

Aggressivity of Hair Shampoo above Stainless Steel Type AISI 316L

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Abstract

This paper contains some aspects regarding the corrosion behavior of stainless steel type AISI 316L in hair shampoo medium. The electrochemical parameters by potentiodynamic methods at different temperatures and also corrosion rate by gravimetric methods for stainless steel type 316L with passive layer and without passive stratum were established. The medium and temperature influence above corrosion rate are shown in the work.

Key words: *stainless steel, corrosion rate, shampoo.*

Introduction

Metallic equipments made of austenitic stainless steels have gained significant advantages in cosmetic industry due to their immense mechanical features that match with the demands. The biocompatibility and corrosion resistance of these materials are primarily determined by their constituent material and surface microstructural properties such as surface roughness, grain size, etc. However, the use of stainless steel type 316L has been relegated to tanks, pipes, mixers etc.

From an electrochemical viewpoint, the corrosion potential of 316L is typically more active than titanium alloy and hence the corrosion rates are higher. The most significant difference is the absence of a true potentially independent passive region. The anodic polarization curve of pristine 316L has a positive slope indicating that the passive/ oxide film is not truly protecting the material from corrosion even in its passive region and hence a quick transition to transpassive region occurs.

The considerable size of the hysteresis loop suggests that the material is unable to repair or repassivate. It is anticipated that a thin oxide film is immediately formed on 316L surface, when it is exposed to an oxygen containing environment. The thickness of this passive oxide film is about a few nanometers and acts as a protective barrier in the corrosive media. However, the film is not sufficient during long-term production and is susceptible to corrosion-related problems and lack of biocompatibility to cosmetic products. Paper presents the effect of passivation and temperature above electrochemical parameters of stainless steels type AISI 316L in medium of hair shampoo.

