IMPROVED TESTING OF LONG-LENGTH PRODUCTS BY USING CONTACT AND NON-CONTACT TECHNIQUES

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Topicality. Intensive industrial development and the use of new constructional materials and technological production processes suggest new methods of non-destructive testing which could provide reliable and cost-effective product testing [1]. Currently, rolled products made of diverse metals and alloys are being used in almost every brunch of industry. Thus, non-destructive testing of rolled-stock accomplished prior to its further treatment becomes really important ensuring significant decrease in the expenses. The acoustic method of non-destructive testing, ranking first by its application in industry, is rapidly developing and considered one of the most universal methods. This technique detects impurities, porosities, cracks, shrinkage cavities, segregation areas, internal stress areas, etc.

Introduction. Faults in technological process of producing long-length products may cause defects oriented along the product guiding line which can impair the product's characteristics and even damage it. Flaw detection in rod-shaped products according to the standard ГОСТ 21120 [2] must be made from several directions of the perimeter along the whole length of the product. This is a time-consuming and ineffective operation especially for rods and other elongated objects with small cross-section, e.g. work pieces of circular, rectangular, hexahedral and other sections, rolled sheets, tubes, etc. It is usually performed by using low-frequency flaw detection methods and instruments. On the one hand, the low-frequency equipment increases its efficiency, but on the other hand it is insufficiently sensitive especially to the defects stretched along the generating line. Thus due to high sensitivity of the traditional method with its low efficiency and insufficient sensitivity of low-frequency methods with their high efficiency, there appear an industrially important scientific problem. Its aim is to develop a method which could detect defects in elongated products and ensure high efficiency.

Discussion.

A new technology was developed to detect flaws without scanning the object surface. It is based on the application of diffraction effects to reveal defects in rods. The method forms a wave packet in a rod with the help of an inclined piezoelectric sensor, Fig.1. The piezoelectric sensor 2 excites elastic ultrasonic vibrations in the long-length object 3 through the contact liquid 1 angularly to the normal line. Reflecting from the object's boundaries these vibrations transform into other wave types. For instance, a transverse wave reflecting from the surface of an object transforms into transverse, longitudinal and surface ones. Multiple re-reflections and transformations in the object will cause the formation of a wave packet at a definite distance from the source of the acoustic waves. Since the object is limited in its section, the wave packet will propagate to large distances, i.e. in order to test a long-length object there is no need to scan the whole surface. If the object contains a flaw 5, the pulse packet diffracts at its end face 6 and forms the corresponding packet 7 in the direction of the transducer. The diffracted pulses are read by the transducer and displayed on the flaw detector screen 4.

Using this technology, a number of experiments were performed which showed that ferromagnetic samples 10-50 mm in diameter and up to 6m long are positively tested with a standard piezoelectric transducer with pulse stuffing frequency of 2.5 MHz and the angle of ultrasonic wave introduction of 50°, since at high frequencies and introduction angles the pulse dies out along the object. If the frequency of the monitoring pulses and the introduction angle are less than the given ones, the ratio of the pulse packets "defect-end face" is rather large.

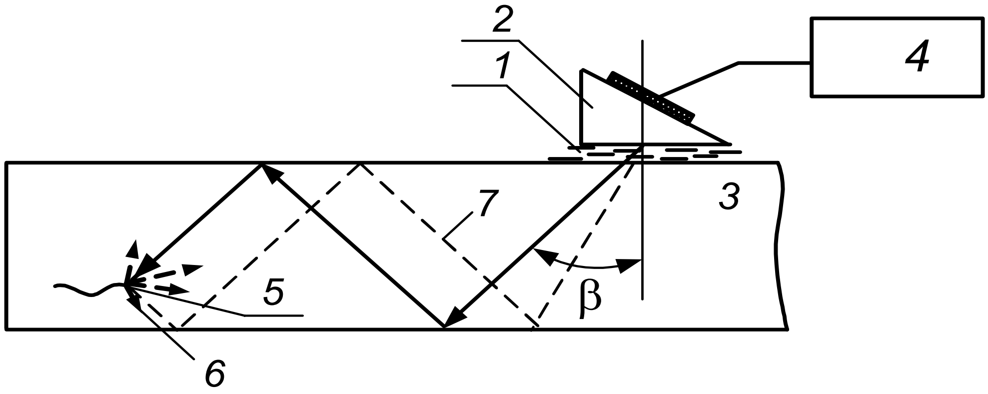


Figure 1. Scheme of the high-efficiency technology for rod testing using the effect of acoustic wave diffraction on defects

