APPLICATION OF THE ROD AND TORSION WAVES FOR TESTING THE EXTENDED OBJECTS OF OIL-EXTRACTING INDUSTRY

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ABSTRACT. The new progressive technology of extended objects acoustic testing and the equipment realizing it are presented. Technology is based on the Pochammer rod and torsion waves application. Results of using new technology for the defectoscopy of the extended objects of oil-extructing industry (pump rods and pump-compressor pipes) are demonstrated. The advantages and prospects of new technology utilization are shown.

KEYWORDS: Oil-extructing Industry, Extended Objects, Rod and Torsion Acoustic Waves

INTRODUCTION

Among variety of oil-extracting industry products there is a wide nomenclature of extended objects which length surpasses the cross-section sizes in 100 and more times - pump rods, pump-compressor and boring pipes, steel cables, springs and others.

Traditionally eddy-current, magnetic and ultrasonic methods are used for the non-destructive testing of such extended ferromagnetic objects. All these techniques have one common disadvantage - necessity of scanning of a body of object that requires the corresponding mechanized equipment. Besides ultrasonic methods on high frequencies require high surface roughness of the object under testing (Rz40) and as a rule coupling liquid application. These facts negatively affects on the productivity of these equipment. Eddy-current and magnetic methods detects only surface and undersurface failures despite of advantage of contactless operation. The main problem of these methods utilization is complexity of defect identification, because of absence of unambiguous connections between mechanical properties of the testing object (defect parameters) and measured magnetic and electric values.

THE PHYSICAL BASES OF THE NEW TECHNOLOGY

The new progressive technology of acoustic defectoscopy is based on the use of waveguide effects and assumes the choice of a wave with minimal velocity dispersion (rod wave for the bars testing and torsion wave for pipe testing – Fig.1) and maximal offset from interfering wave types (symmetric and antisymmetric of higher orders). The velocities of these wave types are following:

- zero symmetric mode in the area of minimal velocity dispersion (rod wave)

$$C_{S0} = \sqrt{\frac{E}{\rho}}\,. \quad (1)$$

where E - elasticity module, ρ - material density;

- torsion wave

$$C_T = \sqrt{\frac{D}{\rho I}} = \sqrt{\frac{\mu I_T}{\rho I}}\,, \quad (1)$$

where *D* - torsional stiffness, I_T – torsion moment of inertia, *I* - moment of inertia of tube section relatively of its center of inertia, μ – shear modulus.

For tubes of round section shape without defects moment of inertia of section I and torsion moment of inertia I_T are equal and torsion wave velocity is maximum and equal to velocity of transverse wave C_t.

Presence of defect in tube leads to decrease (in different range) both of torsional stiffness D and moment of inertia of section I. Then torsion wave velocity reduces.

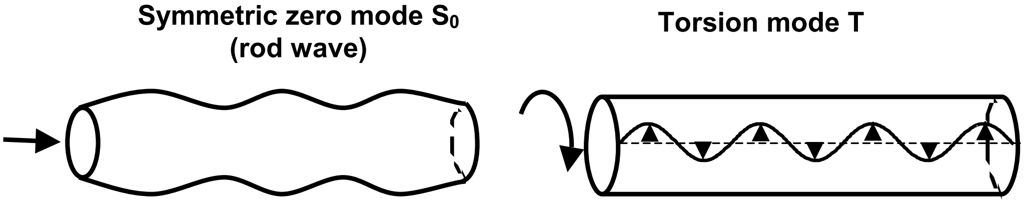

Fig.1. The types of acoustic waves used

The distinguish peculiarities of these wave types are extremely low attenuation that allow to test by sonic very extended objects (length of some hundreds meters); insignificant velocity dispersion (or its absence), therefore the echo-pulses propagating along the extended object are not practically distorted; the displacement distribution in S_0 mode wave is uniform on all object section that allows to guarantee the same sensitivity to the internal and external defects (unlike eddy-current and magnetic techniques); torsion wave has higher sensitivity (on the average in 3 times on the defect area) to surface defects, smaller dead zone and the best resolution in comparison with a rod wave at other equal conditions.

