

High Strength Spiral Linepipe for Strain-Based Pipeline Designs

Laurie E. Collins, Dengqi Bai, Fathi Hamad and Xiande Chen
Frontier Pipe Research Unit, IPSCO
Regina, Saskatchewan, Canada

ABSTRACT

Over the next decade, it is anticipated that construction of two major pipelines will be undertaken to transport natural gas from the Mackenzie River delta and the Northern Slope of Alaska to southern markets. These pipelines will traverse hundreds of kms of permafrost and discontinuous permafrost. Of critical concern will be the stresses and strains which may be expected to be imposed on the pipelines by frost heave and sagging. To assure the safety of these pipelines, builders will adopt a strain-based design. In anticipation of these projects, a significant amount of research and development work has been undertaken to produce steel and pipe that meet the stringent specifications of strain-based designs. This paper will examine the development of high strength steels for Arctic application and will particularly focus on Grade 550 (X80) linepipe fabricated by a spiral double submerged arc welding process. In addition to the strength and toughness requirements of the base metal, particular attention has been given to ensuring suitable strength and toughness can be achieved in weld heat-affected zones.

KEY WORDS: Linepipe; Welding; Mechanical Properties; Strain-based Design; X80.

INTRODUCTION

Over the next decade, it is anticipated that construction of two major pipelines will be undertaken to transport natural gas from the Mackenzie River delta and the Northern Slope of Alaska to southern markets. These pipelines will traverse hundreds of kilometers of permanent and discontinuous permafrost. Of critical concern will be the stresses and strains which may be expected to be imposed on the pipelines by frost heave and sagging.

Stress-based designs, utilized for onshore pipelines throughout North America, focus on the radial stresses arising from the containment of the pressurized gas. The maximum pressures are such that the steel will be operating well within the elastic range (80% of the specified minimum yield stress (SMYS) or less). While addressing these same circumferential loads, strain-based designs must also account for the longitudinal stresses that may arise from movement of the pipe. It is

anticipated that designs for Northern applications will require a tolerance for plastic strain of 2% in the longitudinal direction.

Linepipe steels exhibit high strength, ductility and toughness and in general can be expected to tolerate strains on the order of several percent in the longitudinal direction. However one important factor is the yield behaviour. Continuous work hardening is required to prevent strain localization. The girth weld and associated heat affected zone are also areas of concern as these areas can be expected to exhibit less ductility and toughness than the body of the pipe. Furthermore, in order to preserve the permafrost surrounding the pipe, it is anticipated that operating temperatures for the pipeline will be less than 0 C and design temperatures of -20 C must be considered.

Over the past two years, a significant program has been undertaken to optimize the properties of Grade 550 (X80) spiral-welded pipe intended for strain-based applications. This study has included:

- a) Characterization of longitudinal tensile properties;
- b) Determination of heat affected zone properties by means of Charpy impact testing and CTOD testing;
- c) Assessment of the tolerance of the pipe to defects by curved wide plate tests; and
- d) Assessment of the effects of field welding procedures on girth weld HAZ performance.

As will be shown in this paper, Grade 550 (X80) spiral linepipe can be produced which will meet the stringent requirements of Arctic strain-based designs.

Development Approach

In view of the low temperature fracture toughness requirements of both the pipe and weld HAZ, the development process has focused on achievement of fine acicular microstructures. The Grade 550 alloy for strain-based designs incorporates a low carbon (~0.06 wt%), Ti-Nb microalloying strategy. Titanium and Nb are utilized to achieve a fine, pancaked austenite microstructure upon completion of rolling which in turn transforms to an acicular ferrite microstructure upon accelerated cooling. Manganese and molybdenum are added to the alloy to promote the formation of the acicular microstructure upon transformation from austenite (Fig. 1). A scrap-based EAF melting