TCR Advanced Engineering P. Ltd

Experts in Metallography, Failure Investigation and RLA

Metallurgy for Industries

Power | Petrochemical | Fertilizer | Chemical | Refinery | Engineering | Automobile

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Automated Reformer Tube inspection System(ARTiS)

An Advanced NDT technique

Introduction

The primary reformers are used in various industries like steel making, fertilizers, petrochemical and refineries, for cracking of hydrocarbons in presence of nickel based catalyst in reformer tubes. These reformer tubes normally operate at temperatures exceeding 800°C with high internal pressures. During prolonged period of service, the material undergoes creep strain, often indicating increase in diameter of tubes with or without formation of creep fissures at the mid-wall section. The extent of damage is quantified through various non-destructive tests like visual inspection, bowing measurement and creep strain assessments. ARTiS is a proprietarily developed advance NDT method abbreviated for Automated Reformer Tube Inspection System. It overrides the manual ultrasonic scanning. ARTiS aids ease of scanning, precise and meticulous job execution and provides detailed result.

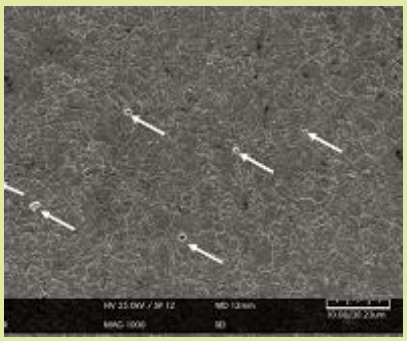
TCR Advanced has indigenously developed the technology and necessary instrumentation for ARTiS. This technique can be used to test furnace alloys and others which are generally used in primary reforming application.

M/s TCR Advanced offers single window service for advanced NDT requirements and owns necessary equipments. Also, it employs qualified ASNT Level II & Level III personnel.

About ARTiS

ARTiS is abbreviated for Automated Reformer Tube Inspection System. This is a robotic crawler to aid ultrasonic testing of reformer tubes in more systematic manner and provide tabular and interactive digital output. The 1st point on every tube is referred at one of the tube ends. On climbing up to the full height of around 16 meters, detailed output at predefined segment lengths is provided. The output consists of ultrasonic dB level of

Microstructure of the Month



Magnification:*1000X*

MOC: *T91*

Component: Super-Heater tube

Observation: The photograph shows SEM image after metallographic specimen preparation. The arrows point locations of creep voids in microstructure of tempered martensite. The general condition of tube indicates onset of creep damage and is classified nearly to TW507-VGB-Class 3a or empirically between stage III and IV as per classical creep damage charts.

Useful hints:SEM is a useful tool in identifying material degradation; especially at initial stage of creep damage. It is necessary to perform thickness & OD measurement along with in-situ metallography & hardness measurement of tubes.

attenuation, diameter of tube and bowing of each tube. A digital report is generated along with conventional hardcopy print in tabular format. The advantages of automation of inspection are multifarious.

- The method follows same technique of manual ultrasound coupling, and hence it is industry wise proven for the intended inspection.
- The outcome of inspection work becomes more systematic and traceable with point wise reading on internal flaws/attenuation and creep strain.
- It avoids the need of scaffolding requirement and saves total tube inspection time, achieving reduction in shutdown of plant.
- Automation deploys limited water source for coupling and nearly eliminates need for overhead water drum arrangement. Thereby it overcomes additional issues related to drum filling, vacuum water clogging etc.
- The pre-requisite of tube cleaning is often eliminated, which increases inspection time, as the same crawler may be used for cleaning of loose scale deposit in first run, followed by actual inspection.

Inspection Techniques

The various NDT techniques in subsequent sections describe the theoretical aspects covered for application of respective method with respect to envisaged damage assessment of reformer tubes. Measurement of quantifiable parameters include tube diameter, bowing assessment of reformer tube, ultrasonic inspection for flaw detection or attenuation measurements, inspection of weld joints by DP, ferrite count of weld joints and in-situ microstructural examinations.

Fissure Detection by Ultrasonic Inspection

The ultrasonic inspection of reformer tubes is done in T-R (Transmit-Receive) mode where ultrasound energy is transmitted from one sensor, passed through middle of the wall section and received at other sensor (Figure 1). The energy transmitted is the sum of energy received and the energy lost in beam scatter. The phenomenon of ultrasonic beam scatter is illustrated in Figure 2.

