

**C. Influence of procedure variables on C-Mn-Ni-Mo metal cored wire ferritic all-weld metal: Welding position, number of layers, arc energy and shielding gas type were considered**

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**Introduction**

The knowledge of the relationship between welding parameters and mechanical properties of the weld deposits made with a given electrode allows to optimize the welding procedure specification for the consumable. The objective of this work was to study the influence of welding procedure parameters on mechanical properties (tensile strength, hardness and Charpy-V notch toughness) and microstructure of an ANSI/AWS A5.29-98 E91T5-K2/E101T5-K3 metal cored wire all weld metal.

**Procedure**

Weldments: eight all weld metal test specimens were prepared with the indicated consumable using the flat position test coupon design according to ANSI/AWS A5.29-98. The electrode diameter was 1.2 mm and two different shielding gases (CO<sub>2</sub> and a mixture of 80% Ar-20% CO<sub>2</sub>), and two heat inputs levels (2 and 3 passes per layer) were used both in the down-hand and vertical up welding positions.

Mechanical and microstructural characterization: all weld metal chemical composition, Vickers hardness (1000 g), tensile properties (using Minitrac tensile specimens) and Charpy-V impact properties between -80 °C and 20°C were determined. Microstructural studies were carried out using light microscopy.

**Results and Discussion**

Ar-CO<sub>2</sub> shielding led to an increase in C, Mn and Si in the weld metal and to a decrease of oxygen contents. No significant chemical composition changes were observed with heat input variation within the range considered, although an increase of C, Mn and Si was observed when welding in the vertical up position for both shielding gases. The content of other elements remained approximately constant. E101T5-K3 chemical composition specification was met in all conditions.

In general, the fraction area of columnar zone increased with diminishing heat input. The microstructural analysis conducted in the top bead showed that for the flat position the Ar-CO<sub>2</sub> shielding promoted the formation of acicular ferrite [AF] and intragranular primary ferrite [PF(I)] at the expense of ferrite with second phases [FS] and grain boundary primary ferrite [PF(G)]. The test specimen welded in the vertical up position showed a microstructure with very low PF(G), the amount of AF increasing in welds made under Ar-CO<sub>2</sub> while [FS] decreased. For both welding positions, it was observed that an increase in the heat input led to an increase in the amount of AF. The microstructure corresponding to the location of the Charpy-V notch showed that the well defined equiaxed nature of the reheated zones of the plain C-Mn system was modified, and the ferrite grains were replaced by clusters of FS. The fraction area of the reheated zones was lower for the vertical up welds. Primary austenitic grain width could be measured only in the welds made in the flat position due to the fact that in the other the grain boundary ferrite was almost completely absent.

Test specimens welded under the Ar-CO<sub>2</sub> mixture exhibited higher tensile strength values than samples welded under CO<sub>2</sub> as expected from the chemical composition results. No effect of heat input was found in tensile strength, since with both heats inputs tensile properties were similar for each welding position. A tensile strength increase was achieved with test specimens welded in the vertical up position, when compared to those made in flat position. ANSI/AWS A5.29-98 E91T5-K2 tensile property requirements were satisfied under Ar/CO<sub>2</sub> shielding. The hardness values obtained in the welds made under CO<sub>2</sub> were lower than those made with the gas mixture. A similar effect was found with two passes per layer as compared to three passes per layer. A general agreement was found between all-weld metal tensile strength, hardness values and chemical composition.

Impact properties were excellent in all the conditions considered. Best toughness down to -40°C was obtained in welds made under the gas mixture. Nevertheless, no definite trend could be identified with the parameters variations studied. Under CO<sub>2</sub> shielding the best toughness was found in the weld made in the vertical up position with two passes per layer if the whole testing temperature range is taken into consideration. The toughness requirements of the ANSI/AWS A5.29-98 E91T5-K2/E101T5-K3 electrode were amply satisfied. The impact test results showed that although all the specimens satisfied the minimum AWS requirement of 27J at -51°C, ample variations in toughness were found when welding procedure parameters were changed.

## **Conclusions**

The results obtained in this work show as in the case of SMAW electrodes or when using a wire-flux combination in submerged arc welding depositing C-Mn-Ni-Mo or C-Mn-Ni-Mo-Cr alloyed ferritic weld metal, 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.