New Products

Industrial Hydrovar™

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therefore tend to be shut down and restarted about three or four times a month. So maintaining the plant in restart condition is important for maintaining supply to the grid.

District heating

The final application for the Vogel Hydrovar pumps at the Theiss station is for pumping hot water to the district heating system supplying the nearby community of Krems, 6 km from the plant. Cooling water leaves the power station between 90 and 120 degrees centigrade and this heat would go to waste without the district heating system. (Krems, incidentally, is famous for its white wines and peach growing.)

Hydrovar experience

Commenting on his experience of the Hydrovar speed control system in the plant, Horst Kleinrath says: “The energy saving is the most important feature for us. We have almost certainly saved about 40% of the energy we would have used without the Hydrovar speed control. None of our pumps ever need to run at full power so the control system has been very useful for us.”

He also comments that the soft start of the Hydrovar pumps simplifies the plant restart. ‘Hard’ pump starts, i.e. from zero to immediate full speed, can cause water hammer which can damage a system so without soft start facilities, automatic relief valves would have to be fitted. A minimum of one such control valve would be needed for each of the pumps, making a total of 23-24 valves at least. These are not required when Hydrovar equipment is fitted.

Another big advantage that Horst Kleinrath has noted, even after this relatively short period of operation with the Hydrovar, has been the noise reduction. Not only does this make for a much more pleasant work environment but it also enables the station to meet noise control regulations. In areas where personnel work the noise level may not exceed 80 dB and the variable speed pumps provided by Hydrovar ensure compliance.

The Theiss power station is owned and operated by EVN (Energie Versorgung Nieder-Österreich) which translates as Energy production and distribution for lower Austria. ▬

Material Matters

Duplex Stainless Steels - Several Generations in the Making

Stephen J. Morrow
Global Manager of Materials Technology

Question

What is duplex stainless steel, how does it differ from the austenitic stainless steels such as CF8M or Type 316, and what are its advantages or disadvantages? Also, what's the significance of nitrogen all about?

Introduction

Duplex stainless steels (DSS) comprise a family of stainless steels with a wide range of compositions and corrosion resistance. They are typically higher in chromium and lower in nickel than austenitic stainless steels have similar molybdenum levels, generally contain nitrogen, and some grades contain copper

The term “duplex” will refer to those stainless steels that are chemically balanced to solidify primarily in the ferrite phase, with austenite forming as the secondary phase upon cooling. Composition balancing results in these dual-phase alloys (hence the name duplex), with yield strengths two-to-three times that of the austenitic grades.

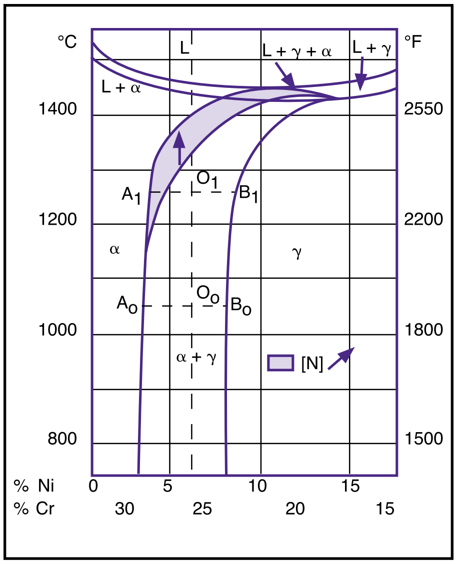
Historical Background & Alloy Development

DSS were principally developed to provide an alternative material having improved resistance to chloride stress corrosion cracking, compared to the austenitic stainless steels such as CF8M or Type 316. At first glance, the literature might appear to suggest that the duplex stainless steels are a recent development. However, DSS first appeared in the late 1920's. A nickel shortage in the early 1950’s sent steel producers looking for alternative alloys to replace nickel. Manganese and nitrogen were tried, but the materials were difficult to cast and had insufficient corrosion resistance. After considerable testing, alloys of approximately 22Cr-5Ni (2205) showed promise, but were later shelved when the nickel shortage ended, and interest diminished.

In the late 1950's, the Alloy Casting Institute (ACI) commissioned metallurgists at Ohio State to develop a high strength cast stainless steel having a corrosion resistance comparable to CF8M but with improved chloride stress cracking resistance. This cast alloy became known as CD4MCu and appeared as a standard duplex grade in 1959. Wrought alloys were also developed during this period, with Type 329 being the first grade commercially offered.

