. News & World Report and many other national publications have regularly listed LeTourneau University as one of the top small universities in the United States.

For Dr. Yoni Adonyi and his colleagues, part of the ingenuity at LeTourneau involves a Gleeble thermomechanical simulation system. The Gleeble is at the heart of a number of research projects and serves as a key tool in undergraduate education.

The machine is a Gleeble 1500 that has been retrofitted with a Series 3 control system as well as a number of upgrades. "We've changed everything but the frame," Dr. Adonyi says. "If ever there was a 'hot rod' Gleeble, this is it."

"The Gleeble is an important part of our undergraduate education," he says. "We use the Gleeble in several senior level classes to understand solid state transformation phenomena and to study welding design."

He adds, "The Gleeble is also a key part of undergraduate research worth $1.5 million."

Some of the work includes investigations for a centrifugal casting project

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LeTourneau University students Daniel Ryan (sitting) and Jonathan Davis operate the Gleeble 1500 equipped with Series 3 Upgrade controller.

Recent Gleeble Papers

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Microstructure Response to Elevated Temperature Compression of XD® TiB2 Reinforced Ti-48 Al (at.%) Composites

by Ernest S.C. Chin, Kenneth F. Ryan, Jr., and Ronald R. Biederman

Microstructural evolution in elevated temperature compression test samples of a Ti-48Al (at.%) and titanium diboride (TiB2) reinforced Ti-48Al (at.%) composites was investigated. During the high temperature deformation process, breakdown of the initial lamellar microstructure is associated with slip, twinning and recrystallization processes. The stress-strain response from the compression testing correlated well with the deformation mechanisms identified from detailed microstructural analysis. The effect of the reinforcement in homogenization of the microstructure during thermomechanical deformation will be discussed.

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Evaluation of the High Temperature Fracture Limit of Ductile Materials Using Gleeble Systems

by W.C. Chen and H.S. Ferguson

There are several fracture criteria for ductile materials based on the fracture mechanism. The most widely used plastic-work criterion considers the contribution of both the stress and strain to fracture. This fracture criterion was modified in this paper, and the high temperature fracture limit of a plain carbon steel was evaluated at different temperatures and thermal gradients using the Gleeble® Fracture Limit (GFL) testing technique. Not only can the fracture limit be used as a criterion in computer modeling to predict potential cracking during industrial processing, such as continuous casting, hot forming, and welding, but also for hot workability evaluation of ductile materials. It is found that the fracture limit is more conservative than the hot ductility to delineate poor workability regions, because it considers both the tensile stress and tensile strain which govern the fracture behavior of a material during processing. Besides the effect of temperature and strain rate, the fracture limit is also dependent on thermal gradients in the specimen. The larger the thermal gradient along the axis of the specimen, the lower the fracture limit. This result indicates that the thermal gradient present in a workpiece during industrial processing has to be considered in laboratory workability studies. The fracture limit can also be used to predict the maximum tensile true stress and maximum strain before fracture, which could become a guide for production engineers to avoid cracking in industrial processing.

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Fusion Welding of a Modern Borated Stainless Steel

by C.V. Robino and M.J. Cieslak

Experiments designed to assess the fabrication and service weldability of 304B4A borated stainless steel were conducted. Welding procedures and parameters for manual gas tungsten arc (GTA) welding, autogenous electron beam (EB) welding and filler-added EB welding were developed and found to be similar to those for austenitic stainless steels. Following the procedure development, four test welds were produced and evaluated by microstructural analysis and Charpy impact testing. Further samples were used for determination of the postweld heat treatment (PWHT) response of the welds. The fusion zone structure of welds in this alloy consists of primary austenite dendrites with an interdendritic eutectic-like austenite/boride constituent. Welds also show an appreciable partially molten zone that consists of the austenite/boride eutectic surrounding unmelted austenite islands. The microstructure of the EB welds was substantially finer than that of the GTA welds, and boride coarsening was not observed in the solid state heat-effected zone (HAZ) of either weld type. The impact toughness of as-welded samples was found to be relatively poor, averaging less than 10 J (7.38 ft-lb) for both GTA and EB welds. For fusion zone notched GTA and EB samples and centerline notched EB samples, fracture generally occurred along the boundary between the partially molten and solid-state regions of the HAZ. The results of the PWHT study were very encouraging, with typical values of the impact energy for HAZ notched samples approaching 40 J (29.5 ft-lb), or twice the minimum code-acceptable value. The PWHT results in the spheroidization of the boride such that the heat-treated welds have microstructures and failure modes similar to the as-received material. A weld process-PWHT combination that results in acceptable properties was identified and the feasibility of joining these alloys was demonstrated.

