TCR Advanced Engineering P. Ltd
Experts in Metallography, Failure Investigation and RLA

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Use of ultrasonic inspection for creep detection

A case study

Introduction :

Creep is the time-dependent, thermally assisted deformation of a component operating under stress. Pressure components such as reformer tubes and headers operate at creep temperature range and are subjected to creep damage over the period. To ensure safe and reliable operation of these components, periodic inspection is performed by non-destructive evaluation (NDE) techniques.

The inspection is largely targeted at detecting the creep fissures/cavities and provides valuable data for predicting the remaining life. Recent advances in NDE technology have provided enhanced capabilities for incipient creep failure detection.

Ultrasound testing is one of the proven techniques to identify early stage creep damage. There is readily available data pertaining to correlation between the ultrasonic attenuation and corresponding microstructure for a given type of flaw. This can be aimed for providing inspection limits. Ultrasonic attenuation thereby enables accurate life prediction for components under inspection.

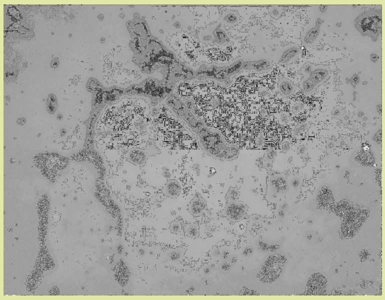
Background:

Ultrasonic attenuation data generated for HP Modified or 35Ni 25CrNb alloys can be used for creep detection and life assessment.

The ultrasonic creep detection principle and use of this technique for comparison between the unused and failed material is explained below.

Generally, the inspection of the tubes is performed in T-R (Transmit-Receive) mode where ultrasound energy is transmitted from one sensor, passed through the section and

Microstructure of the Month



Magnification: *400X*

Etchant: *- Kallings*

MOC: *HP Modified*

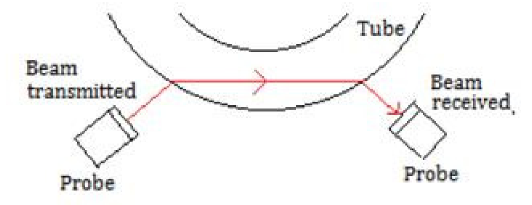
Component: *Reformer tube*

Cause: *Creep damage*

Useful hints: Replicated microstructure is showing presence of intergranular aligned cavities at the eutectic carbides indicating creep damage. Secondary carbides appear to have coarsened and tendency to migrate towards primary carbides.

received by sensor at the other end. The energy transmitted is given by the difference between incident energy and the energy lost mostly in the form of beam scatter. The following figures illustrate the same.

The ultrasounds when passed through randomly oriented creep voids; aligned creep voids or intermittent micro cracks, refract and attenuate the energy because of impendence mismatch. However, creep cracks (such as fissures) significantly attenuate the energy and lead to loss of signal.



Principle of Attenuation Measurement: Ultrasound test in TR mode with specific angle of incidences such that beam travel is from mid-wall.

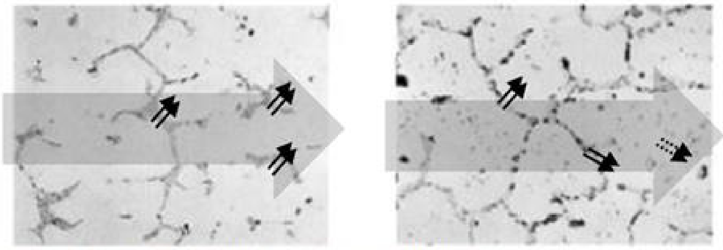


Figure 4 Potential regions for ultrasound attenuation
Dendrite boundary — *Secondary carbides* — *Creep voids*

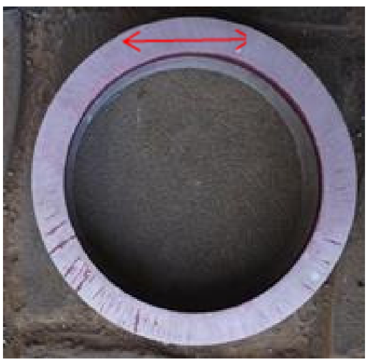
<u>Experiment</u>

Comparison between two samples shows difference in attenuation behaviour. The first sample is from an unused (new) tube, that was never exposed to service. The second sample is drawn from the reformer tube which is exposed to service with severe service degradation. However, it is local at one orientation where DPT (dye penetration test) detected mid-wall fissures and area away from it was found to be free from any detectable indication in DPT.

