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Weld metal cracking in cellulosic welds of X80 steel

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WELD METAL CRACKING IN CELLULOSIC WELDS OF X80 STEEL

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CONTENTS

ABSTRACT

The development of steel chemistries which result in highly weldable niobium - molybdenum micro-alloyed thin walled, high strength X80 grade is resulting in increasing consideration for use by Australian industry, particularly in offshore and pipeline applications. Despite the significant material cost saving through reduced thickness and increased strength, a limiting factor controlling widespread use of X80 is the susceptibility to weld metal cracking. The excellent weldability of this grade of line pipe steel has enhanced the potential for the use of high strength cellulosic consumables like E 9010 and E 8010 in root pass welding, but the risk of hydrogen assisted cold cracking (HACC) is also increased because of the high strength weld metal. To quantify the cracking susceptibility and to alloy guidance for field welding condition, the Welding Institute of Canada (WIC) restraint test was used in the present investigation. This thesis outlines the use of two grades (E 9010 and E 6010) and five different brands of commercial cellulosic consumable to assess conditions leading to hydrogen assisted cold cracking and solidification cracking in the diluted weld metal. The investigation also involved clarification of the relationship between microstructure, preheat temperature and hardness values for the various weld consumables and their effect on cracking susceptibility.

Tests were carried out using a standard restraint length of 25mm on 8.6mm strip preheated to various temperatures to determine the critical crack free temperature. For E9010 electrodes, a preheat of 40°C or more was found to be effective and For E6010

electrodes, a preheat of 30°C or more was effective in avoiding cold cracks in the weld metal. Most of the cracks found on welds preheated at room temperature were initiated by a defective weld feature such as undercut or lack of penetration. An attempt was made to correlate the hardness values and carbon equivalents (IIW) of weld metal to cracking. However, it was found that there was no significant effect of these variables on cracking over the range of welding conditions investigated.

The cracking morphology studies indicated that there are many ways in which the crack can propagate in the weld and HAZ. The modes of cracking observed were microvoid coalescence, quasi cleavage and intergranular. In some cases solidification cracking was detected.

The testing program indicated that despite the high hydrogen content of the weld metal for E 9010 electrodes, crack-free root pass welds can be obtained for 8.6mm X80 steel strip provided a preheat of 40°C or higher is used to ensure a low cooling rate.

INTRODUCTION

The Australian gas pipeline industry started significant projects in the 1960's and there has been a significant upsurge in construction since then. The development of pipeline steel is a continuous improvement process driven by complex interaction of many factors. Over the recent years, some 90,000 tonnes of X70 grade has been successfully applied to several Australian projects. The importance of achieving high strength in pipes without compromising field weldability has been a major focus in the evolutionary development of X70 grade, which has effectively laid the foundation for X80 grade pipeline. X80 pipeline steel provides good potential for reliable low cost construction of oil and gas pipelines, decreased transport to site cost, reduced welding cost due to smaller and thinner wall thickness. The improved alloy design for X 80 grade using the carbon, manganese, niobium, molybdenum and titanium (C - Mn - Nb -Mo - Ti) system is based on a low carbon content, a restricted IIW carbon equivalent (CE_{IIW})*, niobium addition for grain size control and precipitation hardening and titanium to restrict grain growth during rolling and the weld thermal cycle. Molybdenum (Mo) is used to increase the hardenability and increase the strength through the formation of fine low carbon bainite. The use of cellulosic electrodes in pipeline welding offers high arc stability and good root penetration at high travel speed. However, the electrodes must also produce strength matching weld metal which is crack free.

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* $CE_{IIW} = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$

The Welding Institute of Canada (WIC) restraint test was adopted to carry out the laboratory welding, because it was considered that field welding stress conditions can be closely simulated using this test. Two grades of commercial (E 9010 and E 6010) consumables were investigated with standard restraint lengths of 25mm and different preheat temperatures. The critical preheat temperature to avoid hydrogen assisted cold cracking (HACC) in the weld metal was determined.

Microscopic studies of the samples were carried out using optical microscopy. Hardness tests were conducted on HACC and solidification cracked samples. An attempt was made to relate microstructure and fracture topography. Finally scanning electron microscope studies were carried out to study the nature of HACC and solidification cracked fracture surfaces.