The testing of non-ferromagnetic samples of the same sizes and length is performed best with a piezoelectric transducer with pulse stuffing frequency of 1.8 MHz and introduction angle of 40° [3].

The results of rod testing by the contact method largely depend on the presence of a contact liquid on the surface of the object. The pulses from the liquid droplets mask the desired signals thus decreasing the technique's sensitivity to the defects.

The impact of the contact liquid on the results of testing can be eliminated by the use of non-contact ways of excitation and reading of the ultrasonic pulses. The electromagnetic and acoustic (EMA) technique is the most developed [4]. An electromagnetic and acoustic transformer can excite bulk waves similar to those excited by the piezoelectric transducer, i.e. shear waves with vertical polarization. Besides, EMA transducers have a double acoustic field radiation pattern. Thus, the acoustic field from EMA transducer propagates from the middle of the elongated in one direction object simultaneously to the both sides [5]. This helps to double the effectiveness of the new flaw detection technique.

To create an acoustic field directed so that its axis is inclined to the introduction surface, the transducer conductors must be zigzag shaped with a given pitch and repeat the shape of the tested object when the transducer excites or reads the acoustic vibrations [5]. In this case, in a very thin metal surface layer there appear disturbing forces caused by space distribution of alternating electromagnetic field and constant polarizing magnetic field. In the experiments, the inductor consumes the current with central frequency of 1.5 MHz and its design provides excitation of bulk vibrations at an angle of 37°.