While these “first-generation” DSS offered improvements, the localized corrosion resistance and weldability were inadequate since the welded alloys lost their optimal microstructure balance. In order to restore corrosion resistance, a post-weld solution anneal heat treatment was needed to restore properties. CD4MCu was particularly troublesome due to cracking tendencies, resulting from a microstructure imbalance that could exceed 70% ferrite in welds, and heavy casting sections.

Significant refinements occurred in the following decades, which improved the welding, ductility, and corrosion resistance through the use of nitrogen. The introduction of the argon-oxygen-decarburization (AOD) steel melting technology, which began in the early 1970's, permitted precise and economical control of nitrogen. The effect of the AOD and related processes opened up new ranges of alloy compositions to commercial development. The distinction between first, and second-generation duplex stainless steel, focuses on the use of nitrogen as a deliberate alloy addition.



Effect of nitrogen addition on the pseudo-binary diagram at constant iron section (68 Wt% Fe) of the Fe-Cr-Ni ternary system.

Typical CD-4M Cu alloy. Solution annealed at 2000°F.

Composition And Microstucture

Duplex stainless steels (DSS) are dual-phase alloys based on the iron-chromium-nickel system. The structure is achieved by proper control of the composition and thermal processing. DSS solidify primarily as ferrite with the austenite forming as a secondary phase upon cooling. Solidification and processing temperatures affect the transformations, which affect the amount of ferrite formed during cooling or heating.
DSS contain elements that promote the formation of ferrite (e.g. Cr, Si, Mo, W); and those that promote the formation of austenite (e.g. Ni, Mn, Cu, C, N). It is composition balancing that determines the final microstructure and properties.

Selecting the proper ferrite level depends upon the application and service requirements. The steel industry generally accepts a range of 40-60% ferrite in DSS, although the ASTM A890 cast duplex stainless steel standard specification recognizes a range of 30-60%. Ferrite levels below 30% decrease the strength and increase the risk of stress corrosion cracking; while levels greater than 60% reduce corrosion resistance, toughness, and increase the risk of cracking.
A minimum of 55% austenite is suggested to maintain toughness and localized corrosion resistance. Yet a level of 55% ferrite is also recommended for strength, resistance to corrosion fatigue, and chloride stress corrosion cracking resistance. Adjusting the composition to provide for an optimum ferrite level of about 45-50% is widely recommended.

Nitrogen Enhancement

The addition of nitrogen (a strong austenitizer), allows the chromium and molybdenum levels (strong ferritizer) to be increased. This has led to more highly alloyed “second-generation” DSS in use today. Although nitrogen was first utilized to replace the more expensive nickel as an austenite former, it was discovered that it offered additional benefits such as improved weldability, increased strength, toughness, and better corrosion resistance. Nitrogen also causes austenite to form from the ferrite at higher temperatures, which increases the austenite volume, and greatly reduces cracking.

As stated previously, the AOD technology permitted the precise and economical control of nitrogen, which allowed for composition optimization. Nitrogen greatly reduces the chromium partitioning between the two phases, and enhances the localized corrosion resistance. Preferential partitioning of elements between the ferrite and austenite occurs, leading to increased Cr, Mo, and Si levels in the ferrite phase. This increases corrosion resistance of the ferrite, but also increases susceptibility to alpha-prime, and sigma-phase embrittlement. Partitioning also lowers the corrosion resistance of the leaner austenite phase, unless the alloy is nitrogen enriched. Nickel and nitrogen partition mainly into the austenite, improving its corrosion resistance. Nitrogen along with nickel also reduces the tendency towards sensitization, suppressing the formation of sigma phase, and other brittle precipitates. When considering corrosion performance, the effect of alloy partitioning (between phases) and nitrogen enhancement is very important.

Advantages & Disadvantages

DSS offers several advantages over conventional austenitic stainless steels. The combined mixture of ferrite and austenite provides unique properties, which makes the duplex alloys excellent choices to solve many problems. They are more resistant to sensitization and intergranular corrosion; chloride stress corrosion cracking; exhibit better localized and general corrosion resistance in many environments; and have yield strengths that are two-to-three times stronger.

