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Corrosion resistance of FeAl intermetallic phase based alloy in water solution of NaCl

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Materials

ABSTRACT

Purpose: Recognizing of corrosion mechanisms in liquid mediums can lead to obtain corrosion-proof material e.g. by applying passivation phenomenon. In this paper attention was paid to determine the corrosion resistance of Fe40Al intermetallic phase based alloy in corrosive medium of liquid NaCl. Research of material susceptibility to surface activation in the pipeline of corrosion processes are conducted.

Design/methodology/approach: In the corrosion research electrolyser, potentiostat „Solartron 1285" and computer with „CorrWare 2" software were used. Results of the research were worked out with „CorrView" software. The potentials values were determined in relation to normal hydrogen electrode (NEW). The recording of potential/density of current - time curve was conducted for 300 s. Polarization of samples were conducted in range of potential from 300 mV lower than stationary to E_{cor} + 1500 mV. Potential change rate amounted 10 mV/min every time.

Findings: The results of research conducted in 3% NaCl solution, the best electrochemical corrosion resistance were showed by samples after annealing during 72 hours. It was confirmed by the lowest value of corrosion current density, low value of passive current density, pitting corrosion resistance much higher than in other samples.

Practical implications: The last feature is the reason to conduct the research for this group of materials as corrosion resistance materials. Especially FeAl intermetallic phase based alloys are objects of research in Poland and all world during last years.

Originality/value: The goal of this work was to determine the influence of passivation in water solutions of H_2SO_4 and HNO_3 on corrosion resistance of Fe40Al intermetallic phase based alloy in 3% NaCl solutions.

Keywords: Metallic alloys; Corrosion; Microstructure

1. Introduction

Search of new engineering materials is connected with determining of physical-chemical properties, which one of most important is corrosion resistance [1-3]. Research conducted during last years in group of intermetallic phase based materials showed corrosion resistance in oxygen and sulphur medium in increased temperatures [3-7]. Research of resistance in medium of liquid NaCl solutions were published in few articles. Initial research of corrosion resistance showed different mechanism of corrosion processes [8-15]. Physical-chemical aspects recognition of reactions during corrosion processes can allow to characterize.

The methods for decreasing the velocity of corrosion among other things by using surface passivation phenomenon. In this work corrosion resistance of Fe40Al intermetallic phase based alloy were characterized in medium of 3% NaCl solutions. Research of susceptibility to surface activation during corrosion processes were conducted.

This work is continuation of previous research of corrosion resistance evaluation for FeAl intermetallic phase based alloy in liquid acid solutions of HCl and H_2SO_4 [7].

2. Material and methodology

The goal of this work was to determine the influence of homogenizing treatment time on corrosion resistance of Fe40Al intermetallic phase based alloy in 3% NaCl solutions. Following samples were examined: after grinding, electrolytic polishing, passivation in HNO_3 and H_2SO_4 solutions and annealing in 950°C/72h.

The research programme included: potentiostatic examinations, galvanostatic examinations, potentiodynamic examinations, cyclic voltammetry, evaluation of surface condition after corrosion tests.

In the corrosion research electrolyser, potentiostat "Solartron 1285" and computer with "CorrWare 2" software were used. Results of the research were worked out with "CorrView" software. The potentials values were determined in relation to normal hydrogen electrode (NEW). The temperature of the solutions was kept on 21ºC level. The recording of potential/density of current - time curve was conducted for 300 s. Samples polarization was conducted in range from potential smaller by 300 mV from normal potential to 1500 mV in case of the test in 3% NaCl solution.. Rate of changing the potential amounted 10 mV/min in each case. Observations of the surface state were conducted using scanning electron microscope HITACHI S-4200 with magnifications from 30 to 1000.

3. Results

The results of potentiodynamic research for alloy examined in 3% NaCl solution are presented in Table 1. Results of the potentiostatic and galvanostatic tests are presented in Table 2 and 3. At Figure 1 the potentiodynamic curves matching for 3% NaCl solution is presented. At Figures 2-5 surface state of the samples after corrosion research, which was observed using the scanning electron microscope, are presented.

4. Analysis of research results

Analysis of potentiostatic and galvanostatic dependences showed high susceptibility of surface-grinded Fe40Al alloy to self-passivation, that is spontaneous reproduction of protective passive layer on the surface. Owing to danger of damaging this layer during operating, this property should be considered as advantageous.

Significantly lower susceptibility to self-passivation characterized samples passivated in water solution of HNO_3. Also galvanostatic research showed that passive layer covering surface is unstable. Other samples did not show susceptibility to self-passivation.

