

## DEVELOPMENT OF HIGH STRENGTH SMAW CONSUMABLES FOR SBD APPLICATIONS

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### ABSTRACT

Strain based design of pipelines for seismic environments using high strength materials is a relatively recent approach in the world of line-pipe installation. The development of suitable welding consumables for these applications has also been lagging. This paper outlines the efforts of a consumable manufacturer to fill that gap and design SMAW consumables for strain based applications. The main challenge in this exercise lies in achieving a high enough strength level while at the same time maintaining adequate toughness levels. A microstructure-optimization approach was followed in the design process to achieve the optimum combination of properties. Since the balance of strength and toughness is pivotal to the application, the welding procedure becomes a critical component of the design process. This paper highlights the importance of maintaining a tight control on the welding process in order to achieve consistently acceptable mechanical properties. Due to the high strength levels involved, a low hydrogen system was used as the design basis. Testing was done with both an uphill and downhill welding electrode slag system. Since the choice between these two types of low hydrogen SMAW electrodes is largely a matter of contractor preference and/or a function of the availability of skilled welders, it was considered important to have a choice of both types of strain-based electrodes.

**KEY WORDS:** Welding Consumable; Stick Electrode; Low Hydrogen; Vertical Down; Downhill; Strain Based; Pipeline Welding

### NOMENCLATURE

ASWM	As-Solidified Weld Metal
CTOD	Crack Tip Opening Displacement
CVN	Charpy V-Notch
CWPT	Curved Wide Plate Test
DOE	Design Of Experiments
FL	Fusion Line
LHD	Low Hydrogen Downhill
PGMAW	Pulse Gas Metal Arc Welding
RHWM	Re-Heated Weld Metal
SMAW	Shielded Metal Arc Welding

SPJ	Simulated Pipe Joint
UTS	Ultimate Tensile Stress
WCL	Weld Center Line
YS	Yield Stress

### INTRODUCTION

Strain based design of pipelines is a fairly new approach in the industry. This area has been reviewed in the past (Mohr, Gordon and Smith, 2004) with the conclusion that no one existing industry specification completely addresses strain based design concerns. DNV 2000 was found to be the most comprehensive strain based pipeline design code. On the welding side, it was considered necessary to have supplemental requirements alongside the basic code minimums. Neither the API 1104 nor the BS 4515 (the two more widely used codes) were considered comprehensive enough to serve as the sole basis for choosing welding consumables for pipeline welding. It was also emphasized that in order to truly predict in-field behavior of welds, it was important to test the welds in real world conditions with, for example, applied internal pressure if needed.

Weld-testing was performed at ExxonMobil (Lillig, Hoyt, Hukle, Dwyer, Horn and Manton, 2006) to look at qualification testing of consumables for strain based line-pipe. A CWPT was used for the testing with an increased emphasis on heat input to better control the weld metal strength. A set of E9016-G/E11016-G consumables were used for the SMAW welding. A consistently high yield strength overmatch (~15%) was recommended for consumable selection.

This concept was investigated in more detail for PGMAW through several CWPT and full scale qualification welds (Hukle, Lillig, Newbury, Dwyer and Horn, 2007). Welds were made at the ideal 15% overmatch as well as a lower and higher overmatch to simulate a ‘degraded’ weld in worst case conditions. For defect-free welds, the results exceeded the minimum requirements. The weld metal remained elastic and most the strain was taken up by the base metal. However, when a defect was introduced in the weld remote yielding was expected only if the weld toughness stayed above 40 J with an average CTOD of 0.10 mm. This work demonstrated the importance of defect size in