

MONDAY, AUGUST 22, 2005, P.M.

SESSION 9: INTERNATIONAL SYMPOSIUM ON PIPELINES FOR THE 21ST CENTURY IN HONOR OF DOUG BOYD

PROCESSING AND PROPERTIES I — LINE PIPE DESIGN AND MICROALLOYING

Sponsor(s): Iron and Steel Section, The Metallurgical Society of CIM

Room: Imperial Ballroom 1

Chairman: L. COLLINS, IPSCO Inc., Canada

14:00 — OPENING CEREMONY IN HONOR OF PROFESSOR DOUG BOYD

PAPER 9.1 — 14:20 (KEYNOTE)

EFFECT OF QUENCH AND INTERPASS TIME ON SOFTENING BETWEEN REDUCTIONS DURING THE PROCESSING OF PIPELINE STEELS.

J.J. JONAS, McGill University, Canada

The categories of interpass time encountered in hot rolling are characterized. These are shown to fall into three broad categories: short (in rod rolling); intermediate (in strip processing); and long (in plate schedules). The effects of interpass time on recrystallization and carbonitride precipitation are described, and particularly on the interaction between these two mechanisms. The interactions, in turn, determine the final microstructure produced as well as the mechanical properties.

PAPER 9.2 — 14:55

DUAL PHASE STEEL FOR LINE PIPE APPLICATIONS.

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Heat treated seamless tubular products are processed in a fashion that can be easily modified to produce dual phase microstructures, through the implementation of intercritical soaking prior to quenching. Dual phase steels are known to possess low yield strength compared to tensile strength. The steel line pipe market is interested in low yield-tensile ratio materials for application in reel barge pipe laying operations. In the current work compositions of commercially produced material already in use for the line pipe market were examined and dual phase microstructures were successfully developed. The microstructure and properties of the materials were found to be stable over the range of intercritical temperatures employed. Tempering temperature and, somewhat unexpectedly, small chemistry differences were found to have the largest influence on properties. Excellent toughness performance was observed in samples tempered at temperatures in excess of 550°C. Tempering in this temperature regime produced materials with strength suitable for application as API X60 line pipe. A difference in tensile strength between steels of similar chemistry was observed, and is not fully understood at this time. Welding performance was considered through simulation of three regions of the heat-affected zone. Neither intercritical temperature, nor tempering temperature, were found to have a significant influence on the heat-affected zone properties. The peak temperature achieved in the thermal cycle was the only significant factor. The hardness of the heat-affected zone was found to increase continuously with increasing peak temperature. While toughness was found to be low for both partially-transformed and coarse-grain heat-affected zones, the toughness of the fine-grained heat-affected zone was substantially better. Based on the results found in this laboratory study, a limited production trial is expected.

COFFEE BREAK — 15:20 – 15:40

PAPER 9.3 — 15:40

DEVELOPMENT OF HIGH-STRENGTH & HIGH-TOUGHNESS PLATES FOR API X-100 AND X-120 LINEPIPE STEELS FOR THE 21ST CENTURY.

C.I. GARCIA, W. GAO, A.J. DEARDO, University of Pittsburgh, U.S.A. and

G. ZHOU, Wuhan Iron and Steel Company, P.R. China

The development of X-100 and X-120 linepipe steels was investigated using a series of low-carbon Mo-Nb-B steels. The laboratory steels were vacuum melted and processed using advanced thermomechanical processing (TMP) philosophies. Prior to the laboratory hot-rolling experiments, the grain coarsening temperature, the conventional T95 and T5 start-stop recrystallization temperatures and the transformation behavior of were studied using a computer-controlled high temperature deformation MTS-458 and a Theta-IV High Speed dilatometer systems. The results from these experiments provided the guidelines for the design of the laboratory hot-rolling TMP processing experiments. The mechanical properties of the experimental steels showed yield strengths in the range 700-850 MPa and CVN impact properties of over 80 J at -20°C. The best balance of mechanical properties was obtained by using CCR+DQ+Tempering treatments. The major microstructural features responsible for the observed mechanical

