Electrochemical Machining for Penetrant Testing in Field Conditions

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Abstract
The technology and the equipment for carrying out an electrochemical machining (ECM) of welds and other objects with a high surface roughness in field conditions are developed. The technology is intended for preparation of parts for dye and fluorescent penetrant testing after preliminary abrasive machining of surfaces. Using the ECM by means of the developed devices provides complete removal of background fluorescence in developer layer, considerably increases detectability of defects that allows carrying out high-quality fluorescent penetrant testing of objects with a high surface roughness.

Keywords: electrochemical machining, penetrant testing, weld, pipeline

Introduction
At present penetrant testing (PT) is widely used at plant facilities (machine building, petrochemical industry, aircraft building, etc.). The considerable part of PT activity relates to seams of parts and products. Considering that the majority of welds are formed at manual electric-arc welding and have a number of defects (slag inclusions, weld spatter, defects of welded seam form, etc.), there is an objective necessity of their cleaning before the testing. The most widespread method of welds preparation to penetrant testing is mechanical cleaning.

Mechanical cleaning is a cleaning by brush, emery, grinding, polishing, scraping, etc. Mechanical methods of cleaning a tested surface remove corrosion products, oxide films, firm carbonaceous sediments, scale, paints and other contaminations.

In spite of the fact that this type of detail’s preparation to penetrant testing is the most widespread, it has a number of shortcomings, the main of which are the following. At mechanical cleaning the cavity of surface defects are filled with metal and abrasive dust. Highly-intensive conditions of mechanical cleaning with cutting speed of 60-70 m/s, large tool advance and cut depth, an absence of a coolant fluid usually result in essential plastic deformation of surface layers of metal and decreasing the defects width (Figure 1) [1, 2]. Revealing of such defects by using penetrant testing methods becomes rather problematic. Besides, the surface microrelief of welds after their abrasive machining causes significant background fluorescence at penetrant testing process. All the above strongly decrease reliability and quality of dye penetrant testing and does almost impossible usage of most sensitive fluorescent method.

Figure 1. Mechanical precleaning of tested surface with abrasive wheel: crack of 20 µm width with (a) and without (b) mechanical precleaning
In connection with the above mentioned the improvement of detail’s precleaning before penetrant testing providing maximum sensitivity and detectability of available defects is of great interest.

**Electrochemical machining (ECM)**

For the above problem solving we had been proposed and researched the process of electrochemical machining of steel parts before penetrant testing at *unlimited electrolyte supply*, which has shown high efficiency of such kind of machining at fluorescent penetrant testing of welds [1, 2].

The mechanism of metal removal during ECM is based on electrolysis – process at which there is an oxidoreduction of surfaces of electrodes (electric current conductors), connected to the power supply and placed in a conductive solution of electrolyte. One of the electrodes (part) attaches to a positive pole of power supply and is the anode, and the second (tool) – to a negative, being cathode.

These researches were conducted with the use of special installation including a bath with electrodes, filled with electrolyte of the certain concentration, allowing carrying out the process of ECM at unlimited electrolyte supply in shop conditions [1, 2]. Results of using this installation are presented in figure 2. We used the fluorescent penetrant Magnaflux ZL-60C and dye penetrant Sherwin DP-51. After abrasive machining of parts by means of various grinding and polishing discs the ECM in a bath was carried out.

As one can see from figure 2, the detectability of defects after the ECM considerably increases. The fluorescent background is completely removed and the areas of defects indications are significantly increased after the ECM.

As follows from the results of a quantitative estimation of defects indications the application of ECM of a samples after their abrasive machining by grinding and polishing discs before carrying out penetrant testing leads to increasing of the area of defects’ indications (by 1,5–2 times) and to complete removal of a interfering fluorescent background (figure 2) that considerably increases sensitivity and quality of the testing.

The purpose of the present work is development the devices and research of ECM process of welds (namely, pipeline inserts) at the *limited electrolyte supply in field conditions*. 

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Figure 2. Influence the ECM of test samples on detectability of defects at fluorescent (a) and dye (b) penetrant testing after their abrasive machining:

On the left – an initial condition of samples, in the center – abrasive machining, on the right – after the ECM
The scheme of the installation developed by us for the ECM of pipeline inserts welds with a segment tubular electrode is presented in figure 3. Such installation includes special block of electrolyte supply 1, power supply 2 and device 3 for the ECM of welds with the segment tubular electrode, intended for manual machining of weld seams with complex spatial orientation.

The installation works as follows. Periodic electrolyte supply into working zone is performed by the pump 1. The electrolyte from the pump arrives in the device 3 for the ECHO and further in the tubular segment electrode 4, which has apertures on a working surface. Through these apertures the electrolyte comes on a sponge 5 in the form of two-layer capillary-porous system in a working zone. During the ECM process of welds according to this scheme a positive pole of power supply 2 (anode) is connected to the tested part (pipeline insert 6), and negative (cathode) – to the device for the ECHO 3 and electric potential is transferred to a segment tubular electrode 4. The operating clearance between a segment electrode 4 and a welded seam is determined by the thickness of the sponge 5 and holding pressure of the electrode. Duration of the ECM process depends on working electric current value, length of a segment tubular electrode 4 and is determined experimentally on the assumption of required energy conditions – 1,2–1,8×10⁴ A/(м²×с) (energy conditions are determined by the density of electric current flowing through electrolyte during preset time interval).

![Figure 3. Installation for the ECM of pipeline inserts with the limited electrolyte supply:](image)

1 – pump, 2 – power supply, 3 – device for the ECM; 4 – segment tubular electrode; 5 – sponge; 6 – pipeline insert

The scheme of the device for ECM of pipeline inserts with a ring tubular electrode is presented in figure 4. The device consists of two bow-shaped arms 1 and 2 with sealant strips 3. Arms 1 and 2 are fixed on pipeline insert by means of screw nuts 4. There are holders 5 for fixing the ring tubular electrode 6 consisting of two semirings (copper pipe Ø12 mm) with a required operating clearance. Two-layer sponge is placed between a ring tubular electrode 6 and a welded seam.

According to results of our testing, this device also can work without the electrolyte supply. In this case preliminary impregnation of a sponge with electrolyte before the ECM is necessary, besides the electric current specific density should not exceed 0,3×10⁴ A/m².
Experimental data on practical use of the above mentioned devices are presented in figure 5.

**Conclusion**

As one can see from figure 5 the use of the devices developed by us for ECM of welds after their preliminary abrasive machining provides complete removal of background fluorescence of a penetrant. Such devices can be efficiently used at ECM of welds and other objects with a high surface roughness in field conditions and provide high-quality dye and fluorescent penetrant testing.

**References**