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# Impact of electrolyte concentration on surface gloss in electropolished stainless steel

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**Abstract**

Electropolishing is a surface finishing process of metals and alloys that enhances brilliant surface finishes with low surface roughness values. The most widely used electrolytes for the electropolishing of stainless steel are varying concentrations of phosphoric and sulphuric acid, and occasionally additives such as chromic acid. The objective of this study was to assess the performance of three commonly used industrial electrolytes in terms of the surface gloss of electro polished stainless steel AISI 316L. Each electrolyte had varying sulphuric-phosphoric acid combinations with or without chromic acid. The following electropolishing conditions were assessed: current density, bath temperature, electropolishing time, electrode position, and initial surface texture. The results revealed that adding chromic acid to the electrolyte did not significantly enhance gloss ranges. Current density and electropolishing time were the most significant parameters of surface gloss.



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## 1. Introduction

Electropolishing is an electrochemical surface finishing process for metals and alloys that enhances brilliant surface finishes with low surface roughness (Ra < 0.2 μm), without residual surface tension, and improves corrosion resistance [1-4]. Moreover, as electropolishing has its greatest impact primarily on surface texture peaks, it achieves high degrees of surface gloss. The material to be polished is connected to the anode in the electrolytic cell, with a uniform separation between electrodes, using two plates of the same material as cathodes (see Fig. 1a). When an electrical current is applied a polarized layer is formed on the metal surface that generates the diffusion of metal ions (see Fig. 1a).

The microscopic high points or "peaks" and the micro-depressions or "valleys" receive greater current density and dissolve faster than other surface areas, and levels the peaks and valleys by polarizing the anode in the viscose electrolytic surface layer containing the loose metal debris. The electrical conductivity of the anodic layer is less than in the remaining electrolyte, and the layer is thicker in the micro-valleys than on the micro-peaks. This reduces current resistance in the micro-peaks and dissolves them faster than in other areas of the anode surface.

The electrolytes used for the electropolishing of steel stainless consist of varying phosphoric and sulphuric acid concentrations according to type of material to be electropolished [5]. Occasionally, additives are used to improve process properties such as glycerol [1,2], or chromic acid for brilliant surfaces [6], but with the drawback of being highly toxic and dangerous to handle. The optimization of electropolishing conditions is a critical aspect involving a host of factors that influence process performance [7,8].

The aim of this study was to assess the influence on surface gloss [9,10] of three industrial electrolytes (Table 1) widely used for the electropolishing of AISI 316L. This stainless steels is one of the most frequently used for the manufacture of deposits, containers and instruments for the food industries [5,7,8], and biomedical applications [11]. Table 1 shows two electrolytes with varying phosphoric (45% and 63%) and sulphuric acid (15% and 35%) concentrations, and a third electrolyte with chromic acid (3%) that were assessed to determine their impact on electropolishing performance in terms of improving surface gloss. The electrolyte concentrations interaction with process control conditions were analysed i.e., influence of current density ($J$), bath temperature ($T$), electropolishing time ($t$), electrode position ($P$), and initial surface roughness ($R_a^0$).

Table 1. Electrolyte concentrations.

| Electrolyte | $H_2SO_4$ [%] | $H_3PO_4$ [%] | $Cr_2O_3$ [%] | $H_2O$ [%] |
|---|---|---|---|---|
| E1 | 35 | 45 | 0 | 20 |
| E2 | 35 | 45 | 3 | 17 |
| E3 | 15 | 63 | 0 | 20 |

## 2. Experimental Set-up

A total of 768 rectangular 70x30 mm$^2$ and 2 mm thick stainless steel workpieces AISI 316L (ISO 4954, X2CrNiMo17133E, C-0.03%, Si-0.50%, Mn-1.38%, Ni-10.08%, Cr-16.93%, Mo-2.05%, N-0.05%, S-0.01%, P-0.034%, bal. Fe) [12] were electropolished (Fig. 1a). Two initial surface roughness and electrode positions were evaluated: texture $Ra_1^0$ ($0.5 \leq Ra \leq 0.8$ μm), and texture $Ra_2^0$ ($1 \leq Ra \leq 1.3$ μm); and electrode position *P1* (distance between electrodes 150 mm), and electrode position *P2* (distance between electrodes 300 mm), respectively. The Fig. 1b shows the workpieces and sampling areas for the characterization of the surface gloss (area 1, area 2 and area 3 at 25-40-55 mm respectively) using the Elcometer 6012 glossmeter [9,10]. The 10 mm workpiece length used for clamping was not submerged into the electrolytic bath. For the analysis of process control parameters: current density $J$ [A/dm$^2$], bath temperature $T$ [ºC], and immersion time $t$ [min], a factorial design with 3 variables at 4 levels: current density (10, 29, 48 and 67 A/dm$^2$), bath temperature (35, 45, 55 and 65°C), and electropolishing time (3, 14, 25 and 36 minutes) was performed for both textures and the two previously specified electrode positions. The electropolishing process involved 5 stages: (1) ultrasonic degreasing with tensoactive agent diluted in water at a temperature of 50°C; (2) washing with deionized water, (3) hot air drying of workpieces (4) electropolishing under controlled electrical current intensity, bath temperature and immersion time; (5) washing of workpieces to eliminate electrolytic residue; and (6) hot air drying of workpieces.