

Failure Cases of Super Duplex Stainless Steel Pump Components

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ABSTRACT

25 Cr super duplex stainless steel (SDSS) centrifugal pumps have found vast applications in the Oil & Gas industry for produced water injection systems. An important factor in water injection pump material selection is the need to provide adequate corrosion resistance throughout the operating life cycle. Presence of solids and/or other contaminants in the pumped fluid (e.g. traces of solids, water cut percentage, hydrogen sulphide, chlorides, oxygen, and carbon dioxide content) can impact the corrosion resistance of water injection pumps. SDSS material is used in critical pump components such as casing body, impellers, shafts, balancing lines etc. The main focus of this paper is to present two cases of SDSS centrifugal pump component failures associated with a casing body and balancing line. Pitting corrosion mechanism was found to be the root cause of the both pump component failures. The factors contributed to these two failures will be discussed, in addition lessons learned & mitigation measures will be proposed.

Key words: Super duplex stainless steel, pumps, material selection, pitting corrosion, corrosion threats

INTRODUCTION

The application of corrosion resistance alloys such as 25% Cr super duplex stainless steel (25Cr SDSS) has expanded in the oil & gas industry recently as new technologies made it feasible for Oil and Gas operators to invest in high sour and corrosive fields. 25Cr SDSS material is often used in critical applications such as piping, rotating equipment, coolers, and instrument components etc. SDSS materials are well known for the 50/50 austenite (γ) and ferrite (α) microstructure which provides the combination of corrosion resistance and high-performance mechanical properties.^{1,2}

The selection of SDSS material for produced water systems is normally driven by many factors, such as presence of high chlorides levels, high H₂S partial pressure and presence of containments (e.g. oxygen). Premature failures of this equipment can be very costly, not only from repair and maintenance cost point of view but also the business implications, such as oil deferment, safety and environment aspects.^{3,4} Therefore, it is very critical for the oil & gas operators to proactively incorporate learnings from premature materials failures to prevent re-occurrence.

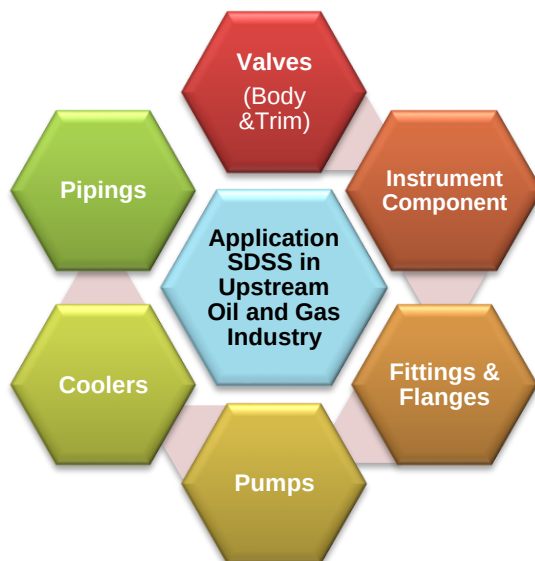


Figure 1: Super Duplex Stainless Steel Applications in Upstream Oil and Gas Industry

This paper is a compilation of two important cases where lessons learnt from each case related to SDSS pump component failures will be discussed. The first case study (designated #1) was regarding casted pump casing failure, whereas the second case study (designated #2) was related to 2" pump balancing line leak.

Case Study #1: Failure Investigation of SDSS Pump Casing

1.0 Background

SDSS water injection pump constructed in 2010 failed after 10 years in operations. The pump was procured in accordance with ASTM A995^{(1) 4} equivalent to UNS J93380 grade. Under pressure, what appeared to be a pinhole failure was identified on the underside of the SDSS casted pump casing. The operating suction pressure of this pump is approximately 20 barg, whereas the operating temperature range was between 20 to 50 °C. The maximum value of H₂S reported from the water analysis was 10 ppm and the chloride levels were less than 170000 ppm, which indicates that SDSS is operating within the integrity operating window of the company standards.