Samples passivated in water solution of H_2SO_4 are characterized by presence of unstable passive layer. Samples after electrolytic polishing and after annealing showed susceptibility to surface activation, which should be considered as disadvantageous.

Table 1.
Results of potentiodynamic research in 3% NaCl solution for Fe40Al

Sample		E_{cor} [mV]		i_{cor} [μA/cm^2]
1. Grinding		402.9		4.55
2. Passivation HNO_3		-364.8		1.78
3. Passivation H_2SO_4		-491.1		2.24
4. Annealing 950°C/72h		-568.3		5.25
5. Electrolytic polishing		211.1		98.0
	initial		finish	
Sample	E_p [mV]	I_p [μA/cm^2]	E_{cp} [mV]	I_{cp} [μA/cm^2]
1	450.0	5.2	680.6	89.3
2	-336.0	3.7	-109.0	39.0
3	-432.0	14.3	-88.0	67.0
4	-355.0	112.0	-300.0	112.0
5	348.0	119.5	413.0	119.5

where: E_{cor} - corrosion potential; i_{cor} - density of corrosion current;, E_{cp} - critical potential of passivation, i_{cp} - critical current density of passivation, E_p – potential of passivation, i_p – current density in passivation range.

Table 2.
Results of potentiodynamic research in 3% NaCl solution for Fe40Al

Sample	
1. Grinding	heavy decrease, increase of current density with time than stably state
2. Passivation HNO_3	unstable state
3. Passivation H_2SO_4	unstable state
4. Annealing 950°C/72h	increase of current density with time
5. Electrolytic polishing	decrease, increase of current density with time than stably state

Table 3.
Results of galvanostatic research in 3% NaCl solution for Fe40Al

Sample	
1. Grinding	heavy increase, decrease of potential with time than stably state
2. Passivation HNO_3	increase, decrease of potential with time than stably state
3. Passivation H_2SO_4	decrease of potential with time than stably state
4. Annealing 950°C/72h	slow increase, heavy decrease of potential with time than stably state
5. Electrolytic polishing	slow increase of potential with time than stably state

From among researched samples, the lowest value of corrosive current density characterized samples after passivation in HNO_3 solution, then samples after passivation in H_2SO_4 water solution. Annealed samples revealed value of corrosive current density insignificantly higher then samples after grinding. The highest value of corrosive current density characterized electrolytic polished samples. In their case the value was higher by an order of magnitude than for the other samples. Thus, the lowest corrosion rate in stationary conditions would characterize samples passivated in solutions of H_2SO_4 and HNO_3. Annealing, as well as electrolytic polishing, did not show significant changes.

On potentiodynamic curve of annealed and electrolytic polished samples passive range occurs. In case of other samples passivation can not be affirmed because increasing potential value caused continuous increase of corrosive current density value. But because this growth is not very high, that range to the value of puncture potential was described as prepassive range. This range can be responsible for local corrosion beginning.

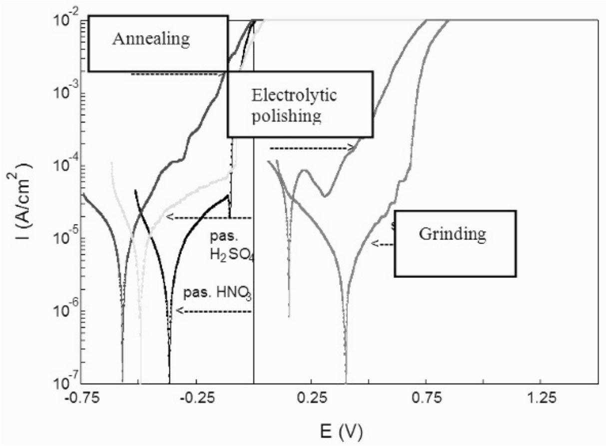

Fig. 1. Potentiodynamic curves matching of Fe40Al alloy in 3% NaCl solution

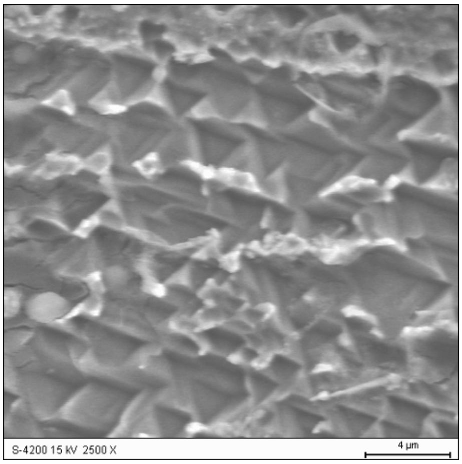

Fig. 2. Surface state of Fe40Al alloy after grinding, tested in 3% NaCl solution, scanning electron microscope

Corrosion rate for annealed and electrolytic polished samples in passive range was high, and significantly higher than for other samples in prepassive range. It is showed by high value of passive current density. Characteristic, and disadvantageous property was also narrow passive range. Passive layer covering surface of annealed and electrolytic polished samples is unstable and not fully tight and in this connection does not provide effective protection against corrosion.

