HYPER-DUPLEX STAINLESS STEELS

HOW A NEW GENERATION OF HIGH-ALLOY STAINLESS STEELS IS HELPING TO OVERCOME CHALLENGES IN THE OFFSHORE OIL AND GAS INDUSTRY

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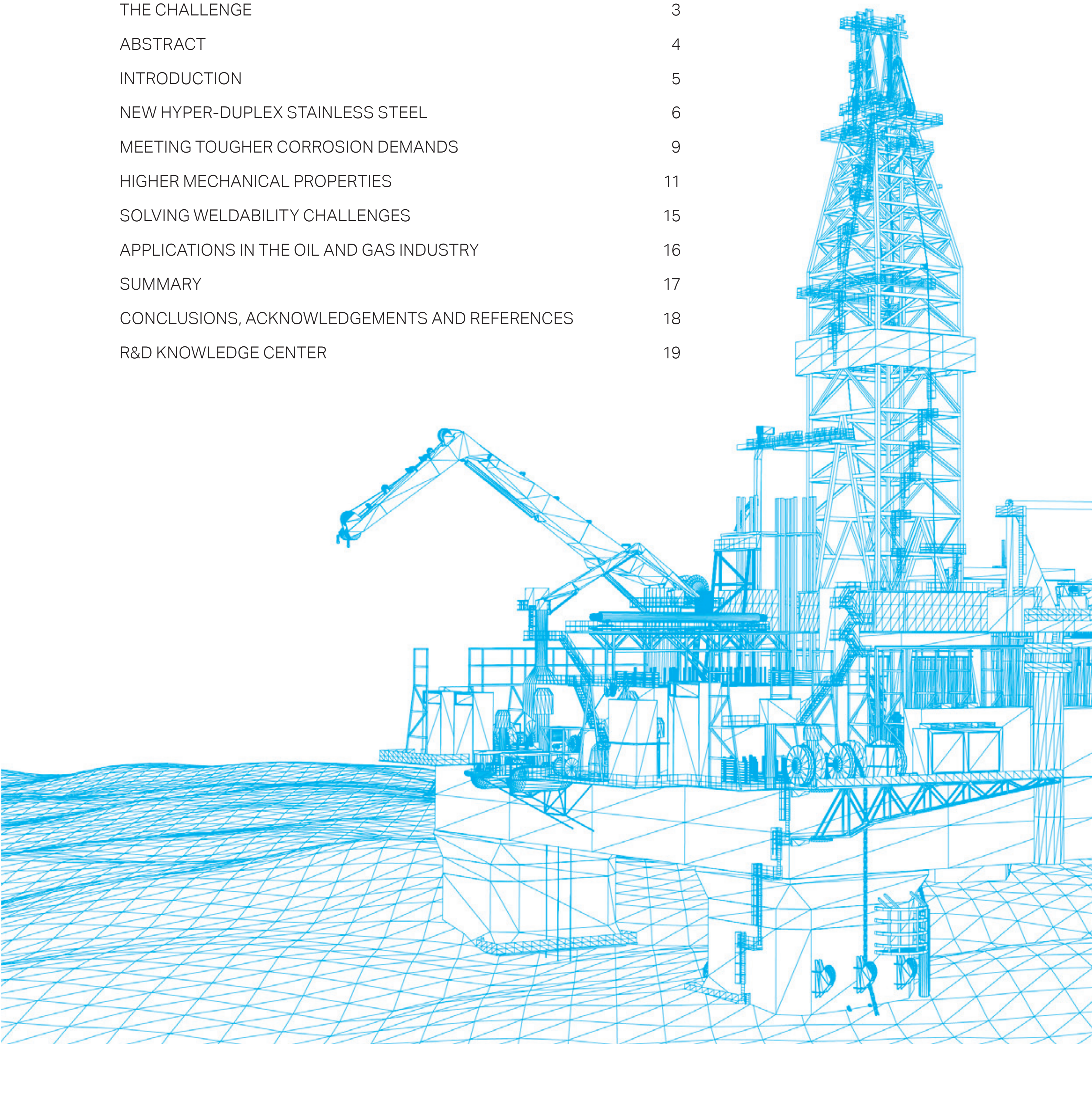

THE CHALLENGE

As the oil and gas industry moves further offshore into deeper waters, the need for stronger, lighter and more corrosion-resistant materials is more acute than ever. Today, the use of duplex stainless steels, such as Sandvik SAF 2507 (UNS S32750), has become commonplace for meeting such challenges. Most recently, the development of the modern duplex family continues with the introduction of new high-alloy hyper-duplex steels that deliver PRE values up to 50. This opens new possibilities for the oil and gas industry to design even lighter subsea infrastructure that is stronger and more corrosion resistant. But when should you use which materials? What materials challenges can this "new breed" of steels help you overcome?

This white paper provides some of these answers. It is part of a series from the Research and Development department of Sandvik, based on published scientific papers with NACE International and other independent institutes. The content has been slightly modified in agreement with the authors to make it more accessible for a broader range of professionals. It is part of our ongoing efforts to open up new opportunities for the oil and gas industry, reinforcing our commitment: WE HELP YOU GET THERE.

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ABSTRACT

Hyper-duplex stainless steel (HDSS) is a new type of duplex steel that offers pitting resistance numbers (PRE) higher than 48.

Within the modern duplex family, these duplex stainless steels exhibit both the highest levels of corrosion pitting resistance as well as mechanical strength. Two newly developed grades are Sandvik SAF 2707 HD and Sandvik SAF 3207 HD. This paper provides a general description of the main characteristics of these two materials and compares their corrosion and mechanical properties with those of super-duplex stainless steels. Their applications and potential in the offshore oil and gas industry are also analyzed and discussed.

"THIS PAPER PROVIDES A GENERAL DESCRIPTION OF THE MAIN CHARACTERISTICS OF TWO HYPER-DUPLEX STAINLESS STEELS AND COMPARES THEIR CORROSION AND MECHANICAL PROPERTIES WITH THOSE OF SUPER DUPLEX STAINLESS STEELS"

GUOCAI CHAI

INTRODUCTION

Since the launch of the first duplexes back in the 1960s, duplex stainless steels have built a global reputation for their strength and corrosion-resistant properties.