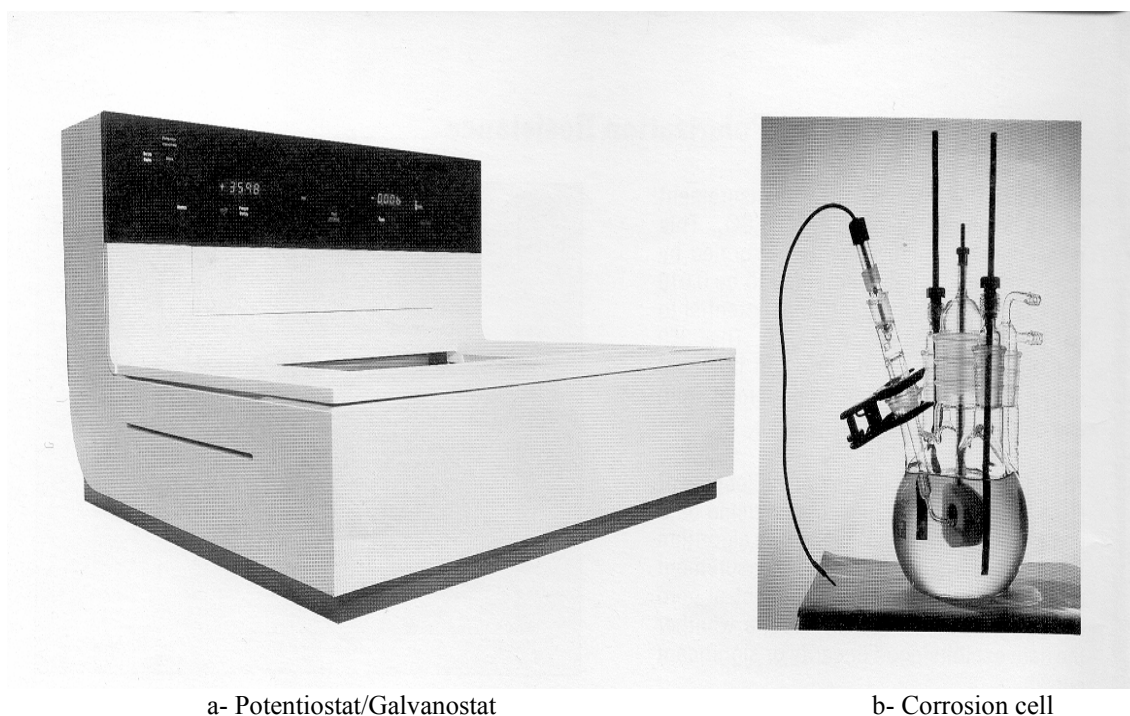
Experiments

There are several electrochemical techniques that can be used to evaluate the behavior of materials in aggressive medium such as [1, 2, 3]: potentiodynamic anodic, cathodic or both polarization measurements, galvanic corrosion measurements, potentiostatic measurements, linear polarization, pitting scans, Tafel plots measurements etc. Tafel plots technique quickly yields corrosion rate information. The linear portion of the anodic or cathodic polarization logarithm current vs. potential plot is extrapolated to intersect the corrosion potential line. This permits rapid, high accuracy measurement of extremely low corrosion rates. For this reason to determine electrochemical parameters we used this technique.

According to the mixed potential theory [3], any electrochemical reaction can be divided into two or more oxidation and reduction reactions, and can be no accumulation of electrical charge during the reaction. In a corroding system, corrosion of the metal and reduction of some species in solution is taking place at same rate and the net measurable current, i_{meas} is zero. Electrochemically, corrosion rate measurement is based on the determination of the oxidation current, i_{ox} at the corrosion potential, E_{corr} . This oxidation current is called the corrosion current, i_{corr} .

$$i_{meas} = i_{corr} - i_{red} = 0 \quad \text{at } E_{corr} \quad (1)$$

After extraction from stainless steel type AISI 316 cosmetic equipments, specimens were machined with small cutting conditions and with cutting fluid in order to avoid the influence above metallographic structure at dimensions $\varnothing 16.0_1 \times 3$ mm. One samples surface was polish with 500 Mesh abrasive papers. In Figure 1 is presented the corrosion measurement system EG&G Princeton, New Jersey- model 350 that works together with compensator IR 351,[6,7,8,9].



a- Potentiostat/Galvanostat

b- Corrosion cell

Fig. 1. Corrosion measurement system

Corrosion cell works with a saturated calomel reference electrode and specimen holder exposes 1 cm^2 of the specimen to the test solution. Using Tafel plots technique were determined the

electrochemical parameters presented in Table 1. Electrochemical tests were made according to ASTM G5-94, [7] and ASTM G1-90, [8]. The reference electrode was Calomel (Pt/Hg/Hg₂Cl₂). For tests at 72^oC was used a thermometer and a thermostatic plate were placed corrosion cell.

Table 1. Results of electrochemical parameters

<i>Sample material AISI 316L Passivated</i>			
Working medium	Corrosion potential, E_{cor} , V	Corrosion current, I_{cor} , μ A	Corrosion rate, V_{cor} , mm/an
Hair shampoo at 22 ^o C	0.352	0.2375	0.003
Hair shampoo at 72 ^o C	0.369	0.6112	0.007
<i>Sample material 316L Active (not passivated)</i>			
Hair shampoo at 22 ^o C	0.364	1.436	0.017
Hair shampoo at 72 ^o C	0.428	1.827	0.021

In Figure 2 it is shown the Tafel curves obtained for shampoo at 22^oC for stainless steel type AISI 316L active.

