

# Corrosion resistance study of grey cast iron implanted with C, N, Cr and Cu ions.

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**Abstract.** This article deals with the corrosion resistance of gray cast iron implanted with C, N, Cr and Cu ions in sodium chloride solution and sulfuric acid solution. The potentiodynamic research was conducted in atmosphere, simulating corrosion conditions: in 3% sodium chloride solution and in 0,1 N sulfuric acid solution. Potentiodynamic curves were obtained and surfaces of samples were observed. The research proves that the implantation of ions with N and Cr leads to an increase in the corrosion resistance of cast iron in sodium chloride solution, and the implantation of ions with N and Cu leads to increased corrosion resistance in sulfuric acid solution.

## 1. Introduction

Materials used for manufacture of mechanism parts should provide reliable operation during the estimated service life, taking into account specified operating conditions, composition and nature of the corrosion environment [1]. Increased requirements for the reliability of condensers and heat exchangers of TPP and NPP attract the attention of designers to corrosion of the material which they are made of.

For units and parts of heat exchanger alloys such as steel and cast iron, containing carbonyl, are used among other alloys. These alloys are corrodible. Along with various methods of corrosion protection, it is important to choose the right material depending on the medium properties, taking into account constructional, operational and economic factors. At the same time, details of these materials are characterized by high resistance to erosion and cavitation attacks and corrosion resistance in atmosphere that contains ammonia.

Cast iron is still widely used in many fields of engineering, including in heat-exchange equipment. In addition to standard, widely used methods of corrosion protection, it is assumed that in some mechanisms under certain conditions it is advisable to use ion implantation as a method of protection against corrosion. The effect of ion implantation on corrosion resistance has not been studied yet.

The purpose of this article is to study the effect of ion implantation on the corrosion resistance of cast iron.

## 2. Preparation of samples

For the electrochemical test, cylindrical samples with a diameter of 1 cm were prepared. Ions of C, N, Cr or Cu with energy 40 keV and dosage  $10^{16} \dots 10^{17}$  cm<sup>-2</sup> were implanted beforehand in each sample.



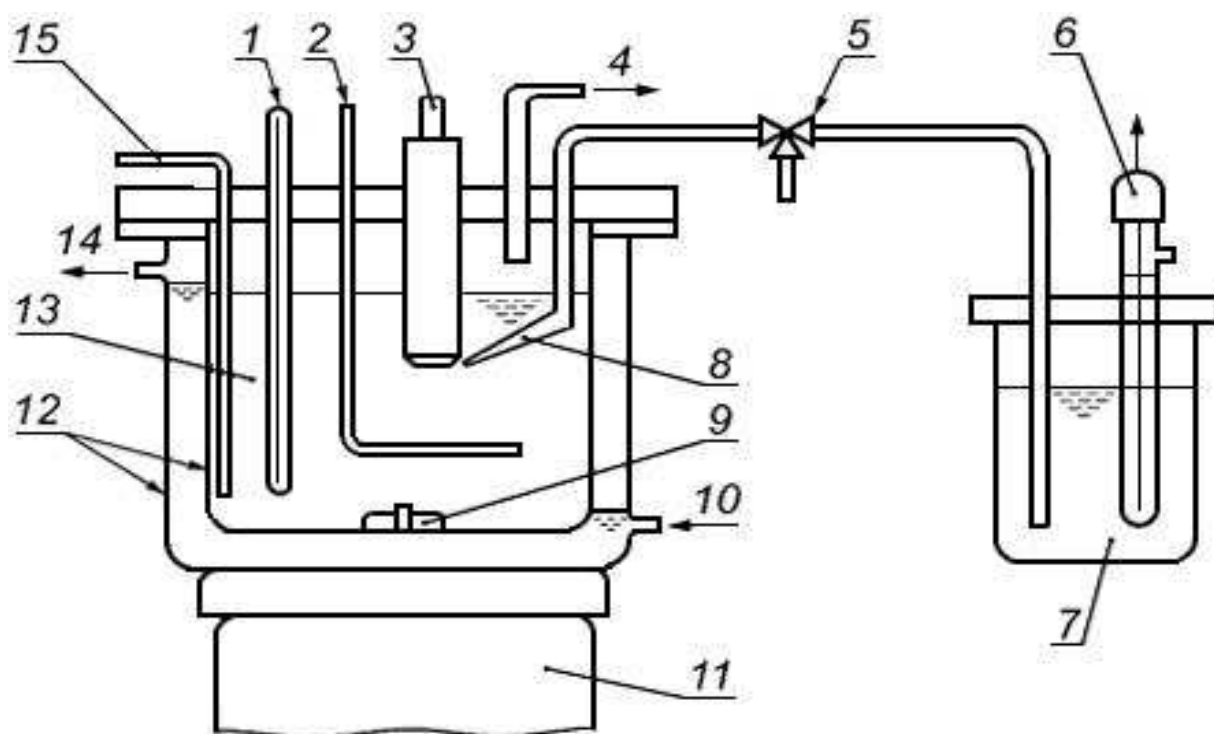
Samples were ground by a grinding wheel and polished with special chromium oxide paste and a woolen cloth. The samples were degreased with ethanol. All processing was done manually in order to obtain smooth edges and regular forms of samples. A proper contact for connection with the electrochemical device was provided without backlash by means of a clip.