Over the years, several generations of commercial duplex stainless steels have been developed and applied in a range of demanding industries. During the mid-1980s, for example, we witnessed the introduction of highly alloyed duplex stainless steels such as UNS S32750, S32760 and S32520. Since the PRE-values of these alloys are higher than 40, they were designated as super-duplex stainless steels (SDSS)[1 2].

SUPER DUPLEX – A TRUSTED WORKHORSE

Today, in the offshore oil and gas industry, for example, super-duplex stainless steels have become trusted workhorses for demanding offshore applications ranging from subsea umbilical tubing to hydraulic control lines. As a relatively new group of austenitic-ferritic steels, they offer an attractive combination of excellent corrosion resistance, high mechanical strength and good weldability. Since their introduction, super duplexes have been widely used in the oil and gas industry – upstream, midstream and downstream. Due to their corrosion resistance and strength, they have become an attractive alternative to other high-performance materials such as super-austenitic stainless steels and nickel-based alloys.

“DUPLEX STAINLESS STEELS OFFER AN ATTRACTIVE COMBINATION OF EXCELLENT CORROSION RESISTANCE, HIGH MECHANICAL STRENGTH AND GOOD WELDABILITY.”
GUOCAI CHAI

EXTENDING THE SERVICE LIFE

Over the past 15 years, despite the very successful applications and experiences with super-duplex stainless steels, research continues into how to further improve them. There are still application areas, for example, in which the corrosion resistance of such alloys is insufficient to withstand a long service life or handle higher temperatures. As a result, there has been an onging interest in the further development of new duplex stainless steel alloys that offer even higher corrosion resistances at high temperatures.

SUPERIOR CORROSION RESISTANCE

For certain demanding applications, such as deep waters in the offshore oil and gas industry, there is a growing need for duplex stainless steel materials that provide a superior combination of corrosion resistance and even higher strength. For these challenges, two new highly alloyed duplex stainless steels, UNS S32707 (Sandvik SAF 2707HD) and UNS S33207 (Sandvik SAF 3207HD), have recently been developed [3-5].

SUPERIOR FABRICABILITY AND WELDABILITY

The nitrogen content in these alloys is now up to 0.5% and their PRE-values are close to 50. Compared with the existing family of modern duplex stainless steels, they show superior pitting corrosion resistance and the highest strength. They also offer good fabricability and weldability, and have now been designated as hyper-duplex stainless steel (HDSS). This paper will therefore provide a general description of these two latest duplex stainless steels and their applications in the offshore oil and gas industry.

NEW HYPER-DUPLEX STAINLESS STEEL

New research into the properties of duplex steels is opening up a range of possibilities for oil and gas companies faced with extreme offshore conditions. Such developments are not just theoretical improvements, but have shown themselves to be workable in fabrication, commercial production and operation as well.

FINDING THE RIGHT BALANCE

To improve corrosion resistance and strength, modern duplex stainless steels are alloyed with chromium (Cr), molybdenum / tungsten (Mo/W), nitrogen (Ni) and nickel (N). The challenge of developing new, highly alloyed duplex stainless steels by increasing these alloying elements is to balance the alloying level to control the risk for formation of undesirable intermetallic phase.

AVOIDING ADVERSE FORMATIONS

Such adverse formations can be seen in Figure 1a (sigma phase) and Figure 1b (nitride). In highly alloyed duplex stainless steels, the risk of such formations increases in parallel with increases in alloying elements like Cr and Mo or N.

FIGURE 1: INFLUENCE OF CR AND N CONTENTS ON THE FORMATION OF SIGMA AND CR2N AT 900°C.

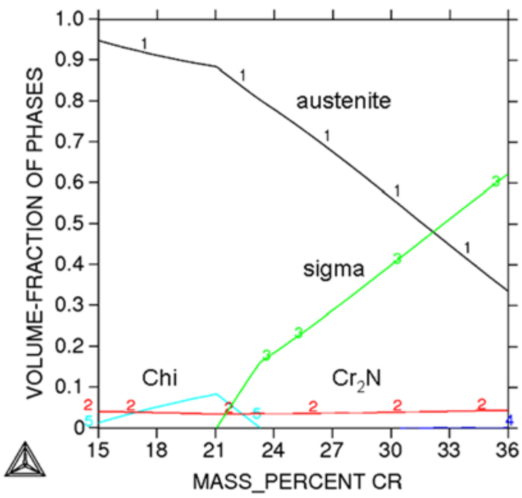

Figure 1a: Influence in 0.03C-0.6Si-1.5Mn-4Mo-7Ni-0.4N-xCr system.

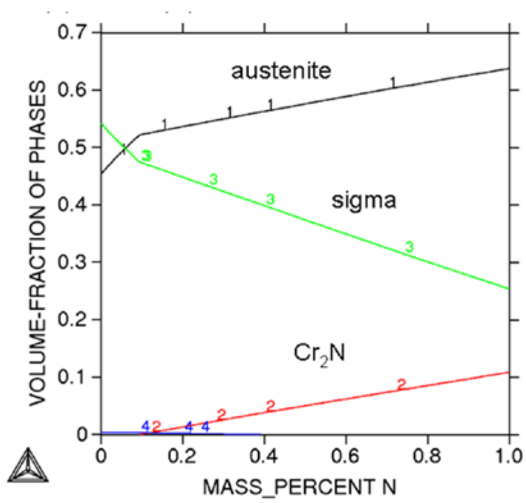

Figure 1b: Influence in 0.03C-0.6Si-1.5Mn-4Mo-7Ni-30Cr-xN system.

UNEXPECTED POSITIVE SYNERGIES

However, during the development of hyper-duplex stainless steels, it was also discovered that the simultaneous addition of elements such as Cr, Mo and N can have unexpectedly positive synergistic effects. For example, research showed that the solid solution content of N in a duplex stainless steel can be much higher than expected. As shown in Figure 2a, the simultaneous addition of Cr, Mo and N does impact the temperature for nitride solution or formation. However, the influence of variation in or increase of Mo and Cr contents on this temperature is relatively small. Low Cr and Mo contents in the alloy do not correspond to a low temperature for nitride formation. This indicates that increases in the amounts of Cr and Mo can increase the solubility of N.