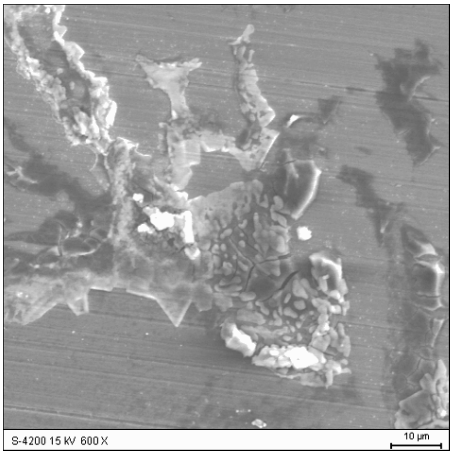

Fig. 3. Surface state of Fe40Al alloy after passivation HNO_3, tested in 3% NaCl solution, scanning electron microscope

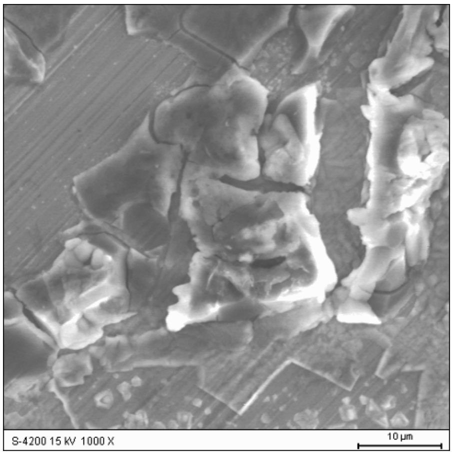

Fig. 4. Surface state of Fe40Al alloy after passivation H_2SO_4, tested in 3% NaCl solution, scanning electron microscope

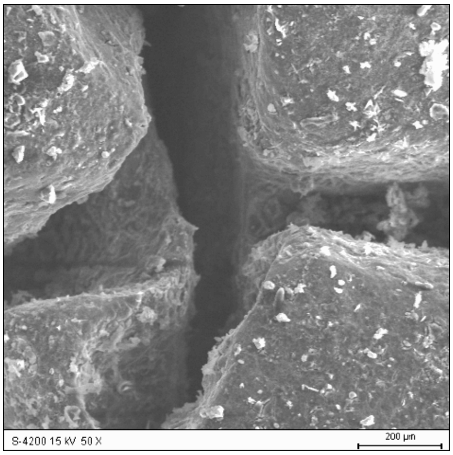

Fig. 5. Surface state of Fe40Al alloy after electrolytic polishing, tested in 3% NaCl solution, scanning electron microscope

Therefore annealing and electrolytic polishing decreased corrosion resistance in non-stationary conditions. The smallest increase of current density in prepassive range was registered for samples after passivation in HNO_3 solution, then samples after passivation in H_2SO_4 solution. The highest increase was registered for samples after grinding. Therefore passive layer on the surface of samples after passivation is not fully stable but is tighter than layer covering samples after grinding. Also initiation of local corrosion, in Fe40Al proceeding along grain boundaries, would be slower. The highest difference between corrosive and puncture potentials was registered for samples passivated in H_2SO_4 solution. For samples after grinding and after passivating in HNO_3 solution this values was similar. In Fe40Al corrosion proceeds along grain boundaries, so large increase of current density for potential value higher than puncture potential would be combined with rapid falling out of individual grains. It should be presumed that in case of samples passivated in HNO_3 solution, this process will proceed significantly slower than for other samples. Thus in non-stationary conditions the highest corrosion resistance characterized samples after passivation in H_2SO_4 solution, then samples passivated in HNO_3 solution. In case of these samples, passivation caused increase of corrosion resistance in non-stationary conditions.

5. Conclusions

1. Fe40Al alloy in 3% NaCl solution is characterized by susceptibility to surface passivation.
2. Increase in corrosion resistance in stationary conditions through surface passivation in H_2SO_4 and HNO_3 solutions.
3. In non-stationary conditions annealing and electrolytic polishing caused decrease of corrosion resistance. Surface passivation in H_2SO_4 and HNO_3 solutions increased corrosion resistance.

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