THE SCHEME OF THE TECHNOLOGY REALIZATION

The technology uses the variant of echo-pulse technique from the ends of extended object, thus doesn't demand scanning, additional surface preparation and application of coupling liquid or immersion environment. Method has high productivity of the equipment realizing technology, makes up to 1000 pieces or about 10 km of length and equally high sensitivity to dangerous internal and surface defects.

The scheme of the technology realization for acoustic defectoscopy of extended objects is presented on Fig.2.

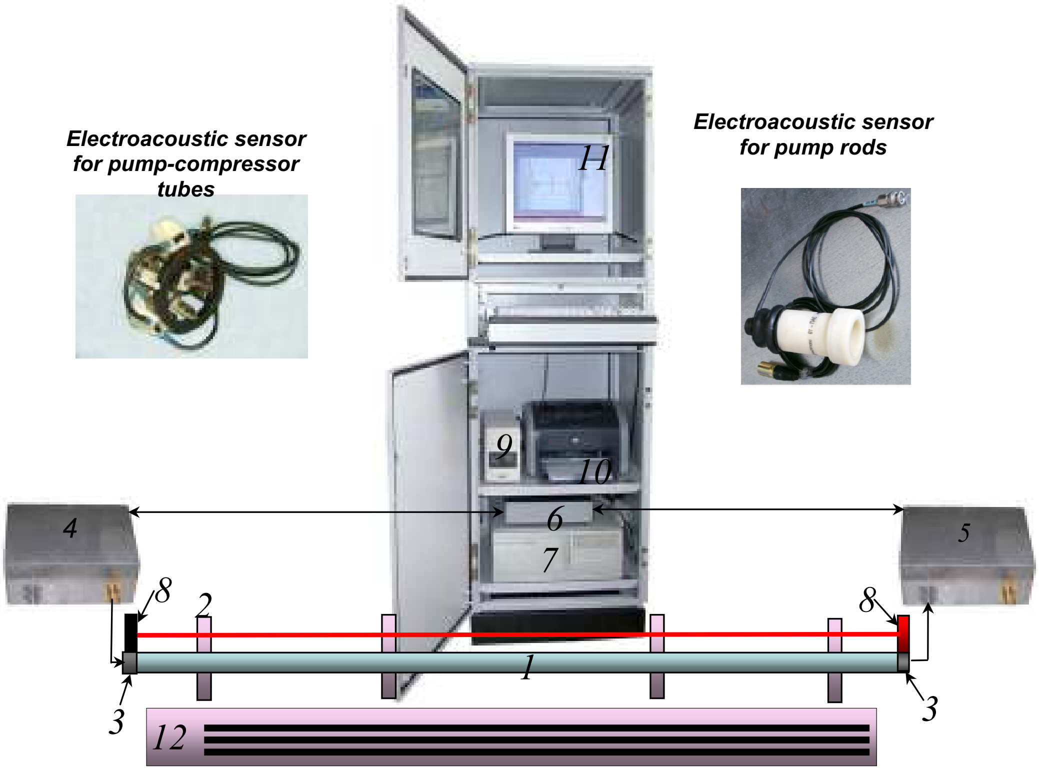

Fig.2. The scheme of technology realization: 1 -extended object, 2 - testing rack, 3 - source and receiver electroacoustic sensors, 4,5 - generator and preamplifier units, 6 - control and switching unit, 7 - PC system with ADC, 8 - laser roulette with a reflector, 9 - UPS unit, 10 - printer, 11 - monitor, 12 - rack for rejected objects

The extended objects under testing ***1*** are placed on a special rack ***2***. Electronic units of generators and preamplifiers ***4,5*** are located near the object ends. Electronic unit of the control and switching ***6***, PC system with ADC ***7***, UPS unit ***9***, printer ***10***, monitor ***11*** are arranged on the distance 2-3 meters from a rack in a special industrial case. Laser roulette with a reflector ***8*** is intended for measuring the object length. Auxiliary workers mount the electro-acoustic transducers ***3*** on end faces of the object. The object graph defectogram and the table information on object length, presence of defects with echo-signal amplitude above the rejection level, their coordinates and the conclusion "Fitness - Reject" are obtained within the period no more than 10 seconds. Than the transducers are rearranged on the following object and the process repeats. The rejected objects are transported on a rack of rejected articles ***10***, fit objects - on the following technological operation.

