

# Weld Defects and Automation of Methods for their Detection

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**Abstract.** The article analyzes the process of electric arc welding. We identified the main types and causes of defects in welded joints and analyzed their main non-destructive testing methods. We show the advantages and disadvantages of each method. The method of ultrasonic control is considered in sufficient detail. We show the advantages of ultrasonic testing of welded joints with a flaw detector with antenna arrays on a practical example. The advantages of this method make it widely used to control the quality of welded seams. We considered peculiarities of application of the "USD-soft" PC program, which allows one to automate the control of welded seams. We found out that it is most effective to carry out automated ultrasonic testing in combination with other types of testing. Automated control, which makes it possible to quickly process the information received at the object of research, allows one to save time and immediately start repair work at the object.

At the construction site, electric arc welding of metal joints is mainly used. The main point of such welding is that the source of temperature is an electric arc between two electrodes. In this case, one of the electrodes is the metal of the structure.

A short circuit is needed to warm up the electrode acting as a cathode. The temperature of an electric arc can be up to 6000 °C. In this case, the metal is exposed to thermal action. Fig. 1 shows a diagram of the thermal cycle of low-carbon steel welding.

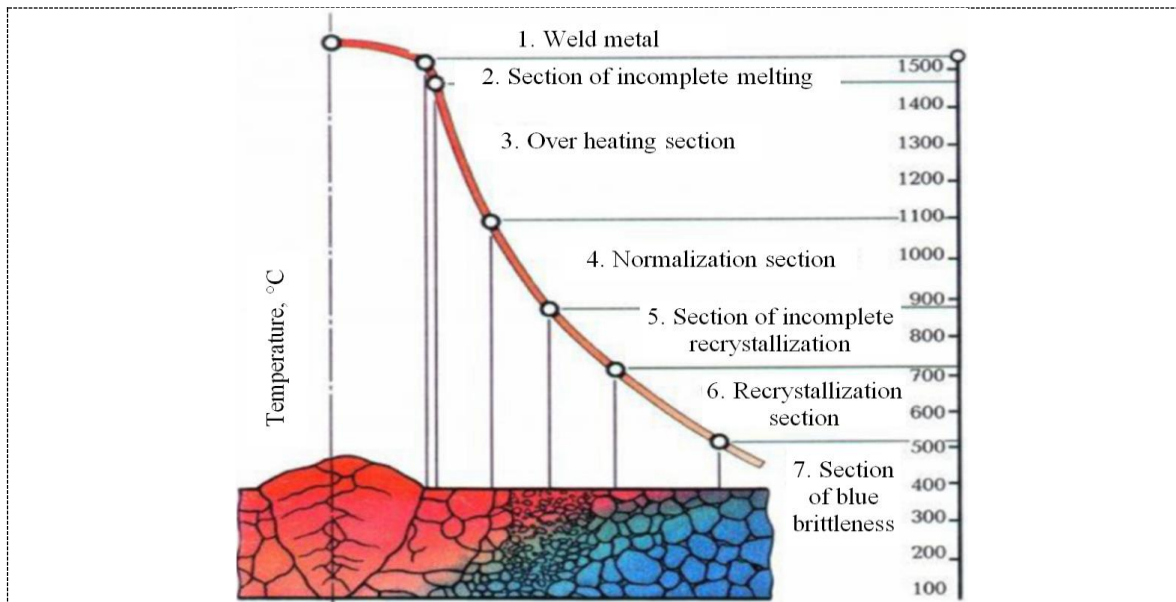
Under certain conditions, a welded joint may be defective. Therefore, quality control of welded joints is necessary.

The purpose of the research is to analyze defects in welded joints and select the optimal method for controlling their quality.

In practice, up to ten non-destructive methods of quality control of welds are used, which are applied on the basis of the requirements of technical specifications. Along with these methods, all welds should also be visually inspected. The external examination helps to identify almost all types of external defects.

Visual inspection is also carried out through a tenfold magnifying glass. This inspection may include measuring welds and edges, using specially designed tools. The impermeability of container under pressure is usually diagnosed by pneumatic and hydraulic tests.

During the hydraulic test, the container is filled with water. It is also necessary to create an overpressure for 5-10 minutes, which is 1.2-2 times higher than the working pressure. In this case, the reliability of the joint depends on the presence of moisture on the joint and on how much the pressure will drop. Filling tests are carried out in the same way.



**Figure 1.** Low-carbon welding thermal cycle diagram.

The watering test is carried out on large products for which it is possible to examine the seams on both sides. The proofness of the seam is checked by pouring water under pressure from a hose from one side of the product to the other side.

