A. SMAW, FCAW, MCAW and SAW low alloy ferritic deposits: the challenge is tensile strength

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Introduction

In general when the objective is to design a low alloy ferritic steel weld metal the first concern from the beginning is to take into account the factors that influence toughness, especially at low temperatures. At the same time, the possibility to find difficulties to achieve tensile properties is seldom considered.

The objective of this work is to analyze the results obtained from mechanical property measurements and microstructural studies in SMAW, FCAW, MCAW and SAW C-Mn-Ni-Mo and C-Mn-Ni-Mo-Cr high strength ferritic deposits from all-weld metal coupons welded according to the relevant AWS standards.

The different tensile property requirements of the standards that classify these consumables, used with different welding processes that produce weld metal of similar chemical composition and for similar applications, are also discussed.

Procedure

ANSI/AWS A5.5-96 E10018M, E11018M and E12018M types SMAW electrode, 4 mm diameter (3 samples), ANSI/AWS A5.29-98 E91T5K2/E101T5-K3 and E111T5-K3 types MCAW wires, 1.2 mm diameter (2 samples), ANSI/AWS A5.29-98 E110T5-K4 and E120T5-K4 types FCAW wires, 1.6 mm diameter (2 samples) and ANSI/AWS A5.23-97 F9/F10/F11/F12A6-ECM2-M2 types SAW flux / wire combinations (7 samples) were used. Results generated in this work and data from previous papers were used for the discussion.

All-weld metal test coupons for mechanical testing were welded with the mentioned consumables in the flat position according to the corresponding AWS standards, varying heat input, number of passes per layer, type of shielding gas and/or interpass temperature within the standard requirements.

All weld metal chemical composition, Vickers hardness (1 kg), tensile and Charpy-V impact properties at -51 ºC were determined. Microstructural studies were carried out using light microscopy.

Results and Discussion

SMAW: The all weld metal samples were welded with three different heat inputs: low, medium and high, within the standard tolerances. Weld metal strength for electrodes of the E10018M type was insensitive to heat input variations, being all three samples in agreement with AWS requirements. On the other hand, weld metal from electrodes E11018M and E12018M were sensitive to changes in heat input in such a way that only samples welded with intermediate heat input satisfied the relevant standard requirements. The high heat input samples did not achieve the required minimum and the low heat input samples exceeded the yield strength requirements. Thus the higher strength weld deposits exhibited a marked sensitivity to heat input.
The Charpy-V impact values comfortably satisfied the requirements for all welding conditions. A good correlation was found between weld metal chemical composition, hardness and tensile strength of the deposits.

FCAW and MCAW: Samples were welded varying the shielding gas type (CO_2 and 80%Ar-20%CO_2) and the heat input through the number of passes per layer (2 or three), always within the corresponding AWS specification for the MCAW and FCAW consumables. In all cases it was found difficult to achieve the minimum requirements for yield and tensile strength, becoming sometimes necessary to exceed the specified alloying limits. In some instances the total alloy content had to be dangerously close to the maximum limits of all the alloying elements. Again, toughness was high for all welding conditions and amply satisfied the corresponding standard requirements. The expected correlation between chemical composition, hardness and tensile properties was found.

SAW: Samples with were prepared with increasing alloy content (C, Mn and Cr) and using two different interpass temperatures. It was again found necessary to bring the alloying elements content to levels dangerously close to the specified maximums in order to achieve the minimum tensile property requirements, while toughness requirements were comfortably satisfied.

All the weld deposits were analyzed with light microscopy and microstructures obtained with the different processes but producing weld metal of similar chemical composition were compared giving particular consideration to the weld metal oxygen content. The standard requirements of the consumables employed with the different processes that produce weld metal of the same composition and consequently employed in similar applications, were analyzed. Important differences were noted in the requirements for different processes, being the most stringent those corresponding to manual electrodes.

Conclusions

The results obtained in this study show that for all the consumables analyzed depositing C-Mn-Ni-Mo or C-Mn-Ni-Mo-Cr high strength ferritic weld metal using different welding processes and welding variables within the AWS limitations, the main difficulty resides in obtaining adequate tensile strength values rather than in satisfying toughness requirements that can be obtained almost in any welding condition, within the requirements of the appropriate standard.

Then, when designing low alloy high strength ferritic all weld metal and striving for an adequate balance between tensile property and toughness: what is the challenge? The challenge is tensile property.