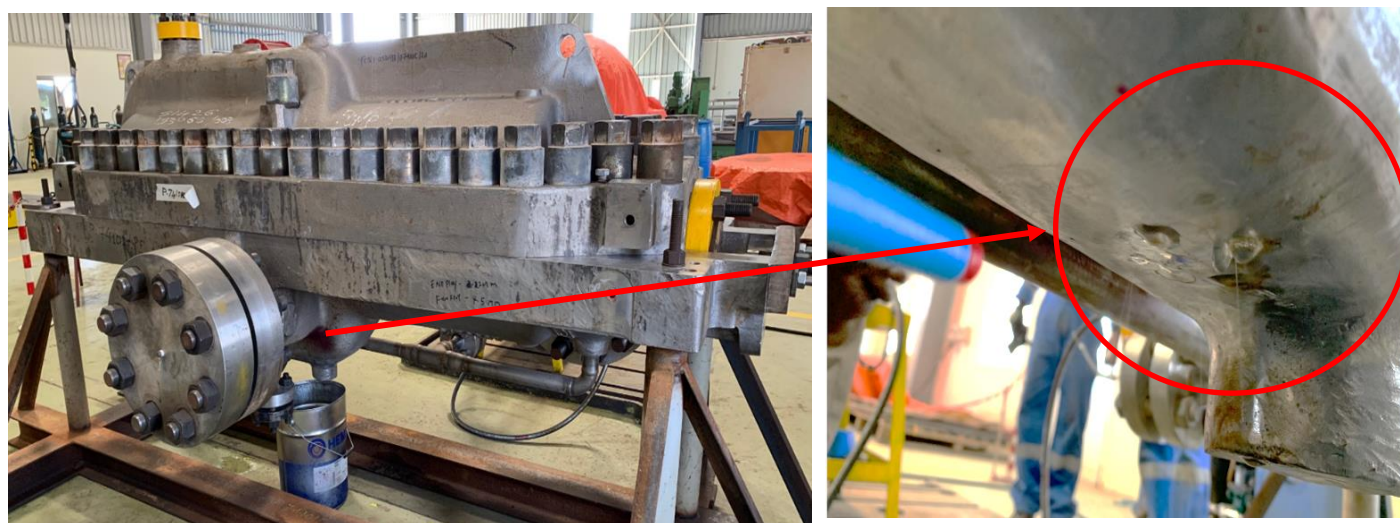


Figure 2: Pump Casing Failure Location

¹ American Society for Testing and Materials (ASTM), 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA

1.1 Metallography – Optical & Scanning electron Microscope observations

Two circular sections of material were extracted from the failed section of the casing. The microstructure of J93380 should consist of islands of austenite in a matrix of ferrite, and once etched the ferrite phases take on a darker appearance. However, immediately after etching it was clear that the microstructure of majority of the samples had a distinctly different appearance. This could be identified visually as weld material. The two cross sections of samples are shown in Figure 3 after etching. These samples clearly showed that weld material is present in the casted material, which could have been used as a repair method for casing material defect.

