Main Developments of the E.O. Paton Electric Welding Institute in the Field of Non-Destructive Testing

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Abstract
The E.O. Paton Electric Welding Institute of the NAS of Ukraine is a world-known technological complex in the field of welding and related technologies, one of which is non-destructive testing. Described are the most famous developments of the Institute in the field of non-destructive testing, being performed together with other companies and implemented in different countries, namely X-ray television system based on CCD matrix and luminescent screens; technology of tangential radiography and radioscopy; pilot model of ultrasonic system for testing of extended objects without scanning of their surface using low-frequency ultrasonic waves; systems of automated control using piezo- and EMA–excitation of ultrasonic waves for detection of pipe defects; procedures for evaluation of dimensions of internal crack-like defects based on TOFD, SAFT, phased-array method; movable magnetizing devices on constant magnets; system of magneto-optical testing for detection of thin defects without intermediate carriers of information about magnetic leakage fields etc.

Keywords: NDT-wide, guided waves (lamb waves), phased array, movable magnetizing devices, EMAT, X-ray television system

1. Introduction

Today development of welding technologies is impossible without application of methods of non-destructive testing. They promoted increase of quality of materials and welded structures of critical designation. This, in turn, resulted in development of fundamentals of flaw detection and rise of number of developments on NTD.

2. Main developments

The most famous developments of the E. O. Paton Electric Welding Institute of the NAS of Ukraine in area of NDT, being performed together with other companies and implemented in different countries, are NDT systems, combining different forms of NTD and types of automated units, for ultrasonic testing of quality of welded joints in large diameter pipes, evaluation of products of chemical machine building, rocket production and special parts and ultrasonic simulators, statistical radiographic references, portable magnetic flaw detectors based on constant magnets from rare-earth metals and portable X-ray television equipment etc.

Technologies for evaluation of thickness and adhesion of the different base thin protective coatings were developed and means for examination of corrosion damage of the buried pipelines, loss of their geometry and damage of insulation were created. Much attention is given to development of means and technologies for monitoring of hydrogen-induced and corrosion cracking and crack formation appearing during cooling of metal after welding.

Thus, NDT technologies for rocket-and-space techniques, automated ultrasonic testing (UST) of large-dimension structures, means and procedures for evaluation of geometry of large volume constructions, equipment for testing of drill bits, drill-pipes and their screw joints were developed
in different years. There are very important developments in quality testing of pipes and rolled metal, technologies and equipment for automated UST.

Two laboratories of radiation methods of testing work at the Institute. The researchers of these laboratories developed X-ray detectors with low content of silver, X-ray television systems, devices for automatic image interpretation and portable dose meters. In particular, among the development of these laboratories of recent years are the equipment for digital radioscopy of welded joints based on CCD-matrix, systems of digital processing of X-ray images and documents archiving. The Institute also has the unique high-energy radiation laboratory with biological protection up to 18 MeV in which testing of the parts (to 80 mm in steel) is carried out. Tangential radiation examination of bodies of revolution etc. in combination with digital processing of information is realized. Figure 1 shows the fragments of technology of tangential radiation examination of bodies of revolution allowing determining residual metal thickness, gaps between sheath and body and internal volume filling etc. Till now, only the E. O. Paton Electric Welding Institute realizes this unique technology in Ukraine. Procedure of color differentiation of boundaries in radiation images of pipe wall and further layers, for example, thermal insulation, was developed for this method. As an example, Figure 1 shows pipe section of 60 mm diameters, pipe wall thickness 5 mm and 2 mm insulation thickness; $H_w$ is a pipe wall thickness, $H_i$ is an insulation thickness.

![Figure 1. Technology of tangential radiation examination](image)
Principle of the tangential radiation examination is clarified in Figure 1 and received information is presented in Figure 1, b–d. Accuracy of pipe wall thickness determination in standard processing of the images makes 5±1.5 mm. Developed algorithm of the digital image processing provides for increase of measurement accuracy of pipe wall thickness to 5±0.2 mm.

Means of magneto-optical testing, which in addition to defect detection provides for information about residual magnetic fields on the surface of ferromagnetic materials, were developed. This method has found application in the criminalistics. The investigations showed that it can be used for evaluation of quality of precision treatment of metallic surfaces, for example, polished hold-down blots of high-power turbines, surfaces of valves and their seats of heavy motors etc. This is the most accurate method allowing detecting of thin defects as well as local loading of metal.

Figures 2 and 3 show a principle scheme of the magneto-optical method and results of comparison with other methods (visual, penetrant testing, magnetic particle). Numbers 1 and 2 in Figure 3 show light pigmentations (object noises) and fine cracks, being visualized by all comparable methods, number 3 indicates very fine cracks, detected only by magneto-optical method. The magneto-optical method is based on visualizing of topography of magnetic leakage field of the defects with the help of ferrite-garnet film, in which structure of magnetic domains is sensitive to insignificant external magnetic fields. The methods of magneto-optical testing of rolled metal and welded joints with the help of intermediate information carrier (magnetic tape) as well as directly using magneto-optical transducer were studied. The magneto-optical method allowed detecting fine defects which are not “seen” by other methods. An important peculiarity of the given method with laser-optic visualizing of magnetic fields is presentation of surface and subsurface defects as well as local loading of metal structure in actual size.