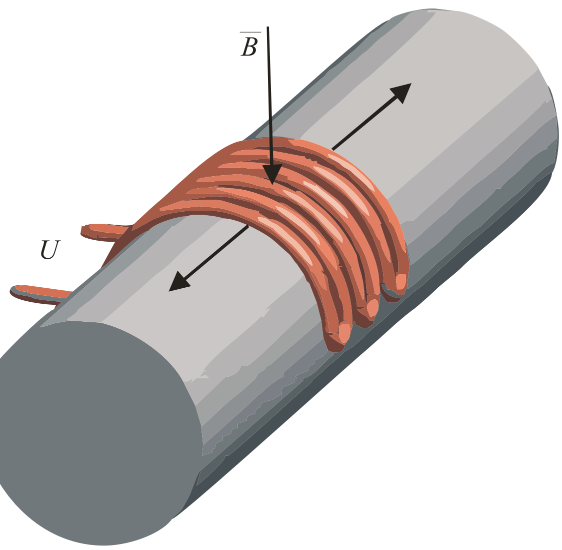
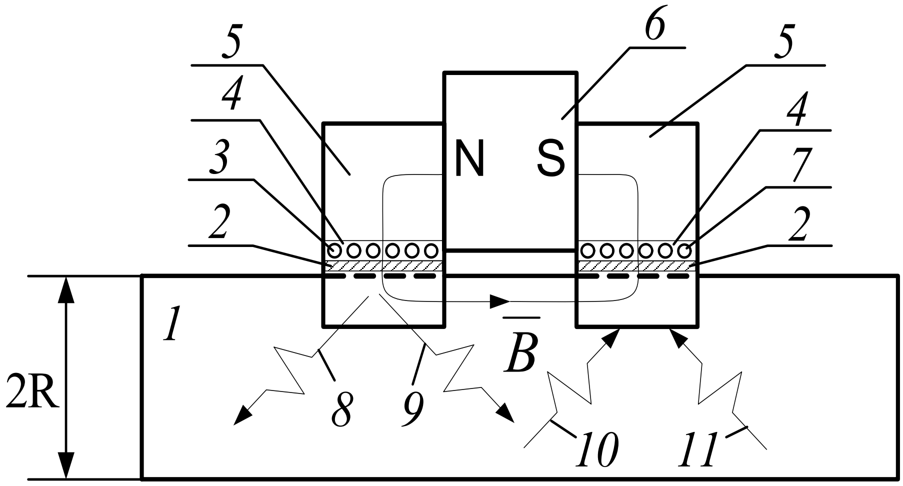
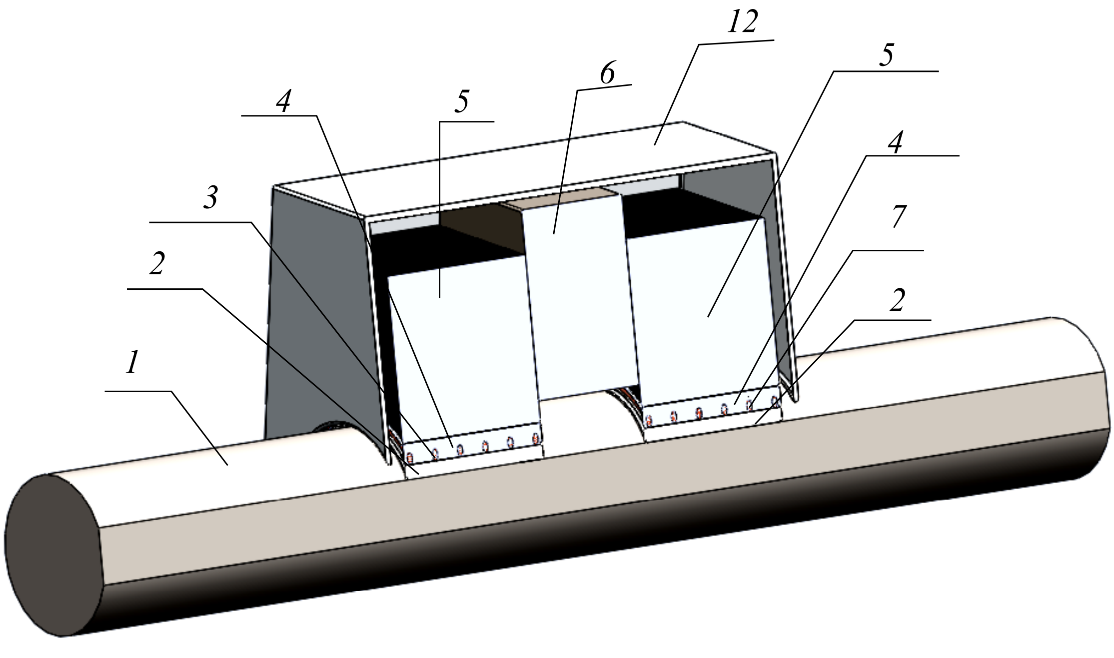


Figure 2. Model view of a high-frequency inductor for testing circular section rods

It is quite expedient to form the magnetic field of the EMA transducer by creating a closed system (Fig.3 *a*). Such approach is the most rational since most of the products manufactured by metallurgical enterprises are ferromagnetic. 3D view of the transducer placed on a rod is shown On a Fig. 3 *b*)/



a)



b)

Figure 3. Simplified presentation of a source of constant magnetic field of an EMA transducer for testing circular section ferromagnetic rods:
1 – test object; 2 – protector; 3, 7 – radiating and receiving high-frequency coils stuck to the insulating plate 4; 5 – magnet core; 6 – permanent magnet; 12 - case.

