A Modern Approach for In-service Inspection of Heavy Walled Hydrocracking Reactors using AE and AUT

The increasingly competitive oil refining business is pushing the operational life of high temperature process reactors and piping to tens of thousands of hours beyond the original design life.

The short outages between runs, for maintenance, inspection and to reload (catalyst) make these operating units extremely profitable. Operators are therefore under extreme commercial pressure to keep outage times to a minimum. Current state, local and federal regulations such as OSHA 1910.119, API 510, etc., allow plant operators to utilize state-of-the-art inspection techniques, such as acoustic emission (AET) and automated ultrasonics (AUT), to investigate the structural integrity of such components, in lieu of costly internal inspection.

Metallurgical studies supported by finite element analysis, have demonstrated that heavy walled Cr-Mo reactors suffer most of the damage during start-ups and shutdowns. If these reactors could be kept operating at steady conditions, their life would be extremely long. However, process catalysts degrade and the hydro-cracking efficiency decreases with time, forcing plant operators to shutdown the unit to either reactivate the catalyst, or to remove the old charge and reload a fresh catalyst batch.

The process of shutting down the unit, is executed through three phases: • cut the feed stock, • a hydrogen sweep, to remove liquids, • heaters are slowly cut back, reducing the temperatures at a "controlled" rate (<75¡ F/hr.). During the so called "Cooldown" of the unit, both the reactors, and the piping system experience the highest levels of thermal stresses ever imposed during operational life. The cooler gases bring down the reactor's internal surface temperature faster than the hot external surface temperature. This creates a "thermal gradient" across the

During a recent AET monitoring of a hydrocracking unit in a refinery in Louisiana, ID (internal diameter) connected crack-like indications were detected qualitatively and located by acoustic emission. These flaws were then confirmed quantitatively by automated ultrasonics. Cracks were located at the ID emanating from internal attachments and tray supports. Some of the flaws quantified measured 6.00" to 10.50" in length, with depths varying from 0.30" to 1.00" . Other crack-like indications were found at "dump nozzles", and several other circumferential cracks were confirmed in pipe elbows.

The measured indications previously mentioned are not deep relative to the 8.00" wall thickness of the reactor. However, these defects must be monitored regularly to assess their growth with time. Repairs on these types of Cr-Mo reactors are extremely complex and demand several months of work, causing a lengthy and costly outage. It is consequently very important to find these defects, and measure their rate of growth, so the decision of whether to repair or order new reactors can be made based on solid facts.

Piping systems and reactors are inspected externally with AUT equipment, which can accurately detect and size ID and mid wall defects, with state-of-the-art techniques such as Time of Flight Diffraction (TOFD) technology.

Typically, reactors present a variety of defects, depending on the operating conditions, consumed life, metallurgy, number of uncontrolled outages, etc. Cladding, disbonding and cracking which initiate at the reactor's wall. This is known to be the main cause of thermal cracking and other damage mechanisms. Similarly, the piping system is restrained as it cools down due to mechanical constraints. This sets up longitudinal thermal stresses which can cause severe circumferential cracking.

Monitoring all these components simultaneously (piping, reactors, heat-exchangers), with AET during the cooldown of the unit, increases the chances of detecting and locating thermally induced discontinuities. It is important to highlight the fact that these severe stress levels will be present at each outage, regardless of whether the AET inspection is being done or not.

A few hours after the temperature reaches 250¡ F, all areas with indications of active defects are mapped. Reliability and inspection personnel can then proceed inspecting only the areas recommended, optimizing financial and personnel resources. Concentrating manpower on active areas that contains defects reduces inspection costs and outage time.

ID and could penetrate the Cr-Mo wall, are the main concern. Mid wall defects and cracking originating from fabrication defects, lack of fusion (LOF) could reduce the remaining life of the reactor. Another concern is the possibility of brittle fracture which can occur during shutdowns and start-ups. Nozzles are stress concentration areas with their own set of possible defects and associated causes. Dump nozzles present risk of thermal fatigue cracking, while quench nozzles pose potential risk of thermal cracking. Tray supports are also elements that may initiate ID connected cracks.

Over the past ten years, acoustic emission followed by automated ultrasonics have contributed to structural inspection programs for refineries around the world, by accurately and repeatably detecting, sizing and monitoring significant ID and midwall cracking. This allows plant operators to continue running their units until repairs or replacement components can no longer be safely avoided. These decisions are, of course, based on fracture mechanics calculations, economic concerns, safety factors, and current law. These engineering decisions which have significant financial implications could not be made safely without the reliable application of AET and AUT technology.◆