Monitoring of degradation of a pipeline of hydrocracking installation by Phased Array and Acoustic Emission methods

Marcin Wielgat (1,2) - marcin.wielgat@inmat.pw.edu.pl, Łukasz Sarniak (1,2) - lukasz.sarniak@inmat.pw.edu.pl, Wojciech Spychalski (1,2) - wspych@inmat.pw.edu.pl, Wojciech Manaj (2) - wmanaj@megroup.pl, Wojciech Spychalski (2) - wspych@inmat.pw.edu.pl, Krzysztof Jan Kurzydlowski (1) - kjk@inmat.pw.edu.pl

(1) Warsaw University of Technology
Faculty of Material Science and Engineering
st Wołoska 141
02-507 Warsaw, Poland

(2) Materials Engineers Group
st Wołoska 141
02-507 Warsaw, Poland

ABSTRACT

In the present study, series of non destructive tests were used to detect damage in a pipeline of a hydrocracking installation, including Acoustic Emission and ultrasonic flaw-detection. Both standard and Phased Array (PA) ultrasonic techniques were used. It has been found that Phased Array method allow to obtain precise images of the hydrogen de-laminations and by using C-scan, estimation of the size of the de-lamination which can be used for Finite Element Modeling to estimate the critical size of the defect.

INTRODUCTION

Properties of materials used in petrochemical installations degrade with time of in-service exploitation. In the last stage of the in-service degradation process numerous micro-cracks and de-laminations lead to macroscopic damage of the elements of industrial installations, which may result in serious damage and lost of lives.

In the present study a segment of pipeline from hydrocracking installation was investigated. It was suspected to undergo the hydrogen degradation [9]. A series of non destructive test were used to detect the defects in the pipe, including Acoustic Emission (AE) and ultrasonic detection of flaws.

The examined pipeline was made of A106B steel with wall thickness of 65 mm and diameter of 30 inch (762 mm). It was exploited in approximately 50˚C temperature and 13MPa pressure in presence of hydrogen. During one of the routine ultrasonic inspections, changes in wall thickness were detected in elbow area. Defected area was approximately 0,5 m² so the Hydrogen corrosion were suspected (blistering). Speed of formation of hydrogen bubbles depends, in the first place, on hydrogen absorption and diffusion rate. Assuming constant temperature, in the case under discussion, absorption is of crucial importance, it grows considerably in the presence of hydrogen sulphide and water. At low flow velocity, for medium as well as high NH4HS concentrations (above 7%) passive layer is created on the surface of material which constitutes a barrier for hydrogen. Rise of the
flow velocity leads to corrosion potential change. This effects in vanishing of passive layer and hydrogen diffusion increase. From the point of view of structural strength the most dangerous are bubbles generated at different depths, which later during growth of volume join together (stepwise crack). Bubbles emerging near the surface that can burst are equally dangerous. In both cases we are dealing with wall thickness reduction leading to stress increase.

Because of possibility of the growth of the defects might have cause unseal of the whole pipeline, AE and ultrasonic monitoring was performed. Ultrasonic results were used for to Finite Element Method to calculate the critical size of defects.

ULTRASONIC INSPECTION
Standard ultrasonic inspection used in the examination is called pulse-echo method. Such an inspection is widely used to measure distance of the defects form the surface. It also allows to estimate size of the defects.

The physics of phased array method is the same. The difference is that many transducers are used simultaneously which give lots of new possibilities for flaw detection. Phased array systems pulse and receive signals from multiple elements of an array. These elements are pulsed in such a way as to cause multiple beam components to combine with each other and form a single wave front traveling in the desired direction. Similarly, the receiver function combines the input from multiple elements into a single presentation. The benefits of PA technology over conventional UT come from its ability to use multiple elements to see, focus and scan beams with a single transducer assembly. Beam steering, can be used for mapping components at appropriate angles. Electronic focusing permits optimizing the beam shape and size at the expected defect location increasing probability of detection. Focusing in Phased Array technique significantly improves signal-to-noise ratio. Electronic scanning across many groups of elements allows to create C-scan images very quickly. The example of beam deflection and focusing is shown on figure 1.[1,2,3]

![Fig. 1](image_url)

Fig. 1 This pictures shows the elements in the array, and the delay applied to each element. Different delays on each element enable steering of the beam and focusing.

MATERIAL EXAMINATION AND MONITORING
AE monitoring, using multichannel Vallen AMSY-5 system, revealed high acoustic activity as shown on figure 3 as “Source I”. This source were in the main area of interested of ultrasonic inspection. AE was also used to monitor cracks growth in the defective pipe.
To control changes in the defect size and wall thickness, ultrasonic tests were performed using Krautkramer USN60 ultrasonic flaw detector provided with 4 MHz transducer. Pulse-echo method was used in examination. Ultrasonic testing was carried out according to a measurement grid, where distance between nodes was 20 mm. First examination was performed during the installation standing still. After restart the pipeline was regularly monitored using ultrasonic testing. Results of ultrasonic measurements presented on the map of thickness (C-scan) on figure 3.[4,5]

ULTRASONIC PHASED ARRAY TESTING

Ultrasonic PA examination was performed using OmniScan MX (32) ultrasonic flaw detector provided with 5L64 (5 MHz) transducer. Examination area is shown in figure 4.
Phased Array system allow to collect data during on-line scanning. A, B and C-scans data were analyzed. Very important was possibility of visualization of size and shape of the defect. Thanks to that defect size and geometry were tracked in time during exploitation. The example of the results is shown in figure 5. The same piece of the elbow were manually scanned in 2 months time. It is clearly shown that some of the de-laminations change their shape and size.

Phased array results were compared with classic ultrasonic mapping. Not only they confirmed classic ultrasonic results but also reveal new cracks and de-laminations. The whole set of non destructive tests were used to monitor conditions of the defective pipeline. Finite Element Method was performed to analyze critical size of the de-laminations. This modeling based on ultrasonic examination results permitted prolongation service of the installation. After installation shut down the defective elbow was cut out and cut into smaller pieces which were again examined to confirm previous results. A great
example how accurate and helpful phased array method can be is demonstrated in figure 7 [6,7,8].

**Fig. 6** Deformation close to crack on the hydrogen bubble analyzed by Finite Element Method

**Fig. 7** Results of measurement of delaminations with corresponding ultrasonic B-scans

**CONCLUSION**

On the basis of examinations performed during standstill and after restart of the installation it was found that de-laminations enlarged over time. Nevertheless the paper shows combination of non-destructive methods and FEM which allows for a safe operation of the defective pipeline till new parts arrive.

**REFERENCES**


