Use of Duplex Stainless Steels in the Oil Refining Industry

API TECHNICAL REPORT 938-C
SECOND EDITION, APRIL 2011

AMERICAN PETROLEUM INSTITUTE

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Downstream Segment

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Introduction

Duplex stainless steels (DSS) are finding increasing use in the refining industry, primarily because they often offer an economical combination of strength and corrosion resistance. These stainless steels (SS) typically have an annealed structure that is generally half ferrite and half austenite, although the ratios can vary from approximately 35/65 to 55/45. The benefits expected from the use of DSS are maintained even to a ratio of 75/25 ferrite/austenite volume fraction (except for possible problems with weldability). Most refinery applications where DSS are used are corrosive, and DSS or other higher alloys are required for adequate corrosion resistance. However, some plants are also starting to consider DSS as a "baseline" material. [1] They are using it in applications where carbon steel may be acceptable, but DSS have been shown to be more economical considering their higher strength and better long-term reliability.

DSS are often used in lieu of austenitic SS, in services where the common austenitics would have problems with chloride pitting or chloride stress corrosion cracking (CSCC). Figure 1 shows a comparison of some DSS with various austenitic SS showing the difference in strength and chloride corrosion resistance [expressed as pitting resistance equivalent number (PREN)]. [2] This chart shows the excellent combinations of higher strength and corrosion resistance available with DSS. It also shows that there are "subfamilies" of specific grades within both the DSS and austenitic families. This is also illustrated in Table 1.

DSS have existed since the 1930s. However, the first generation steels such as Type 329 (UNS S32900) had unacceptable corrosion resistance and toughness at weldments. [3] [4] Hence, the initial applications were almost exclusively heat exchanger tubing, particularly in corrosive cooling water services, and shafting or forgings. In the 1980s, second generation DSS became commercially available which helped overcome the problems at the welds. These new grades had nitrogen additions, which along with improved welding practices designed for the DSS, led to the welds' mechanical (strength and toughness) and corrosion properties being comparable to the annealed base metal. The DSS most commonly used today in refineries include those with 22 % and 25 % Cr. The 25 % Cr (super duplex grades) usually also contain more molybdenum and nitrogen, and so have higher PREN values than the 22 % Cr duplex steels.

Table 1 lists the chemistries and UNS numbers of various common DSS, including some first generation DSS for comparison. Note that UNS S32205 is a "newer version" of UNS S31803 and is produced with higher nitrogen, chromium, and molybdenum contents. ASME and ASTM standards for these grades are given in Table 2, while Table 3 provides the mechanical properties. Type 316L and other austenitic SS are included for comparison.

This report has four primary objectives, which are to describe:

a) potential environment-related failure mechanisms and preventative measures to avoid them;

b) typical material specification requirements used by refiners;

c) typical fabrication specification requirements used by refiners;

d) examples of applications of DSS within refineries.

Use of Duplex Stainless Steels in the Oil Refining Industry

1 Scope

This report covers many of the “lean,” “standard,” and “super” grades of duplex stainless steels (DSS) most commonly used within refineries. The definitions of these terms have not been firmly established by the industry, and vary between literature references and materials suppliers. Table 1 shows how the various grades are being classified into “families” for the purposes of this report. The UNS numbers of the standard grades being used for corrosive refining services include S31803 and S32205, while the super grades include S31260, S32520, S32550, S32750, S32760, S39274, and S39277. The grades which are labeled as “semi-lean” include S32304 and UNS S32003, have either lower Cr or Mo than the standard grades, and are used in some process services that are less aggressive. These alloys and lean duplexes, such as S32101, have also been used for storage tanks and structural applications primarily for their higher strength compared to carbon steel (CS). It is observed that new DSS alloys are being introduced and are likely to continue to be introduced. These new grades can be reasonably placed in the context of this discussion based on their composition.

The product forms within the scope are tubing, plate, sheet, forgings, pipe, and fittings for piping, vessel, exchanger, and tank applications. The use of DSS for tanks is addressed by API 650, Appendix X. Later revisions of this report may consider expanding the scope to include castings and other product forms for pumps, valves, and other applications. Use of DSS as a cladding is also not included within the scope of this document.

The majority of refinery services where DSS are currently being used or being considered in the refining industry contain:

a) a wet, sour (H_2S) environment which may also contain hydrogen, ammonia, carbon dioxide, chlorides, and/or hydrocarbons;

b) water, containing chlorides, with or without hydrocarbons; or

c) hydrocarbons with naphthenic acids at greater than 200 °C (400 °F) but below the maximum allowable temperatures in the ASME Code for DSS (260 °C to 343 °C [500 °F to 650 °F] depending on the grade).

The specific plant locations containing these services are described in a later section and the report scope will be limited to these environments.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API Recommended Practice 582, *Welding Guidelines for the Chemical, Oil, and Gas Industries*

API Standard 650, *Welded Tanks for Oil Storage*

API Recommended Practice 932-B, *Design, Materials, Fabrication, Operation, and Inspection Guidelines for Corrosion Control in Hydroprocessing Reactor Effluent Air Cooler (REAC) Systems*

ASME *Boiler and Pressure Vessel Code (BPVC)* [1]*, Section VIII : Pressure Vessels; Division 1, Division 2*

ASME *BPVC*, Section IX: “Welding and Brazing Qualifications”

ASME B31.3, *Process Piping*

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[1] ASME International, 3 Park Avenue, New York, New York 10016-5990. www.asme.org.