Advanced Metallic Materials

This article consists of a sampling of abstracts from “Advanced Metallic Materials: Technological Exploitation of Mechanical Properties” a symposium to be presented at MS&T 2010 in Houston, October 17-21. The symposium will spotlight recent achievements in materials development for practical applications.

In the last decade, extensive research on nanocrystalline materials, metallic glasses, and their composites created opportunities for technological exploitation of their advanced properties, such as exceptional strength and hardness. Special interest is focused on improvement of fracture toughness and ductility, whose low values were the main limitation for structural applications. This Symposium is intended to accelerate the development and acceptance of new concepts and methodologies for product fabrication, treatment, and mechanical testing. — A. Sergueeva, Symposium Organizer, Nanosteel Co.

Hydrogen Embrittlement in High Strength Steels as the Limiting Factor for Light Weight Body in White Construction
Matthias Loidl
BMW Group

High strength steels (dual phase, complex phase, and TRIP) with a tensile strength of more than 1000 MPa in the body in white are still limited due to hydrogen embrittlement. In this presentation, a methodology to rank the different steels regarding their susceptibility to hydrogen embrittlement with respect to their microstructure is described and results presented. To correlate the results of the different testing techniques (static, quasi-static, and dynamic), the amount of diffusible hydrogen was measured by means of thermal desorption analysis. The tested samples are being investigated via optical microscopy and SEM to characterize the microstructure and to identify the failure modes caused by hydrogen and to differentiate from classical brittle fracture. Additionally, the EBSD technique highlights the influence of different phases and their respective crystallographic orientations on the crack propagation direction.

Oxidation Behavior of Ni-Al-Cr-Zr Alloy Rolls Inside Ferrous Heat Treat Furnaces
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Austenitic stainless steel rolls have traditionally been used inside ferrous austenitizing furnaces. However, with the advent of nickel-aluminide alloys having superior high-temperature oxidation resistance and strength properties, these materials were increasingly introduced as transfer rolls inside austenitizing furnaces. The rolls have resulted in significant energy reduction and have guaranteed almost maintenance-free operations. However, the long-term high temperature oxidation behavior of these alloys has not been demonstrated, especially in the context of thermo-mechanical interaction with ferrous materials during operation. In the present study, attempts have been made to understand long term oxidation behavior of the Ni-Al-Cr-Zr alloy used as transfer rolls inside austenitizing furnaces.

High-strength steels for potential applications in BMW Group cars such as this are being evaluated by researchers at BMW. Image courtesy BMW.
rolls inside austenitizing furnaces and their complex interaction with ferrous materials during heat treating operations. It was found that the protective Al₂O₃ oxide film was significantly altered due to the thermo-mechanical interaction with ferrous stocks, and structural developments raised concern for the very applications for which these rolls were intended.

**Microstructure Control for High Strength 9Cr Ferritic-Martensitic Steels**  
*Lizhen Tan, David T. Holzer, and Jeremy T. Busby*  
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The need of high-Cr (9-12 wt.%) ferritic-martensitic (F-M) steels with enhanced mechanical properties at higher temperatures becomes imperative to support the desired development of advanced nuclear reactors. Alloying composition adjustment and thermomechanical treatment (TMT) were employed to develop high strength 9Cr F-M steels. Two sets of TMTs were applied to four model steels with controlled compositions in addition to the conventional heat treatment condition. The mechanical properties of the steels were assessed by Vickers microhardness and tensile tests. The preliminary results showed positive proportional relationship between Vickers microhardness and yield strength. Two of the steels in the conventional condition showed greater strength than that of the latest commercial steel NF616. The TMTs significantly enhanced the strength of the steels. One of the TMTs enhanced the yield strength of the steels approaching that of an ODS steel. Microstructural analyses together with computational thermodynamics provided a reasonable interpretation on the strength enhancement.

**In-Situ SEM Micro-Tension and Compression Testing of Nanocrystalline and Ultra-Fine-Grained BCC Metals**  
*Brian E. Schuster, Army Research Laboratory*  
*Jonathan Ligda and Qiuming Wei*  
*U. of North Carolina at Charlotte*  
*William N Sharpe, MTM Testing LLC*  
*Z. Horita, Kyushu University*

We have developed a methodology to investigate the mechanical properties of metallic micro-pillars in tension and compression. In-situ scanning electron microscope experiments allow direct correlation of specimen load to strain calculated from digital image correlation. We have applied this methodology to examine the tensile and compressive properties of fully dense nanocrystalline and ultra-fine-grained body-centered-cubic metals by high pressure torsion, including vanadium and molybdenum processed in bulk form. We have applied site-specific focused ion-beam machining to investigate the response of specimens with grain sizes varying from tens to hundreds of nanometers.

**Mechanical Response of Cu-Nb Layered Nanocomposites to Rolling Deformation**  
*Thomas Wynn, Dhiriti Bhattacharyya, Amit Misra, Duncan Hammon, and Nathan Mara*  
*Los Alamos National Laboratory*

Recently, nanolayered composites have garnered much attention due to their ability to withstand deformation by large strains, shock deformation, and damage under irradiation conditions. These behaviors have been attributed to high densities of bimetal interfacial content. Investigations into the behavior of this class of materials under extreme conditions have been largely limited to those synthesized by physical vapor deposition (PVD), with little work in the literature focusing on bulk materials (greater than one cm³). In this work, the structure of PVD Cu-Nb multilayers rolled to various reductions in thickness is compared to that found in an accumulative roll bonded (ARB) Cu-Nb bulk nano-composite. Scanning and transmission electron microscopes investigated layer stability and thickness changes after rolling. Interfacial evolution in terms of layer morphology, chemical intermixing, crystallography, and interface plane normal was determined as a function of rolling strain, and then related to dislocation/interface interactions.

**Mechanical Properties of In-Situ Formed Cu-Zr-Al-Y-Nb Bulk Metallic Glass Composites**  
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Copper-based bulk metallic glasses are promising engineering materials due to their relatively low cost and high strength. However, the lack of ductility has limited their applications. In the last few years, attempts have been made to form bulk metallic glass composites with two-phase microstructure to improve their mechanical properties. In the present work, Cu₄₆Zr₄₂-xAl₇Y₅Nbx alloys with Nb = 0, 2, 4, and 8 were prepared by water-cooled copper mold casting. With increasing Nb content, the bulk metallic glass composites with in situ formed Zr-Nb second phase were obtained. The thermal stability, microstructure and mechanical properties of the obtained Cu-Zr-Al-Y-Nb composites were investigated. The fracture surfaces and shear bands of Cu-Zr-Al-Y-Nb bulk metallic glass composites were studied by scanning electron microscopy (SEM). Based on these studies, the fracture mechanisms for the bulk metallic glass composites will be discussed.