Detection of defects initiation in weld joints

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Abstract: Welded joints on various pipelines, especially steam pipelines of fossil power plants, are exposed to high pressure and temperature of steam during operation. The applied stress and temperature together with the chemical composition and microstructure of the material have a major influence on the damage growth in these joints. Growth of defects as a time-dependent event, the sensitivity of the material to damage due to stress temperature and others plays a major role. In the case of steam pipes of fossil power plants, this is mainly creep damage. Early detection of these defects, especially at their initial stage, can help in managing the service life and thereby reducing the costs for operation, both by minimizing unplanned shutdowns as well as by planning any repairs in time. The work is focused on the detection of defect indications, especially creep damage occurring in weld joints and heat-affected areas. The aim is to distinguish manufacturing defects of welded joints from indications of early crack growth by ultrasonic testing. Indications from manufacturing defects may also be detected during testing and, if detected, will be evaluated in the same way as defects that are primarily targeted by the testing techniques. Several different techniques were tested on samples cut from the operated steam pipeline systems and compared with the results of metallographic analyses on selected parts.

Keywords: Ultrasonic Testing (UT), phased array, creep, Ultrasonic testing, pipelines, weld joints
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Motivation

Components exposed to a high temperature for a long time creep damage

Fossil power plant components, especially steam pipelines, are nearing the end of their projected lifetime and are more susceptible to creep damage.

Detection of creep damage by NDT methods is problematic, especially in early stage.
Creep damage phases

1. phase – Primary creep – the rate of creep is decreasing, the material reaches internal equilibrium

2. phase – the creep ratio is almost constant

3. phase – the creep ratio rises rapidly. This stage leads to fracture.

Creep Damage Assessment using Minimally Invasive Measurement Techniques, EPRI, Report No. 68601
Creep damage phases (cont’d)

1. Isolated cavities
2. Formation of microcracks
3. Macrocrack
Steam pipeline test piece

Weld sample from PK15 steam pipeline

- Removed due to the through-wall crack
- Dimensions 324x48 – 60 mm
- Material 15128.9 (14MoV63)
- Service parameters
  - $T = 540^\circ\text{C}$
  - $p = 17.5\ \text{MPa}$
Metallography assessment (38 mm)

A manufacturing defect in the place of welding and HAZ formed by an inclusion and a cavity.

Creep cavities forming a crack in the tangential direction of the pipe.
A manufacturing defect at the place of welding and HAZ formed by an inclusion and partially a cavity.

Lined creep cavities in the tangential direction of the tube.
Metallography assessment (356 mm)

Manufacturing defect

Creep cavity

Creep cavities forming cracks
Equipment used for UT testing

UT device:
Zetec Dynaray 128/128PR + Ultravision 3
Omniscan X3 64

PAUT Probes:
5L64A32 with N55S and 0L wedges
7,5L60A14 – with 0L wedge
AM5-9x7 – with 55SW wedge
PAUT measurement

Through wall crack

Indications on weld bevel
Comparison of PAUT and metalography
headers end cap

Many pressure parts of boilers and piping systems require an end closure, which can take many geometric forms.

Catastrophic failure - separation of the end closure from the main shell.

Limitations for inspection – in some cases only one side access.
Typical configuration for PAUT

Refracted shear header side and end closure side

Refracted longitudinal end closure side
Headers end cap test pieces

Two configurations of headers end cap were removed from power plant

Wall thickness 36 mm

Wall thickness 60 mm
Verification block with SDHs
Verification block with SDHs (cont’d)

Phased array – beam coverage SW
Verification block with SDHs (cont’d)

Phased array – sectorial scan (SW 50 – 89°)
Verification block with SDHs (cont’d)

Phased array – TFM
Verification block with SDHs (cont’d)

Phased array – PCI
Verification block with SDHs (cont’d)

Phased array – beam coverage LW
Verification block with SDHs (cont’d)

Phased array – sectorial scan (LW -25 – 25°)
Verification block with SDHs (cont’d)

Phased array – TFM
Verification block with SDHs (cont’d)

Phased array – PCI
Comparison of PAUT and metalography
Comparison of PAUT and metallography

3 indication from metallography detected
Geometry of the inner surface and relief radius
Other components

Mixing piece
Follow-up project

Development and production of test specimens for materials used in practice with different stages of damage

Test specimens will be creep-stressed and tested in certain stages (every 500 hours up to 3000 hours)

Metallography and UT phased array testing will be performed
Summary

• It is also very important to know the year of production, history of production and operation (repairs carried out, non-standard conditions, etc.), quality conditions, chemical and mechanical properties
• Metallography is a great tool for interpreting the results found by NDT
• Monitoring of critical components from the start of operation
• The goal is to qualify the inspection procedure for creep damage detection
Thank you for your attention

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