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INFLUENCE OF ABRASIVE BLAST CLEANING AND VIBROFINISHING ON SURFACE PROPERTIES OF THE STAINLESS STEEL OH18N9

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ABSTRACT

The effect of the blast cleaning and vibrofinishing on the surface proprieties of the stainless steel 0H18N9 has been presented. Glass beads and alumina have been applied for the blast-cleaned samples, while various types of ceramic chips in the vibrofinishing process have been used. The results have been presented, taking into account such surface proprieties like roughness, residual stresses, microstructure as well as a susceptibility to pitting and general corrosion.

KEY WORDS

Austenitic stainless steel, abrasive blast cleaning, vibrofinishing, residual stress, surface roughness, corrosion.

1. INTRODUCTION

Austenitic stainless steels are used not only in medical industry, but also in many fields such as nuclear power industry, medical equipment and chemical or food industry.
Producing of compressing strength or considerable decreasing of tensile strength and / or the depth of their arrange, has an important influence on increase the fatigue strength and corrosion resistance of the surface layer of austenitic stainless steels. The similar trend is observed for decreasing of the surface roughness.

From the literature it results that blast cleaning, and even the vibrofinishing influence the state of stresses in the surface layer, and on the degree of surface roughness of the treated material [1-21].

An increase of the corrosion resistance of the surface layer of the material is important value in the case of articles, which are not to be covered with protection coatings. The role of abrasive blast cleaning in increasing the corrosion resistance of austenitic stainless steels is evidenced by both the literature data [3-14} and the results of own research [15-17].

Due to the fact that corrosion process occurs at the surface layer the degree of corrosion resistance is greatly determined by the state of the surface layer of the material (surface roughness, the amount and character of residual stresses, structure and microhardness). It is well known the stress corrosion cracking results in forming the crevices, which develop generally perpendicular to the direction of the action of stresses, and lead to the cracks in the material. The stress corrosion cracking is macroscopically of the brittle character, nevertheless the cracking materials show normally the high plasticity, as in the case of austenitic stainless steel. It was found the stress cracking occurs in the presence of tensile stresses, irrespectively of their origin, external or internal. It results that the decreasing level of tensile stresses in the surface layer, or their change into compressing stresses, should counteract to stress corrosion cracking of metals. Thus it is advisable to use such a surface treatment which permits to produce the compressive stresses in the surface layer with concurrent decreasing of the surface roughness; these demands fulfils both the abrasive blast cleaning [1,2,5-8] and wet blasting [15]. Vibrofinishing results in wear of roughness peaks, rounding of corners and edges [21], as well as the change of the state of surface layer of material. Due to the mechanical action of chips compressing stresses are produced in the surface layer [20]. As the vibrofinishing is a long lasting process (several hours), with low intensity, it additionally produces the relaxation of residual stresses [21], produced in previous processes of forging, milling, grinding and polishing.

It should be noted that with the exception of previous own research [18,19] we did not found in the accessible literature the data concerning the influence of combined abrasive blast cleaning and vibrofinishing on the properties of the surface layer of metal material, especially stainless steel.

2. EXPERIMENTAL

The studies were carried out on samples made from OH18N9 [19] steel, which contains (≤0,7 % C, ≤ 0,8 % Si, 1-2 % Mn, max 0,03 % P and S, 17-19 % Cr, 9-10 % Ni). Hence, the chemical content of this steel is similar to AISI 304. The following tests were conducted: determination of surface roughness, evaluation of susceptibility to intergranular and pitting corrosion, determination of internal stresses, resistance against general corrosion as well as metallographical examinations. The details of experiments were described elsewhere [19]. Surface treatments with modifications that were applied during this study are listed in Table 1.

TABLE 1. Various kinds of surface treatments applied in this study

Designation of treatment	Kind of treatment	Number of Samples
I	As-received	1-6
II	Grinding by vibrofinishing chips	7-12
III	Grinding and polishing by vibrofinishing chips	13-18
IV	Abrasive blast cleaning using glass beads	19-24
V	Abrasive blast cleaning using alumina	25-30
VI	Abrasive blast cleaning using glass beads + grinding and polishing using vibrofinishing chips after treatment	40-45
VII	Abrasive blast cleaning using alumina + grinding and polishing using vibrofinishing chips after treatment	46-51

Abrasive blast cleaning using alumina and glass beads was performed by means of air blast type machine, while vibrofinishing was done using ceramic and porcelain chips in rotary vibrator machine.

