Application of Non-destructive Methods of Stress-strain State at Hazardous Production Facilities

2016 IOP Conf. Ser.: Mater. Sci. Eng. 132 012021

(http://iopscience.iop.org/1757-899X/132/1/012021)

IOP Conf. Series: Materials Science and Engineering **132** (2016) 012021 doi:10.1088/1757-899X/132/1/012021

Application of Non-destructive Methods of Stress-strain State at Hazardous Production Facilities

V Shram[1], Ye Kravtsova[1], A Selsky[2], Yu Bezborodov[3], N Lysyannikova[1] and A Lysyannikov[1]

[1]Associate Professor, Siberian Federal University, Krasnoyarsk, Russia
[2]Leading Specialist, NK NOU «NUC «RTS», Krasnoyarsk, Russia
[3]Head of Department, Siberian Federal University, Krasnoyarsk, Russia

E-mail: shram18rus@mail.ru

Abstract. The paper deals with the sources of accidents in distillation columns, on the basis of which the most dangerous defects are detected. The analysis of the currently existing methods of non-destructive testing of the stress-strain state is performed. It is proposed to apply strain and acoustic emission techniques to continuously monitor dangerous objects, which helps prevent the possibility of accidents, as well as reduce the work.

1. Introduction

The Unified System of Conformity Assessment, the current structure of Rostekhnadzor and distillation columns belong to the category of "Equipment for chemical, petrochemical and refining industries with operating pressure up to 16 MPa." According to the rules of Rostekhnadzor, these facilities should be subject to technical diagnosis at least 1 time in 8 years. But first, the rare mode of the survey is unlikely to contribute to the total exclusion of the risk of accidents, secondly, a large size and complexity of the design causes high labor intensity of the full survey by conventional NDT methods.

As a result, gas explosion followed by fire took place in the industrial zone of the Achinsk oil refinery, on June 15, 2014. This incident was caused by the destroyed distillation column. As a result of the technical examination carried out by Rostekhnadzor, it was found that there was depressurization of gas fractionation of the plant columns followed by explosion. The cause of the depressurization was critical thinning of the metal walls of the column supplied to the process piping the hydrocarbon gas as a result of localized corrosion followed by the destruction of the pipeline. Such accidents occurred earlier in Russia (for example, an oil refinery in Kirishi, 2012), and abroad (San Juanito, Mexico, 1984; Texas City, USA, 2005). All these accidents resulted not only in major economic loss, but also loss of life.

Therefore, the search and study of a new method of nondestructive testing of the stress-strain state of distillation columns and piping is an urgent task.

2. Constructive part

Since such accidents are often caused by deterioration of the column adjacent to the technological pipelines, the pre-analysis of the corrosion processes and subsequent destruction was made (Figure 1).

It was found that, due to the impact of condensation, the horizontal sections are most exposed to pitting corrosion, at the upper part of the image, on the sloping surface, erosion grooves can be formed at the bottom and vertical sections are weakly subject to deterioration. Gaps in pipes caused by corrosion and deterioration of walls caused by the pressure of the transported medium are usually directed along the generatrix, hence tensile stress acts on the circumference of the cross section [1].

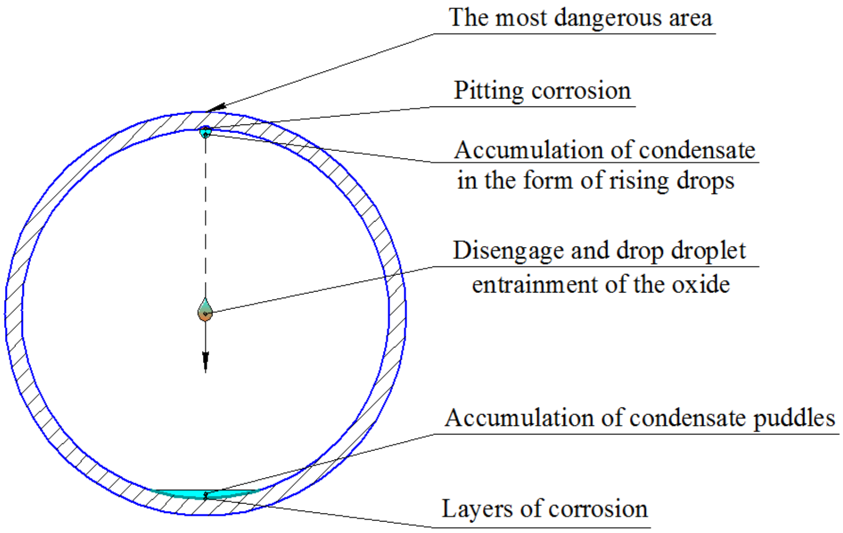

Figure 1. The accumulation of wet condensate in the horizontal section of the pipeline.

We analyzed the existing methods of nondestructive testing of the stress-strain state, their purpose, capabilities and regulatory and technical support (see table 1) [2–6].

Table 1. Nondestructive testing of the stress-strain state of the facilities.