Since ferrite and nitrogen increase the yield strength, the threshold stress required to produce stress cracking is higher. Improved fatigue strength, erosion resistance, and cavitation resistance are also offered due to greater strength and hardness. Pump and valve manufacturers have taken advantage of this strength benefit to allow for higher operating pressures, while offering cost effective designs that can reduce weight by utilizing DSS of thinner wall thickness.

Although DSS provide good mechanical properties and corrosion resistance, their use has some restrictions. Even with their advantages, DSS are more likely to form harmful compounds due to improper processing, than the austenitic stainless steels. The high alloy content makes them susceptible to embrittlement when exposed to high temperatures. For this reason a maximum operating temperature is usually placed on the duplex alloys, which is seldom considered for applications over 575°F (300°C), due to alpha-prime precipitation within the ferrite. This results in embrittlement and reduces impact toughness. The severity increases with chromium content and other ferrite forming elements. Since the maximum rate of embrittlement occurs around 885°F (475°C), it has become known as 885°F embrittlement.

The higher chromium and molybdenum content in DSS increases sensitivity to sigma-phase, which reduces ductility, impact toughness, and corrosion resistance. The high chromium content of the sigma phase leaves the surrounding matrix depleted of chromium, reducing the corrosion performance. The probability of sigma becomes important during solidification of heavy cast sections, prone to sigma formation when slow cooling. Proper solution anneal treatment, followed by a water quench will generally eliminate sigma and reverse its adverse effects.

Applications

Duplex stainless steels have found widespread application in recent years owing to their competitive combination of properties, corrosion resistance, and economics. Cost efficiency is one of the main reasons for selecting DSS. Reduced nickel (an expensive alloying element) and higher mechanical properties (reduce design thickness and weight savings), improve cost ratios. The corrosion resistance, increased strength, and erosion resistance make these alloys very attractive when considering life cycle cost.

The duplex alloys are produced in both cast and wrought forms in a number of chemical

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Tech Talk

Duplex Stainless Steel

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compositions of varying alloy contents.
In recent years DSS have become increasingly popular for seawater service, pulp & paper, and other process industries because of their corrosion and erosion advantages. They are commonly used in aqueous, acidic or chloride-containing services as replacements for austenitic stainless steels that have suffered either from chloride stress corrosion cracking, localized pitting or crevice corrosion, or when greater erosion resistance and strength are needed.

In many environments, duplex alloys show excellent resistance to general and localized corrosion. In this regard, they often rival the performance offered by more expensive high-alloyed austenitic stainless and nickel alloys. The slowness to adopt the DSS has been due to inherent conservatism within the engineering community, fear of prior generation welding issues, and the lack of specific performance details. While much of this is changing, the challenge for application engineers is to know when to make informed cost-effective use of the duplex stainless steels.

Concluding Comments

While I hope this has helped dispel much of the mystery and confusion associated with these materials, there are many other related topics that could be discussed in a general overview, but due to time restraints, must be omitted. Much more could be said about duplex stainless steel (DSS), and each grade could be discussed in detail with specific services in mind. However, this can not be accomplished here. Those who have specific applications in mind should contact their nearest application engineer to discuss the possibility of a duplex stainless solution to their service problem.

For those interested in learning more about duplex stainless steels there are many excellent publications and handbooks on the subject available from ASM, NACE, and numerous stainless steel producers or associations. Many technical papers and conference proceedings have been published over the past 30 years, which are generally available from these organizations, and others. ■

Initial Considerations of Medium Consistency Stock Pump System Design in the Pulp & Paper Industry

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Paper stock pulp in the consistency range of 8 to 16% is referred to as medium consistency pulp. Pulp fibers become a strong interlocked network and create high friction between the fiber and pipe wall. The fluid characteristics of pulp are clearly non-Newtonian. Traditional methods to pump pulp in the 8 – 16% consistency ranges began with positive displacement pumps and were extended to centrifugal pumps over the past twenty years.

The non-Newtonian fluid characteristics both within the pump and with respect to friction loss characteristics in the pipe system along with air content of the pulp present specific challenges for either positive displacement or centrifugal pumps in order to operate satisfactorily. This will explore some of the aspects involved with medium consistency centrifugal pump systems. Perhaps the first question to address is - Why a medium consistency centrifugal pump versus a positive displacement unit?