3. RESULTS AND DISCUSSION

3.1. Surface roughness

The results of determination of the surface roughness in relation to kind of surface treatment are presented in Fig. 1 and Table 2. It was found that polishing using vibrofinishing chips decreases surface roughness by 40% in comparison with as-received samples (from 0,28 μm R_a or 2,42 μm R_z to 0,18 μm R_a or 1,50 μm R_z). Abrasive blast cleaning increases surface roughness but application of polishing by vibrofinishing chips as an after treatment removes surface irregularities and resulted surface roughness remains at the same level i.e. 0,18 R_a or 1,50 R_z.

TABLE 2. Average values of surface roughness parameters for subsequent kinds of surface treatments (according to the list in Table 1)

Treatment designation		I	II	III	IV	V	VI	VII
Surface Roughness	R_a [μm]	0,28	0,29	0,17	0,57	1,05	0,18	0,22
	R_z [μm]	2,42	2,13	1,45	3,55	7,04	1,33	1,50

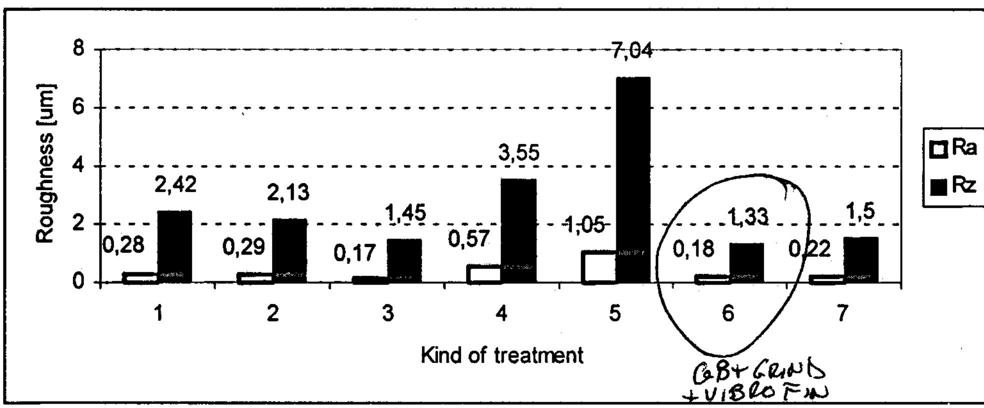


Fig 1. Surface roughness parameters Ra and Rz obtained for particular surface treatments.

After particular surface treatment determination of surface gloss was also determined. In general, as-received samples exhibited 5% of gloss, while gloss for all treated surfaces were about 50%.

3.2. Residual stresses

Fig. 2 presents graphically the changes of residual stresses in the material of the surface layer in dependence on treatment variant (Table 1). From Fig. 2b it results that grinding and polishing by vibrofinishing produces quantitatively similar compressing stresses of maximum value *ca.* 600 MPa. It means the increase of stresses by *ca.* 140% in relation to stresses remaining in the surface layer of material without the surface treatment (Fig. 2a). It was found moreover that blast cleaning with fused aluminium oxide practically does not produce changes in residual stresses of the surface layer, whereas the blast cleaning with glass beads produces the compressive stresses of *ca.* 250-1000 MPa (increase of 300%).

