Super-duplex steels that resist corrosion in demanding topside oil and gas installations

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Abstract

Joseph Osta, Product Manager for Hydraulic & Instrumentation Tubing at Sandvik, explains how the stainless steel manufacturer has developed advanced hydraulic and instrumentation tubing in super-duplex material for topside applications.

Introduction

Energy and petrochemical suppliers worldwide are highlighting the need for innovation and collaboration in order to meet the most pressing issues facing the global oil and gas industry. These challenges include greater needs for cost-efficiency as well as growing health, safety and environmental (HSE) demands.

Global demand for energy continues to grow, especially in developing economies such as China and India. Market pressures are driving oil and gas companies towards deeper wells in more exposed locations to achieve higher productivity and efficiency. This subjects rigs to even greater threats of localized corrosion.

On offshore platforms stainless steel tubing is used in process instrumentation, hydraulic lines, chemical inhibition and utility applications. Many of these applications are topside and in tropical sea waters corrosion of ASTM 316L stainless steel tubing often occurs, primarily due to marine atmospheric corrosion. In the main this is pitting and crevice corrosion that takes place in inaccessible locations such as beneath clamps, support trays and connections. Both types of corrosion depend on chloride concentrations and moisture levels. However, they can be further exacerbated by surface contamination caused by iron particles from welding and grinding operations, surface deposits from handling, drilling and blasting and from sulfur-rich diesel engine exhaust. Even periodic testing of seawater firefighting systems can leave undesirable chloride salt deposits.

Operational experience in tropical waters, such as the Gulf of Guinea and the Gulf of Mexico, prove that ASTM 316L tubing service life is less than 5 years while in some extreme cases it can be under 1 year. Obviously, this has serious implications not least of which is life hazard accidents resulting from sudden failures as well as the potential serious damage to the platforms.

Improved corrosion resistance for longer lifecycles

The normal lifecycle of ASTM 316L steels can exceed 100 years in non-corrosive environments. However, tests in chloride containing environments have demonstrated that tubing made from ASTM 316L has a service life shorter than 5 years and, in some cases, less than one year. This has since been confirmed by operational experience. Low levels of Mo in ASTM 316L steels was a contributing factor.

Such corrosion failures are adverse to the increasing performance demands faced by oil and gas companies. In process systems found on topside platforms – consisting of various vessels, heat exchangers, separators and compressors – poor equipment life spans pose serious risks of sudden equipment failures and may even lead to hazardous, costly and highly-publicized accidents. Consequently, some oil and gas suppliers have gone so far as to implement a 'zero tolerance policy' against accidents.

Table 1 – Range of chemical composition and PRE values for some corrosion resistant alloys. (Okeremi & Simon-Thomas, 2008.) PRE (Pitting Resistance Equivalent) is a practical application for selecting appropriate materials, today widely recommended by stainless steel manufacturers. PRE = % Cr + 3.3% Mo + 16% N.

	Composition Ranges								PRE	
	Cr		Mo		W		N		Minimum	Maximum
AISI 316	16	18	2	3	-	-	-	-	22.6	27.9
AISI 316L	16	18	2	3	-	-	-	-	22.6	27.9
AISI 316L, >2.5%Mo	16	18	2.5	3	-	-	-	-	24.3	27.9
AISI 317	18	20	3	4	-	-	-	0.1	27.9	34.8
AISI 317L	18	20	3	4	-	-	-	0.1	27.9	34.8
Alloy 20	19	21	2	3	-	-	-	-	25.6	30.9
Alloy 825	19.5	23.5	2.5	3.5	-	-	-	-	27.8	35.1
22Cr Duplex	22	23	3	3.5	-	-	0.14	0.2	34.1	37.8
25Cr Duplex	24	26	3	5	-	-	0.24	0.32	37.7	47.6
AI-6XN®	20	22	6	7	-	-	0.18	0.25	42.7	49.1
254 SMO™	19.5	20.5	6	6.5	-	-	0.18	0.22	42.2	45.5
Alloy 625	20	23	8	10	-	-	-	-	46.4	56.0
Alloy C276	14.5	16.5	15	17	3	4.5	-	-	69.0	80.0

As exploration goes deeper and more countries, like China and India, move towards refining their own oil and gas with processing environments becoming more extreme and corrosive to meet production targets, the industry is turning to corrosion resistant alloys (CRAs). These CRAs include grades from 13Cr and upwards and 6Mo austenitic steel types (containing 6% Mo) such as 254 SMO™, AL-6XN® and alloy 625. However, because they have higher levels of Ni and Mo and somewhat lower market availability they are more costly than super-duplex steels.