The pulse-echo method with application of the rod wave S_0 is used for the testing of rods and pump rods. While the numerous reflections method [2] with application of the torsion wave T is used for the pump-compressor tube testing and include three techniques: an echo-transparent, a amplitude-shadow, a time-shadow. As an example on Fig. 3 the typical defectograms of the pump rod and pump tube with local defects are presented.

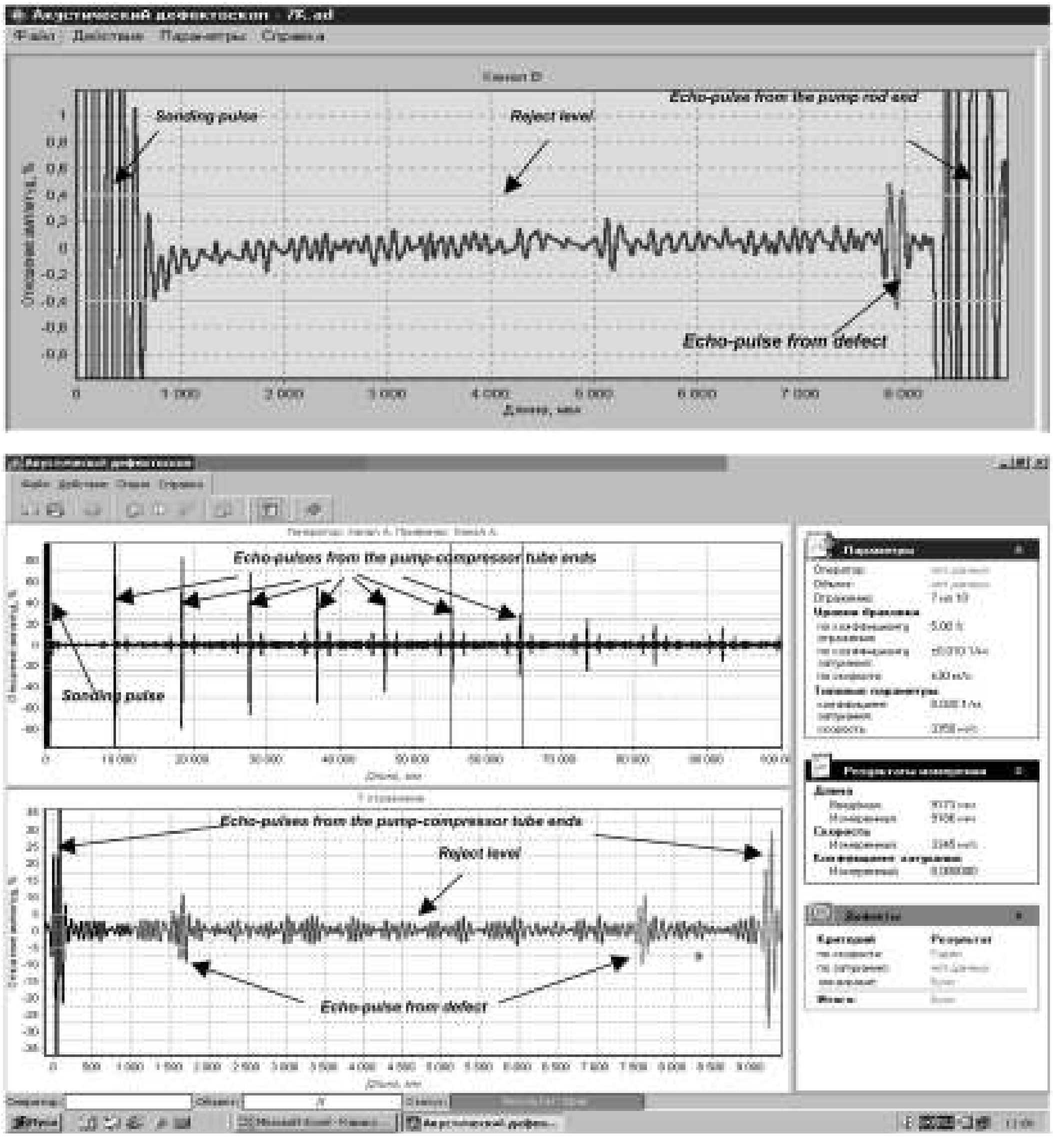

Fig. 3. Typical defectograms of the pump rod (a)
and the pump-compressor tube (b) with local defect