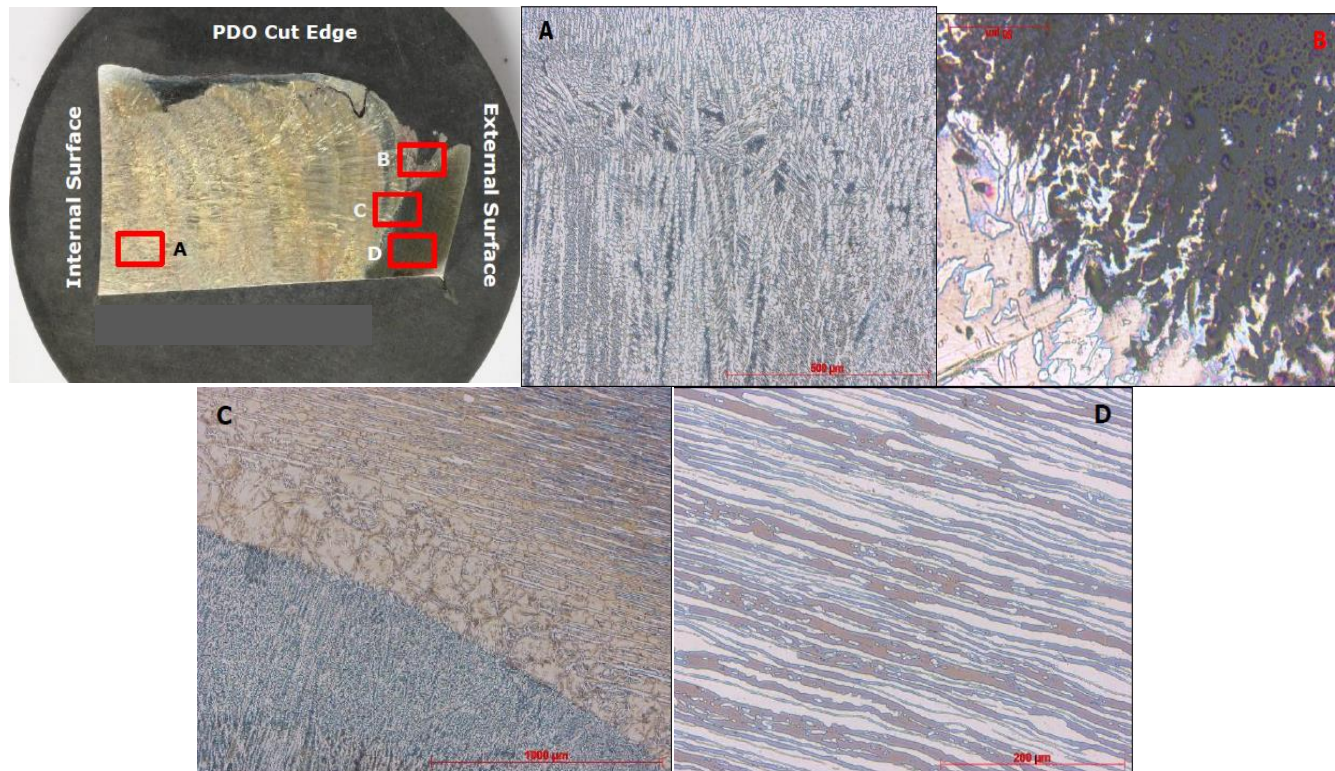


Figure 3: Micrographs from the cross section of the failed sample. A - Weld microstructure. B - corrosion around sample edges. C - Weld heat affected zone. D - Super Duplex Stainless Steel microstructure.

Phase balance analysis was conducted using the methods described in ASTM E562-19.⁶ A. The parent material phase count showed that the Volume Fraction (VV) of the ferrite phase was 52.5 ± 7.2 %, and for the weld material Volume Fraction (VV) of the ferrite phase was 48.6 ± 6.7 %. The acceptable range of ferrite is between 30 and 60%, and so both the parent material and the weld have an acceptable phase balance.

There is evidence of a leak path through the weld material, as shown in Figure 4. Either side of the weld porosity, there seemed to be variation in the microstructure of the parent material. The parent material at the top of the image in Figure 4 above had a typical banded microstructure, whereas the microstructure of the material below the pore was globular, as shown in Figure 5. In addition to the microstructural variation, another structural anomaly observed was evidence of recrystallisation of the ferrite phase in the material immediately adjacent to the pore. The banded microstructure in the parent material (left) particularly in the upper left-hand region of the image indicates that this material was hot worked. Clearly it is evident that this is not the structure of cast duplex stainless steel but appears to be forged material. The microstructure shown on the (right) is more consistent with a cast structure