New Technology and Equipment of Acoustic Testing of Extended Objects

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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 waves application. Results of using new technology for the defectoscopy of the rods, pump rods and pump-compressor pipes are demonstrated. The advantages and prospects of new technology utilization are shown.

Introduction

Among variety of metallurgical, machine-building, oil-extracting industry products there is a wide nomenclature of extended objects which length surpasses the cross-section sizes in 100 and more times (bars, pipes, wire and products from it - 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 essence of new technology

The new progressive technology of acoustic defectoscopy of extended objects is based on the use of Pochammer waves and assumes the application of the symmetric zero mode S_0 (rod wave) in the field of the minimal dispersion of velocity (small products of object diameters d and wave frequencies f), or zero torsion mode T, in which the dispersion is absent in general. The distinguish peculiarity of these wave types is extremely low attenuation that allow to test by sonic very extended objects (length of some hundreds meters). Because of insignificant velocity dispersion (or its absence) 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). While 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 [1] at other equal conditions.

The scheme of the technology realization for acoustic defectoscopy of extended objects is presented on Fig.1.

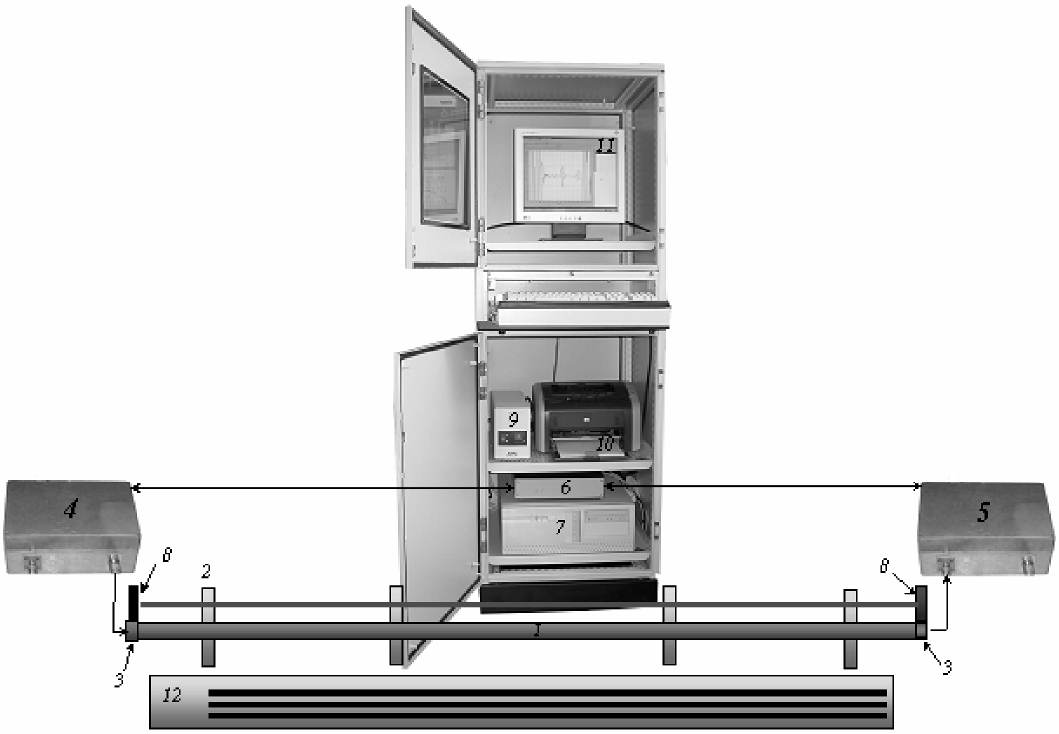

Fig.1. **The scheme of technology realization:** 1 -extended object, 2 - testing rack, 3 - source and receiver electroacoustic sensors, 4,5 - generator and preamplifier units, 6 - control and switching unit, 7 - PC system with ADC, 8 - laser roulette with a reflector, 9 - UPS unit, 10 - printer, 11 - 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. 2 the typical defectograms of the pump rod and pump tube with local defects are presented.

