A Review of Duplex Stainless Steel- Applications, Advantages and Disadvantages

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Abstract- *One of the most crucial materials in the field of engineering is stainless steel. One of the most dependable materials, it is used extensively in chemical, petrochemical, off-shore, constructions and power production plants. Duplex alloys are the newest and fastest-growing family of stainless steels. The ferritic-austenitic grades are known as "Duplex" stainless steel because they contain an island of austenite inside a continuous matrix of highly alloyed ferrite. Ferritic/austenitic Fe-Cr-Ni alloy with between 30% and 70% Ferrite is what duplex stainless steel is made of. Steels with high concentrations of Cr, Mo, and N have high resistance to pitting and stress corrosion cracking in environments containing chloride. Since chloride-containing process streams, cooling waters, or deposits pose a concern for SCC and localized corrosion, it is frequently employed in oil refinery heat exchangers and other common applications. Modern duplex stainless steels may be welded well in general. This article focuses on:*

- *The properties of duplex stainless steel*
- *Duplex stainless steel grades and standards*
- *Duplex stainless steel applications*
- *Advantages and disadvantages of duplex Stainless steel*
- *Future trends of duplex stainless steel*

Keywords- Duplex Stainless steel, austenite, austenitic, ferritic, crevice corrosion

I. INTRODUCTION

As early as the 1920s, the idea of duplex stainless alloys was being studied. However, it wasn't until the 1930s that the first duplex alloys were put into production.

Due to their relatively high carbon content, the first duplex alloys were only used for casting and a limited range of applications.

Decarburization, however, enabled metal foundries to produce low-carbon steels with high chromium and nickel content by the end of the 1960s while also further balancing the ferrite and austenite structure.

A new generation of duplex alloys with improved performance and fewer drawbacks resulted from this.

Numerous parallels exist between these duplex stainless steels and contemporary alloys currently in use, particularly Duplex 2205 (UNS S21803/32205).

This alloy, which was created in the middle of the 1970s, is still widely used today because it offers corrosion resistance that is greater to that of typical austenitic stainless steel grades like 304 (UNS S30400), 316 (UNS S31600), and 317. (UNS S31700).

Although more recent standards employ a variety of chromium, molybdenum, and nickel concentrations, the original grades developed in the 1970s are to be credited for the variety of duplex stainless steels used today.

Duplex stainless steels have a two-phase microstructure, therefore it is called duplex.

The majority of duplex steels have a structure that is around 50% austenite and 50% ferrite, however specific ratios vary by grade.

Due to this, duplex stainless benefits from many of the advantages of the austenitic and ferritic steel families while also limiting their drawbacks. [3].

The specific metallurgic makeup of the steel varies by grade, as it does with other stainless steel families, but common elements include:

- Carbon
- Manganese
- Silicon
- Chromium
- Nickel
- Phosphorous

- Sulphur

Molybdenum, nitrogen, and copper may also be used to further influence characteristics of the final product. [3]\

II. THE PROPERTIES OF DUPLEX STAINLESS STEEL

- Duplex stainless steels have a crystalline structure that is composed of roughly 50% ferrite (a body-centered cubic structure) and 50% austenite (a face-centred cubic structure). Unlike two-phase alloys, where one of the two phases appears as precipitates, both of these phases coexist as a stable combination. In duplex stainless steels, the alloying components are either austenitisers (such as carbon, nickel, or nitrogen) or ferritisers (such as chromium, silicon, or molybdenum), which means they favour the production of the ferritic and austenitic phases, respectively.
- Duplex steels lose mechanical qualities like strength and toughness as well as corrosion resistance at high temperatures because the comparatively unstable ferrite phase in these steels transforms into the undesirable "(alpha prime) phase. Embrittlement is the term for this phenomena.[7]
- The maximum service temperature of duplex steels is limited by the creation of the alpha prime phase, which can begin to occur as low as 300oC. The worst temperature at which embrittlement occurs is 475oC.
- In comparison to typical martensitic, austenitic, and ferritic grades, typical duplex stainless steels exhibit a higher yield strength. Due to the precipitation of intermetallic phases, which begins to happen beyond 300oC, and the commencement of brittleness as they approach cryogenic temperatures, they have a limited range of operating temperatures [8].

III. DUPLEX STAINLESS STEEL GRADES AND STANDARDS

There were just a few grades available in the early days of duplex stainless steel manufacture, with UNS S31803 being the most often used. Following then, the creation of new grades began, and they were based on their final application, which may be divided into two categories:

- Stainless steels that were designed to function in extremely corrosive environments but with less emphasis on strength, such as hyper-duplex and super-duplex stainless steels.
- Lean and standard duplex stainless steels, which were intended for use in mildly corrosive conditions like structural applications and placed a greater emphasis on enhanced strength.

IV. DUPLEX STAINLESS STEEL APPLICATIONS

Duplex stainless steels are mostly utilized in specialised applications due to their drawbacks, which include poor formability and machinability as well as a more sophisticated metallurgical manufacturing process than ferritic, austenitic, and martensitic stainless steels.

