Abstract Title - Furnace tube life optimization

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SPCo (Saudi Polymer Company) furnace re-tubing frequency was based on established industrial best practice as 4 years since the commissioning of the ethylene plant in 2012. During the service life of 4 years no tube failure was reported. Radiant tube's mechanical and metallurgical performance was thoroughly studied on 4 years aged tube sample to assess the remaining life.

SPCo furnace tubes were typically made up of centrifugally cast Ni-Cr-Al alloys along with certain micro alloying elements such as Nb, Ti etc. The alloy was designed for excellent structural stability, good high temperature stress rupture strength and excellent carburization /oxidation resistance due to aluminum forming layer on inner surface layer.
Couple of samples were collected from 4 years' serviced tubes during planned re-tubing opportunity. Visual inspection of the tube sample has not indicated any significant damage. Dimensional inspection has revealed no relevant outer diameter expansion or thickness reduction or bulging / swelling. The samples were found within the tolerances as per the drawing. The chemical analysis by Optical Emission Spectroscopy confirmed the correct alloy composition within the tolerance. The accelerated creep rupture tests were performed on three specimens at the test condition taken from the production test plan (ITP), all specimen ruptured as expected but one ruptured on it's 80% expected life. Micro structural inspection was conducted with Inverted optical microscope and Scanning Electron Microscope (SEM). The microstructure consists of rounded and coarsened primary carbides which are surrounded by Beta phase (Ni-Al) and a huge amount of secondary carbides and acicular precipitations (Al, Cr) in austenitic matrix. Isolated creep voids were detected in the tube wall and weld heat affected zones. Most of the tube inner surface is covered by a close and protective Al oxide scale. Some areas (dark spots - visual inspection) reveal internal oxidation with adjacent minor carburization.

From the collected mechanical and metallurgical experiment data for life limiting active damage mechanism, it could be inferenced that the radiant tube life has been affected, but tube could have considerable remaining life if the future operating conditions are the same as the historic conditions. It should be noted that numerous isolated cavities in the heat affected zone (HAZ) of each tube weld could be potential concerns and would eventually form to circumferential creep cracking at the HAZ.

If tube life can be increased to 5 years then a tube sample should be collected after 5 years to monitor and quantification of active damage mechanism for further life optimization. Each furnace re-tubing schedule can be evolved from such life assessment study on representing furnace tube sample that being collected during PM opportunity.