Some of the advantages offered by centrifugal pumps over positive displacement pumps are:

- Lower installation cost
- Lower maintenance cost and significant ease of maintenance when required
- Removal of air from pulp which can be detrimental in further unit operations such as chemical mixing in bleach plants
- Hydraulic capability to develop higher pressure required for O2 Delignification systems, EOP (pressurized peroxide) stages, and delivery of pulp to HD storage towers.

For effective centrifugal pumping of pulp suspensions in the 8 to 16% range there are three key areas to success. They are:

- Delivery system to the pump
- Air removal
- Simple control scheme

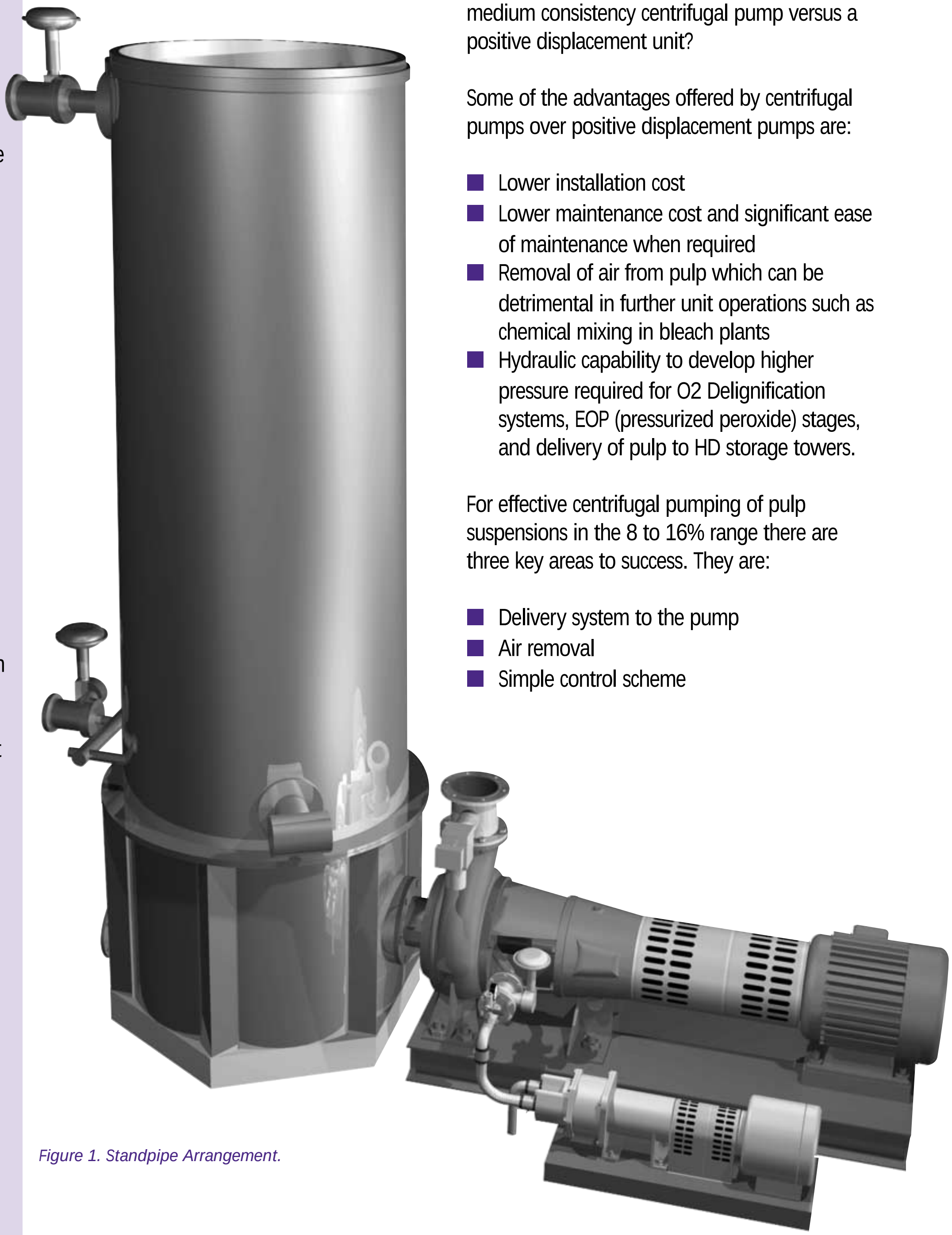

Figure 1. Standpipe Arrangement.