Twice the strength of high-alloy steels

Fortunately, there is a further alternative material that is helping the oil and gas industry face emerging market challenges, while also achieving lower lifecycle costs and other operational benefits. Super-duplex steels have been gaining a bigger market share thanks to their higher strength which can reduce the wall thickness of tubes and pipes in hydraulic and instrumentation systems, thus reducing both costs and weight.

Among these materials is the super-duplex austenitic-ferritic steel Sandvik SAF 2507™, which has a PRE (Pitting Resistance Equivalent) value of 42.5 due to its chemical composition of 25% Cr, 4% Mo and 0.3% N compared to other steels (see Table 1).

Sandvik SAF 2507 is specially designed for highly corrosive conditions and chloride-bearing environments. Its high mechanical strength can also enable lighter constructions with weight savings of up to 50% over standard steels. With these qualities, the material can endure long and secure equipment durations, as was clearly proven when it was installed alongside ASTM 316L in Sandvik's Gulf of Mexico tests.

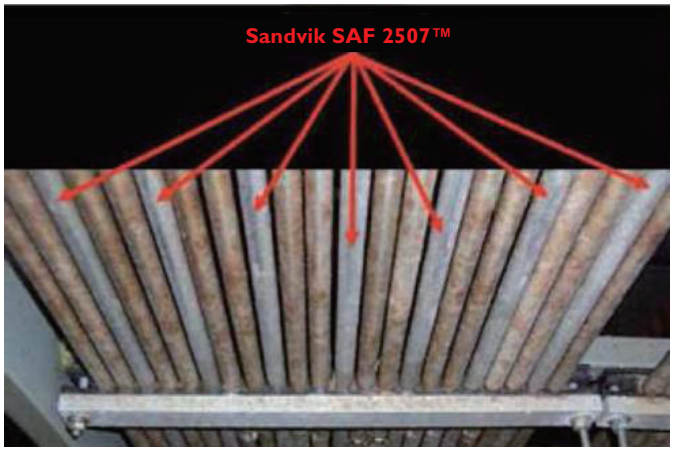

Figure 1 – ASTM 316L stainless steel and Sandvik SAF 2507™ super-duplex tubing installed side by side, with the ASTM 316 tubing showing extensive corrosion and the super-duplex tubing showing none. (Schiroky, Dam, Okeremi and Speed, 2009.)

While ASTM 316L experienced heavy corrosion in the tests, no signs of corrosion were detected in the super-duplex tubing, Figure 1. The latter material's mix of austenite and ferrite provides a very high mechanical strength with a minimum proof strength of 550 MPa (N/mm^2) – nearly twice that of high-alloy austenitic steels. The material's excellent resistance to stress corrosion cracking (SCC), pitting and crevice corrosion in chloride bearing environments makes it a natural choice for hydraulic and instrumentation tubing applications on offshore platforms.

Material selection and chemical composition

Pitting and crevice corrosion at temperatures above 50°C to 60°C (122°F to 140°F) and stress corrosion cracking (SCC) are the most common of all types of corrosion in oil and gas topside applications. Such corrosion is caused predominantly by localized attacks from seawater. Here the chloride content, alongside other factors such as fouling and galvanic effects induce stress corrosion cracking, particularly if the material is too low alloyed for the service conditions.

Corrosion challenges are driving companies to refit and upgrade their platforms with intelligent infrastructure to reduce costs and prolong equipment lifecycles. Materials selection is of paramount importance for these improvements.