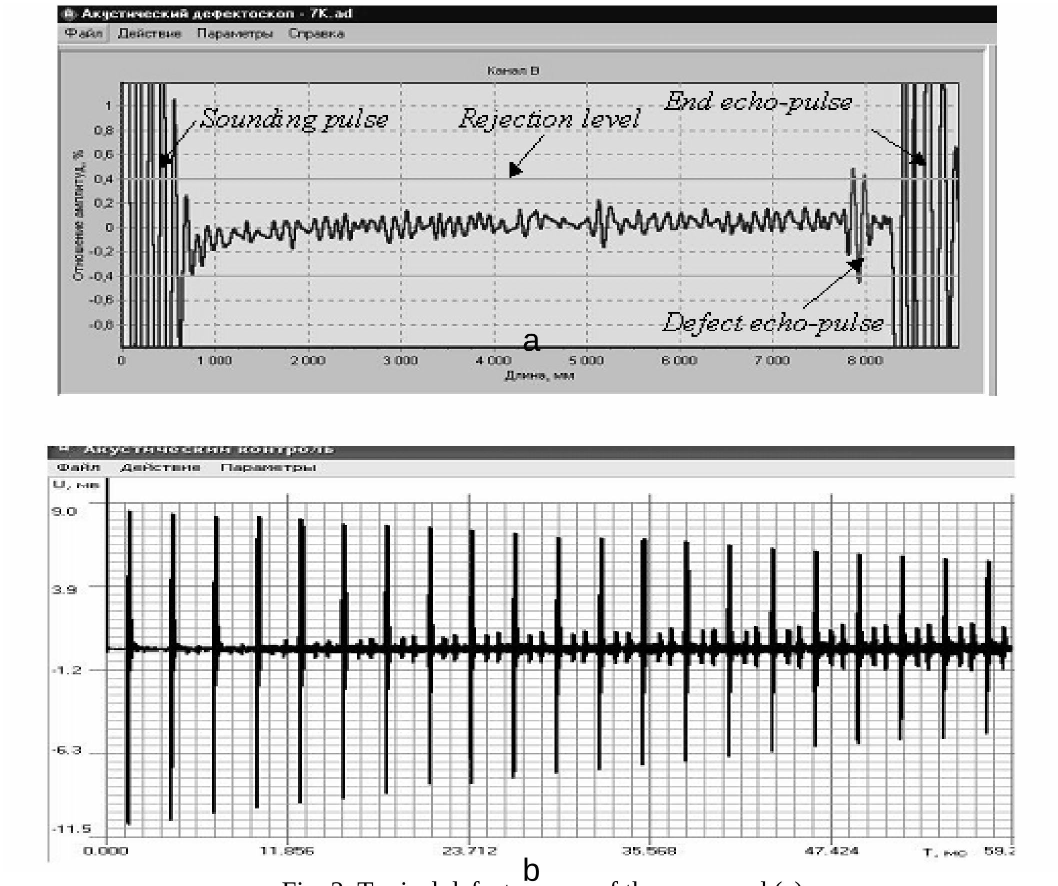

Fig. 2. Typical defectograms of the pump rod (a)
and the pump-compressor tube (b) with local defect

Types of revealed defects

The results of theoretical and experimental research [3] 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.). 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.3,4.

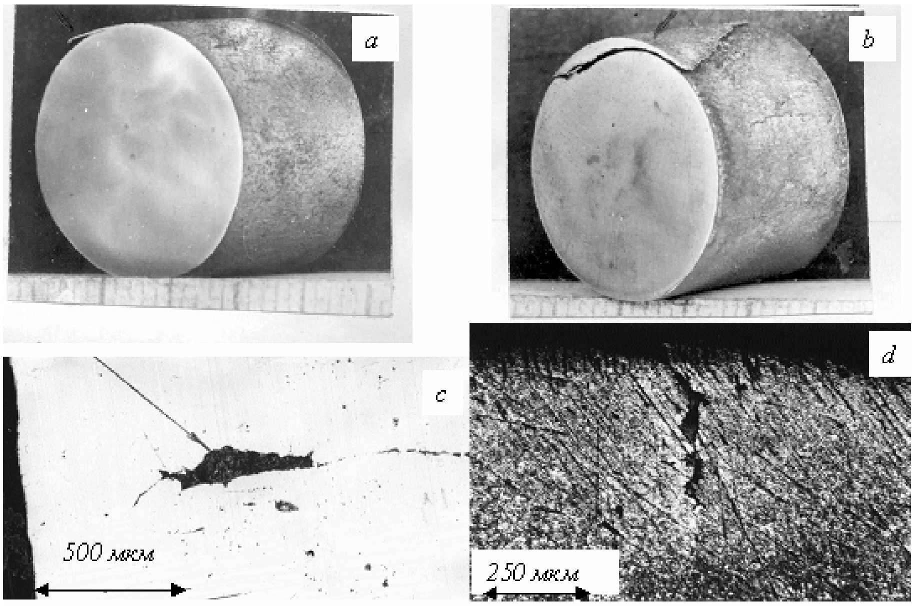

Fig. 3. Microsection metallograhyic specimens of some defects in the pump rods ∅19 mm: a - rolling defect - fold, b- steelmaking defect - scab, c - slag inclusion, d - hair seams