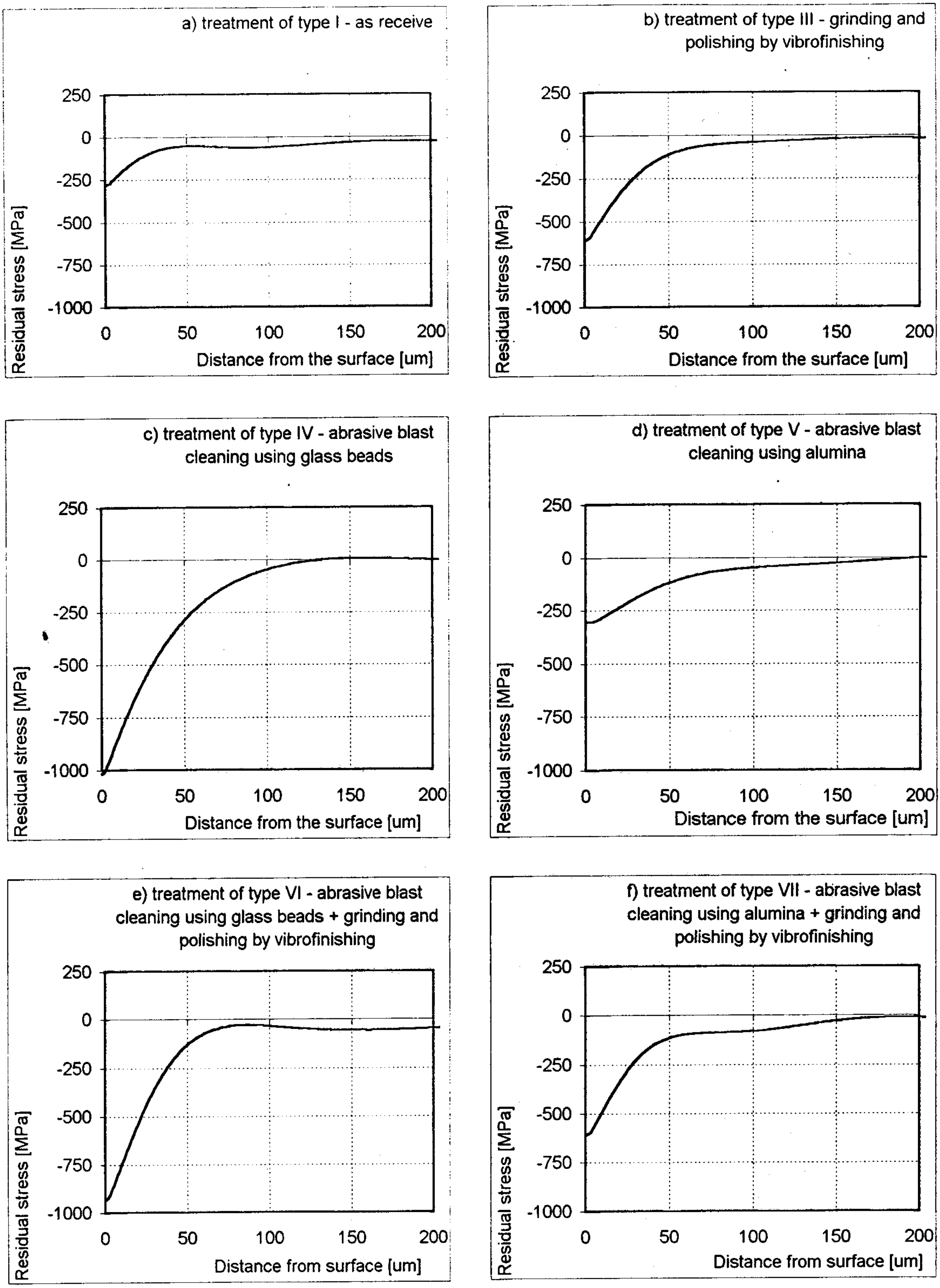


Fig 2. Residual stresses in surface layer prior (I - as-received) and after particular treatments (treatments III-VII)

The application of blast cleaning with glass beads followed by grinding and polishing by vibrofinishing permits to get the stresses of *ca.* 900 MPa (increase of 260%) (Fig. 2e). From Figs. 2B and 2F it results the preliminary blast cleaning with fused aluminium oxide does not influence the state of stresses produced during posterior grinding and polishing by vibrofinishing.
The analysis of values of stresses and the depth of their arrange results that grinding and polishing by vibrofinishing insignificantly levels the results of abrasive blast cleaning with beads. Despite the amount of compressive stresses results using glass beads, and the depth of their
arrange is low comparing to that obtained during shot peening (Fig. 3), it would be expected that they could involve in positive changes in the surface layer.

