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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ARTiS

Integrated Approach for RLA of Reformer Tubes by NDT

The primary reformers / hydrogen crackers are widely used in fertilizers, petrochemicals and refining industries. They produce hydrogen by endothermic reaction at elevated temperature above 800°C in pressurized condition. Challenge to combat creep and thermal damages for long term durability has catapulted research in alloy development. There had been continuous development in design of tubes to achieve operating life in excess of 100,000 hours. The tube replacement strategy therefore often depends on NDT inspection results. Various NDT methods are deployed in isolation and judgments are taken mainly based on past experience of the end user.

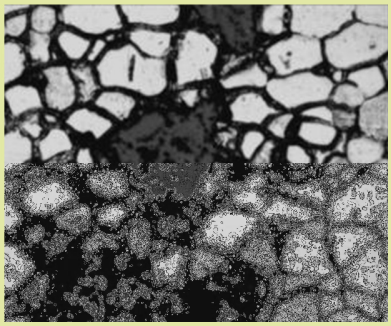
Normally decisive factors for tube replacement are: (a) increase of diameter in the range of 3-6% as considered a limiting creep strain, (b) More than 65 dB of ultrasonic attenuation signals warning about creep fissure detection on vis-a-vis tube bowing and (c) overall service life – if it exceeds designed operating hours it may call for tube replacement.

The integrated approach of reformer tube inspection by ARTiS – can provide correlation between tube metallurgy and inspection findings. Comprehensive approach for tube retirement plan based on combination of NDT inspection and metallographic techniques is arrived through ARTiS.

ARTiS is abbreviated form for "Automated Reformer Tube Inspection System". This is a robotic crawler that maneuvers ultrasound scanning of reformer tubes in a more systematic manner and provide tabular output. The method imbibes same principle of manual scanning widely accepted by the industry with necessary improvements. During scanning, ARTiS provides attenuation (dB level), diameter of tube throughout the length, and a specially installed electronic device for trajectory detection provides bowing of the tube.

The inspection output thereby becomes more categorical and traceable throughout the tube height. ARTiS avoids the need of scaffolding and saves inspection time, achieving reduced shutdown of plant. Comparison between ultrasonic inspection by