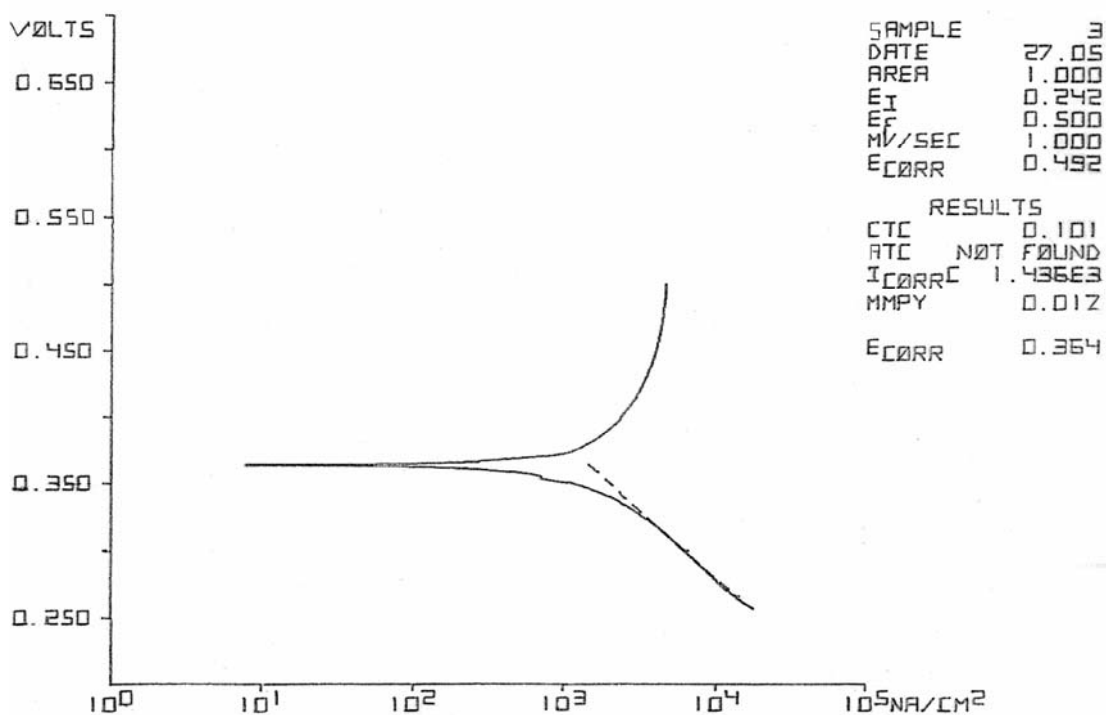


Fig. 2. Electrochemical parameters obtained by Tafel technique for shampoo at 22^oC for stainless steel 316L active

In cosmetic industry many equipments works in open circuit, so oxygen has an important role in materials behavior at corrosion. Thus appear an important difference in oxygen concentration and this generates galvanic cells and rise corrosion rate. Due to these conditions was realized also corrosion tests in conditions of film product applied on samples surfaces. Parallelepiped shape samples were realized with area $S=2958 \text{ mm}^2$. The passive stratum on this AISI 316L material samples were obtained in similar conditions as the real equipment.

Samples were covered with shampoo film by immersion and then the product in excess was released to flow before continuing the tests. Specimens were weighted before applying the product and after remove it at times of 10, 23.5 and 48 hours with a analytic Mettler H 35 device with measuring precision of 0.1 mg. Temperature of medium was of 22°C, 50°C and 72°C and was obtained with a Heraus owen. Samples were maintained in vertical position during the tests times in air with relative humidity RH=38% using nylon wires, avoiding contact between them.

Corrosion rate was determinate with the relation [1, 2]:

$$V_{cor} = 8.76 \cdot (m_f - m_i) / S \cdot \gamma \cdot \tau \quad , \text{ mm/year} \quad (2)$$

Were: m_f represents the final mass, g;

m_i – initial mass, g;

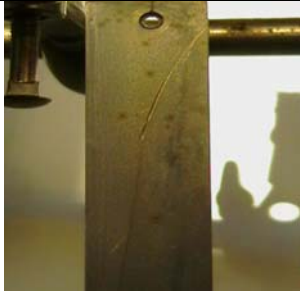








S - sample area, m²;

γ – specific weight, g/cm³;

τ - time of test, hours.

In Table 2 are presented the pictures of samples at different temperatures and different test times.

Table 2. Specimens pictures with shampoo film after different exposure times

Temperature, °C	Time, hours		
	10	23.5	48
22			
50			
72			

In Table 3 are presented the corrosion rate values obtained by gravimetric method.