3. 3. Intergranular corrosion

The results of determination of resistance against intergranular corrosion according to PN ISO 3651-1 are shown in Fig. 4 and 5. It was observed that:

- corrosion rate for as-received samples increases with time of exposure to an aggressive environment and attains 0,7 to 1mm/year;
- corrosion rate for samples polished by vibrofinishing chips changes from 0,5 to 0,8 mm/year;
- corrosion rate for samples after surface grinding and polishing by vibrofinishing chips slightly changes and is equal 0,43 mm/year, that makes 48% of a rate achieved for as-received samples;
- corrosion rate for samples treated in two stage process i.e. abrasive blast cleaning by glass beads and polishing by vibrofinishing chips after treatment is approximately constant and equal to 0,32 mm/year, i.e. 31% of rate achieved for as-received samples.

The effect of surface roughness on intergranular corrosion rate is shown in Fig. 5. One may concluded that the application of air blast cleaning using glass beads and polishing by vibrofinishing chips after treatment leads to significant decrease of the rate of intergranular corrosion.

3. 4. Susceptibility to pitting corrosion

The pitting potentials (E_p) and repassivation potentials (E_{rp}) determined from cyclic polarisation curves are shown in Table 3. The more positive both values are, the better resistance against pitting corrosion is achieved. An ability to surface repassivation is illustrated by the small "histeresis" of the cyclic polarisation curve (see Fig. 5b versus 5a for example). Therefore from results shown in Table 3 and Fig. 5 one may conclude that the best resistance against pitting corrosion is achieved for surfaces after two-stage process: air blast cleaning using glass beads and polishing by vibrofinishing chips. Pitting potentials were always close to 550 mV versus SCE (saturated calomel electrode).

TABLE 3. Pitting and repassivation potentials for samples treated in various processes (type I, II, III and VI according to Table 1).

Designation and kind of treatment	Pitting potential E_p [mV]	Repassivation potential E_{rp} [mV]	Potential difference $E_p - E_{rp}$ [mV]
I- as-received	+ 400	- 50	450
II- polishing by vibrofinishing chips	+ 440	+ 430	10
III- grinding and polishing by vibrofinishing chips	+ 450	+ 220	230
VI- air blast cleaning by glass beads + grinding+polishing by vibrofinishing chips	+ 550	+ 299	201

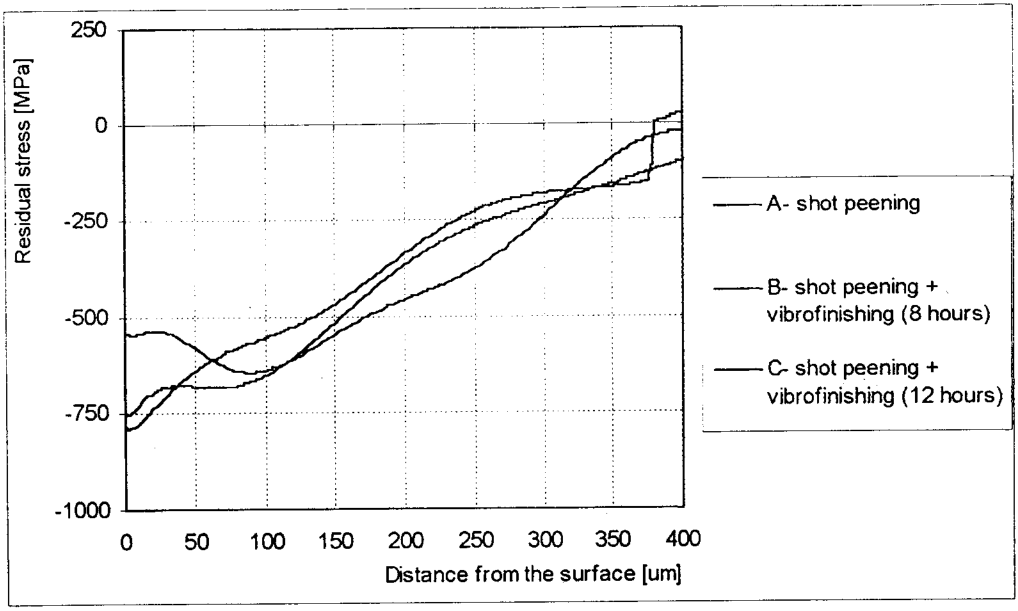
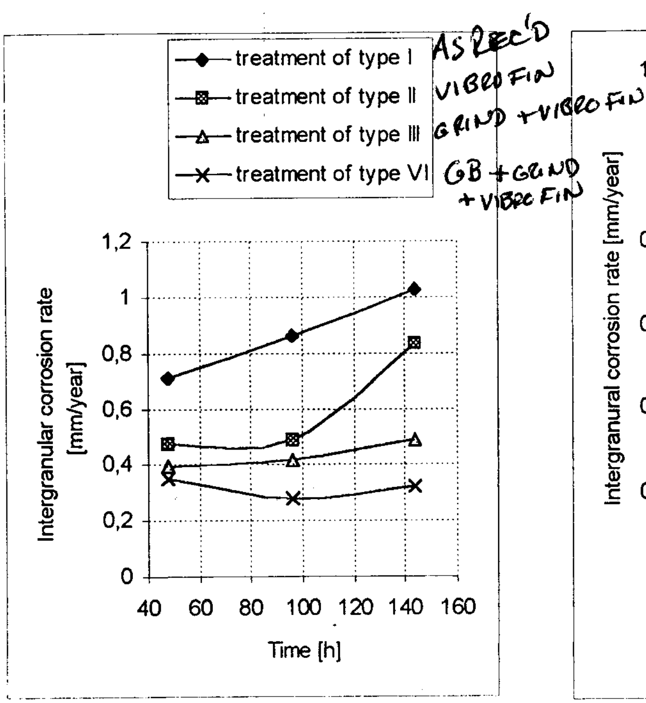


