

## Hydrogen Pick-up and Diffusion in TIG Welding of Supermartensitic 13% Cr Stainless Steel with Superduplex Wire

Supermartensitic 13% Cr stainless steels have been qualified and taken into use in offshore satellite flowlines. Due to the low carbon content, typically below 0.01wt%, the weldability of these steels is extensively improved, when comparison is made with the conventional martensitic steels with 0.05-0.2wt% C.

However, due to their martensite micro-structure, they are still susceptible to hydrogen cracking, provided that critical combinations of hydrogen supply and stress level are achieved. Such incidents have been reported.

Therefore, the present investigation was initiated with the objective to provide information on mechanized TIG (tungsten inert gas) welding with superduplex consumables. Multipass welds were performed, and hydrogen analyses were carried out in weld metal (WM) and heat affected zone (HAZ) positions. Degassing was performed to evaluate the diffusion of hydrogen at room temperature, 90°C and 150°C in order to simulate field joint coating sequences and typical service temperature of super 13% Cr flowlines.

### Hydrogen Pick-up

When using 70%He-30%Ar shielding gas (no addition of hydrogen) and not degassed wire, surprisingly low hydrogen concentration (1-2 ppm) was found in the weld metal immediately after welding. The resulting hydrogen pick up data after hydrogen addition in the shielding gas are shown in Fig.1. The hydrogen pick up increased rapidly with increasing hydrogen content in the shielding gas. The maximum hydrogen content approached 10 ppm, when more than 8% H<sub>2</sub> was added to the shielding gas.

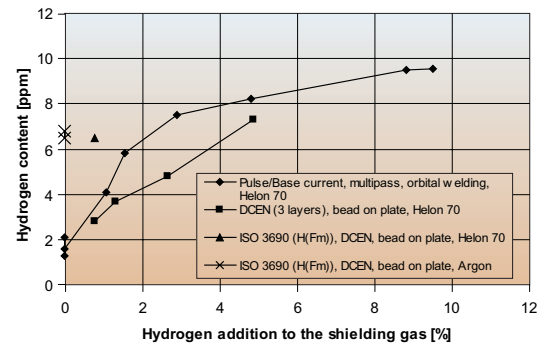


Fig.1 Effect of hydrogen addition to the shielding gas on the hydrogen content in the superduplex weld metal.

### Hydrogen Diffusion

Hydrogen diffusion from the weld metal into the heat affected zone was estimated using the uniaxial diffusion model presented in Fig.2.

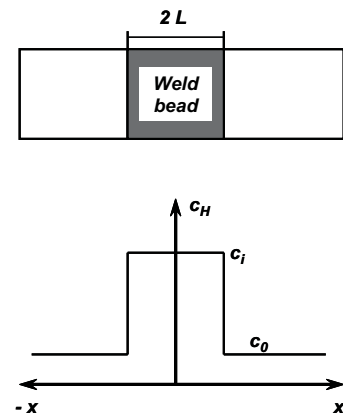


Fig.2 Uniaxial diffusion model.

### Weld metal

Diffusion of hydrogen in both weld metal and HAZ was calculated at different temperatures and the calculations were fitted with measured values by adjusting the diffusion coefficient.

An example of results is shown in Fig.3. The superduplex WM is close to an even mixture of ferrite and austenite. Hydrogen is mainly present in the austenite which has very slow hydrogen diffusivity due to the close packed fcc lattice. Published values [1,2] for diffusivity of superduplex stainless steels vary between  $1.8 \times 10^{-12}$ -  $1.1 \times 10^{-15}$  m<sup>2</sup>/s.

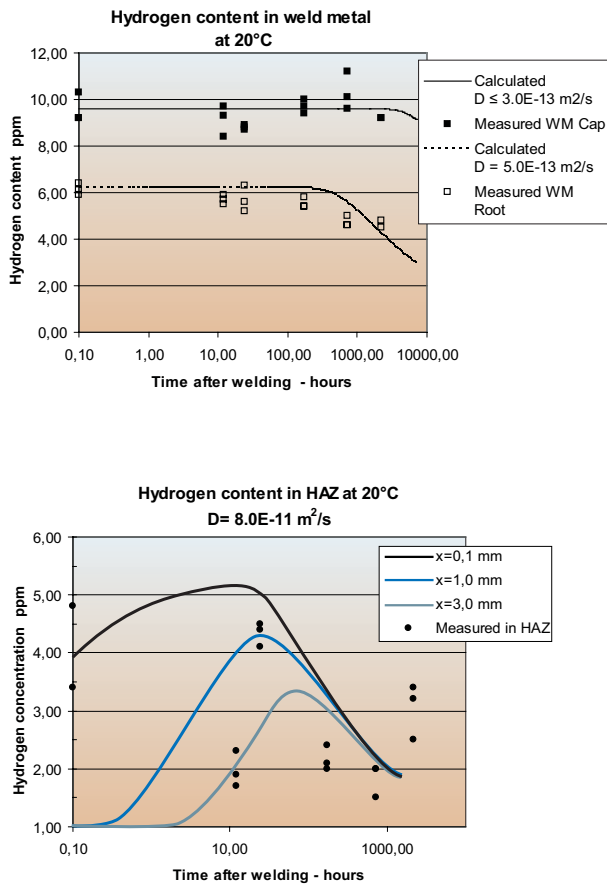


Fig.3 Effect of time on the hydrogen content in weld metal (top) and HAZ (bottom) Symbols are measured values.

An important practical implication of the results is that a WM with high hydrogen content will act as a reservoir for H for a long time after welding. At 90°C, which is a typical service temperature,

a superduplex WM with 9-10ppm hydrogen will supply hydrogen to the 13Cr HAZ for a period of more than 2 years. This underlines the importance of keeping the WM hydrogen low. It can be noticed that the diffusivity in general is higher in the root area. This is expected due to a larger dilution with the supermartensitic base metal giving a mainly martensitic structure allowing higher hydrogen diffusivity rates.

## HAZ

Supermartensitic steel has mainly a bct lattice structure, which allows higher mobility of the hydrogen atoms than in the austenitic fcc-structure, but less than in a ferritic bcc-lattice. 5-30% retained austenite can be present. Large amounts of retained austenite will slow down the diffusion. Reported hydrogen diffusivity in literature is in the range  $1.6 \times 10^{-9}$ -  $6.1 \times 10^{-14}$  m<sup>2</sup>/s. The supermartensitic HAZ reveals a diffusivity rate clearly higher than the WM (Fig.3). The calculated diffusivities using the simplified uniaxial model are within the range of those reported for similar steels in literature.

## References

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