Table 3. Corrosion rates values

Medium temperature, °C	Corrosion rate, mm/year			
	Time tests to shampoo film, hours			Average
	10	23.5	48	
22	0.00766	0.00351	0.00328	0.00482
50	0.00964	0.00826	0.00802	0.00864
72	0.00526	0.00526	0.00351	0.00468

In Figure 3 it is shown the composition in deep of passive layer, [4].

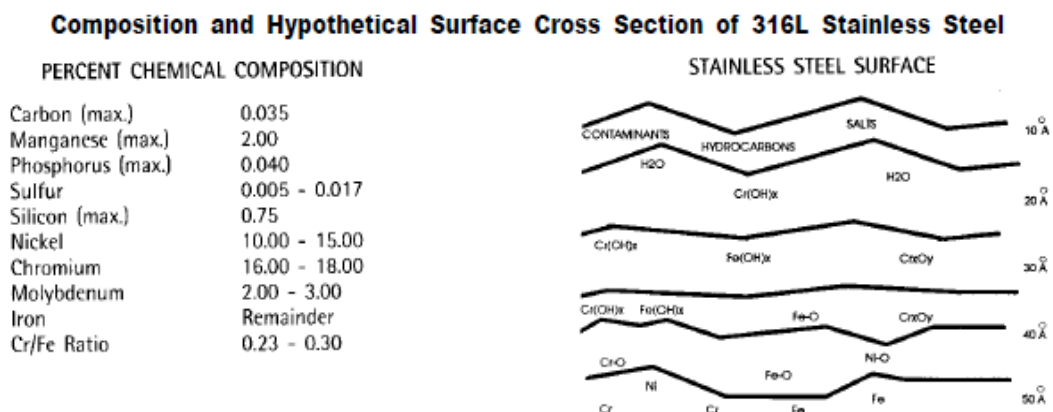


Fig. 3. Passive layer structures

Because maximum thickness of passive layer could be of 5 nm (5×10^{-9} m), if this maximum thickness are taking into calculus for a corrosion rate of 0.003 mm/year it means that iron appear in surface in 14.6 hours. Many researchers admit an average of passive layer at material AISI 316L of 3.17 nm, [5]. For this value iron appear in surface in 9.25 hours. In the case of corrosion rate of 0.004 mm/year for a thickness of 5 nm, iron will appear in surface in 10.95 hours and for a thickness of 3.17 nm in 6.93 hours. In the case of corrosion rate of 0.007 mm/year for a thickness of 5 nm, iron will appear in surface in 6.25 hours and for a thickness of 3.17 nm in 3.96 hours.



Fig. 4. Specimen of AISI 316L covered with shampoo film at 50°C after 3h30min.

Experimental tests made by the author's show that first time the corrosion piques appear at temperature of 22°C after 4h30min., at 50°C after 3h30min. and at 72°C after 4h45min. In figure 4 it is presented the picture of sample covered with shampoo film after 3h30min. at 50°C exposures.

Conclusions

Hair shampoo is a product with high aggressivity against stainless steel type AISI 316L.

Experimental corrosion rates values obtained by both potentiodynamic method and gravimetric method shows that hair shampoo is more aggressive than crude oil against stainless steel 316L.

For shampoo medium tested temperatures the corrosion rate presents a maximum value at 50°C. At 72°C at surface shampoo film makes a pellicle that reduces oxygen diffusion.

The passive layer must be restored at stainless steel equipments after each production charge in contra case the corrosion rate became less 3 times greater.

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Agresivitatea șamponului de păr asupra oțelului inoxidabil tip AISI 316L

Rezumat

Lucrarea prezintă unele aspecte privind comportarea la coroziune a oțelului inoxidabil tip AISI 316L în medii cu șampon de păr. S-au determinat parametrii electrochimici prin metoda potențiodinamică la diferite temperaturi precum și viteza de coroziune prin metoda gravimetrică pentru oțelul inoxidabil tip 316L pasivat și nepasivat. Influența mediului de lucru și a temperaturii sunt evidențiate în lucrare.