In light of these requirements, the high-alloy super-duplex stainless steel grade Sandvik SAF 2507 has become a favored choice for hydraulic and instrumentation tubing in such exposed locations.

The proven corrosion resistance of Sandvik SAF 2507 makes the grade an increasingly justifiable solution for economic considerations, such as operational reliability and long service life. The steel's Mo content is 4% which gives it performance levels comparable to 6% Mo austenitic stainless steels like 254 SMO and AL-6XN.

Tried and tested improvements over ASTM 316L

Practical experiences with organic acids are among the methods which Sandvik has used to test Sandvik SAF 2507 positioning the grade as an alternative to high-alloy austenitic stainless steels and nickel alloys in topside applications. Standard austenitic steels have been shown to corrode at high rates when exposed to chloride-rich marine atmospheric environments. Tests on Sandvik SAF 2507 shows that the grade's high resistance to such environments is comparable to, or even better than high-alloy austenitic stainless steels in certain concentration ranges.

For example, a direct comparison between the corrosion rates of ASTM 316L and Sandvik SAF 2507™ respectively was performed in 80% acetic acid with 2000 ppm chloride ions at 90°C (194°F). The results showed that ASTM 316L has a corrosion rate of up to 1 mm/year in such conditions. This compared to a corrosion rate of roughly 0.01 mm/year on super-duplex stainless steel. A 100% improvement on standard steels.

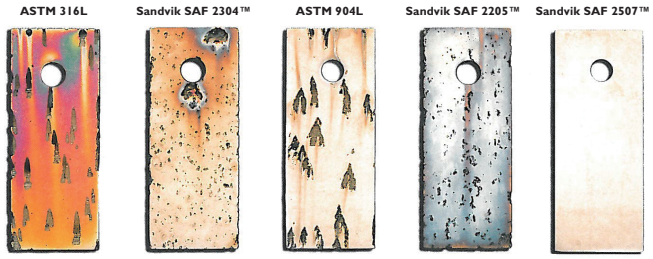

Figure 2 – Test samples after pitting corrosion test in accordance with ASTM G48 clearly demonstrate the corrosion resistant capabilities of Sandvik SAF 2507™.

Tests for pitting corrosion were carried out by Sandvik, in accordance with industry-recognized criteria, such as ASTM G48. Samples were immersed in a highly corrosive 6% $FeCl_3$ solution, which is high in chloride ions and oxidizing ferric ions. After cleaning, the samples were weighed and inspected for pitting. As can be seen in Figure 2, Sandvik SAF 2507 is less prone to corrosion than most comparable standard steels in chloride-heavy environments, Figure 3.

The Pitting Resistant Equivalent, or PRE number, is widely accepted as the best method to rank the pitting resistance of stainless steels. It is calculated from the level of Cr, Mo and N present in an alloy, PRE= %Cr + 3.3% Mo +16%N.

For offshore applications the common specified minimum PRE number is 40. While ASTM 316L and its variants, like ASTM 317L, have insufficient corrosion resistance with maximum PRE numbers of 27.9 and 34.8 respectively, Sandvik SAF 2507 is a satisfactory alternative with a minimum PRE of 42.5. Other 25Cr type duplex stainless steels that are not super-duplex have insufficient corrosion resistance. For example, UNS S31260, has a PRE number of 33.

