MONDAY, AUGUST 23, 2004, P.M.

SESSION 9: INTERNATIONAL SYMPOSIUM ON ULTRA-FINE STRUCTURED STEELS

Producing Ultrafine Steels I
Sponsor: Iron and Steel Section, The Metallurgical Society of CIM
Room: Webster C
Chairmen: E. ESSADIQI, J. THOMSON, CANMET, Ottawa, Ontario, Canada, and
M. MILITZER, University of British Columbia, Vancouver, British Columbia, Canada

Paper 9.1 — 14:00

Ultrafine-grained Steels: Basic Researches and Attempts for Application.

K. NAGAI, National Institute for Materials Science, Tsukuba, Ibaraki, Japan

The Asian projects are now in their second terms after the five-year first terms. Ultrafined-grained steels were developed in lab-scale and/or in practical process. Basic approach has been performed to explore the evolution mechanisms of ultrafine-grained microstructures. There have been investigated two approaches to make the ultrafine grains: the “recrystallization route” and the transformation route. In the “recrystallization” route, heavy deformation at low temperature is necessary for the ultra-refinement. In the transformation route, making the high density of ferrite initiation sites in the deformed austenite, especially of the heavily compressed austenite structures, is essential for the ultra-refinement, and further hindering the ferrite growth is also inevitable to utilize the high initiation rate. Strength and toughness are dramatically improved by the ultra-refinement. Fatigue property is also excellent. The poor uniform elongation can be enhanced by the design of the second phase dispersion. At the same time the application has been also pursued from various viewpoints of engineering to take advantages of the ultrafine-grained steels. Bridge, ship, construction, automobile and other high strength parts are being attempted for the application.

Paper 9.2 — 14:40

The Development of Ultrafine Grained Steels through Thermomechanical Processing.

P.D. HODGSON, H BELADI and G L KELLY, Deakin University, Geelong, Victoria, Australia

The formation of ultrafine ferrite by strain induced transformation is assessed using rolling and hot torsion experiments. These experiments are used to examine the impact of thermomechanical processing conditions and steel chemistry on strain induced austenite to ferrite transformation and the formation of ultrafine ferrite. The critical strain for dynamic strain induced transformation increased with increasing carbon equivalence, deformation temperature and austenite grain size. The deformation structure in the austenite grains changes with the thermomechanical processing conditions. Drawing on these results and the current literature, the important factors for the production of ultrafine ferrite are described and a mechanism proposed.

Coffee Break — 15:10 – 15:30

Paper 9.3 — 15:30

ECAE of a stack of metal sheets.

O. BOUAZIZ, P. CUGY, IRSID, ARCELOR R&D, Maizières-lès Mets Cedex, France
E.F. RAUCH and O. MAGNEA, Labratoire GPM2, Saint-Martin d'Hères Cedex, France

The experimental difficulty to perform Equal Channel Angular Extrusion (ECAE) of a bulk sample of hard material such as steel was overcome. The original method proposed in this paper consists in replacing the bulk sample by a stack of alternated hard metal (steel) and soft metal (aluminium) sheets. By applying this procedure to an Interstitial Free steel (IF steel), 2.7µm grain sized material was obtained after recrystallisation. Its mechanical properties (hardness, formability in shear, hardenability and faigue limit) were investigated and compared with the properties of the same IF steel with conventional grain sizes (12µm and 25µm).

Paper 9.4 — 16:00

Ultra-fine grained high carbon steel by innovative deformation.

A.W.F. SMITH, D.N. CROWTHER, Corus Research, Development & Technology, Swinden Technology Centre, Rotherham, South Yorkshire, United Kingdom,
P.J. APPS and P.B. PRANGNELL, Manchester Materials Science Centre, University of Manchester, Manchester, United Kingdom

It is well known that the refinement of grain size in metals leads to a significant improvement in important mechanical properties. As part of a European collaborative project, processing schedules have been investigated aimed at producing a homogeneous ultra-fine ferrite and spheroidised carbide aggregate microstructure structure in high carbon (CMn) steels (0.6-1.2wt%C), via conventional ‘warm’ rolling and innovative Equal Channel Angular Extrusion (ECAE). Suitable deformation schedules were determined from dilatometry and thermo-mechanical Gleeble simulations. Evidence of an ultra-fine ferrite and carbide aggregate microstructure following ‘warm’ rolling is given. A significant improvement in tensile strength, particularly proof stress (0.2%) was also noted in comparison to material deformed at higher temperatures.

Concurrent Equal Channel Angular Extrusion (ECAE) experiments investigated microstructural evolution with incremental strain. Extensive analysis was carried out using various techniques, including high resolution Electron Back Scattered Diffraction (EBSD). Evidence of ferrite grain refinement was noted in a eutectoid composition steel. A sub-micron ferrite structure was observed following high strains ($\varepsilon \sim 3.33$) and the mechanical properties exhibit a marked increase in tensile strength.

PAPER 9.5 — 16:30

GRAIN REFINEMENT IN AUSTENITIC AND FERRITIC STAINLESS STEELS.

H.J. MCQUEEN, N.D. RYAN, Concordia University, Montréal, Québec, Canada and
R.G. ZARIPOVA, Insititute for Superplasticity, Ufa, Russia

The austenitic and ferritic stainless steels do not undergo any phase transformation that induces very fine grains in the product through thermomechanical processing as practiced in most other steels. Considerable grain refinement can be achieved by intense multistage deformation descending through warm to cold working; notably multi-axial forging of bulk material can attain high strains with diminished risk of cracking. Hot working to improve ductility yields finer grain sizes as the T is reduced and strain rate $\dot{\varepsilon}$ raised; increased strain has limited effect due to the steady state regime. Ferritic steels develop subgrains with size diminishing as $\dot{\varepsilon}$ rises and T falls with the advantage of retained strain hardening; recrystallization delivers grains several times the cell size. In austenitic steels, dynamic recrystallization (DRX) provides finer grains at higher $\dot{\varepsilon}$ and lower T with a lower limit due to intergranular cracking. The DRX grains contain a strengthening substructure that can easily be retained by quenching; if static recrystallization is allowed to occur the grain size rises markedly. Multistage rolling with diminishing T is able to provide grain refinement to the same degree as straining at the finishing T yet provides better ductility grains on recrystallization. As a result of the strain induced transformation to martensite, small subzero deformations of austenitic or duplex steels produce very high dislocation densities that yield marked grain refinement when they revert upon reheating.