

E. Weld Metal Chemistry of Underwater Wet Welds with Cellulosic Electrodes
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Introduction

Cellulosic electrodes are recommended for welding in all positions and have as a characteristic aspect that other electrodes do not have which is its good penetration. This electrode grade is typically used for welding pipelines. However, there is no information on the performance of this electrode grade in wet welding conditions. For these reasons wet welding was carried out with this electrode on A36 steel plates.

Technical Approach

Bead-plate wet welds were deposited with this electrode grade using direct current electrode positive. The arc readily starts and presents good stability. The BOP wet welds were deposited in a pressure vessel to simulate different water depths (1, 45, 92, 138, and 164 ft). The BOP wet welds were cross-sectioned for bead morphology measurement, micro-hardness, metallographic, and chemical analysis.

Results and Discussion

From the chemical analysis it was determined that manganese, silicon, and carbon content decreased with increasing water depth. Oxygen content increased with increasing water depth. Manganese dropped from 0.71 to 0.2 wt. pct. with increasing water depth from 1 to 92 ft, and remained at 0.2 wt. pct. from 92 down to 164 ft. These results are similar to those reported by Ibarra, et al. (1988), where manganese content drops fast from 0.55 wt. pct. at surface to 0.25 wt. pct. at 100 ft and water depths deeper than 300 ft manganese remains constant at approximately 0.15 wt. pct. The manganese content in the weld metal depends on the electrode and base metal chemical composition (in this case, the base metal had 1.15 wt. pct. manganese). This element reacts with oxygen (that increases with depth) to form manganese oxides that could be transported into the slag or as inclusions in the weld metal. The silicon content in the weld metal showed a decreasing trend with increasing water depth; mostly similar to the trend reported by Ibarra, et al. (1988).

Carbon content decreased from 0.18 to 0.1 wt. pct. with increasing water depth from 1 to 164 ft. This behavior is entirely different from the one reported by Ibarra, et al. (1988) in which the carbon content increases with increasing water depth. The difference in behavior could be attributed to the chemical composition of the flux coating. Carbon from the weld could react with oxygen to form carbon monoxide or carbon dioxide that could escape from the weld metal.

Oxygen content varied linearly from 0.05 to 0.2 wt. pct. in the water depth range from 0 to 92 ft. In the literature, a rapid increase in oxygen is reported, going from 0.09 to 0.19 wt. pct., for water depth varying from zero to 60 ft. The increase is then followed by a decrease to 0.15 wt. pct. at 250 ft. Oxygen remained constant beyond this water depth. The maximum oxygen content with E6010 electrodes is 0.25 wt. pct. at 130 ft, higher than the value - 0.19 wt. pct. - reported by Ibarra, et al. (1988), but comparable to those reported by Pope, et al. (1994). From the recorded arc signals, the average voltage was larger than the one obtained with rutile electrodes. As the arc length increases, the volume of water vapor that decomposes into hydrogen and oxygen could also increase modifying the chemical reactions in the weld pool.

Conclusions

Even though this electrode type is not intended for wet welding applications, it exhibited good performance underwater. The carbon loss behavior was unique and different from that observed for other types of electrodes. Alloying recovery in the weld pool was determined for all major elements, which allowed for compositional design with adequate replenishment of the elements lost in the welding process.