### 3. Electrochemical test

The research was conducted in atmosphere of 0,1 N sulfuric acid solution and 3% sodium chloride solution simulating corrosion conditions in acidic and neutral atmosphere.

Potentiodynamic polarization curves were obtained at a potentiostat PI-50-1 with speed sweep capability of 1 mV /s, access to the programmer PR-8 and self-recording LKD-4. The main electrode was silver chloride; the auxiliary electrode was a platinum electrode. Before the electrochemical measurements, the samples were kept in the electrolyte [6].

Figure 1 shows the scheme of the electrolytic bath.



**Figure 1.** The scheme of the electrolytic bath: 1 - thermometer; 2 - counterelectrode; 3 - working electrode; 4 - gas discharge; 5 - electrolytic bridge; 6 - control electrode (saturated with silver chloride, SSC); 7-saturated solution of KCl; 8 - capillary; 9 – teflon-lined magnetic mixer, 10 - water intake; 11 - motor for the magnetic mixer; 12 – double-walled vessel; 13 - electrolyte solution; 14 - water outlet; 15 - bubbler (using nitrogen)

The tests were performed at a room temperature ( $20 \pm 2$ ) °C. At first, a control electrode was placed, then a counter electrode, and finally a working electrode, without immersing it in the electrolyte solution. The magnetic mixer was launched and it was bubbled with free of oxygen nitrogen admixture at a speed of about 100 cm per minute, passing through the electrolyte for 30 minutes. After that the working electrode was immersed in the electrolyte and the control electrode was installed. Nitrogen was switched to weak bubbling and the measurement was made.

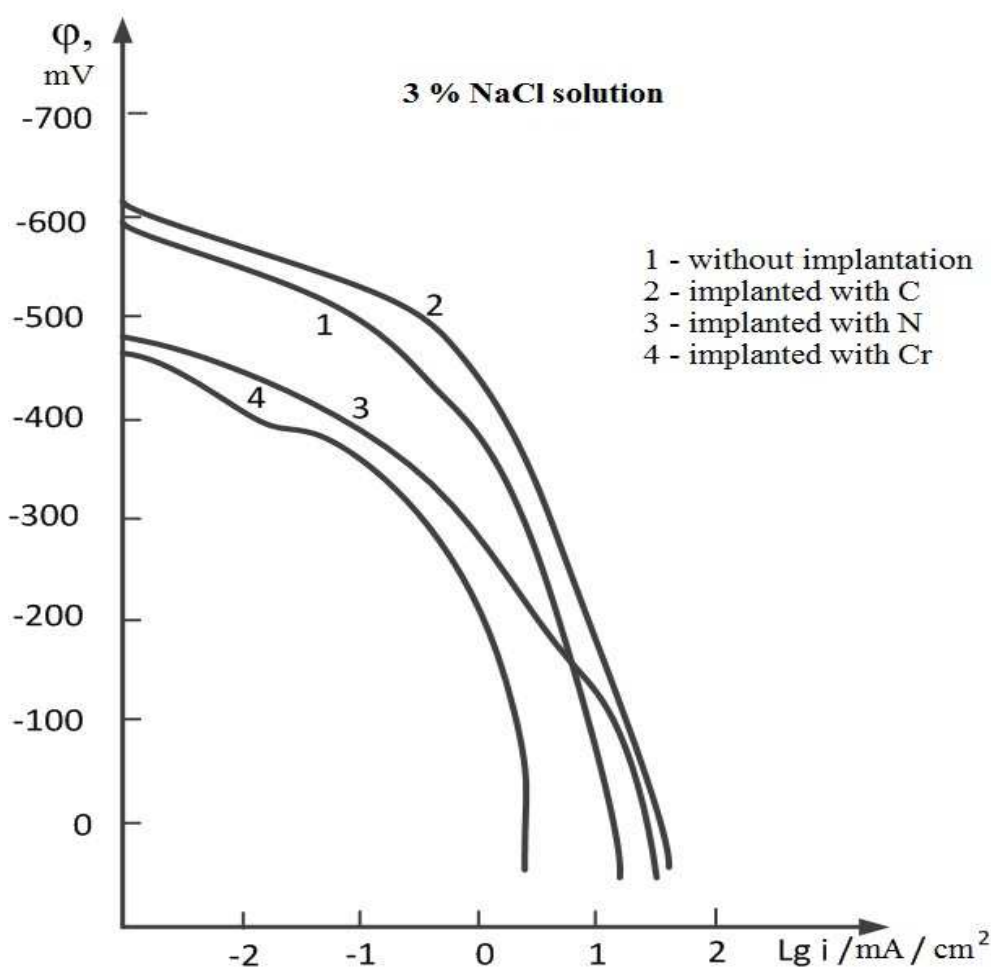
The influence of the open-circuit potential curve on time was recorded within 2 hours after immersing for  $(2,0 \pm 6)$  minutes. Five minutes later after the open-circuit potential measurement potentiodynamic scanning started at minus 150 mV [3].