Fig 3. Residual stresses in surface layer in 0H18N9 stainless steel after shot peening by steel shot and vibrofinishing by chips



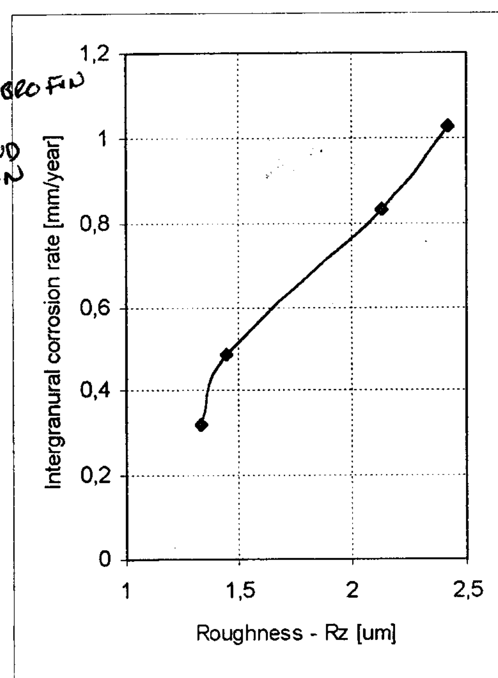


Fig 4. Time dependence of intergranular corrosion rate for OM18N9 steel in H_2SO_4 / Cu SO_4 solution determined according to PN ISO 3651-1.

Fig 5. The influence of surface roughness on the intergranular corrosion rate for OM18N9 steel in H_2SO_4/$CuSO_4$ solution.

