

## Anisotropic Behavior of X100 Pipeline Steel\*

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### ABSTRACT

While steel is generally treated as being isotropic, tension and compression tests in the different pipe orientations for API X100 grade pipeline steel show that this is not the case. To better understand the anisotropy, tests in the longitudinal, transverse, short transverse and at 45 degrees in the L-T plane were performed. Three extensometers were oriented orthogonally to each other on the specimen, allowing for the calculation of the strain ratio,  $R$ . The results of these tests along with an analysis of the ratios are discussed.

**KEY WORDS** Anisotropy, Anisotropic Ratio, Pipeline, UOE, X100

### INTRODUCTION

Fully understanding the material behavior of pipelines produces safer, more cost-effective pipelines. The use of complex material models can increase the accuracy of models of pipe behavior under buckling, wrinkling, reeling and other applied loads (Adeeb Zhou, and Horsley 2006, Wiskel et al. 2001, 2004, Martinez and Brown 2006, Liu and Wang 2006a,b). These analyses have emphasized modeling the kinematic shift in the yield surface in the transverse direction due to the expansion (E) stage of the UOE pipe forming process, where the pipe is first bent to a "U", then to an "O," welded together, and then (E)xpanded. During cold working of the steel during the UOE process, the grain orientations and dislocations are further modified (Dieter 1986). Also, complex thermo-mechanically controlled (TMCP) forming processes introduce textures or preferred orientations within the steel. Both of these are known to affect the anisotropic behavior of the steel.

One method to quantify the anisotropic behavior is to use the Lankford strain ratio, or  $R$ -value (Dieter 1986). It is beneficial to understand this strain behavior, particularly under large deformations, as a supplement to anisotropic yield stress determination. In this study of the anisotropy of API X100 pipeline steel, three extensometers were used to measure the orthogonal strains in both tension and compression specimens with different orientations relative to the pipe. From the extensometers it was possible to calculate the anisotropy ratios.

### TEST PROCEDURE

The X100 linepipe used in this study had a 914 mm diameter and a 14.3 mm wall thickness; the chemical composition is given in Table 1.

Table 1. X100 Chemical Composition

C	Si	Mn	P	S	Nb	V	Ti	Al
0.058	0.223	1.960	0.007	0.002	0.045	0.000	0.014	0.003
Ni	Cu	Cr	Mo	B	N	O	Ceq	Pcm
0.300	0.210	0.020	0.180	0.000	0.003	0.002	0.460	0.190

Tensile tests were performed in three different directions relative to the pipe orientation, as shown in Figure 1. Unfortunately due to the small wall thickness of the pipe, it is not possible to extract the tensile properties through the thickness using standard specimens. To supplement the tensile tests, compression tests were also performed using specimens in the same three directions as the tensile tests and also in the short-transverse direction (ST). The tensile specimens had a 6.35 mm diameter and 31.8 mm uniform gage length with 12.7 mm diameter threaded ends. Testing was performed with a 100 kN servo-hydraulic test frame and a constant strain rate of  $1.0 \times 10^{-4} \text{ s}^{-1}$ . The diameter of the compression specimens was 6.35 mm and length of 10 mm, except specimens CT-1 which had a length of 12.7 mm. They were tested on a 50 kN servo-hydraulic test machine with loading rams fabricated from maraging steel. Teflon tape lubricated the compression specimen ends to minimize barreling due to friction.

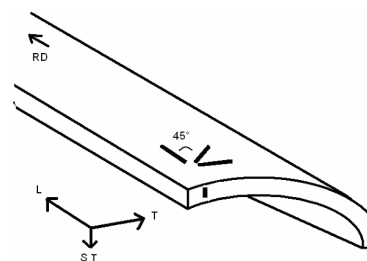


Figure 1. Schematic of test specimen orientation

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