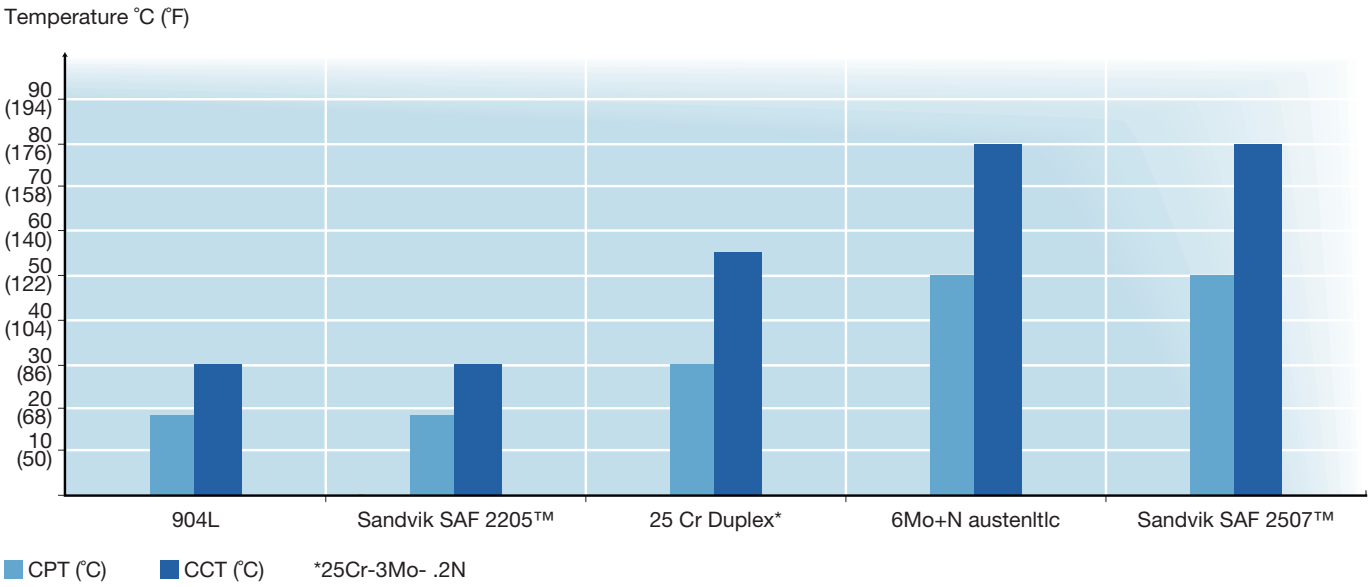

Figure 3 – CPT and CCT in 6% $FeCl_3$, periods of 24 hrs - ASTM G48 modified: ASTM G48 is the most commonly employed standard for testing materials resistance against pitting (CPT) and crevice corrosion (CCT), aiming the comparison of the materials by performance classification. The nominal values for Sandvik SAF 2507™ are CPT = 80°C (176°F) and CCT = 50°C (122°F), according to ASTM G48A and G48B respectively.

Collaborating with long-term partner

The challenge for the oil and gas industry is to continue its long-held track record in overcoming technological obstacles – and no single organization or government can meet these industry changes alone.

This is where Sandvik 150 years of unmatched expertise in metallurgy and steel production for varied applications comes into play. Sandvik can be a long-term productivity partner for its customers, with the know-how and experience to create next generation materials that can bring more value for end users and help to future-proof their business.

Meanwhile, as dynamic and cost-effective steel materials and infrastructures become ever more critical to oil and gas producers, Sandvik is confident that its operationally tested Sandvik SAF 2507 super-duplex is one of the best material grades for the replacement of ASTM 316L in hydraulic and instrumentation tubing on offshore platforms.

About Sandvik

Sandvik Group

The Sandvik Group is a global high technology enterprise with 49,000 employees in 130 countries. Sandvik's operations are concentrated on five business areas in which the group holds leading global positions in selected niches: Sandvik Mining, Sandvik Machining Solutions, Sandvik Materials Technology, Sandvik Construction and Sandvik Venture.

Sandvik Materials Technology

Sandvik Materials Technology is a world-leading developer and manufacturer of products in advanced stainless steels and special alloys for the most demanding environments, as well as products and systems for industrial heating.

Quality management

Sandvik Materials Technology has quality management systems approved by internationally recognized organizations. We hold, for example, the ASME Quality System Certificates as a Material Organization, approvals to ISO 9001:2008, ISO 17025:2005 and PED 97/23/EC. We also have product and/or shop approvals from bodies such as TÜV, JIS, DNV and Lloyd's Register.

Environment, health and safety

Environmental awareness, health and safety are integral parts of our business and are at the forefront of all activities within our operation. We hold ISO 14001 and OHSAS 18001 approvals.

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