properties in order of importance were: a) substructural refinement associated with lower bainite, b) dislocation strengthening, c) fine recrystallized ferrite, and d) small amounts of retained austenite. Fine Nb(C,N) precipitates formed in ferrite were observed, however their contribution to the strength was minimum. Most of the Nb(C,N) precipitation took place in austenite. This precipitation was used to exert microstructural control of austenite during hot rolling. The physical metallurgy and optimum TMP to achieve the mechanical properties are detailed in this paper.

PAPER 9.4 — 16:05

EFFECTS OF NIOBIUM ADDITION AND COOL DEFORMATION ON MICROSTRUCTURE AND MECHANICAL PROPERTIES IN LOW CARBON MICROALLOYED STEELS.

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D. BAI, Research & Development, IPSCO. Inc, Canada

The influence of niobium addition and very low temperature ('cool') deformation on the microstructure and properties of low carbon microalloyed steels was investigated. In this work, the specimens were heated at 1200°C and held at this temperature for 20 minutes. Some specimens were aged at 400°C for times ranging from 10 minutes to 10 hours followed by air-cooling. Others were subjected to deformation at 400°C ('cool deformation') prior to aging. It was observed that the proportion of acicular ferrite was increased as the amount of Nb was increased. It was found that cool deformation increased both yield and tensile strengths significantly compared to that of the aged only specimens.

PAPER 9.5 — 16:30

DEVELOPMENT AND PRODUCTION OF X80 HOT-ROLLED THICK STEEL STRIPS IN WISCO.

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C.-S. XIE, Huazhong University of Science & Technology, China

The microstructure and mechanical properties of X80 hot-rolled thick steel strips with a thickness of 17.5mm produced in Wuhan Iron & Steel Company (WISCO) are introduced in the paper. The steel strips as fabricated through proper thermomechanical processing (TMP)/ on-line accelerated cooling (OLAC) processing have shown high strength and toughness, low brittle transition temperature, good weldability, and high Shear Area (SA) percentage in Drop Weight Tear Test (DWTT). The microstructure of the steel strips is characterized with mainly acicular ferrite, and fine dispersed Martensite-Austenite (M-A) phases. It is determined that the mechanical properties are improved due to the presence of the fine M-A phases and precipitates, which could be formed by reducing the finish rolling and coiling temperatures.

PAPER 9.6 — 16:55

DUAL PHASE BAINITIC LINEPIPE STEELS.

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T. TURI, Stelco Lake Erie, Nanticoke, Ontario and
D. EMADI, E. ESSADIQI, CANMET, Canada

This paper reviews the results of an extensive study of microstructures and mechanical properties in bainitic linepipe steels. The research was carried out as a collaborative project between Queen's, Stelco and CANMET. Basic studies of phase transformations and mechanical properties in these steels established important relationships between processing schedule and microstructure evolution, and between final microstructure and mechanical properties. The best combination of strength and toughness properties is obtained with a microstructure comprising a matrix of intragranularly-nucleated bainite ('acicular ferrite - AF') and small (~ 0.5 µm) dispersed particles of martensite ('M/A'). We describe this as a dual-phase AF+M/A microstructure. An experimental study on 15-mm thick plate determined the window of steel composition and processing parameters which gives the dual phase AF+M/A microstructure. The minimum strength and toughness properties for Grade 621 (X90) linepipe steel can be achieved by either a lean steel composition (0.04C-1.77Mn-0.04Cr-0.32Mo-0.31Ni-0.29Cu-0.08Nb) with extreme processing parameters, or by a higher alloy composition (0.04C-2.07Mn-0.50Cr-0.51Mo-0.04Nb) with a more industrially realistic processing schedule. It is proposed how this approach could be extended to obtain higher strength linepipe grades.