Applications of duplex stainless steels take into account both their advantages and disadvantages, although the primary applications demand corrosion resistance, such as resistance to corrosive conditions that are acidic or caustic or resistance to pitting and crevice corrosion.[7]

Due to their excellent corrosion resistance, increased strength, and affordable pricing, duplex stainless steels are popular in a variety of industries and markets, including:

1. Vessels used in Paper production
2. Desalination
3. Oil and Gas
4. Construction
5. Food and Drink Storage

1. Vessels used in Paper production

For the construction of vessels that contain bleach and other corrosive liquids in the paper-processing industry, duplex stainless steels are preferred to austenitic and ferritic stainless steels.

2. Desalination

A strong test for corrosion resistance is the desalination of seawater, which exposes materials to highly corrosive chlorine in a high-temperature environment. Duplex stainless steels have taken over as the preferred material for making evaporators. Due to the greater strength and corrosion resistance of duplex stainless steels, they can also be produced with thinner cross sections.

Figure 1. Duplex stainless steel used in Desalination Plant

3. Oil and Gas

Manufacturing essential oil and gas sector components like pumps, pipes, and manifolds that require strong resistance to pitting and crevice corrosion is now achievable thanks to the introduction of duplex stainless steels with PRE numbers exceeding 40.

4. Construction

The production of load-bearing elements that also need corrosion resistance uses duplex stainless steels. The building of bridges across bodies of water or of structures that are near the ocean are examples of typical applications.

Figure 2. Duplex stainless steel used in bridge construction.

Figure 3. Sea Bridges

5. Food and Drink Storage

Due to their low cost and outstanding corrosion resistance and strength, lean duplex steels hold promise for the commercial storage of food and beverages during processing.

V. ADVANTAGES OF DUPLEX STAINLESS STEEL

While duplex stainless steel only comprises a small percentage of the global stainless steel market, it has a range of benefits when compared to traditional austenitic stainless steel and ferritic stainless steel grades.

Improved Strength

Many duplex grades are up to twice as strong as ferritic and austenitic stainless steel varieties.

High Toughness and Ductility

In comparison to ferritic grades, duplex stainless steel frequently offers superior pressure formability and greater toughness. Duplex steel's distinctive structure and properties frequently overcome any potential drawbacks, despite the fact that they frequently give lower values than austenitic steels.

High Corrosion Resistance

Duplex stainless steels, depending on the grade, offer equivalent (or superior) corrosion resistance than typical austenitic grades. Steels exhibit strong resistance to both crevice corrosion and chloride pitting for alloys with increasing nitrogen, molybdenum, and chromium content.

Cost Effectiveness

All of the aforementioned advantages are present in duplex stainless steel, which also requires less nickel and molybdenum. As a result, it is a more affordable option compared to many conventional austenitic grades of stainless steel. Since the price of duplex alloys is frequently less erratic than that of other steel grades, it is simpler to predict expenditures both up front and during the course of use. Because duplex stainless steel has more strength and corrosion resistance than austenitic steel, many parts made of it can be produced thinner and at a lower cost.

VI. DISADVANTAGES OF DUPLEX STAINLESS STEEL

Of course, due to this imperfection, duplex stainless steel also has shortcomings.

Duplex stainless steel, in comparison to austenitic stainless steel, has a poorer heat resistance. It is typically utilized in industrial environments with temperatures below 300 degrees Celsius. The degree of hardening, followed by cold working, is applied to high initial deformation of the duplex stainless steel pipe, duplex stainless steel plate, and the internal stress of these tubes, plates. This is in contrast to the effect of 18-8 type austenitic stainless steel. The medium temperature brittleness zones seen in duplex stainless steels, such as sigma and brittleness at 475 degrees, can also effect heat treatment and welding. Processing duplex stainless steel, which has a 25% chromium concentration, is more challenging than processing austenitic stainless steel.

VII. FUTURE TRENDS OF DUPLEX STAINLESS STEEL

Duplex stainless steels are continually being developed in new grades today. This project's primary goal is to further improve pitting corrosion resistance, which is accomplished mostly by upping the amount of important alloying elements like chromium, molybdenum, and nitrogen. The instability of the ferrite phase, which results in undesirable precipitates, is the principal drawback of these enhanced alloying elements. The difficulty is to balance the generation of Cr2N and other unwanted intermetallic phases while maintaining favourable qualities, primarily greater resistance to pitting corrosion. The development of a duplex steel grade, SAF 2707 HD, a 27Cr-7Ni-5Mo-0.4N with a PRE-number of over 50, is encouraging for the future of duplex steels generally.[8]

VIII. CONCLUSION

Due to an alluring mix of superior mechanical qualities, strong corrosion resistance, and relatively inexpensive cost as compared to other high performance materials, duplex stainless steels have become widely used. Duplex stainless steels have higher toughness and strength (in particular, very high proof strength), thanks to smaller grain sizes and a two phase austenitic ferritic microstructure that inhibits grain growth.

The super duplex grade, which was created approximately ten years ago, and other contemporary DSSs have been available on the market for many years. The nitrogen alloying, ferrite and austenite combination, and extremely fine-grained structure of DSSs all contribute to their extremely high mechanical strength.

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