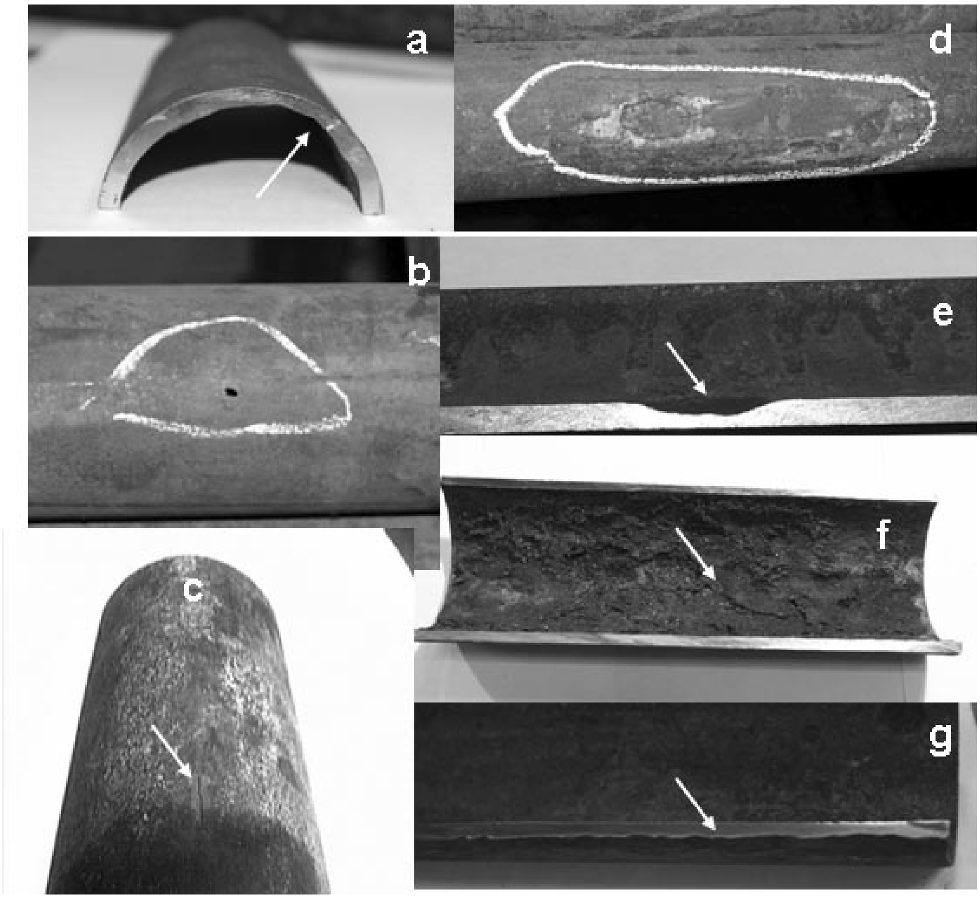

Fig.4. Snapshots of defects, detected in pump-compressor rods:
a - 2,3 mm wear of the inner tube surface caused by the coupling, b – through flaw, c - through crack, d – local corrosion of outer tube surface, e- 2,5 mm local corrosion of inner tube surface, f- extended corrosion of inner tube surface, e- extended corrosion of outer tube surface

Results of new technology introduction

The new technology of acoustic testing of extended objects is realized in the following equipment:

- Acoustic defectoscope of the rods (ADP) (two installations) has been implemented at close corporation “Motovilihinskiy works of oil field equipment” (Perm, Russia) for incoming inspection of the pump rod billets with diameters ∅ 19 mm and ∅22 mm;
- Acoustic defectoscope of the pump rods (ADNS) (5 installations) 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.);
- Portable acoustic defectoscope of the rods (PADP) has been implemented for incoming inspection of the rod billets with diameters ∅4-25 mm of tool steel on DOAO “IIZ” (Izhevsk, Russia).
- Industrial tests of acoustic defectoscope of the pump-compressor pipes ADNKT are carried out at the Chelyabinsk pipe-rolling factory, on the repair bays of pump tubes at the oil-extracting enterprises.

Photo of the pump-compressor tubes testing organization at repair workshop of public company “Belkamneft” (Karakulino, Udmurtia) are presented on Fig.5.

Some characteristics of developed devices ADNS, ADP, 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.

Fig. 5. Pump-compressor tube testing organization
(open society ”Belkamneft”)

The basic advantages of the new technology

1. Mechanical effect of acoustic pulses on the inspected parts of extended objects is similar to operational stresses. Criterion of similarity is not the intensity of force action, and the character of the stressed condition (stretching-compression or torsion). Similarity is achieved by use of rod wave S_0 and torsion wave T_0. The first is accompanied by tension-compression strain, therefore it should be used for rod billets and pump rods inspection, the second – by torsion strain, and it should be used for boring pipes inspection, for example. It allows to increase the sensitivity to most dangerous defects inclined to development at operation, simplifies their identification and danger estimation.

2. 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.

3. High productivity of the equipment realizing technology, makes up to 1000 pieces or about 10 km in shift.

4. Equally high sensitivity to dangerous internal and surface defects.

Acknowledgments

This research has been supported by **Russian Federation President Grant MD-1668.2005.8.**

References

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