

## Sour Service Limit of 17% Cr Stainless Steels grades for OCTG

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### ABSTRACT

Recently, the use of 17% Cr seamless steel tubing has been a cost-effective solution for preventing high pressure and high temperature (HP/HT) CO<sub>2</sub> corrosion environment with small amount of H<sub>2</sub>S. This paper focuses on the sulfide stress cracking (SSC) results of 17% Cr stainless steels in simulated conditions for HP/HT gas wells. In the frame of a qualification program, NACE<sup>a</sup> Standard Tensile Test, Method A was adopted in accordance with NACE TM0177. The influence of partial pressure of H<sub>2</sub>S was investigated at condensed and formation water conditions where SSC is likely to occur. In addition, a previous work on the localized corrosion and the stress corrosion cracking behavior of those grade is also discussed in this paper. The results were summarized in a sour service domain map and compared with previous published data. The results showed the applicability of this alloy for selected gas well conditions.

Key words: 17%Cr, OCTG, CO<sub>2</sub>, H<sub>2</sub>S, SSC

### INTRODUCTION

Due to technological innovation for oil and gas development, new oil and gas fields are getting more extreme conditions, pressure, temperature and corrosion dominant components (CO<sub>2</sub>, H<sub>2</sub>S, chloride

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etc.,) From a material point of view, for the last 30 years, the use of seamless 13%Cr martensitic stainless steel OCTG (Oil Country Tubular Goods) has been a cost effective solution for preventing sweet CO<sub>2</sub> corrosion. More recently, modified 13%Cr<sup>1-3</sup> alloys with low carbon and Ni-Mo additions were introduced for improving the resistance to specific forms of corrosion. For high pressure and high temperature (HP/HT) deep sweet gas wells containing H<sub>2</sub>S require a corrosion resistant alloy OCTG material, such as 22%Cr duplex stainless steel (DSS) and/or 25%Cr Super DSS. Quite recently, 17%Cr<sup>4-5</sup> stainless steel (SS) OCTG has been introduced on the market to fill the gap between Modified 13%Cr SS and 22%Cr DSS. 17%Cr SS is lower alloyed compared to 22%Cr DSS leading to cost reduction and no cold working manufacturing process and shorter lead time.

Different material suppliers proposed a new super martensitic stainless steel for OCTG market and generic pH – pH<sub>2</sub>S diagrams can be found in the literature<sup>6-7</sup>. For example, Figure 1 presents SSC Test Results<sup>6</sup> of Super 17Cr – 125 from Takabe et al. whereas Figure 2 is showing the published diagram<sup>7</sup> from Ishiguro et al.

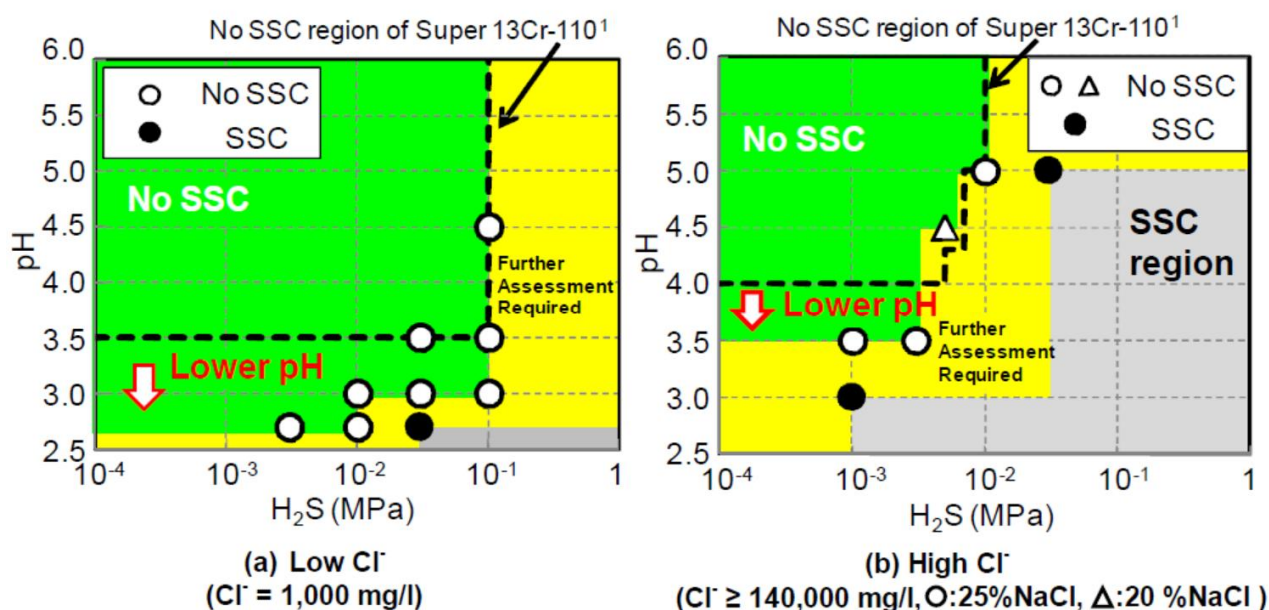


Figure 1 - SSC Test Results of Super 17Cr – 125 published at CORROSION2012<sup>6</sup>