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Mechanical Properties of Partially Molten Aluminum Alloys

by J.A. Spittle, S.G.R. Brown, J.D. James, and R.W. Evans

A technique has been developed for measuring the mechanical properties of aluminum alloys at temperatures between the solidus and liquidus. Such measurements were carried out by re-heating specimens cut from cast ingots to the temperature of interest. A Gleeble 1500 was linked to a low-force mechanical testing machine, enabling rapid heating to minimize the effects of solid state diffusion on the cored dendritic structure, together with the ability to minimize the warm-up forces encountered by the specimen as it expands. Tests on as-cast aluminum 2024 revealed strengths in the range 20–0.003 N/mm^2, and these were compared to strengths of homogenized 2024 at the same temperatures where the specimens were heated by a conventional furnace. In both cases the temperatures were related to the fraction liquid present predicted by Thermo-Calc. As number of tests were also performed at temperatures just below the solidus.

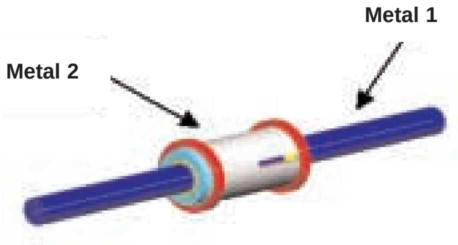

Figure 1. Assembled Gleeble specimen.

Figure 2. Exploded view.

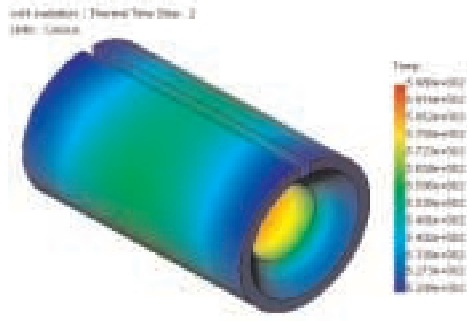

Figure 3. FEA model showing the radiative temperature distribution in Metal 2 (OD cylinder) after 10 minutes heating.