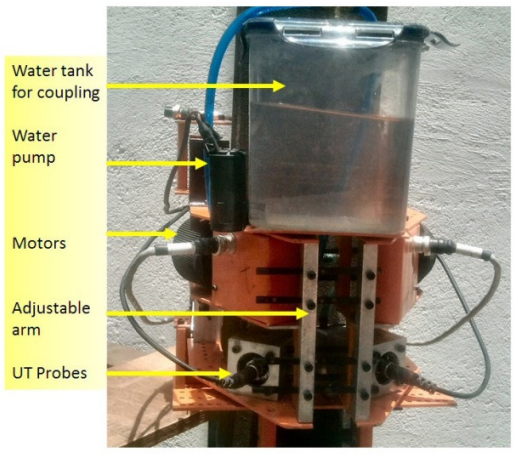
Microstructure of the Month

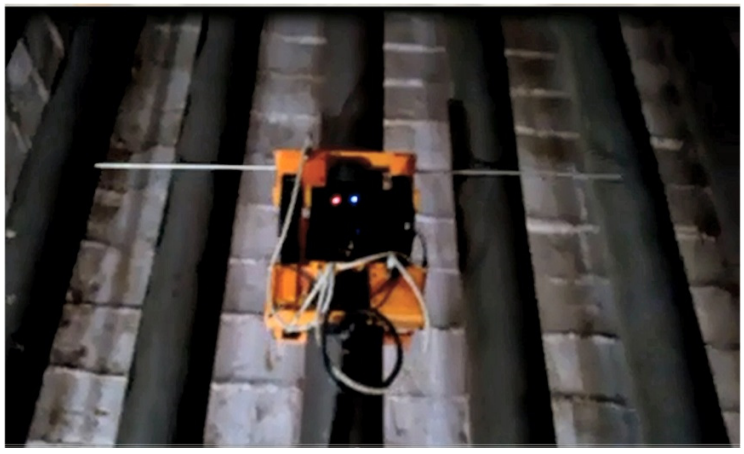


Magnification: *400X*
Component: *Super-heater coil*
MOC: *SA-213 T22*
Observation: Microstructure shows view of OD surface having inter granular cracking with sulphidisation/oxidation observed at the cracks.
Cause: The failure noticed in the super heater coil is due to the long term overheating leading to high temperature sulphur induced corrosion, preferentially attacking the grain boundaries, which is essentially due to localized increase in temperature in view of higher scaling at ID and presence of sulphur from the flue gases.
Useful Hint: OD surface conditions should be monitored by in-situ metallography and hardness to foresee any metallurgical degradation. Degraded coils may be replaced. Thickness measurement on tubes surface after removal of oxide scale. Tubes may be replaced based on thickness criteria. RLA of the super heater coils may be carried out to work out for long term remedial actions.

manual method and by ARTiS is given in table below.

Parameter	Manual method	ARTiS
Requirement of scaffolding	Needed	Not needed
Cost of scaffolding	At actual	Nil
Time required for erection and removal of scaffolding	1 to 2 days	Nil
Requirement of D.M. water	Continuous	Limited
Spillage and wetting of surrounding during test	Uncontrolled	Nil
Time of test (3 persons team)	3 to 5 days for 100 tubes	2 to 3 days for 100 tubes
Resolution of test result	1.5 - 2.0 meters	0.1 meter
Outer diameter measurement	One or two locations manually	Every 0.1 meter
Tube bowing	Qualitative judgment or by plumb measurement, additional time	Quantitative measure during UT scan
Safety consideration	Higher risk (elevated work area)	Lower risk (platform area)
Reporting	Manual data entry	Software based with statistical data analysis





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Based on TCR's past experience of inspection, failure investigations of reformer tubes and life assessment studies, correlation is made with NDT results to arrive at an ageing mechanism. The tube condition indexing is described in following table.

Test	Index [1] (higher is worse)			
	0 (least aged)	1	2	3 (most aged)
General visual examination	Good condition with no significant abnormality.	Apparent change in weld or apparent offset or abnormal coloration	Apparent localized bulging or shiny surface	Presence of crack, bulged with craze pattern
Visual baldness	Good surface roughness	Smooth surface texture on touch and feel	-	-
Bowing of tubes	< 0.1X of tube diameter	Up to 0.5X of tube diameter	Up to 0.8X of tube diameter	Up to 1X tube diameter
Ultrasonic attenuation[2]	Up to 50 db	Up to 58 db	Up to 70 db	> 70 db
Creep strain	< 2%	2 to 3 %	3 to 5 %	> 5%
Microstructural condition	Microstructure without any significant grain coarsening	Dilation of secondary carbides towards grain boundary with coarsening of primary grain boundary carbides	Presence of isolated or oriented creep voids preferably normal to principle stress direction	Presence of interconnected, parallel micro cracks normal to principle stress direction
Overall index	Sum of individual indexing			

Notes:
[1] Proprietary index weightage factor is not shown. Remaining tube life as per API530 is separately addressed in combination of thickness measurement, outer diameter value and microstructural condition.
[2] Value is indicative, dependent on instrument settings, surface roughness of tube, test equipment and coupling conditions.

Conclusion: The non-destructive testing of reformer heater tubes places undue emphasis predominantly on ultrasonic attenuation measurements. However, change in microstructural condition such as carbide coarsening, secondary carbide precipitation and depletion / dissolution of carbides from the grains, largely affect the ultrasound attenuation mechanism. Only conditions like complete loss of ultrasound energy can indicate presence of mid-wall fissures, which still requires confirmation by alternate NDT- like radiography.

The tube life assessment based only on NDT approach has so far remained in isolation, and it can only be improved by comprehensive tube inspection covering not only NDT but also techniques like ARTiS and metallography.

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