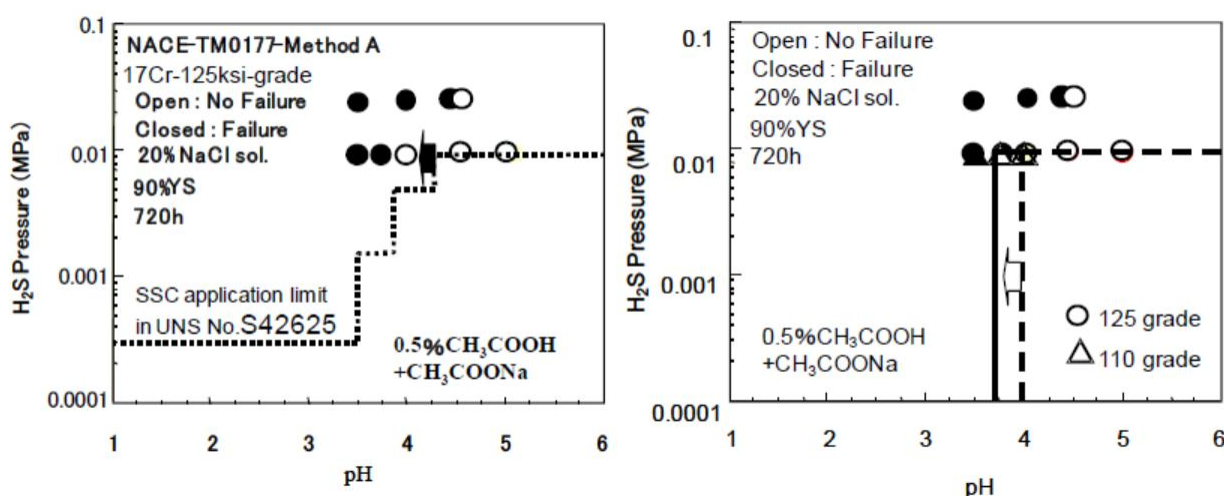


Figure 2 - SSC Test Results of Super 17Cr – 125 published at NACE Corrosion 2013<sup>7</sup>

In addition, Marc Wilms and al.<sup>8</sup> have demonstrated that 17%Cr-125 grade could apply for CW and FW environments under 39 mbar H<sub>2</sub>S, 50 bar CO<sub>2</sub> by using Ripple Strain Rate Tests<sup>9</sup>. These authors conclude that for full qualification of this grade, 30-day exposure tests are necessary. However, in order to investigate the susceptibility of these new super martensitic grades, many factors must be considered prior to establish a qualification protocol of these grades, such as pH and buffer capacity<sup>10-11</sup>, temperature<sup>12</sup>, mechanical properties<sup>13</sup>, microstructure<sup>13</sup>, sample preparation, etc.

In this context, the corrosion resistance of four different 17%Cr SS grades to Sulfide Stress cracking (SSC), Stress Corrosion Cracking (SCC) and localized corrosion is evaluated in order to qualify them for a newly developed HP/HT gas condensate field containing CO<sub>2</sub> with small amount of H<sub>2</sub>S.

## EXPERIMENTAL PROCEDURE

### Tested Materials

The mechanical properties and Pitting Resistance Equivalent Number (PREN) of materials investigated are provided in Table 1. Two different grade ranges of 17%Cr SS materials were investigated. The PREN is regularly used to compare the expected localized corrosion resistance of various types of stainless steels. In addition, modified 13%Cr SS and 22%Cr DSS were also tested in comparison with 17%Cr SS. PREN of 17%Cr SS is around 26, i.e. in between those of Modified 13%Cr SS (PREN: 19) and 22%Cr DSS (PREN: 33).

**Table 1 Mechanical Properties and PREN**

| No. | CRAs           | Strength<br>Grade (ksi) | YS  |     | UTS |      | PREN |
|-----|----------------|-------------------------|-----|-----|-----|------|------|
|     |                |                         | ksi | MPa | ksi | MPa  |      |
| 1   | 17%Cr A        | 125                     | 136 | 938 | 142 | 979  | 25   |
| 2   | 17%Cr B        | 125                     | 133 | 920 | 148 | 1023 | 26   |
| 3   | 17%Cr C        | 110                     | 120 | 824 | 141 | 971  | 27   |
| 4   | 17%Cr D        | 110                     | 128 | 882 | 137 | 945  | 25   |
| 5   | Modified 13%Cr | 110                     | 115 | 793 | 121 | 834  | 19   |
| 6   | 22%Cr          | 125                     | 133 | 917 | 141 | 972  | 33   |

$$\text{PREN (Pitting Resistance Equivalent Number)} = \text{Cr} + 3.3(\text{Mo} + 0.5\text{W}) + 16\text{N}$$

Figure 3 shows the microstructure of the tested 17%Cr SS, Modified 13%Cr SS and 22%Cr DSS. Basically, 17%Cr SS consists predominately of ferrite and martensite phases. Austenitic phases may be present as a third phase as per Schaeffler diagram. The content can be as high as 15%. However, the retained austenite phase cannot be clearly investigated at optical microscopy. The impact of this phase on corrosion properties of martensitic SS were discussed elsewhere<sup>14</sup>.

As for lower grades, the strength of martensitic stainless steels is adjusted during heat treatment through the tempering of martensite after quenching. Therefore, it does not require hardening by cold working as duplex stainless steels. On the other hand, the martensite phase is known to have a high SSC susceptibility compared to austenite and ferrite phases<sup>15</sup>.