TYPES OF REVEALED DEFECTS

The results of theoretical and experimental research of interaction processes of the rod and torsion waves with artificial both natural surface and internal defects demonstrate that waves are reflected from areas with the change of an object mechanical impedance $Z_m = S\rho C = S\sqrt{E\rho}$ (S - the section area, *C* – sound velocity, ρ - object medium density) (such defects as scabs, folds, inclusions, shrinkage cavities, thinning, variations in wall thickness, corrosive damage, mechanical damages etc.). The echo-pulse amplitude is described by the formula for reflection coefficient:

$$R = \frac{S_2\rho_2 C_2 - S_1\rho_1 C_1}{S_2\rho_2 C_2 + S_1\rho_1 C_1}. \tag{2}$$

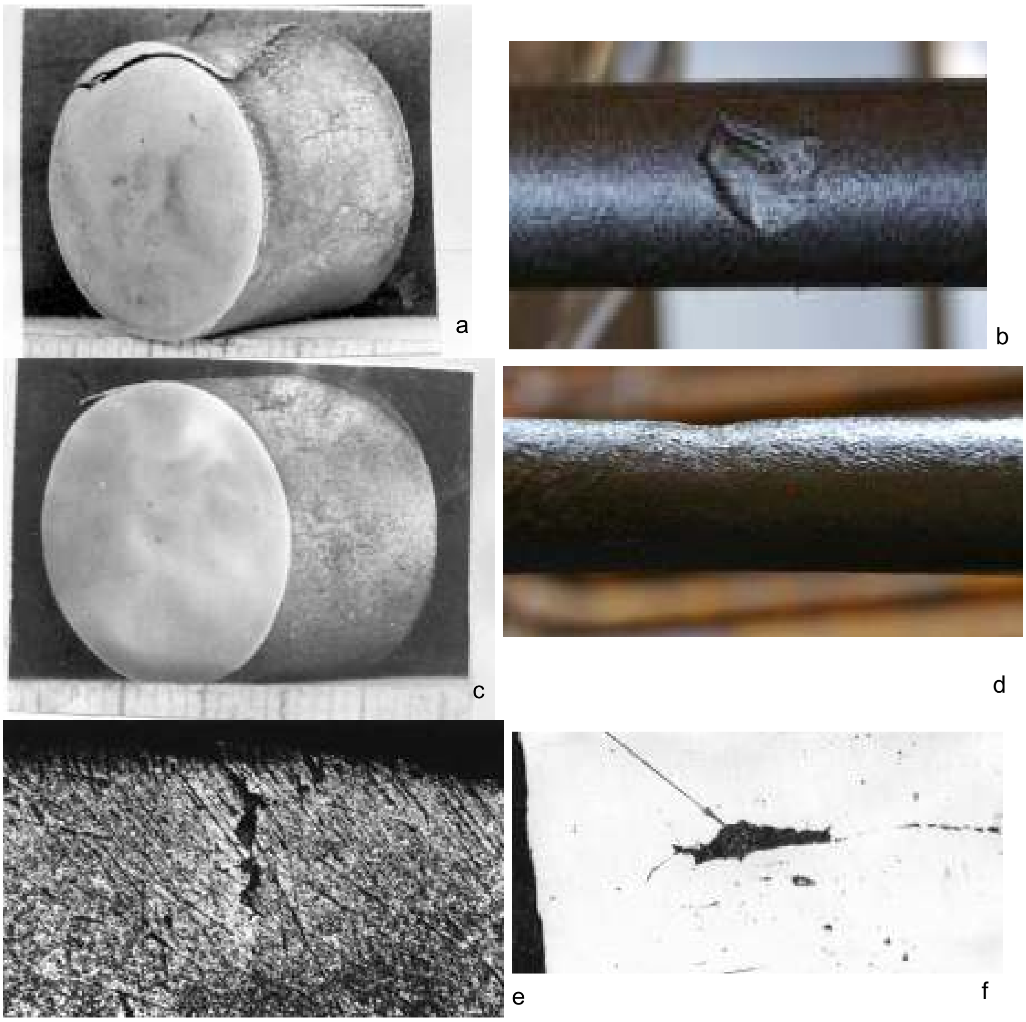

Fig.4. Microsection metallograhyic specimens of some defects in the pump rods ∅19 mm: a - steelmaking defect - scab, b- mechanical impact defect - indent, c - rolling defect fold , d - shrinkage cavity, e - hair seams, f - slag inclusion