If a hydraulic test cannot be performed, a pneumatic test is carried out. This type of test assumes the ability to fill a container with compressed air at a pressure of 10-20 kPa above atmospheric pressure or 10-20% above the working pressure. In this case, it is necessary to moisten the welded joints with soapy water. If there are no air bubbles, the joint quality is good.

Welding proofness is often checked with kerosene. In this case, chalk is applied to one side of the welded joint, then the other side of the joint is moistened with kerosene. Since kerosene has a high permeability, poor quality of the seam is revealed if dark spots or stains appear on the back of the seam.

The chemical method of checking the quality of welded joints involves the use of ammonia and special substances. A mixture of 1% ammonia and air is used, which is pumped into the test container, while the welded seams are sealed with tape moistened with a solution of phenylphthalein or 5% solution of mercury nitrate. If the seam is of poor quality, the color of the tape will change when ammonia hits the tape.

Magnetic control is clearly illustrated in fig. 2. When using this method, an electromagnet core is connected to the test piece; or the piece is placed inside a solenoid.

Substances that react to a magnetic field (e.g. iron shavings, oxide deposits) are applied to the surface of the magnetized joint. When the seam is defective, an accumulation of the substance in the form of a directed magnetic spectrum occurs on the surface of the product.

The stray magnetic fields can also be recorded with a magneto graphic flaw detector. In this case, the welded joint is compared with a reference sample.

Radiation monitoring makes it possible to detect cavities in the joint that are not visible during an external examination. The welded joint is examined using X-rays or gamma rays that penetrate the

metal, see fig. 1. For this purpose, the emitter is placed on the investigated side of the seam, as shown in fig. 3, and the X-ray film is placed in an opaque cassette on the opposite side.

Radiation passing through the metal hits the film and, in the defective areas, leaves spots of a darker color than on the entire investigated surface of the weld since the defects are characterized by lower absorption. The installation of the X-ray method is too cumbersome and therefore used only in certain conditions. This method does not detect cracks that are not located in the direction of the main ray.

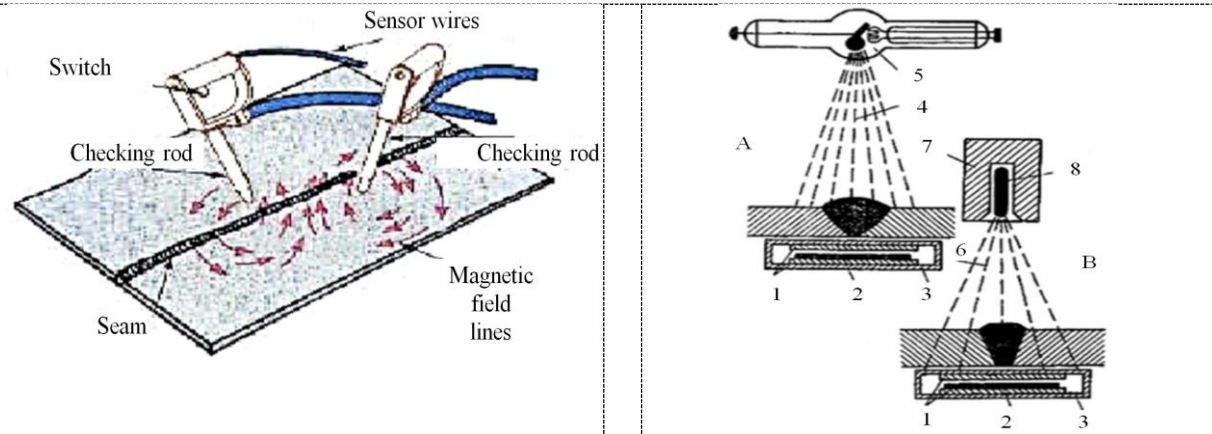
If fluoroscopy is used, then when a signal about a defect is received, the information is displayed on the device screen. The accuracy of this method is actually not less than that of the radiation method.

The methods of acoustic control include the ultrasonic method, which can be used to detect defects with small holes. Its principle of operation is based on the ability of ultrasonic waves to reflect from the interface between two media, as shown in fig. 4.

The piezoelectric method of generating sound waves is the most common. The method is based on the excitation of mechanical vibrations when an alternating electric field is applied to a piezoelectric material. Quartz, lithium sulfate and barium titan ate can be used as piezoelectric materials.

Ultrasonic vibrations can be longitudinal and transverse. If the particles of the medium move parallel to the direction of wave propagation, then such a wave is longitudinal, if perpendicular - transverse. To control defects in welded seams, transverse waves are mainly used, directed in a flow at an angle to the surface of the welded parts.

