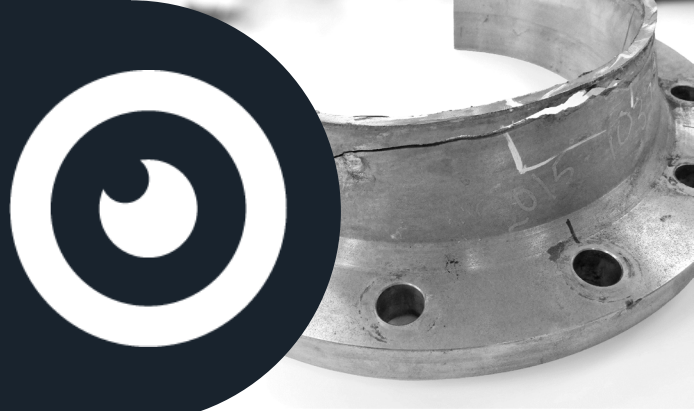
MATERIEX CASE 24-3

LEAKING SEAWATER SYSTEM

Sigma phase embrittlement in pipe flanges



BACKGROUND

Shortly after commissioning, leakage was discovered in a seawater pipe system that consisted of pipes and flanges that had been joined by welding. According to materials certificates, all parts of the system should meet the criteria for EN 1.4410/UNS S32750 super duplex stainless steel. Materiex was commissioned to perform a root cause investigation.

FINDINGS

- Cracks and defects were observed in several flanges whereas the pipes and welds appeared to be in good condition.
- A detailed study using SEM showed that the cracked flange had the character of a typical brittle cleavage mode of fracture (Figure 2).
- EBSD phase mapping of the microstructure confirmed the presence of sigma phase in all investigated flange samples (Figure 3a). However, the pipes had an expected microstructure free from sigma phase and with a homogenous distribution of ferrite and austenite (Figure 3b).
- The hardness was higher than specified in areas rich in sigma phase (>10 wt.-%), as shown in Table 1. The pipe hardness was lower and did meet requirements according to the materials specifications.
- The chemical composition of all analysed pipes and flanges conformed with the specified super duplex stainless steel.

CONCLUSIONS

The flange material had suffered from what in the literature is known as Sigma phase embrittlement that had dramatically reduced the corrosion resistance and ductility of the flange material. Exposure to seawater had subsequently accelerated local corrosion and promoted cracking. Sigma phase is an undesired chromium/molybdenum-rich intermetallic phase that can form during incorrect heat treatment of stainless steel. Most likely, too slow cooling through the 700-900 °C temperature range after heat treatment has led to the eutectoid transformation of ferrite into sigma phase and secondary austenite.

INVESTIGATION

- On-site inspection and collection of samples
- Fractography of cracked flanges (SEM)
- Verification of the chemical composition (XRF)
- Hardness measurements (Brinell)
- Verification of microstructure and secondary phases (LOM and EBSD)

SEM - Scanning electron microscopy
XRF - X-ray fluorescence
LOM - Light optical microscopy
EBSD - Electron backscatter diffraction