SUPPRESSING SIGMA PHASE

As shown in Figure 1b, an increase in nitrogen can suppress the precipitation of sigma phase – a phenomenon that can be observed in a wide range of chromium contents in duplex stainless steels (Figure 2b).

FIGURE 2: SYNERGISTIC EFFECTS OF THE ALLOYING ELEMENTS

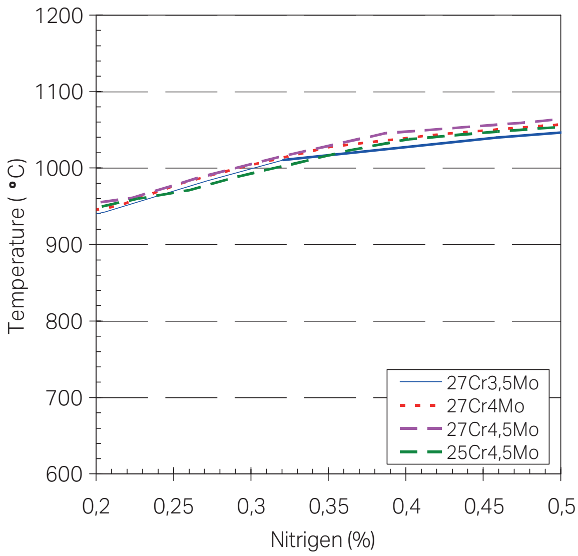

Figure 2a: Influence of addition of Cr and Mo on the solubility of N in the matrix.

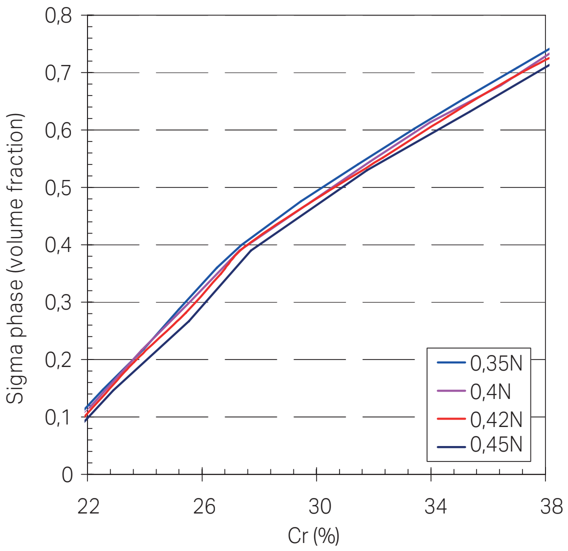

Figure 2b: Influence of nitrogen content on the formation of sigma phase in highly alloyed duplex stainless steels.

EASIER TO MANUFACTURE

In highly-alloyed duplex stainless steels, the synergistic effects of the alloying elements Cr, Mo and N can make it easier to manufacture the alloys into various product forms. However, there are some limitations. Figure 3 shows the influence of solubility of N and Cr in the austenitic phases of highly alloyed duplex stainless steels on the ductility of the alloys. With a combination of an N content of less than about 0.7% and a Cr content of less than about 31% in the austenitic phase, duplex stainless steel alloys can obtain good ductility and also be easily manufactured.

FIGURE 3: INFLUENCE OF SYNERGISTIC EFFECT OF THE ALLOYING ELEMENTS CR AND N ON THE DUCTILITY OF THE HIGHLY ALLOYED DUPLEX STAINLESS STEELS.

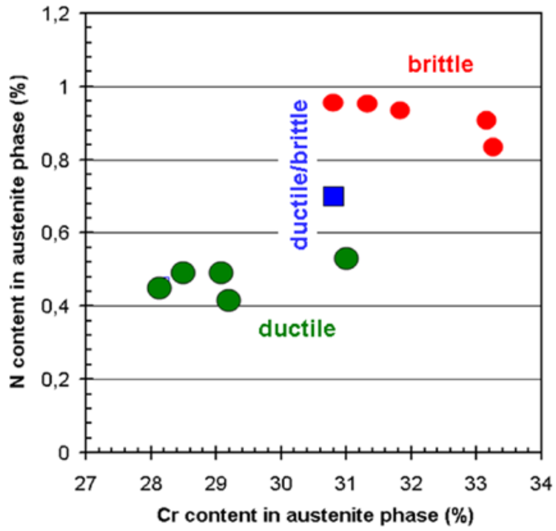

Figure 3: Influence of synergistic effect of the alloying elements Cr and N on the ductility of the highly alloyed duplex stainless steels.

TABLE 1: NOMINAL CHEMICAL COMPOSITIONS AND PRE VALUES OF THREE DUPLEX STAINLESS STEELS (WT_ %)

Grade	UNS	C_max	Cr	Ni	Mo	N	PRE*
Sandvik SAF 2507	S32750	0.03	25	7	4	0.3	42.5
Sandvik SAF 2707 HD	S32707	0.03	27	7	5	0.4	48
Sandvik SAF 3207 HD	S33207	0.03	32	7	3.5	0.5	50

Table 1: The table shows nominal chemical compositions of the hyper duplex stainless steel grades UNS S32707 (Sandvik SAF 2707 HD) and UNS S33207 (Sandvik SAF 3207 HD) as well as super duplex stainless steel grade UNS S32750 (Sandvik SAF 2507). Sandvik SAF 3207 HD contains the highest amounts of the alloying elements. The nitrogen content is up to 0.5%.
* Minimum PRE value for tube material.

For duplex stainless steels, the pitting corrosion resistance is proportional to pitting corrosion resistance equivalent value, PRE, of an alloy, which can be calculated as follows:

PRE= %Cr + 3.3%Mo + 16%N (% by weight)[1]

TOPPING THE CHARTS ON PRE

The pitting corrosion resistance equivalent values (PREs) of these three alloys are also indicated in Table 1. As shown, the hyper-duplex SAF 3207 HD has a minimum PRE value of 50 while SAF 2707 HD has a minimum PRE value of 48, compared to 42.5 for the super duplex. As noted earlier, a duplex stainless steel with a PRE value above 48 is today designated as a hyper-duplex stainless steel (HDSS)[3 5]. The duplex stainless steels UNS S33207 and UNS S32707 are therefore hyper-duplex stainless steels.