Wave reflection can be also caused by the sources containing stress concentrators (such defects as cracks, hair seams). Thus depth and opening of the detected cracks, the sizes of inclusions can make the hundredth or thousand shares from an acoustic wave length ($\lambda/100 - \lambda/1000$), unlike classical ultrasonic methods which detect the defects of $\lambda/2$. Some microsection metallographic specimens of the pump rods and pump-compressor tubes with defects detected are shown on Fig. 4,5.

Mechanical effect of acoustic pulses on the extended objects is similar to operational stresses (for example stretching-compression strain for the pump rod at a chink operation is analogical the strains attendant the rod wave propagation. It allows to increase the sensitivity to defects, simplifies their identification and danger estimation. Thus it is possible to approve that the defects detected by this technique are the most dangerous, inclined to development at operation and can become the reason of breakage of a pump rod column.

Fig.5. Snapshots of defects, detected in pump-compressor tubes: a - 2,3 mm wear of the inner tube surface caused by the coupling, b – through flaw, c - through crack, d – local corrosion of outer tube surface, e- 2,5 mm local corrosion of inner tube surface, f- extended corrosion of inner tube surface, g - extended corrosion of outer tube surface

RESULTS OF NEW TECHNOLOGY INTRODUCTION IN OIL-EXTRUCTING INDUSTRY

The technology of acoustic testing of extended objects is used for development the installations for oil field equipment diagnostics: acoustic defectoscope of the pump rods ADNS, acoustic defectoscope of the pump-compressor pipes ADNKT has been implemented at close corporation in the pump rod repair bays of public oil-extracting enterprises of Russia (“Tatneft”, “Belkamneft”, “Lukoil. West Siberia” etc.); acoustic defectoscope of the rods (ADP) has been implemented the works of oil field equipment (Perm, Russia, Aktjubinsk, Kazachstan) for incoming inspection of the pump rod billets.

Some characteristics of developed devices ADNS, ADNKT are resulted in the Table 1.

Table 1. Basic Technical Characteristics of ADNS, ADP, ADNKT

Diameter of inspected rods (bars), mm Sizes of inspected pump-compressor tube, Diameter mm Wall thickness, mm	19, 22 73 6
Length of inspected rods (bars, tubes), mm, not less than	3000
Installation productivity, pcs/shift, not more than	1000
Length measuring error of the object, mm	±5
Power consumption, W, not more than	400
Installation weight excepting PC and industrial case, kg, not more than	10
Types of revealed defects: scabs, blisters, cavities, folds, exfoliations, cracks, hair-seams, variations in wall thickness, tube wall wear by friction, corrosive damage and other types of external and internal defects, both inherent, and developing in the course of operation.	

During 4 years of operation of ADP equipment about 20000 tons of metal of rod billets with total extent 10000 km (about eight trains) are inspected. Introduction of new technology and the equipment for testing of the rod billets and pump rods has lead to the following positive results:

- Decrease of rejected rod billets put in production of pump rods that leads, on the one hand, to reduction of expensive operations (editing, scrap of the ends, fillet pressing and turning, heat treatment, groove cutting), on the other hand to revealing the reasons of defect emergence and to updating technological process with the purpose of the flow elimination in the further.
- Reduction of rejected pump bars at installation of oil-extracting chinks that decreases a number of failures owing to bar breaks and expenses for liquidation of their consequences.
- The pump rod column failure reduced in 3,5 times and the failure number was established at a level 60-70 one year in “Belkamneft”.

CONCLUSIONS

The technology uses the variant of echo-pulse technique from the ends of extended object, thus doesn't demand scanning, additional surface preparation and application of coupling liquid or immersion environment. Method has high productivity of the equipment realizing technology, makes up to 1000 pieces or about 10 km of length and equally high sensitivity to dangerous internal and surface defects.

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