#### 4. Research results

As the result of samples research in a 3% NaCl solution, the values of the stationary potential were the following:

- for samples without ion implantation  $\sim -500$  mv;
- for samples, implanted with C  $\sim -625$  mv;
- for samples, implanted with N  $\sim -480$  mv;
- for samples, implanted with Cr  $\sim -470$  mv.

Figure 2 shows the anode characteristics of test samples in a 3% NaCl solution at 20 °C.



**Figure 2.** Potentially dynamic (1 Mv / sec) anode characteristics of implanted gray cast iron in a 3% NaCl solution at 20 °C

Figure 2 shows samples, implanted with C and samples without implantation that are more affected by the process of anodic activation, compared to samples, implanted with Cr and N.

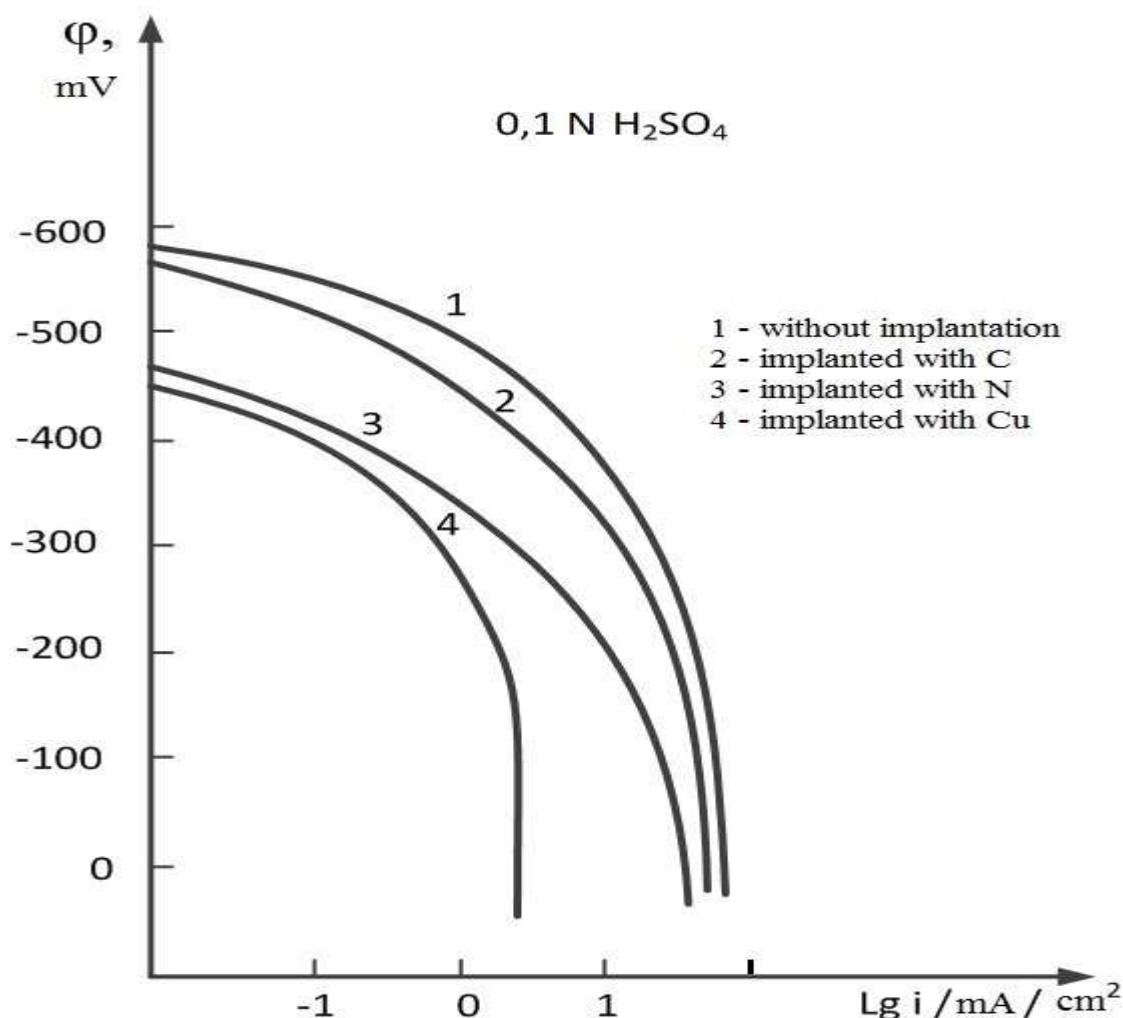
The given data prove that during the implantation of gray cast iron with N and especially with Cr, its resistance to anodic activation increases.