MEETING TOUGHER CORROSION DEMANDS

It's a well-known fact that duplex stainless steels provide excellent corrosion resistance in harsh, chloride-containing environments. But which grades are the most suitable in what environments? What levels of performance can be expected?

To more clearly show the differences in the duplex family, we carried out a test on the critical pitting temperatures (CPT) of these three duplex stainless steels in 6% $FeCl_3$ in accordance with the ASTM G48A Standard Test Method for Pitting and Corrosion (Figure 4).

SUPERIOR PITTING CORROSION RESISTANCE

The pitting corrosion resistance of duplex stainless steels generally corresponds to the PRE values of the alloys: The higher the number, the better the pitting corrosion resistance. Despite this general rule, it can be noted that SAF 3207 HD has slightly lower CPT than SAF 2707 HD, even though SAF 3207 HD has a slightly higher PRE value. A comparison of the critical crevice corrosion temperatures (CCT) of these materials, determined with the MTI-2 crevice former, is provided in Figure 4a.

"HYPER-DUPLEX STAINLESS STEELS SHOW MUCH HIGHER CPT AND CCT THAN SUPER-DUPLEX STAINLESS STEEL SAF 2507"
PASI KANGAS

HIGHER CPT AND CCT LEVELS

As shown, SAF 3207 HD and SAF 2707 HD recorded similar CCT levels. And as expected, hyper-duplex stainless steels show much higher CPT and CCT than super duplex stainless steel SAF 2507. This phenomenon becomes even more apparent in the concentrated sodium chloride solution measured using potentiostatic tests at +600mV (Figure 4b).

FIGURE 4: COMPARISON OF CPT AND CCT BETWEEN SUPER AND HYPER-DUPLEX STAINLESS STEELS

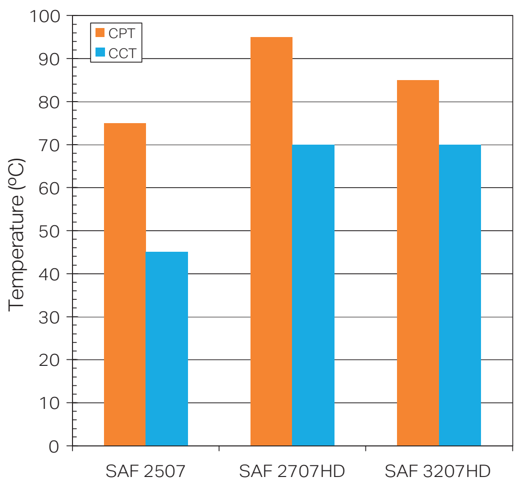

Figure 4a: Critical temperature assessed using modified G-48A and MTI-2 testing.

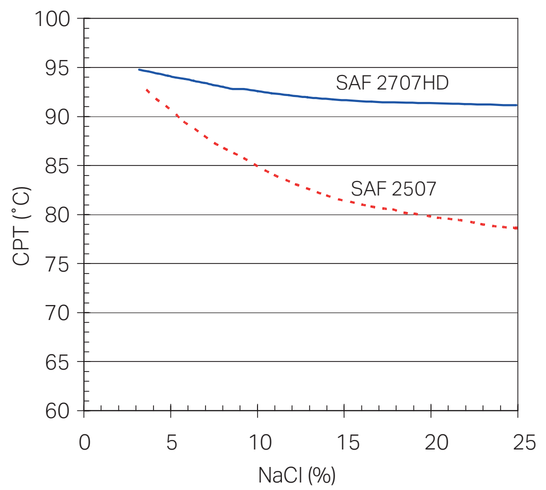

Figure 4b: Critical pitting temperatures (CPT) at varying concentrations of sodium chloride, from 3 to 25% (potentiostatic determination at +600mV SCE with surface ground with 220 grit paper).

AVOIDING MATERIAL FAILURE

Stress corrosion cracking (SCC) is perhaps the most serious form of corrosion encountered in industrial processes as it can lead to rapid material failure. Figure 5 shows a comparison of the stress corrosion cracking resistances of the hyper-duplex stainless steel and the austenitic stainless steels. The SCC resistance of hyper-duplex stainless steel in chloride solutions at high temperatures is much higher than those of the compared austenitic stainless steels. There were no signs of SCC in the hyper-duplex stainless steel in the 1000 ppm Cl-solution at up to 300°C and in the 10000 ppm Cl-solution at up to 250°C.

ADVANTAGES OF DUAL-PHASE STRUCTURE

The standard austenitic grades AISI 304 and 316 can crack at very low chloride levels. In many cases, the austenitic steels become more resistant at Ni levels above 25% (Sanicro 28 in Figure 5). The hyper-duplex alloys, however, have even higher resistance due to their dual phase structure.

FIGURE 5: COMPARISON OF STRESS CORROSION CRACKING RESISTANCE OF HYPER-DUPLEX STAINLESS STEEL AND AUSTENITIC STAINLESS STEELS.

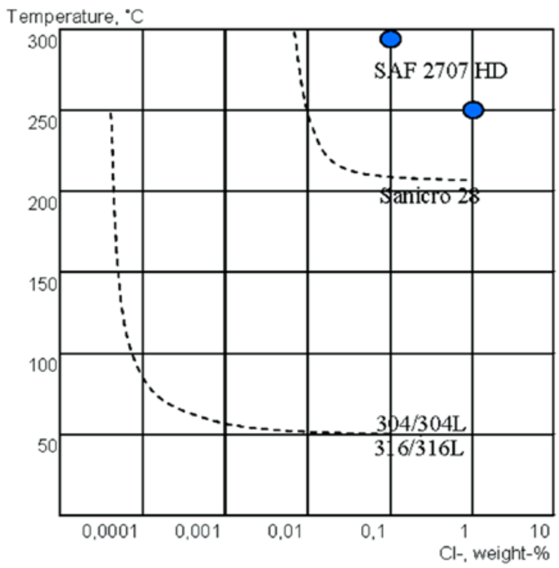

Figure 5: Comparison of stress corrosion cracking resistance of hyper duplex stainless steel and austenitic stainless steels. The tests were performed in an autoclave, where the samples were loaded to the yield strength level. The pressure was approximately 100 bar, oxygen content was 8 ppm. Fresh NaCl solution was pumped constantly into the chamber and duration of the test was 1000h. Sanicro 28 = UNS N08028. For hyper DSS SAF 2707HD, no failure after 1000 hours was observed.

