were recorded in the potential range from −0.3 to −1.2 V. Before fixing the cyclic current–voltage curves, the working electrode surface was updated using MIRKA 2000 (JEPPO, Finland). Emery paper was washed with distilled water, then polished on a paper filter (blue tape), and finally washed with distilled water. The used electrolyte was a solution of 0.3 M Na_2SO_4 [16].

Corrosion tests of adhesive oxide-zirconium coatings with paint were carried out in an Alcott S450iP salt fog chamber (Staffordshire, UK) in accordance with the international standard ASTM B117 [17].

The thickness of the coatings was determined using a SER 800 spectroscopic ellipsometer (SENTECH Instruments GmbH, Krailling, Germany), which makes it possible to accurately measure the thickness and optical characteristics of both monolayer films and multi-layer film structures during deposition. Measurements were performed in the spectral range of light wavelengths of 240–1000 nm [18].

For an accelerated assessment of the coating's protective ability a rapid method using Akimov's reagent (a solution containing $CuSO_4 \cdot 5H_2O$, NaCl, and HCl) was used [19]. According to this method, the protective ability of the coating (ASA) is estimated in seconds as the time necessary for a color change from gray to red-brown to take place with a drop of solution in in the control area. In accordance with this method, the corrosion resistance of the oxide-zirconium coating was evaluated using the time (s) taken for a color change from gray to red-brown to take place using a drop of the control solution on the surface of the coating.

The adhesion strength of the coatings was determined by the method of normal separation (the method of fungi) using the digital adhesiometer Posi Test AT (New York, NY, USA). The method is based on measuring the minimum breaking stress required to separate or tear the coating in the direction perpendicular to the substrate surface.

The morphology of the surfaces of the coated specimens was studied using an MPLAPONLEXT 100 lens with the LEXT-OSL 4100 confocal laser microscope (OLYMPUS Corporation, Tokyo, Japan) [20].

3. Results

To obtain independent information on the processes occurring on steel samples, during the deposition of ceramic coatings, cyclic voltammetric curves were obtained on an iron electrode in the presence of hexafluorozirconic acid and Mo (VI) and W (VI) metal ions, which affect the protective ability of the formed oxide-zirconium coatings. Cyclic volt–ampere curves were recorded in the potential range from −0.3 to −1.2 V.

Figure 1 shows the cyclic volt–ampere curves obtained on iron electrode at a constant concentration of Zr (IV). Electrolyte: 0.3 M Na_2SO_4 + 0.2 g/L Zr (IV).

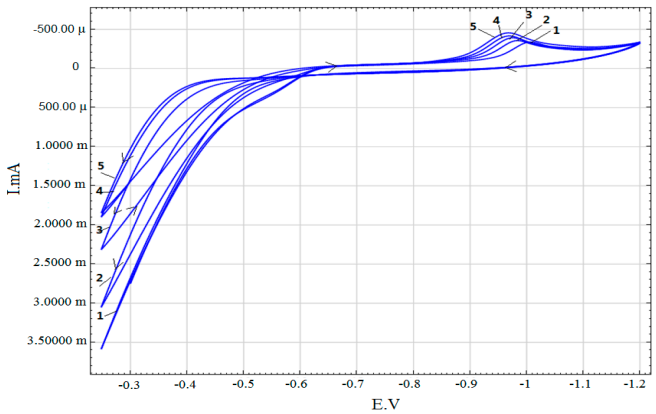

Figure 1. Cyclic volt–ampere curves of an iron electrode (cycles 1–5).