As the result of samples research in 0,1 N H<sub>2</sub>SO<sub>4</sub> the values of the stationary potential were the following:

- for samples without ion implantation  $\sim -500$  mv;
- for samples, implanted with C  $\sim -615$  mv;

- for samples, implanted with N  $\sim -480$  mV;
- for samples, implanted with Cu  $\sim -490$  mV.

Figure 3 shows anode characteristics of test samples in 0,1 N H<sub>2</sub>SO<sub>4</sub> at 20 °C.



**Figure 3.** Potentially dynamic (1 Mv / sec) anode characteristics of implanted gray cast iron in 0.1 N H<sub>2</sub>SO<sub>4</sub> at 20 °C

Figure 3 shows that samples, implanted with C are greatly affected by the process of anodic activation. Initial samples and samples implanted with N and Cu, tend to increase resistance to anodic activation, compared to samples implanted with C, thus increasing resistance of the initial samples to samples implanted with Cu.

Due to these tests, the authors have come to conclusion that the state of sample surfaces in 3% NaCl solution exposed to ion implantation with N and Cr considerably differs from the state of sample surfaces in the same solution without ion implantation and implantation with C. In the latter case, complete oxidation of sample surfaces with numerous releases of corrosion products is observed, whereas during implantation with C in the first case only partial damage to the surface is observed. The surface preservation is about the same quality, as it was before the tests; for implantation with N focal lesions are found with preserved traces of surface treatment.

This may be explained by the fact that cast iron is a fairly porous material, and in 3% solution of chloride sodium for this type of surface treatment it is typical to maintain the same quality surface, as

before processing. But it is not possible to achieve full resistance to anodic activation (except for the implantation with Cr) since the presence of micro- and macropores is a significant catalyst for the occurrence of corrosion processes [4].

Analysis of surface samples after corrosion tests in 0.1 N sulfuric acid showed that the surface sample implanted with C or without implantation is completely oxidized with numerous precipitates of corrosion products. Surface treatment traces are practically not detected.

The surface of samples implanted with N after tests in 0.1 N H<sub>2</sub>SO<sub>4</sub> has the form of focal lesions, with typical discharges of corrosion products. There are traces of surface treatment on many parts of surface.

The surface of samples implanted with Cu after tests in 0.1 N H<sub>2</sub>SO<sub>4</sub> has a "cellular" form, which is characterized by some areas with surface treatment places, where Cu ions interact with Fe atoms in the ion implantation process. In places where Cu ions interact with graphite surface oxidation takes place with numerous products of corrosion.

## 5. Conclusion

The research proves that the implantation of ions with N and Cr leads to an increase in the corrosion resistance of cast iron in sodium chloride solution, and the implantation of ions with N and Cu leads to increased corrosion resistance in sulfuric acid solution. The implantation of ions with C leads to a decrease in the corrosion resistance in sodium chloride solution.

That is why it is important to conduct further research with other materials with implantation of a large ion spectrum.

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