Method	Method	Equipment	Application
Ultrasonic	Normal waves	Special	The extended metal objects
	Body wave	Typical ultrasonic flaw depth gauge with high precision, high-precision thickness measurement	Control efforts fastener tightening compounds
Radiation	Fluoroscopic	Apparatus for fluoroscopy	Laboratory testing of samples
Magnetic	Method of metal magnetic memory (scanning)	Precision coercimeters	Objects of power, steel lifting equipment, steel ropes
	Magnetic noise	Precision coercimeters	No Information
	Magneto-mechanical		No Information
Eddy Current	-	No Information	No Information
Visually-measuring	Visual, measuring	Measuring tool	Laboratory testing of samples
	String	Special	Warp buildings
Optical	Speklinterferometrichesky	Special laser-photographic	Laboratory testing of samples
Strain	Full-scale	Strain amplifier, standard gages	Precise measurement of small deformations of

			objects
Acoustic emission	Pulse (activity of AE signals)	Universal AE equipment	Voltage detection zones
Thermal (infrared)	Thermal	High-precision thermal imagers	No Information

The results of this analysis showed that strain and acoustic emission techniques are most suitable for this task. The strain technique directly indicates the degree of elastic deformation of the object, while the method of acoustic emission shows the signal activity proportional to the voltage source in the metal (figure 2). These indicators are compared with the elastic limit of steel through the Hooke's law and thus characterize the gravity of the object state [7]:

$$\frac{\Delta L}{L_0} = \frac{\sigma}{E}$$

where ΔL is the amount of the deformation portion (elongation); L_0 is the initial length of the section; σ is tensile stress; E is modulus material.

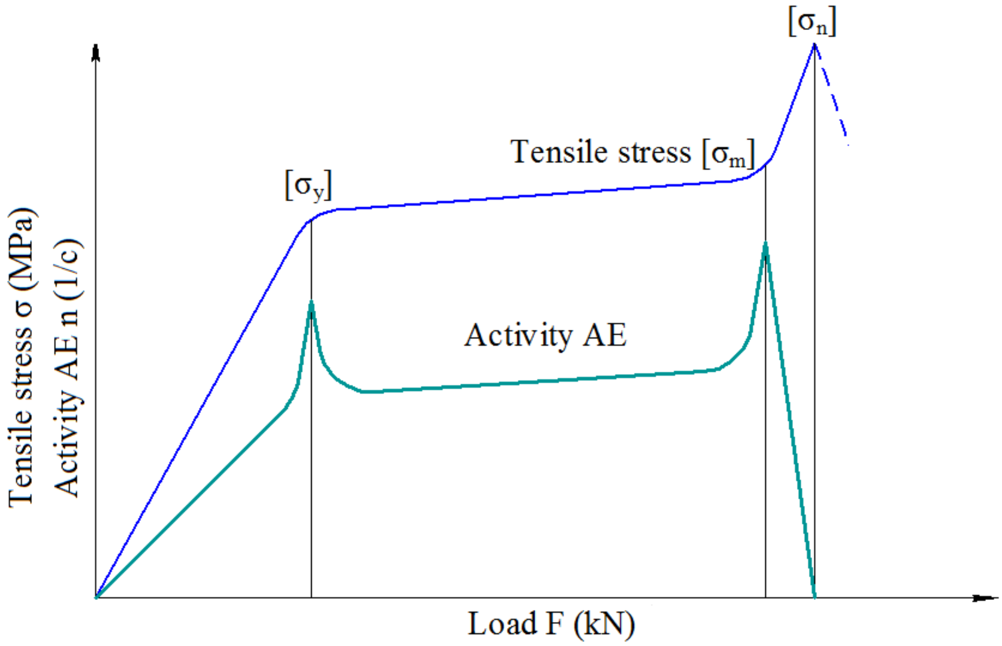

Figure 2. Similarity of the plots of mechanical stress and activity of the AE versus the object load.

Geometrical calculations based on the analysis of the destruction justified the choice of the sensors for these systems: strain is on the top of the generator in the middle of the horizontal portions of the adjacent lines (figure 3); acoustic emission is on the side forming the same areas and a triangulation scheme to scan the body of the column (figure 4).

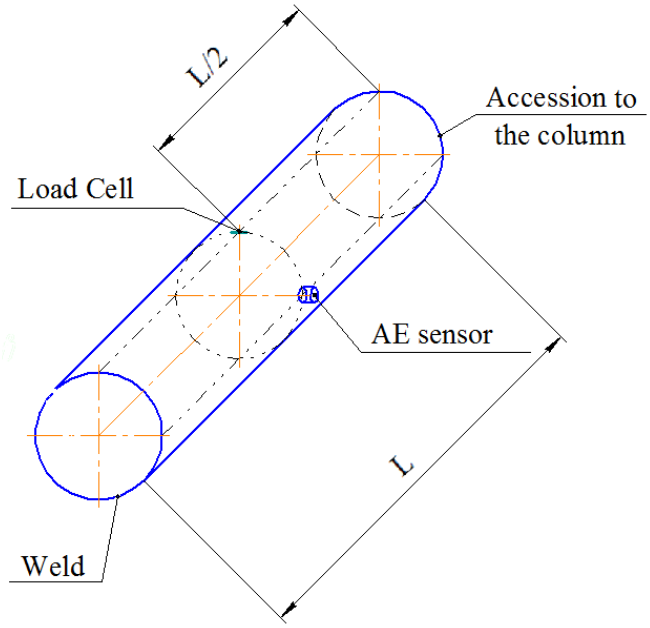

Figure 3. Arrangement of the sensors in the horizontal section of the gas pipeline connected to the column.