The SCC tests were performed in an autoclave in which samples were loaded to their yield strength levels. The pressure was approximately 100 bar and oxygen content was 8 ppm. Fresh NaCl solution was pumped constantly into the chamber and the duration of the test was 1,000 hours. Sanicro 28 = UNS N08028. For hyper DSS SAF 2707HD, no failure after 1,000 hours was observed.

HIGHER MECHANICAL PROPERTIES

Far at sea, in rough conditions and under high subsea pressures, duplex stainless steels are put to the test on a number of mechanical parameters. These include tensile properties, impact toughness, fracture toughness and fatigue resistance.

Let's look at a few of these and see how the new generation of hyper-duplexes stainless steels compare with each other and other duplex grades as well.

"DUE TO THEIR HIGH AMOUNTS OF ALLOYING ELEMENTS, HYPER- DUPLEX STAINLESS STEELS OFFER VERY HIGH TENSILE PROPERTIES"
PASI KANGAS

SUPERIOR TENSILE PROPERTIES

Due to their high amounts of alloying elements, hyper-duplex stainless steels offer very high tensile properties. Actually, the hyper-duplex stainless steel SAF 3207 HD in the quenched - annealed condition shows the highest strength among the existing duplex stainless steels. It offers 20% higher tensile properties than those of super-duplex Sandvik SAF 2507. Figure 6a shows the influence of temperature on the 0.2% proof strength of two hyper-duplex stainless steels – SAF 2707 HD and SAF 3207 HD – and super-duplex stainless steel SAF 2507 tube materials with a wall thickness of up to 4 mm. Note how the strength decreases slightly with increasing temperature.

FIGURE 6: TENSILE PROPERTIES OF HYPER-DUPLEXES SAF 2707 HD AND SAF 3207 HD AND SUPER-DUPLEX SAF 2507 TUBE MATERIALS WITH A WALL THICKNESS OF UP TO 4 MM.

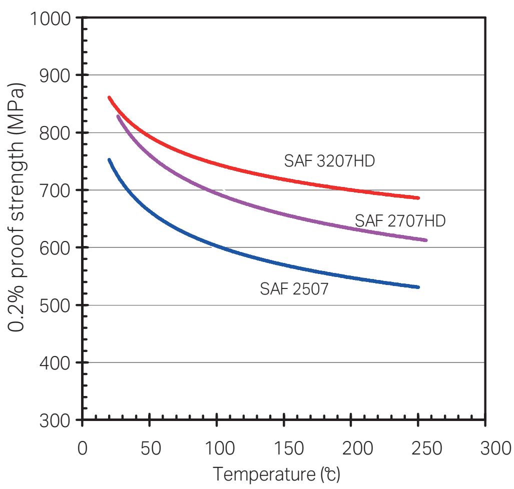

Figure 6a: Tensile properties in 0.2% proof strength versus temperature.

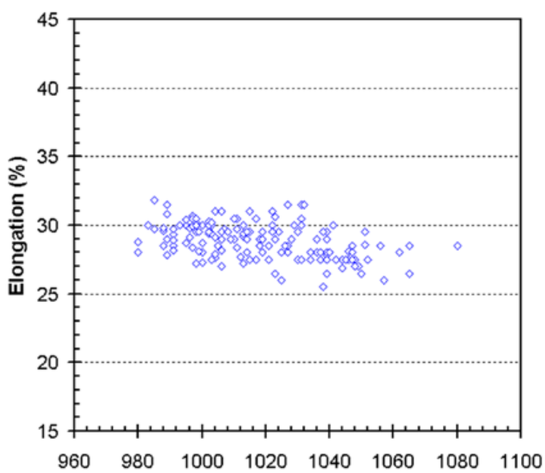

Figure 6b: Elongation versus 0.2% proof strength of SAF 3207 HD tube materials.

HIGH DUCTILITY, HIGH STRENGTH

In spite of their high strength levels, hyper-duplex stainless steels still exhibit high levels of ductility. The elongation of the material in the quenched - annealed condition is higher than 20% (Figure 6b). It is interesting to note that the elongation of SAF 2707 HD tube materials changes little with increasing the strength, as shown in Figure 6b. This can be attributed to the very fine-grained austenitic and ferritic phases in the materials (Figure 7).

FIGURE 7: COMPARISONS OF HYPER-DUPLEX STAINLESS STEEL WITH A DIMENSION OF 14.7X1 MM.

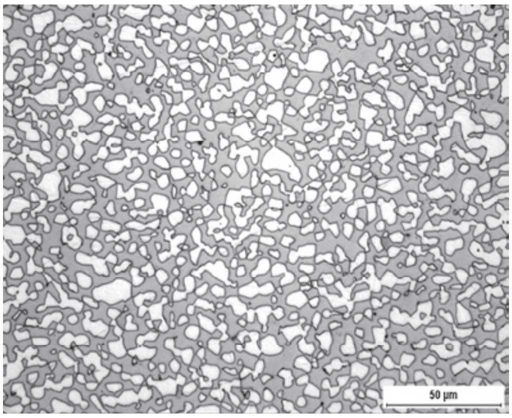

Figure 7a: Microstructure of hyper DSS SAF 3207 HD tube material with a dimension of 14.7x1 mm. The white phase is austenite, and the grey phase is ferrite.

