

# **Mechanical Properties and Microstructure of C-Mn-Ni 1 Ferritic Metal Cored Wire All-Weld Metal**

## ***Solidification and Solid Phase Transformation Studies***

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### **Introduction/Background**

Systematic studies of the relationship between welding procedure and all-weld metal properties of low alloy ferritic steel metal cored wires have so far not been undertaken. The study of solidification and solid phase transformations is necessary to explain and to be able to predict the mechanical properties of the deposits. The objective of this work was to study the microstructural and mechanical characteristics of 0.05% C-1.7% Mn-0.45% Si-0.95% Ni all-weld metal from an ANSI/AWS A5.29-98 E81T5-G type metal cored wire when the welding procedure parameters were changed. On the other hand, solidification and solid phase transformations were analyzed to obtain metallurgical information on this system.

### **Procedure**

#### ***Weldments***

Four all weld metal test specimens were prepared with the mentioned wire (1.2 mm diameter) according to ANSI/AWS A5.29-98 standard using heat inputs of 1kJ/mm and 1.5 kJ/mm under CO<sub>2</sub> and a mixture of 80% Ar-20% CO<sub>2</sub> shielding.

#### ***Mechanical and Microstructural Characterization***

All weld metal chemical composition, Vickers hardness (1000 g), tensile (Minitrac specimens) and Charpy-V impact properties were determined. Microstructural studies were carried out using light microscopy.

### ***Solidification***

The primary solidification structure was studied on cross sections from as welded specimens using a technique specially developed for this purpose. This consisted in submitting the samples to a thermal cycle of austenization followed by slow cooling down to the  $\alpha+\gamma$  field, and then water quenched.

### ***Solid Phase Transformations***

$A_1$  and  $A_3$  temperatures were measured by dilatometry using a heating rate of 5°C/min (41°F/min), up to a temperature of 1200°C (2192°F), holding at this temperature for 5 minutes, followed by cooling at the same rate.

In order to determine  $M_s$  and  $M_{90}$  temperatures the samples were austenitized at 1200°C (2192°F) during 5 minutes, immersed in salt baths at temperatures between 20°C (68°F) and 535°C (995°F) during 15 minutes and finally water quenched.

## **Results and Discussion**

### ***Mechanical and Microstructural Characterization***

Ar-CO<sub>2</sub> shielding led to an increase in Mn, Si, and N contents and to a reduction in C in the weld metal. No significant chemical composition changes were observed with heat input variation.

The lowest tensile strength and the highest ductility were achieved in the specimen corresponding to the highest heat input and Ar-CO<sub>2</sub> shielding. The remaining specimens presented rather similar tensile properties among them. Tensile properties were consistent with hardness measurements.

The best impact properties were obtained with the highest heat input and CO<sub>2</sub> shielding. The remaining samples did not show significant variations among them. In all cases, the 100J transition temperature was below -30°C (-22°F) and the 50J transition temperature was below -70°C (-94°F), which demonstrates the outstanding performance of this consumable.

A lower heat input led to an increase in the columnar zone percentage; no variation was observed due to gas shielding changes. The microstructural analysis conducted in the top bead showed a slight increase in the amount of acicular ferrite with low heat input, being

this increase more marked when the Argon rich mixture was employed. In general, under CO<sub>2</sub> shielding the amount of grain boundary polygonal ferrite decreased as well as the grain size of the fine grain recrystallized zone and the prior austenite grain size. This could account for the best impact properties obtained under CO<sub>2</sub> shielding.

### **Solidification**

The analysis of the primary solidification pattern showed that in the heat treated samples, due to the different solute concentration, martensite transformation following water quenching developed preferentially in those places where austenite had become less stable due to segregation of solute elements. Thus, a cellular solidification substructure was revealed by the martensite precipitated preferentially in the cell boundaries. Curving of the columnar grains needed to keep the grain growth orientation aligned with the temperature gradient was observed. When the grain orientation differed excessively from the <100> direction of preferential growth, re-nucleation was also found.

### **Solid Phase Transformations**

Dilatometric studies showed that A<sub>C1</sub> and A<sub>C3</sub> temperatures were 680°C (1256°F) and 890°C (1634°F) respectively, while A<sub>r1</sub> and A<sub>r3</sub> were 630°C (1166°F) and 760°C (1400°F) respectively, in general agreement with values reported in the literature for similar alloys.

In the samples austenitized at 1200°C (2192°F) a stabilization in the hardness values was observed which allowed to establish M<sub>90</sub> = 220°C (428°F). Quantitative metallography allowed to determine M<sub>s</sub> = 460°C (860°F). To relate temperature with the amount of transformation, the following mathematical expression was obtained:

$$M(T) = \frac{6.057 \times E^{-9} \times T^4 - 5.925 \times E^{-6} \times T^3 + 1.115 \times E^{-3} \times T^2 - 1.084 \times E^{-1} \times T + 119.8}{120}$$

120

M(T) : Martensite transformation fraction as a function of the temperature. T: Temperature in °C

### **Conclusions**

The conducted assessment of mechanical properties and microstructures together with the solidification and solid transformation pattern constitute a complete description of the characteristics of the ANSI/AWS A5.29-98 E81T5-G type metal cored wire weld deposits analyzed in this study.

The techniques developed showed to be useful tools to study the solidification substructure and the transformation characteristics in this type of weld metal.

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