B. Limitations of Cellulosic-Coated Electrodes for Heavy-Wall Pipe and Fittings

By Matthew Q. Johnson, Los Alamos National Laboratory, Susan R. Fiore and William A. Bruce, Edison Welding Institute

Introduction

Cellulosic-coated electrodes (primarily AWS EXX10-type) are traditionally used for "stovepipe" welding of pipelines because they are well suited for depositing one-sided welds and are capable of high deposition rates when welding downhill. Over the past 20 years, the need to increase pipeline efficiency through higher operating pressures and reduced pipelaying costs has resulted in the use of higher strength line pipe steels (i.e., X70, X80). Construction of thick wall X70 pipelines has been achieved using cellulosic-coated welding electrodes designed to produce overmatching weld metal. Also, some fabricators continue to produce pipe-to-fitting welds using cellulosic-coated electrodes. Despite advances in mechanized welding technology, development of low-hydrogen self-shielded flux-cored arc welding consumables, and substantial improvement of basic-coated low-hydrogen vertical-down shielded-metal arc welding electrodes, manual pipeline welding using cellulosic-coated electrodes is still widely utilized throughout the world.

Several incidents involving significant hydrogen-assisted cracking in the weld metal of pipeline girth welds made using cellulosic-coated electrodes have been reported recently. Two of these cases required removal of many welds, in spite of established procedures having been used. This paper reviews the results of a recently-completed PRCI Pipeline Materials Committee project where the objectives were to identify the primary mechanisms contributing to transverse cracking of field welds and to provide recommendations regarding safe preheat/interpass temperatures that should be utilized when welding heavy-wall pipe and fittings using cellulosic-coated electrodes.

Two cases of severe weld metal hydrogen assisted cracking were characterized. In each case, the composition of the weld metal was substantially richer than would typically be expected for E8010-G electrodes. Investigation into factors influencing the composition of weld metal from cellulosic-coated electrodes revealed that arc length has a pronounced effect on carbon, manganese, and silicon recovery. However the increase in composition observed with variation in arc length could not explain the extremely rich compositions observed in the cracked girth welds. Subsequent investigation demonstrated that it was possible to effectively double the weld metal manganese concentration and triple the weld metal silicon concentration when using cellulosic-coated electrodes that have a low coating moisture content.

Procedure

In order to evaluate the effect of electrode moisture content on weld metal composition, multipass welds were produced using as-received electrodes (freshly opened package) and electrodes stored in a baking oven at 186°F (86°C) for a period of 1 week prior to welding. Two electrodes [3/16-in. (4.8-mm) diameter E8010-G and E9010-G] from the same manufacturer were used in this study to deposit multipass welds in X70 pipe. The equipment and welding procedures were consistent with accepted field practice. In addition to producing welds for chemical analysis, weld transfer mode and droplet size was characterized using high-speed data acquisition and high-speed video.

Relative to welds produced with as-received electrodes, manganese and silicon concentrations were significantly higher in welds produced using dried electrodes. A slight increase in carbon concentration was also measured. Carbon equivalent in the welds produced using dried electrodes increased appreciably relative to the welds produced using as-received electrodes. It should be noted that an effort was made to utilize equivalent arc lengths when using the as-received electrodes and the dried electrodes; use of short arc lengths (to overcome dry coating effects on arc transfer) may cause an additional increase in carbon and carbon equivalent.

A variety of multipass weld metal cracking tests were reviewed and a test method that can be performed as part of a procedure qualification/material qualification test to determine appropriate preheat/interpass temperatures was demonstrated in this study. The preheat levels determined in this study agree well with data previously published by others for E8010-G and E9010-G electrodes in the as-received condition. This testing also demonstrated that even when using “safe” welding procedures with cellulosic-coated electrodes which have been dried, it was possible to induce extensive weld metal cracking due primarily to the enriched weld metal composition.