Development of portable digital X-ray television equipment (Figure 4) based on high-sensitive CCD-matrices and luminescent CsJ screens is the undeniable achievement of the recent years. Portability, availability of digital image processing and low cost expand new possibilities for performance of radiation examination in field and shop-floor conditions of number of the objects which could not be examined by NDT capabilities at present time. Thus, numerous gas-, oil- and hydro-distributing pipelines of small diameter and process pipelines of petrochemical production
are virtually not inspected for presence of internal defects due to high cost of film radiography and physical limitations of UST for thin-walled objects of large curvature. Implementation of the means of portable XTT in the next years can solve this problem. Given system of portable XTT allows performing of X-ray testing quicker and cheaper than any other X-ray examination with intermediate information carriers.

![Positioning of equipment over the test object](image1.png)

![Analysis of test results on laptop screen](image2.png)

**Figure 4. Portable XT-system: a) X-ray apparatus; b) Detecting device and laptop**

Movable magnetizing devices (MD) on constant magnets (Figure 5) used for local magnetizing of metal structures gained wide distribution in the last decade. They significantly shifted adjustable MD, since at that MD pull force was reduced by order and testing efficiency and possibility of scanning in different directions increased. Based on this, the E. O. Paton Electric Welding Institute (PWI) developed a series of movable adjustable (Figure 5, a) and rotating (Figure 5, b and 5, c) magnetizing devices which rise by order efficiency of MPT of extended welded joints and provide for detection of different orientation defects. The E. O. Paton Electric Welding Institute has a priority in this direction. The Institute is still the unique manufacturer of the movable magnetizing devices. Besides, the rotating magnets can have smooth surface or surface with moving contact rolls.
One of the main achievements of the Institute are works on study of the possibilities of low-frequency (LF) long-range (LR) UT, allowing examination of long-length structures without scanning of their surface. Figure 6 shows positioning of an array of transducers on heating main which provides for UT of the pipeline without its scanning. LF US-system for detection of corrosion wear and other large damages in the pipeline gives the possibility of evaluation of technical state of the whole object in both sides from the place of array positioning. Basis of the system makes an analysis of low-frequency guided waves capable to propagate at large distances. At that, corrosion damages and other defects of metal loss, depth of which is more than 10% of pipe wall thickness, are detected at up to 100 m distance. These developments of PWI researchers were used in the program of European project LRUCM, in which the scientists from 11 more European countries participated under the leadership of TWI.

An irrefutable advantage of LRUT technology is a possibility of sufficiently quick detection of the most critical sections of the pipeline without scanning of their surface, opening and digging, that is in particular important for difficult-to-reach sections. Therefore, such systems, first of all, are used in Ukraine for diagnostics of the pipelines intersecting the roads; pipelines passing the walls; one-type site circumferential welds of the pipe sections which can number several dozens; in the case of using of different types of saddles with zones of corrosion damages; corrosion under insulation etc.
3. Conclusions

In recent years, the methodical basics of defect detection, using radiography, and statistical reference specimens, increasing quality of radiogram interpretation and detection of thin crack-like defects with small opening, were developed by PWI in area of flaw detection. Interaction of LF-array and extended object of testing was investigated. Proposed are structures of the arrays and equipment for their excitation and processing of LF information. Acoustic path of through-transmission flaw detector was investigated using short and long-focus pulse EMA-transducers that rises the possibility of detection of delaminations and corrosion damages in sheet welded joints.

The technology of tangential radiography and radioscopy was developed for measurement of pipe wall thickness, its insulation and inside filling without interruption of its operation. Investigation of anomalies of own magnetic field of the object under mechanical stresses was carried out that allowed predicting appearance of fatigue cracks. Capabilities of the magneto-optical method were studied for detection of the thin defects without intermediate carrier of information about magnetic leakage fields in form of nickel strip. X-ray television systems based on CCD-matrix and luminescent screens were developed, which open real capabilities for examination of numerous auxiliary objects of oil- and gas distribution complexes in which NDT has not been used till now. The procedures based on TOFD, SAFT and phased-array methods in UT were implemented for estimation of sizes of internal crack-like defects and low-temperature sulfurated hydrogen delaminations.

Thermal NDT method is widely implemented and basics of thermographic defectometry are laid. Development of the systems of automated testing using piezo- and EMA-excitation of US-wave for detection of delaminations-type defects in near-edge zones of weld and base metal of the pipe are still in progress. Development is carried out of automated systems of defect image identification as a result of US-testing, realized in novel automated units.