Such type of a transducer operates the following way. The permanent magnet 6 creates in the operation area the magnetic field induction of a desired value via the core 5. In the same area, the high-frequency inductor 3 creates an alternating field. As a result of the fields' interaction, alternating voltages and corresponding acoustic fields are excited in the metal surface layer and propagate at an angle to the surface in two directions 8, 9 along the rod axis. Re-reflecting and transforming, the waves propagate up to the object's end face or defect and reflect from them thus forming the wave packet 10, 11 which is received by the coil 7.

While testing non-ferromagnetic objects, constant magnetic field should be created by shifting it into the operation area of the EMA transducer, Fig.4. It is quite obvious that it will have both normal and tangential components. In this case, it is a great advantage as it can cause the excitement of both longitudinal and share bulk vibrations.

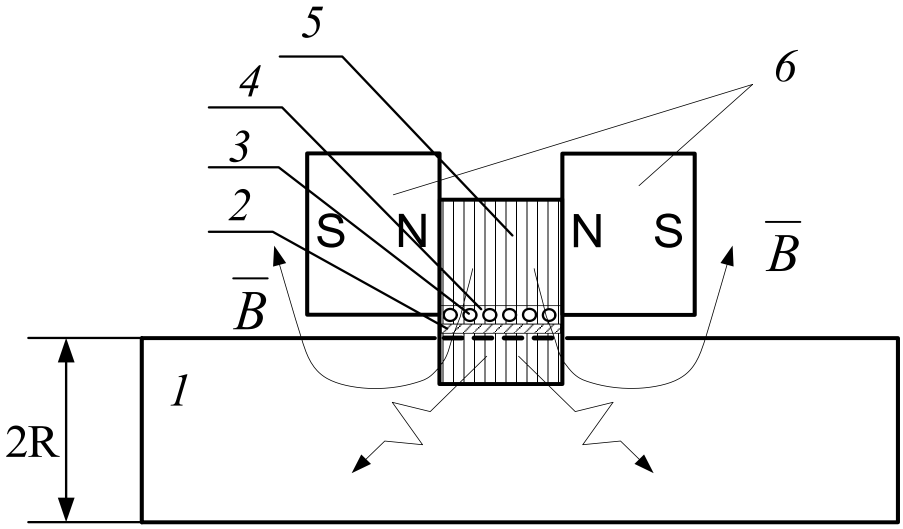


Figure 4. Simplified presentation of a source of constant magnetic field of an EMA transducer for testing circular section non-ferromagnetic objects:

1– test object; 2 – protector; 3 – high-frequency coil stuck to an insulating plate 4; 5 – magnet core; 6 – constant magnets.

From the analysis of the presented technique and the data obtained it is **concluded** that:

1. The developed technique ensures higher reliability of longitudinal defects detection in rods irrespective of their location, shape and filling material.

2. The new technique is highly efficient, e.g. rods up to 6m long can be tested by 3-4 applications of the transducer.

3. It is shown that the probability of flaw detection in long-length objects can be increased by the application of EMA method of excitation and receiving of bulk waves at an angle to the surface.

References: 1. Non-destructive testing: Reference book: In 7 vol. Under general edition of V.V.Kluyev. Vol.3: Ultrasonic testing / I.N.Yermolov, Yu.V.Lange. – G.: Mechanical Engineering, 2004. – 864 p. 2. ГОСТ 21120-75 "Rods and blank parts with circular and rectangular section". 3. Suchkov G.M., Nozdrachova K.L. Increase of the efficiency and reliability of flaw detection in rods // Bulletin of NTU "KhPI". 48, 2008, P. 104-109. 4. Suchkov G.M. Up-to-date capacities of EMA flaw detection. – Flaw detection. -2005. - №2. – p. 24-39. 5. Suchkov G.M., Donchenko A.V., Desyatnichenko A.V., Kelin A.A., Nozdrachova Ye.L. Increase of sensitivity of EMA instruments // Flaw Detection. №2. – 2008. – p. 15-22. 6. Suchkov G.M., Nozdrachova K.L. Electromagnetic and acoustic transducers for testing long-length objects by echo-diffraction method. – Kharkov: Bulletin of NTU "KhPI". 14, 2009, P. 72-81.