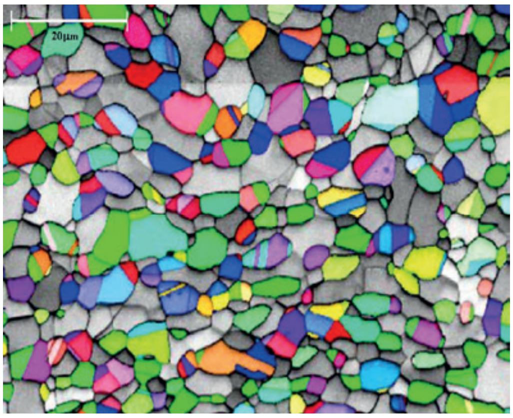

Figure 7b: Grain structure with color grains showing the austenitic phase (3.6mm), and grey grains indicating the ferritic phase (5.1mm).

HIGH IMPACT TOUGHNESS

In the search for new oil, the impact toughness of pipe, tube and other materials when exposed to extreme temperatures becomes increasingly important. When choosing between different steel grades in the duplex family, this can also be a question.

RIGOROUS IMPACT TESTING

Impact toughness is defined as the amount of energy required to fracture a material at high velocity by impact testing. This variable can be used to predict the likelihood of brittle fracture. Figure 8 shows the change in impact toughness of two hyper-duplex stainless steel materials (SAF 2707 HD and SAF 3207 HD) when exposed to various testing temperatures. As shown, both grades have very high impact toughness in the temperature range used, with the ductile-to-brittle transition temperature below -50°C. It seems that although the tensile strength of the hyper-duplex SAF 2707 HD is higher than that of super-duplex steel (S32750), the impact toughness is comparable (Fig 8a).

FIGURE 8: TYPICAL TEMPERATURE TRANSITION CURVES OF IMPACT TOUGHNESS

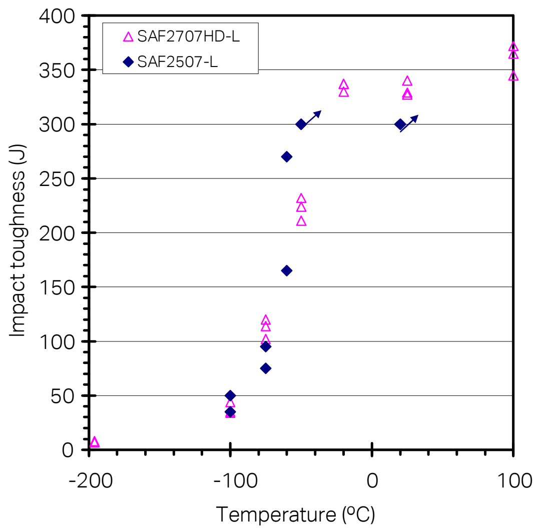

Figure 8a: Impact toughness of SAF 2507 and SAF2707 HD (Charpy-V 10x10mm) in the longitudinal directions. The arrow indicates that the values should be higher because this is the maximum value or limit of the impact tester.

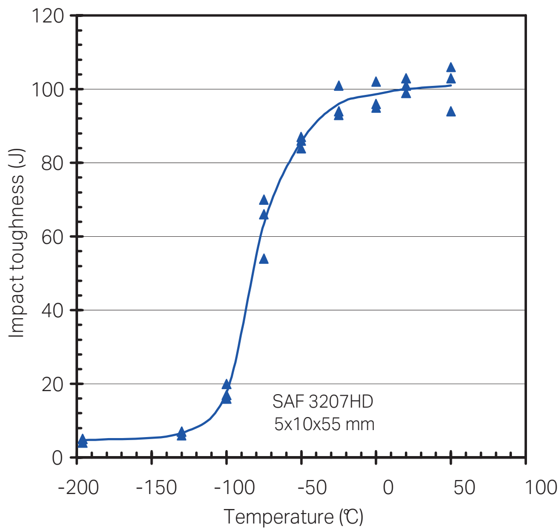

Figure 8b: Impact toughness of SAF 3207 HD in the longitudinal direction, (Charpy-V 10x5mm).

FAVORABLE FRACTURE TOUGHNESS

Another key challenge in the offshore oil and gas industry, particularly in harsh subzero conditions, is fracture toughness. This can be defined as the resistance of a material containing pre-existing sharp cracks to fracture under conditions of crack tip plane strain or stress. For duplex stainless steels, fracture toughness is usually evaluated through the fracture toughness testing such as CTOD (crack-tip opening displacement)[6,7].

"IT SEEMS THAT THE CTOD VALUES OF THE HYPER DUPLEX STAINLESS STEELS ARE MUCH HIGHER THAN THE SPECIFIED CTOD REQUIREMENTS."
PASI KANGAS

SUPERIOR CTOD VALUES

A comparison of CTOD values of the hyper- and super-duplex stainless steels is shown in Figure 9a. Here, it can be noted that the hyper-duplex stainless steel SAF 2707 HD has a CTOD value that is even higher than super-duplex SAF 2507. What's more, the hyper-duplex stainless steel SAF 3207 HD shows a high CTOD value. It should be mentioned that CTOD value depends largely on the thickness and geometry of the testing specimen.

The CTOD value decreases with increasing specimen thickness. Figure 9b shows the influence of specimen thickness on the CTOD requirements[8] for the super or hyper-duplex stainless steel plate materials with surface flaws. It seems that the CTOD values of the hyper-duplex stainless steels are much higher than the specified CTOD requirements.

FIGURE 9: A COMPARISON OF CTOD VALUES OF HYPER- AND SUPER-DUPLEX GRADES

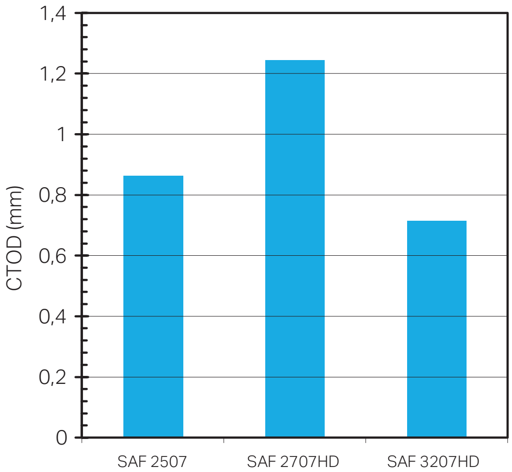

Figure 9a: Comparison of CTOD values of hyper- and super-duplex grades.