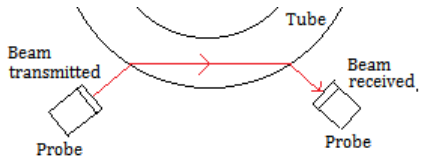


Figure 1 Principle of Attenuation Measurement, Ultrasound Inspection

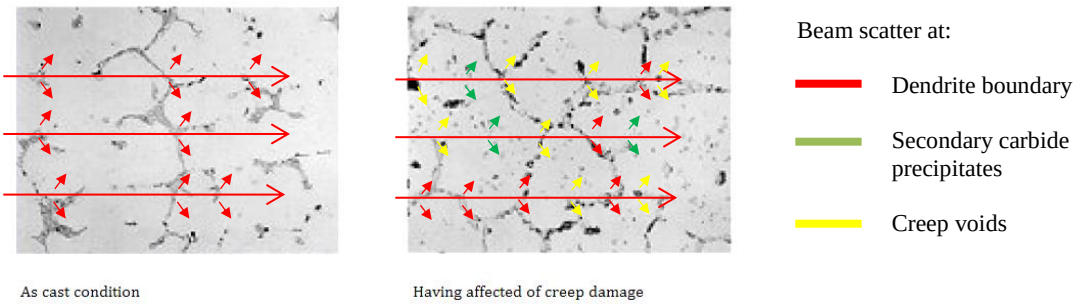


Figure 2 Potential regions for ultrasound attenuation

In as cast material, scattering within the material occurs primarily at dendrite boundaries containing primary carbide chains. After being in service, the alloy tends to precipitate secondary carbides and exhibit creep damage in later stage of life, observed as void formation at mid-wall. Additional scattering of sound occurs at secondary precipitated carbide interfaces and creep voids. The initial scatter pattern of ultrasound beam also changes at primary carbide chain in the microstructure. The additive effect of beam scatter is measured in dB such as 80% full screen height of echo becomes the measure of energy.

The ultrasound attenuation is dependent on internal microstructural condition. The cast tubes possess mixture of columnar and equiaxed structures. The columnar structure scatters higher ultrasound energy than the equiaxed structure of material. The variation in cooling rate during manufacturing results in change of columnar and equiaxed grains depth ratio, which is reflected as varying attenuation of ultrasound. The ultrasonic "attenuation measurement" inspection technique therefore comes under limitation based on ratio of columnar grain v/s equiaxed grains. The HP modified niobium micro alloyed tubes provide large columnar structure to enhance the creep life, and hence would exhibit higher relative attenuation in comparison to other alloy HK40.

The attenuation measurement of unused condition of tubes can provide the basis for comparison of inspection result in future. However, the values of dB obtained by such ultrasonic inspection technique are still dependent on instrument used, energy level of wave transmission, scan settings, probe manufacturer and coupling conditions. Hence, comparison of baseline dB values generated by one set of probes and instrument with other such combination may produce unreliable outcome for creep damage assessment.

Creep Strain Measurement

Diametric measurements are carried out to find out increase from original diameter. The change in diameter is associated with creep strain of material exposed to elevated temperature service for many years. The figure of creep strain depends on use/abuse of material with respect to highest service temperature and pressure fluctuations, number of start-up and shutdowns etc. It is also a material dependent factor. The values of creep strain are generally reported to get judgment on overall condition of tube in comparison to sectorial distribution of rest of tubes in the reformer.

In addition to manual diameter measurement, the automated crawler provides on-board instrumentation by Infrared based diameter measurement, which can be reported at every 100mm distance for 100% of tubes.

Bowing Measurement

Reformer tubes do undergo deformation out of the straightness, referred as term 'bowing'. Bowing is attributed to various reasons like high temperature exposure of tube, restriction in their thermal expansion, process fluctuations or abnormal firing of burner in vicinity. The distance is measured as units of deflection at maximum bowed location from apparent axis along tube length. Visual inspection is generally adopted for measure of bowing. However, ARTiS has the capability to measure angular deflection at segmented lengths and extend the result to determine bowing of each tube.

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