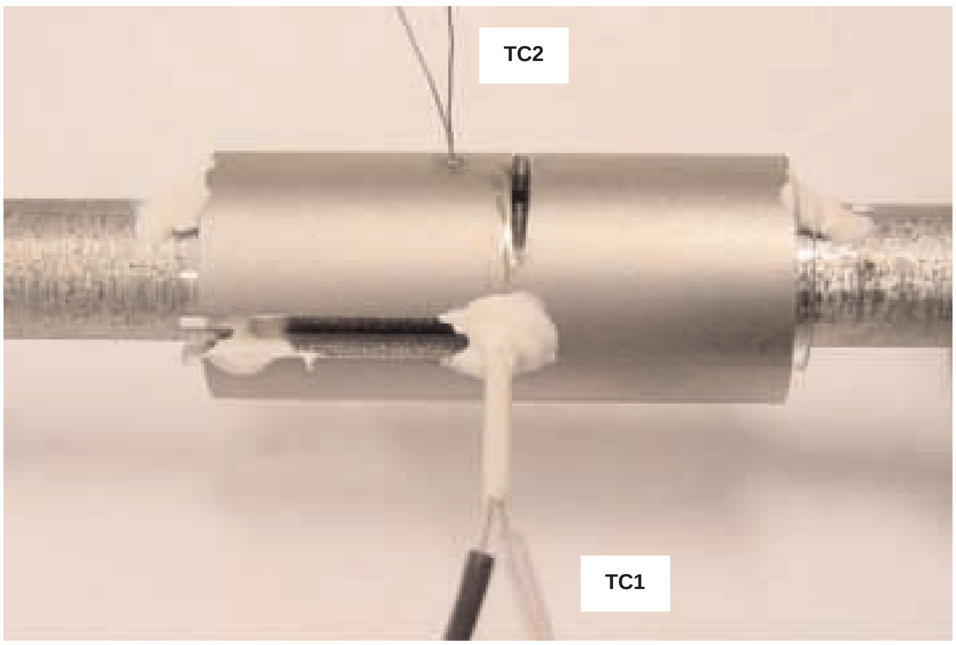

Figure 4. Before simulation.

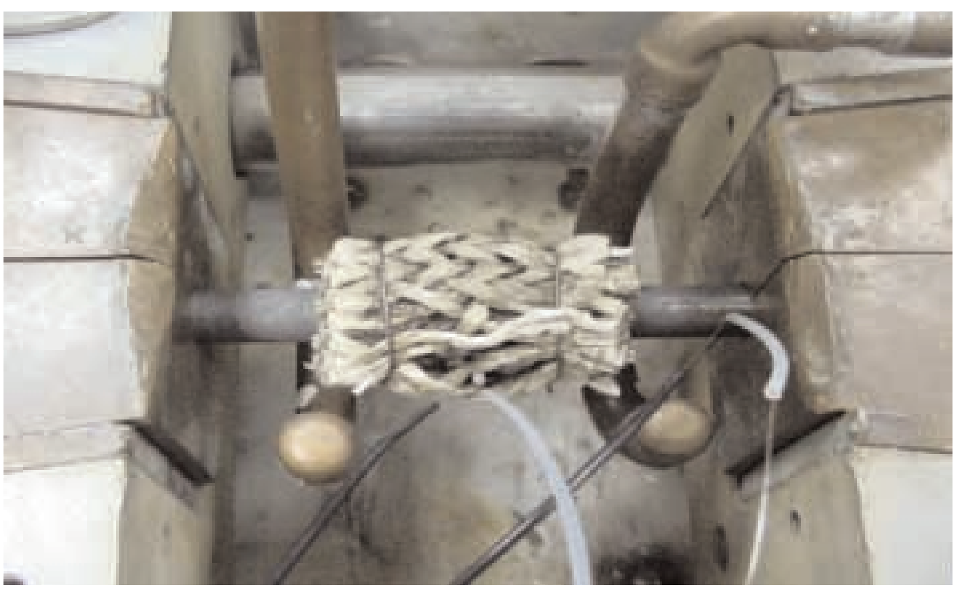

Figure 5. Setup (insulated, argon cooling jets for the ends).

Physical Simulation Used for Solid/Liquid Bimetallic Interface Characteristics

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be known to produce a strong bond. TC1 for the inner cylinder is used for control, while TC2 mounted on the outer cylinder is used for monitoring (Figures 4 and 5). After the core melts, a superheat is produced. Then the Gleeble jaws are pushed against each other and the molten metal fills the cavity (Figure 6).

Figure 7 shows the interface morphology after simulation of a nodular iron core, Metal 1, and a high chromium/carbon tool steel shell, Metal 2 (application for steel producing hot strip mills).

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.

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The Gleeble 1500 at LeTourneau University

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sponsored by the Texas Higher Education Coordinating Board, HAZ simulations on high performance steel for bridges for the Federal Highway Administration, line pipe development for Lone Star Steel, and transformation temperatures on weld deposits for Lincoln Electric, to name just a few.

