

8306-045

MICROSTRUCTURES AND PROPERTIES OF CONTROLLED ROLLED AND ACCELERATED COOLED MOLYBDENUM- CONTAINING LINE PIPE STEELS

A. P. Coldren

Climax Molybdenum Co. of Michigan,
a division of AMAX of Michigan, Inc.
Ann Arbor, Michigan

T. G. Oakwood

Climax Molybdenum Co. of Michigan,
a division of AMAX of Michigan, Inc.
Ann Arbor, Michigan

G. Tither

Climax Molybdenum Co., Ltd.
London, England

ABSTRACT

Modern plate production techniques involving controlled rolling below the Ar_3 temperature and, more recently, the development of equipment for interrupted accelerated cooling after rolling have made it possible to simultaneously reduce the alloy content of line pipe steels while maintaining their strength-toughness balance. Several investigations have been conducted at the Climax Laboratory for the purpose of using these processing methods to develop cost effective steels with strengths sufficient for X-70 to X-80 arctic grade line pipe.

Arctic grade X-70 line pipe properties were achieved by intercritical rolling and air cooling a 0.08% C-1.5% Mn-0.15% Mo-0.04% Nb steel. X-80 strength was obtained in steels containing 0.08% C-1.65% Mn-0.3% Mo-0.055% Nb and 0.08% V. The microstructures observed in these air cooled steels consisted of mixtures of polygonal and acicular ferrite, martensite-austenite (M-A), and various ferrite-cementite aggregates that could be classified as pearlite or upper bainite. Strength was found to increase as finish rolling temperature decreased, and as total percent reduction below the Ar_3 temperature increased.

With the use of interrupted accelerated cooling, improvements in strength and toughness were observed even though finish rolling temperatures were at or above the Ar_3 temperature. For cooling rates of 5 to 15 C/s (9 to 27 F/s) and stop cooling temperatures of 500 to 600 C (930 to 1110 F), the Mo-Nb steels exhibited X-75 strength levels, while the Mo-

Nb-V steels achieved strengths considerably in excess of those required for X-80 applications. In addition, significant improvements in transverse ductility and notch toughness were observed compared to intercritically rolled and air cooled steels. The microstructures ranged from ferrite + pearlite to mixed ferrite + bainite + acicular ferrite + M-A constituent. No significant effects of finish rolling temperature or stop cooling temperature were observed over the ranges investigated. The processing variable which influenced properties the most was cooling rate.

INTRODUCTION

Modern steel plate processing techniques involving controlled rolling into the ferrite plus austenite field¹⁻³ and, more recently, the development of interrupted accelerated cooling after rolling^{4,5} made it possible to simultaneously reduce the alloy content of line pipe steels while maintaining a superior strength-toughness balance. This paper summarizes the results of several investigations in which these processing methods were employed to develop cost effective steels for Arctic grade line pipe in the X-70 to X-80 grade range.

The approach was to employ two base compositions--one for X-70 and the other for X-80 line pipe--and to vary the molybdenum content and processing conditions for each. The X-70 type steels nominally contained 0.08% C, 1.55% Mn, 0.25% Si, 0.04% Nb and 0% to 0.25% Mo, while the nominal composition of the X-80