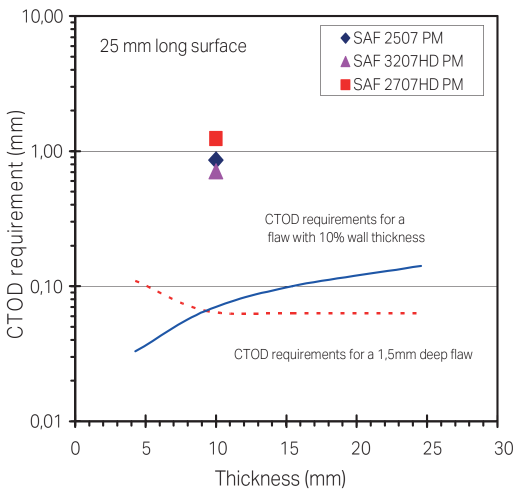

Figure 9b: CTOD requirements for the plate materials with surface flaws.

EXCELLENT FATIGUE PROPERTIES

Another key challenge is materials fatigue. This can be defined as the progressive, localized, permanent microstructure change in a material suffering fluctuating stresses that are usually much lower than the static tensile strengths. The fatigue limit or endurance and fatigue crack growth are the most important fatigue properties to be considered. Figure 10 provides a good overview of the fatigue and corrosion fatigue properties of hyper and super-duplex grades.

HIGHER FATIGUE STRENGTH

As shown in Figure 10a, hyper-duplex stainless steels exhibit higher fatigue strength or limits than super duplex stainless steels. This is mainly due to the fact that hyper-duplex grades have higher tensile strength and similar elongation. Since hyper-duplex stainless steels show excellent corrosion resistance, the influence of artificial seawater on the fatigue life of the steel material is relatively small. As a result, they also show higher corrosion fatigue strength than super-duplex stainless steel (Figure 10b).

FIGURE 10: FATIGUE PROPERTIES OF HYPER- AND SUPER-DUPLEX STAINLESS STEELS EVALUATED USING WOHLERFULLA.*

*The line after 2x106 cycles indicates a fatigue endurance or strength at 2x106 cycles

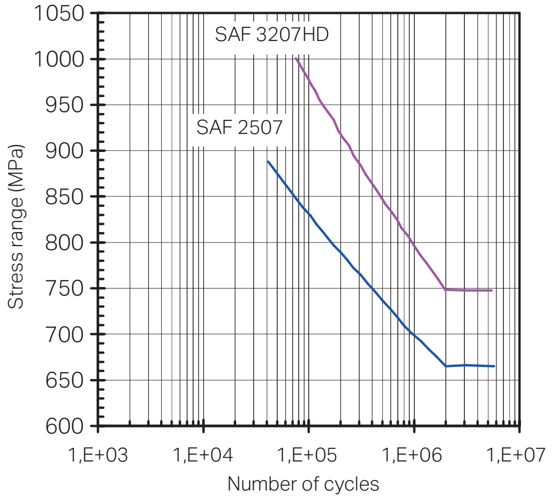

Figure 10a: High-cycle fatigue strength (HCF) in air, tubes.

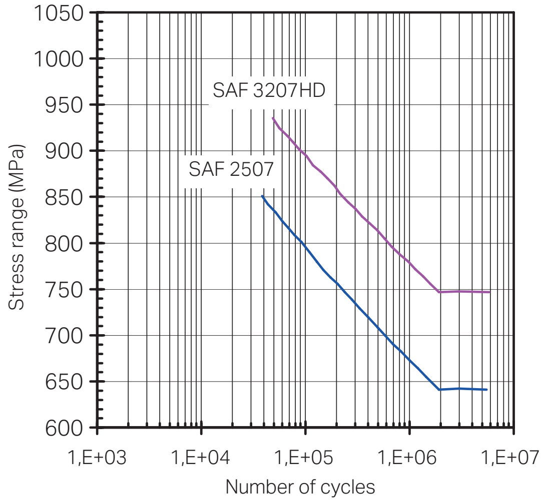

Figure 10b: Corrosion fatigue in artificial seawater tubes.

SOLVING WELDABILITY CHALLENGES

Choosing the right filler materials, temperatures and welding techniques to fabricate hyper-duplex steel can also be a challenge. That is why a welding consumable designated Sandvik 27.7.5.L has been specially developed for this purpose.

High nitrogen content in the material gives a rapid austenite formation during welding. To obtain a microstructure free from intermetallic precipitates, it is important to control the ferrite content. Generally, the weld metal in the heat-affected zone (HAZ) should have a ferrite content of 30-70%.

"BASED ON THE RESULTS FROM EXTENSIVE WELDING TRIALS, IT CAN BE SHOWN THAT THE WELDABILITY OF HYPER-DUPLEX STAINLESS STEELS IS GOOD. BOTH WELDED JOINTS AND OVERLAY WELDS SHOW FAVORABLE STRENGTH AND DUCTILITY AS WELL AS HIGH PITTING RESISTANCE"
PASI KANGAS

FIGURE 11: MICROSTRUCTURES OF THE WELDED SAF 2707HD TUBE MATERIAL

Figure 11a: Welded microstructure in center of weld metal.

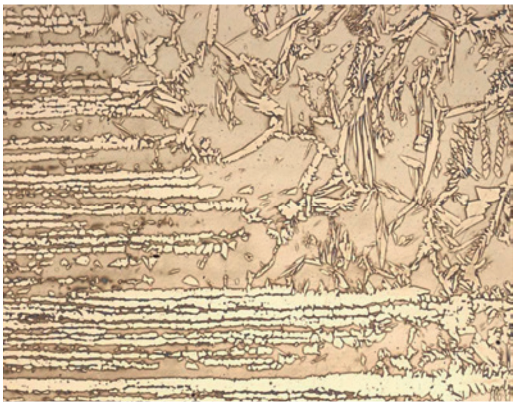

Figure 11b: Welded microstructure in heat-affected zone (HAZ) and fusion line.