Dr. Adonyi says, “Seventy percent of inquires regarding potential research involve the Gleeble. It has a tremendous impact on our future plans.”

“What really sets the Gleeble apart,” he says, “are two things: its ability to produce incredibly high strain rates and temperature gradients and its capability to simulate gradients and transients just like real-work processes.”

The school’s motto is “Faith brings us together. Ingenuity sets us apart.” The Gleeble plays a proud part of that tradition.

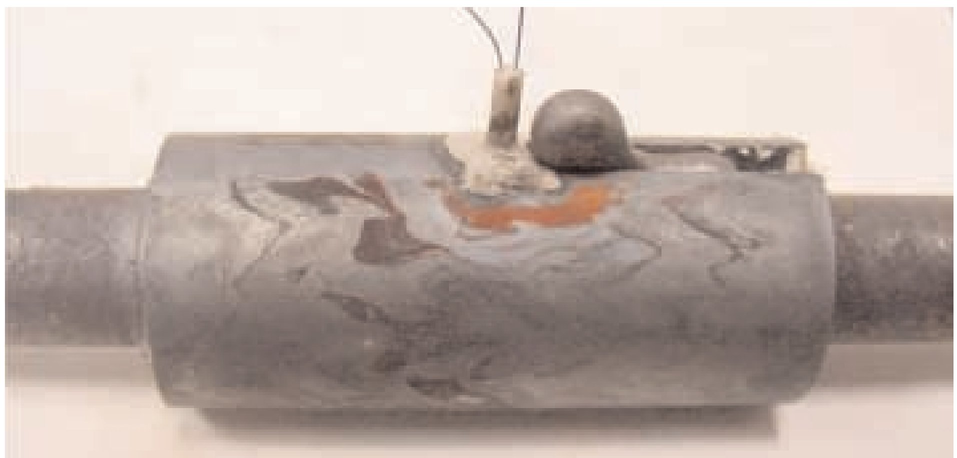

Figure 6. After simulation (shortened by axial displacement). Note excess metal ejected through the TC mounting slot.

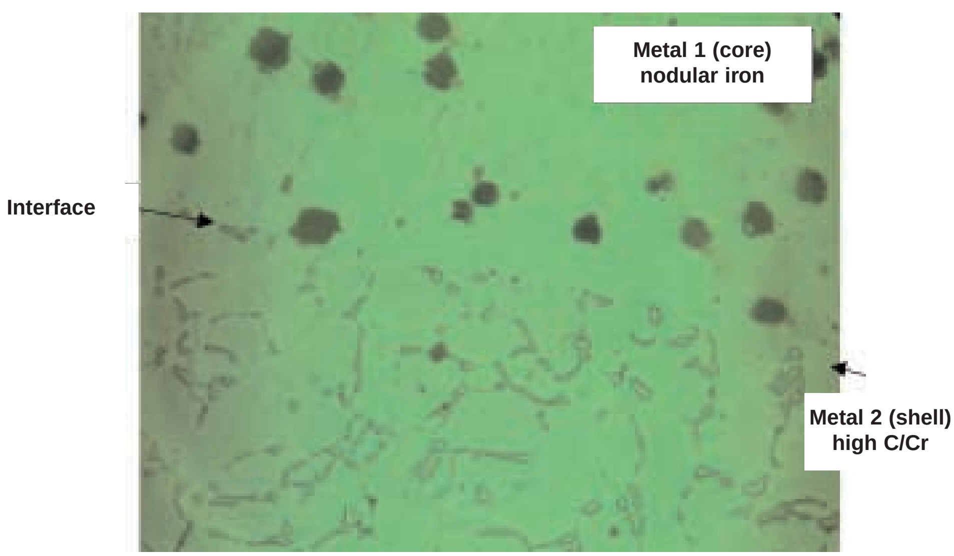

Figure 7. Hot strip mill roll centrifugal cast interface simulation optical micrograph, 200×.