The images below show experimental data on visual appearance, microstructure at relevant location and corresponding ultrasonic attenuation pattern for the three tubes.

Unused Material

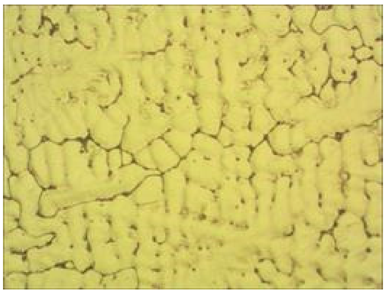
Service exposed material without detectable fissures in DPT



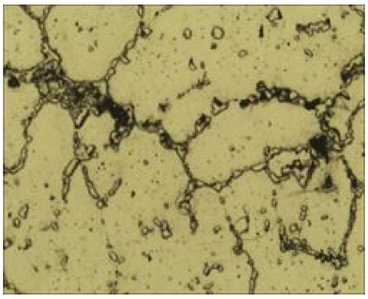
Top area where there are no detectable flaws in DPT

Service exposed material where dense fissures in DPT are observed.

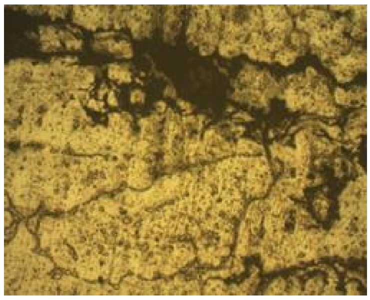
Area between 7 to 9 o'clock location where mid-wall fissures, not open to surface detected in DPT.



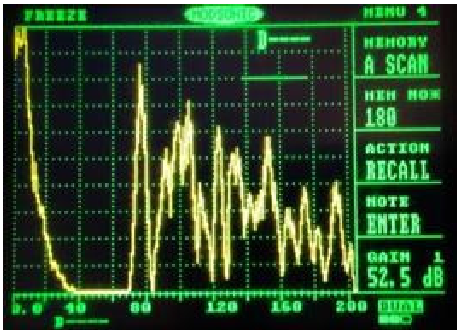
OD surface microstructure of new material showing primary carbides and fine precipitated secondary carbides within austenite matrix. (100X)



OD surface microstructure shows presence of aligned creep voids having tendency to form micro cracks at primary carbides (100X)

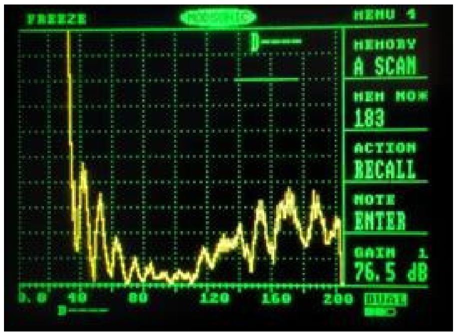


OD surface microstructure showing visible creep fissures with presence of wide, parallel micro cracks. (100X)



Ultrasonic pattern for unused sample

Ultrasonic pattern where no detectable flaws in DPT.



Ultrasonic pattern at mid-wall fissure area.

The received echo is adjusted at 80% FSH and the required dB for that is noted. The comparison between ultrasonic attenuation shows difference of 6dB between the unused tube and used tube where there are no indications of flaw in DPT but microstructure clearly shows the aligned creep voids. In case of the used sample having mid-wall fissures, it is not possible to set the echo 80%FSH indicating complete loss of sound energy.

The above demonstration clearly establishes that the ultrasonic attenuation technique can reveal the mid-wall fissures. Further, coupled with the microstructure study it is possible to correlate the presence of voids and in turn the creep damage using this technique.

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