OPTIMIZING THE MICROSTRUCTURE

Figure 11 shows the microstructures in the weld metal and heat affected zone (HAZ) of the hyper-duplex stainless steel S32707 (SAF 2707HD). The morphology and phase balance are typical one-pass welds in duplex stainless steels. There are no visible intermetallic precipitates in the weld or HAZ.

Based on the results from extensive welding trials, it can be shown that the weldability of hyper-duplex stainless steels is good. Both welded joints and overlay welds show favorable strength and ductility as well as high pitting resistance.

APPLICATIONS IN THE OIL AND GAS INDUSTRY

Due to the extremely high critical pitting temperature (CPT) and critical crevice corrosion temperature (CCT) of hyper-duplex stainless steels, it is possible to use these materials for applications where high corrosion resistance and high service temperature are essential (Figure 12).

The favorable combination of extra-high strength and high ductility enables hyper-duplex stainless steels to be designed with substantial reductions in wall thickness for the same specifications. This, in turn, leads to a reduction of weight in applications such as subsea umbilicals, control lines and ultra-deep seawater injection. In all of these situations, the alloy's superior properties can be fully utilized to ensure reliability and safe service[10,11]. The followings are some examples.

FIGURE 12: POSSIBLE APPLICATION AREAS OF HYPER-DUPLEX STAINLESS STEELS

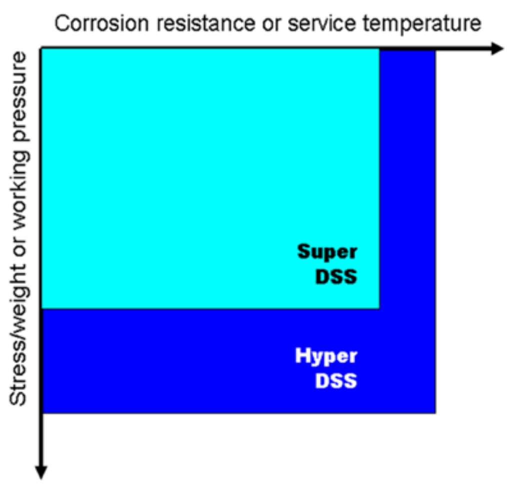

Figure 12: Welded microstructure in center of weld metal.

SUBSEA OR DEEP SUBSEA APPLICATIONS

As the oil and gas industry moves further offshore into ultra-deep waters and extreme conditions, the demands are increasing on the subsea umbilicals that control the infrastructure. Deeper waters and in some cases higher temperatures call for stronger and more corrosion-resistant stainless steel materials than existing duplex and super-duplex stainless steels can handle reliably.

DEEPER, MORE CORROSIVE WELLS

The hyper-duplex material Sandvik SAF 3207 HD has been developed as a problem-solver for deep wells and corrosive conditions. One clear benefit is the proven yield strength of typical umbilical sizes in hyper-duplex, which is roughly 20% higher than for super-duplex steels (UNS S32750). As a result, the weight of longer umbilical tie-backs can be considerably reduced while withstanding even higher external pressure – not to mention corrosion and fatigue resistance.

RAW SEAWATER INJECTION

Another application of Sandvik SAF 3207 HD is raw seawater injection where untreated seawater is injected into the well in order to replace the retrieved oil and hence increase output from the well. Because the tube strings and threaded connectors need to be able to support their own weight, mechanical strength is very important. The ability to resist the corrosive effects of warm seawater along with favorable crevice corrosion resistance are of vital importance.

HYDRAULIC LINES & PRODUCTION TUBING

Research shows that Sandvik SAF 3207 HD is an excellent solution for such application. Other potential applications for Sandvik SAF3207 HD are for hydraulic lines and in production tubing.

SUMMARY

Due to the unexpectedly positive synergistic effects of adding Cr, Mo and N simultaneously in the alloying process, it is possible to develop highly alloyed duplex stainless steels.

The result of this innovative process is hyper-duplex stainless steel with high levels of Cr, Mo and N, providing a clean microstructure, good properties and ease of fabrication. In short, this advancement represents a major technology leap in the ongoing development of high-alloyed duplex stainless steels.

Research shows a number of key findings about hyper duplex stainless steels that set them apart from the rest of the modern duplex family. Specifically, they offer the following key properties:

SUPERIOR PROPERTIES OF HYPER DUPLEXES

- Highest critical pitting temperature (CPT)
- Highest critical crevice corrosion temperature (CCT)
- Highest tensile and fatigue strengths
- Good weldability and high toughness

With a good combination of extreme high corrosion resistance and strength, hyper-duplex stainless steels have been successfully used in the chemical and petrochemical industry and oil refinery, and can be used in the areas where even higher corrosion resistance and service temperature or high strength/weight ratios are required.

"THE RESULT OF THIS INNOVATIVE PROCESS IS A HYPER-DUPLEX STAINLESS STEEL WITH HIGH LEVELS OF CR, MO AND N, PROVIDING A CLEAN MICROSTRUCTURE, GOOD PROPERTIES AND EASE OF FABRICATION."
GUOCAI CHAI

CONCLUSIONS, ACKNOWLEDGEMENTS AND REFERENCES

Test showed that no cracks or corrosion were observed after using the four-point bend method at up to 55kPa (8 PSI) partial pressure of H_2S. When tests were carried out using constant load at a partial pressure ranging from 35 kPa (5 PSI) H_2S at 25% NaCl, no cracking or corrosion was present.

However, with a pressure of 52kPa (7.5 PSI) H_2S and concentration of 15% NaCl, slight pitting corrosion was present, indicating that the material is close to its limit. It thus seems reasonable to conclude that a limit of 5 PSI H_2S would be suitable for this new UNS S33207 hyper duplex.

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Do you have further questions regarding corrosion, temperatures, pressure, pitting and other subsea challenges? If so, we'd be happy to help you – even with basic advice. Having worked with the oil and gas sector for 50 years and serving 100% of all major fabricators and oil companies in all offshore regions, we have a depth of knowledge to share. Please go to our R&D Knowledge Center to get in touch with our experts or to download white papers, case studies and other relevant product information.

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