Ultrasonic horizontal waves are capable of penetrating material media to a great depth, refracting and reflecting when they hit the boundary of two materials with different sound permeability. It is this ability of ultrasonic waves that is used in ultrasonic flaw detection of welded joints, fig. 5.



**Figure 2.** Magnetic method diagram.

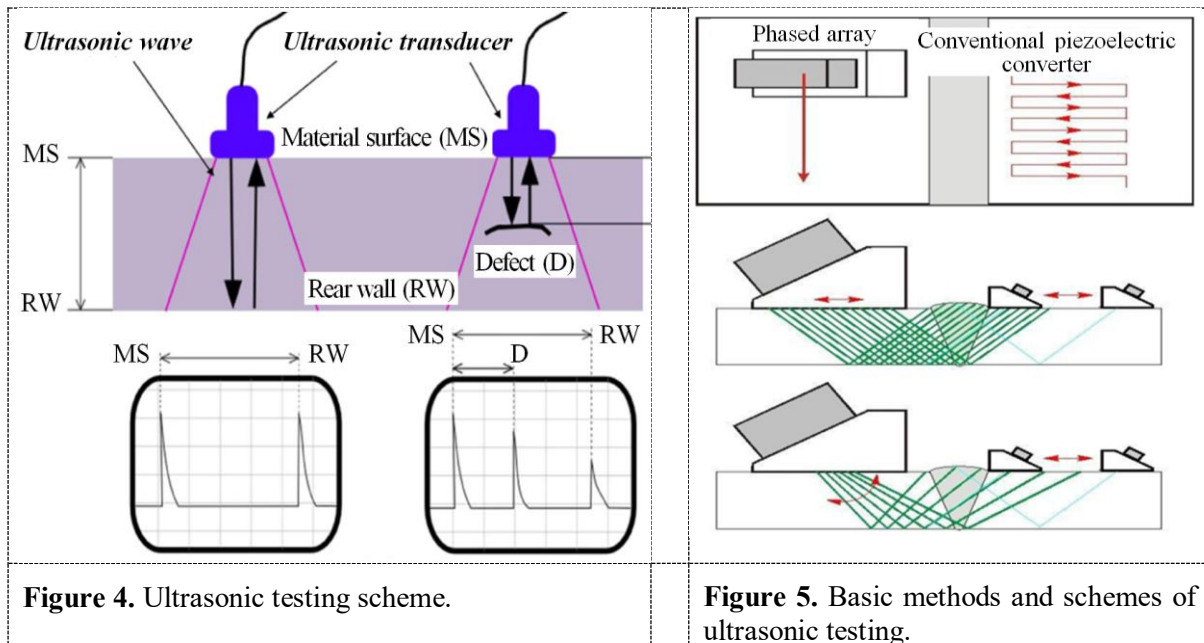
**Figure 3.** Radiation monitoring scheme: A - X-ray radiation, B - gamma radiation: 1 - amplifying screens; 2 - X-ray film; 3 - cassette; 4 - X-ray radiation; 5 - X-ray tube; 6 - gamma radiation; 7 - lead casing; 8 - ampoule of radioactive substance.

For the purpose of quality control of welds, alternative signs of reliability assessment are most often used. We checked a double-sided weld with a thickness of 10 mm when determining the required parameters. We used a flaw detector with a piezoelectric converter and a converter with an antenna array. We used Ultrasonic Flaw Detector A1214 EXPERT and Flaw Detector with Antenna Arrays A1550 Intro Visor for ultrasonic testing of the welds. When the samples were opened, we measured the actual size of the defect.

Compared with the assessment of one parameter during the inspection, the use of two parameters for evaluating the inspection results reduced the likelihood of incomplete detection of defects by 9.6% and

by 16%. A two-parameter assessment increases the probability of rejection but decreases the likelihood of a more important error - the probability of missing an unacceptable defect.

Timely quality control of welded joints is important to ensure the safe operation of equipment and can be carried out using information technology.



External Automatic Ultrasonic Scanner USD-60-8K-A is widely used in combination with non-destructive testing methods, fig. 6.

Technical diagnostics is possible provided that the linear part of the pipeline is opened when replacing the insulating coating, in the areas under study when examining the level of corrosion of pipes and welded joints.

Automated ultrasonic testing makes it possible to detect defects in factory welds, as well as internal and external defects in the metal of the product, including corrosion and stress-corrosion defects, which make up more than 10% of the pipe wall thickness.

The defect scanner can detect defects in welded joints (lack of fusion along the edges, cracks, lack of penetration, pores, slag inclusions) and defects in the base material of the pipe (cracks, delamination, corrosion and others) with an indication of the nominal dimensions, position and their number.