Figure 1. *Chemical characterisation of pipe system on-site.*

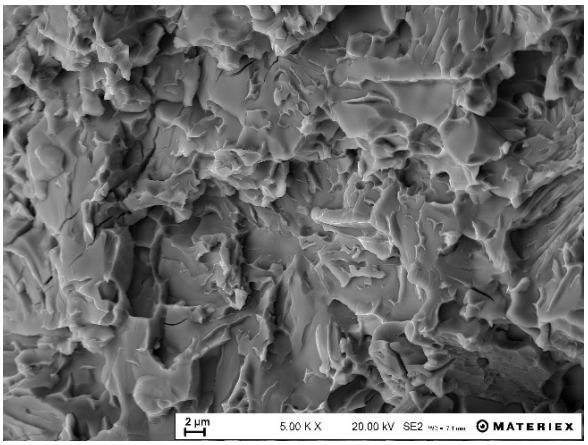


Figure 2. *Brittle cleavage mode of fracture, fractured flange.*

MATERIEX

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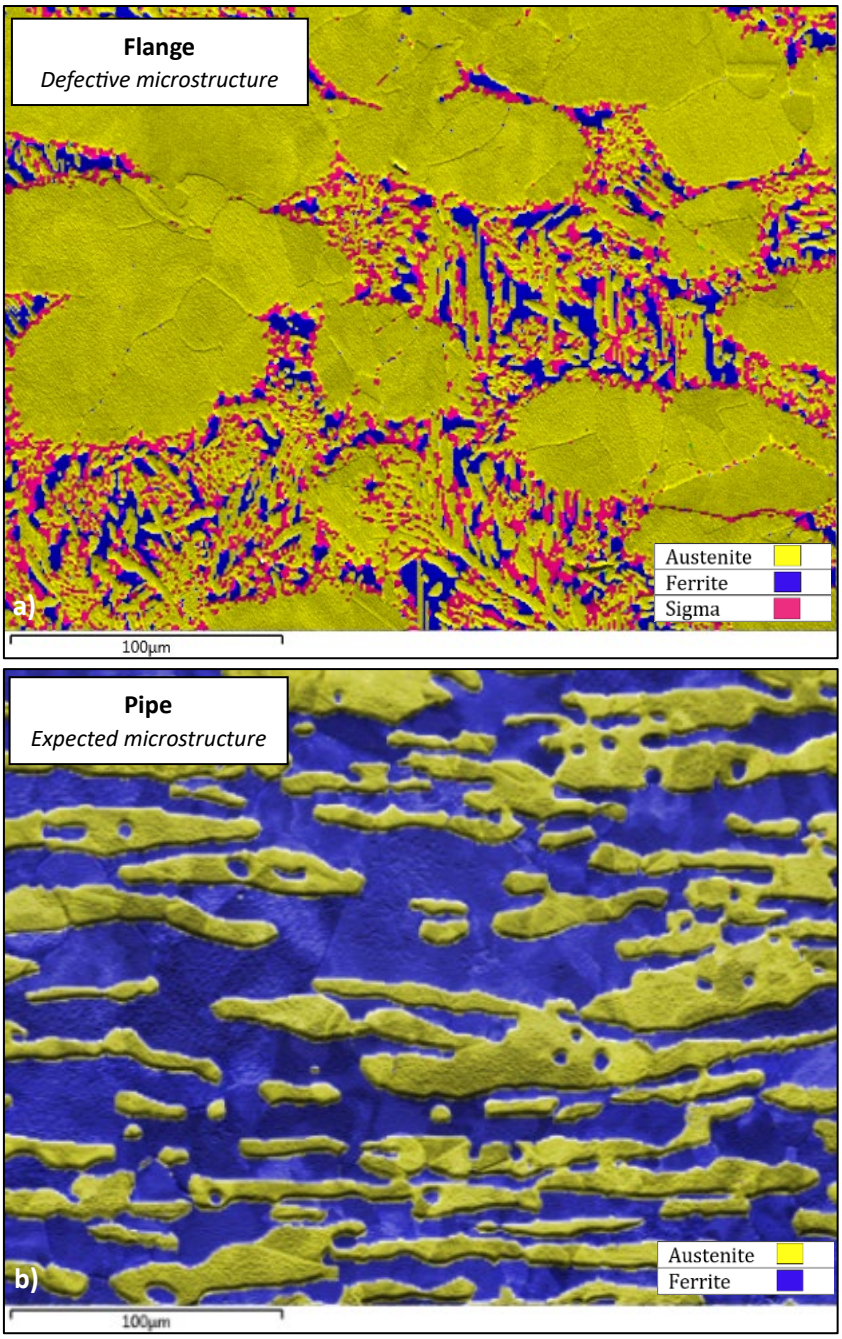

Figure 3. *EBSD- phase mapping showing a) a defective microstructure with the presence of sigma phase, b) expected microstructure with a homogenous distribution of austenite and ferrite.*

Table 1. *Hardness measurements and phase fraction.*

Sample	Hardness [HB]	Austenite [%]	Ferrite [%]	Sigma [%]
Flange	350	79	5	16
Pipe	225	67	33	-
Specification	*≤ 310*	*45-75*	*35-55*	-