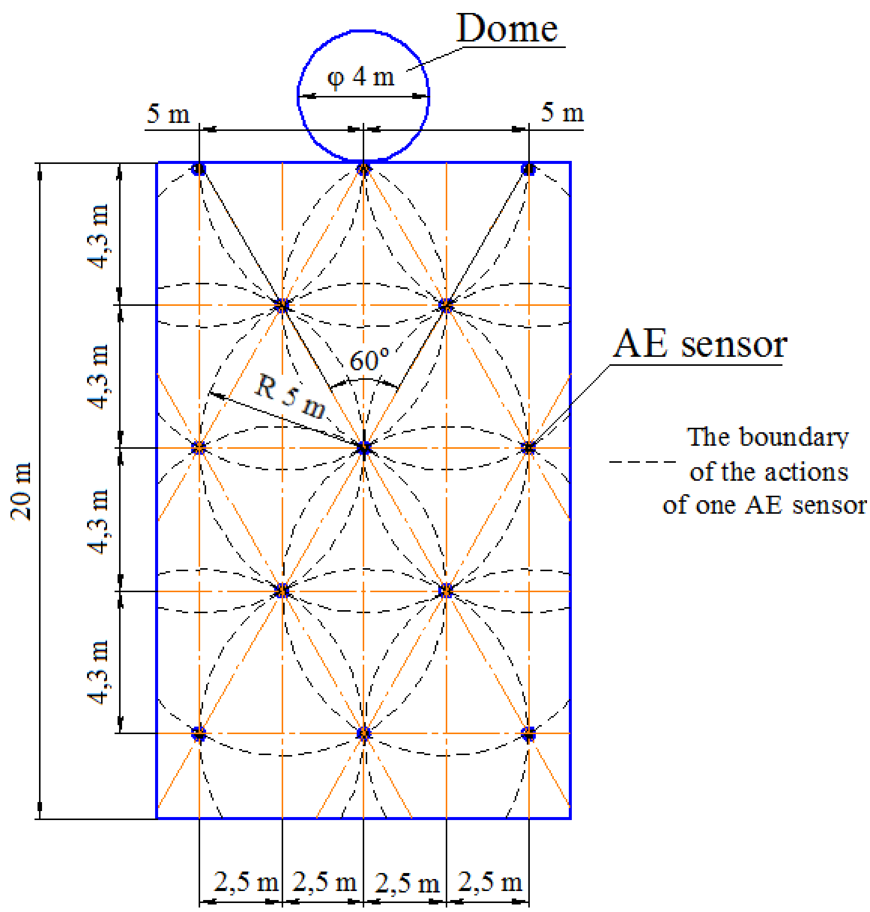

Figure 4. Arrangement of AE sensors to scan the body of the distillation column.

In order to avoid large amounts of footage and connecting cables wireless sensors to the central system were used. With respect to the AE system, there are such devices in Russia, for example, "EXCITON-4040 P". For the strain gauge system, with the help of specialists in electronics, it was developed the concept of autonomous information transmitters: the amplitude of the broadcast monotone continuous radio frequency is proportional to the degree of the individual tension measuring gage. At the reception center, the frequency of the signal system determines the number and location of the sensor, and the amplitude of the signal, i.e. the degree of deformation of the pipe wall. There is off-grid power for all the sensors from solar panels. Three common rod receiving antenna systems surround the central column equipped with sensors so that it fits perfectly in the triangle made up by them.

3. Summary
Thus, application of the strain and acoustic emission techniques enables continuous monitoring of the object, which helps prevent the possibility of accidents and reduce the complexity of the work performed.

References
[1] Nestleroth J B 2006 *Proc. Of ECNDT (Berlin, Germany)* Mo.2.5.1.
[2] GOST R 53965-2010 2011 *Non-destructive Testing. Evaluation of Mechanical Stresses. General Requirements to the Methods Classification* (Moscow: Standartinform)
[3] Blitz J 1971 *Ultrasonics: Methods And Applications* (Newnes-Butterworth)
[4] IAEA Training Course Series 1992 *Industrial Radiography* (Vienna: IAEA) **3**
[5] IAEA Training Course Series 2000 *Liquid Penetrant and Magnetic Particle Testing at Level 2* (Vienna: IAEA) **11**
[6] Yu T R *et al* 1990 *CIM Bulletin* **83 (937)** 46–52
[7] GOST R 53006-2008 2009 Estimation of potential dangerous objects lifetime on the basis of express methods (Moscow: Standartinform)