To track the position of the scanner relative to the weld, a weld tracking sensor is installed on the USD-60-8K-A. Thanks to the independent suspension and the use of magnetic wheels with a diameter of 80 mm, USD-60-8K-A can move along butt and longitudinal welds in any spatial position, fig. 6.

As the scanner flaw detector moves, the base material is marked on the left and right sides at a half the distance from the pipe circumference, fig. 7.

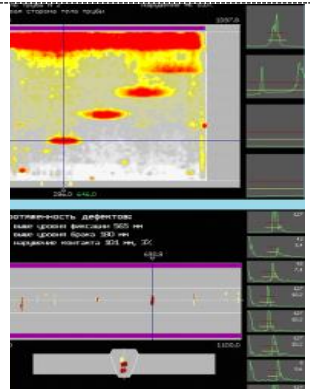
After completion of automatic ultrasonic testing of a pipe of a certain length, the scanner automatically stops, and the test results are saved in the archive.

According to the test results, the area of the defect (anomalous zone) identified in the main material of the pipeline is subjected to manual non-destructive testing in order to clarify the type, size and coordinates of the detected defect.

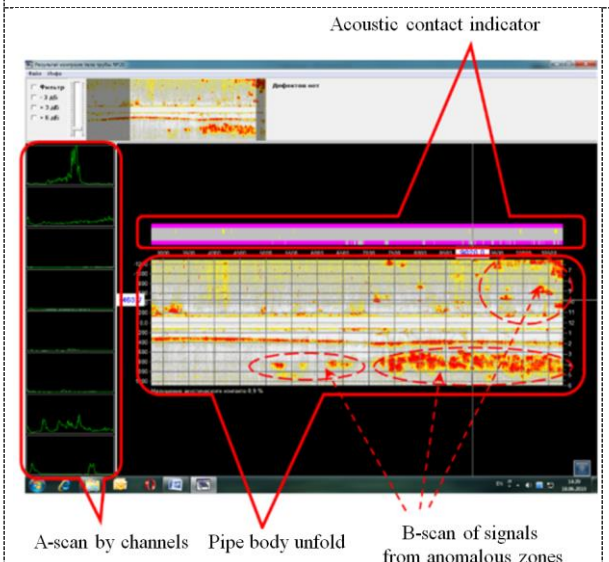
With the help of a special program "USD-soft" for displaying and analyzing data on a personal computer, it is possible to evaluate the results of automatic ultrasonic testing of the current state of the pipe body and welded joints on them, fig. 8, presence of defects, fig. 9.



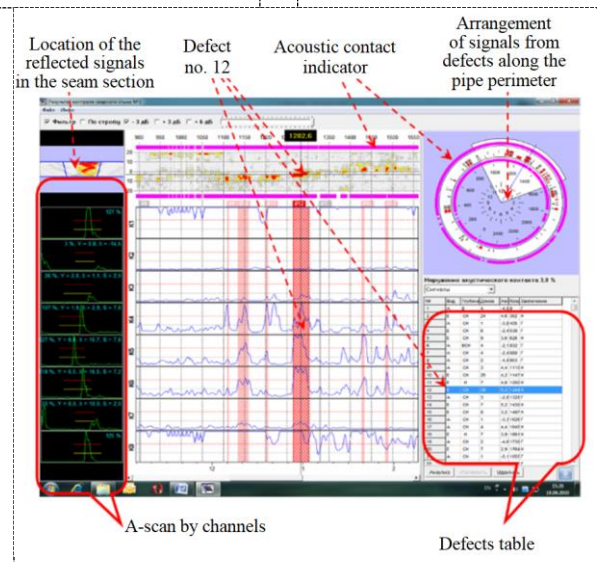
**Figure 6.** Application of USD-60-8K-A Scanner.



**Figure 7.** Information display when the scanner flaw detector moves.



**Figure 8.** "USD-soft" program interface.



**Figure 9.** Information about defects processed using the "USD-soft" program.

We considered the technology of welded joints and showed the main types of defects in welded joints by location (external, internal, through). We considered the main methods of testing welded joints, which allow one to detect defects. We established that of all the methods, ultrasonic flaw detection is relatively simple in terms of the method of conducting and allows to determine the number, type and depth of defects by a number of visual signs displayed on the screen of a device. However, it is difficult to establish the exact nature of the existing deviation in the metal structure.

We showed the advantages of ultrasonic testing of welded joints with a flaw detector with antenna arrays on a practical example. Thus, the advantages of this method allow one to use it widely for quality control of welded seams.

We considered the features of processing and analysis of experimental data using the application package "USD-soft".

By processing the information received using a personal computer in combination with other types of control and provided that the control file is decrypted on the site, time can be saved and the maintenance team can quickly carry out repairs at the identified area.