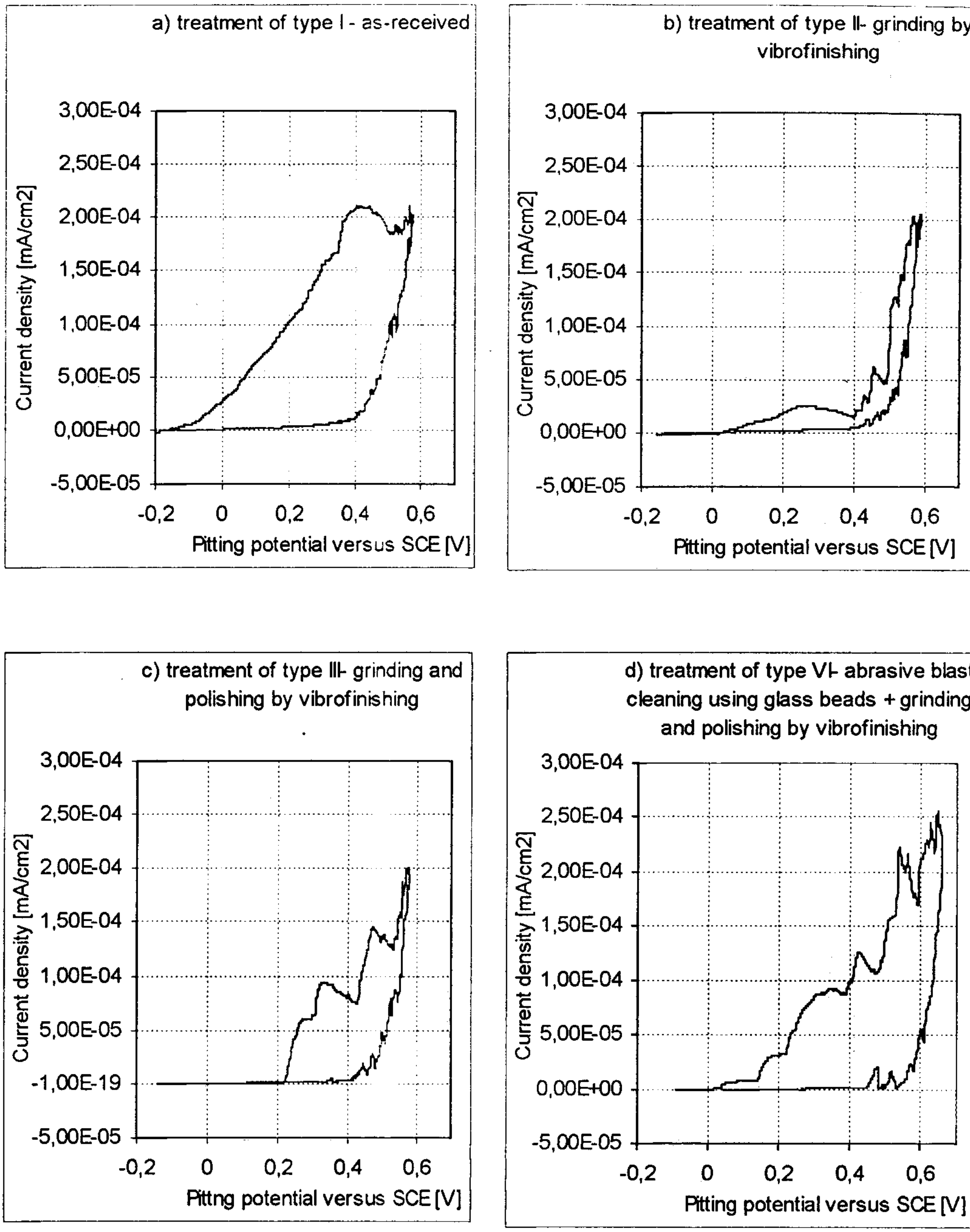


Fig. 6. Cyclic polarisation curves for 0H18N99 steel immersed in 0,5 M NaCl after selected (I, II, III, VI) surface treatments.

4. METALLOGRAPHICAL EXAMINATIONS

Microscopic observations shown that corroded areas tend to diminish in series of treatments listed in Table 1, i.e. I, II, III ...VII, especially taking into the consideration traces of intergranular corrosion. It has to be concluded that decrease of the number of deep surface defects after polishing, decrease the surface susceptibility to intergranular corrosion.

5. CONCLUSIONS

1. The application of vibrofinishing treatment leads to decrease of the surface roughness from 0,28 μm R_a and 2,42 R_z (as received sample) to 0,18 R_a and 1,50 R_z, that means about 40% of an as received sample. Almost the same surface profile can be obtained after two-stage process: abrasive blast cleaning by glass beads or alumina and polishing by vibrofinishing after treatment.
2. The application of abrasive blast cleaning using glass beads before surface grinding and polishing using vibrofinishing chips yield compressive stress of -900 MPa (increase of 260% in comparison with as received samples).
3. The rate of intergranular corrosion after two-stage treatment, i.e. abrasive blast cleaning using glass beads and after treatment by vibrofinishing is approximately stable with time and is equal to 0,32 mm/year. This is about 31% of the corrosion rate of as received samples. It also indicates that observed decrease of corrosion rate results from the increase of compressive stresses.
4. The decrease o number of deep surface defects decreases the susceptibility to intergranular corrosion.
5. The pitting potential determined from anodic polarisation curves is the highest (550 mV vs. SCE) for samples treated in two-stage process (abrasive blast cleaning by glass beads and vibrofinishing by chips).

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