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Metallurgical Design of Ultra High-strength Steels for Gas Pipelines

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ABSTRACT

This paper describes the metallurgical science used to develop a new, weldable, high-strength linepipe (X120) for the transport of natural gas. A domain-based microstructure design has been used to ensure ductile fracture behavior at temperatures down to −20°C. Ultra refinement involving careful chemistry design and thermomechanical controlled processing (TMCP) produced fine domains below about 2 μm within prior austenite pancakes below about 6 μm in thickness. To achieve the target properties in the pipe body, seam weld and girth weld heat-affected zones (HAZ), 3 low-carbon microstructure designs have been produced. Low-carbon chemistry and Nb/V micro-alloying combined with boron additions were used to impart sufficient HAZ cold cracking resistance and to limit softening in the seam weld HAZ. Both the lower bainite and the dual-phase microstructures provided superior property combinations.

INTRODUCTION

Natural gas is an increasingly attractive energy source, but major reserves are often remotely located from potential markets. While high operating pressures and/or thin-wall pipes are a means to reduce gas transmission costs, conventional steels typically lack sufficient strength. To address these challenges, a significant advance in steel-making and plate-manufacturing technology is necessary. This paper describes the metallurgical design basis for X120-grade pipeline steel for low-temperature service, including Arctic environments.

Over the past 30 years, the trend toward increased transportation efficiency has largely been achieved by increasing the diameter of pipelines. Currently, large systems that are installed on land consist of 1420-mm–diameter (56-in) pipe operating at pressures in the range between 70 and 100 bar (1015 − 1450 psi). In such cases, the pipelines are typically constructed from X65 or X70 API grades. At the present time, the highest-strength linepipe that has been applied in sufficient quantities to be considered commercial is the X80 grade, which has a yield strength of 560 MPa (80 ksi).

Fig. 1 shows the commercial evolution of high-strength linepipe technology. Historically, the linepipe industry has been introducing higher grades at the rate of about 69 MPa (10 ksi) per decade (Tamehiro and Chino, 1991). Consistent with historical trends, the

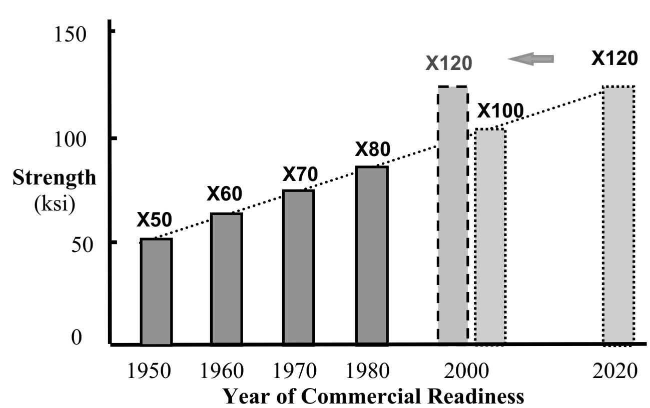

Fig. 1 Evolution of linepipe technology (ksi/0.145 = MPa)

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KEY WORDS: High-strength linepipe, weldable, TMCP, UOE, boron, bainite, dual phase.