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The Effect of Electro Pickling Parameters on Surface Quality in Stainless Steel Plate Production

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Abstract. Stainless steel flat product is a finished or semi-finished product whose demand is increasing day by day in terms of our country and world market. With the developing rolling technology and control mechanisms, even 0.1 mm thickness can be reduced in cold rolling processes. Stainless steel is an engineering material that attracts investors due to its significant share in the world economy and increasing demand. For this reason, surface quality and efficiency are becoming increasingly important in the emerging competition. With the material thickness and increasing deformation rate, the final annealing temperature or time decreases in stainless steels as in every metallic material. The shortening of the pickling time, the increase in line speeds and the expectation of surface quality have caused many changes in stainless steel surface treatment lines. Electrolysis units are used in many processes. The disadvantage of the system is that half of the electrodes are consumed and dissolved together with the material during the loading of the plate. This significantly increases production costs. In addition, almost half of the supplied current is spent for the depletion of these electrodes. The aim of this study is to increase the surface quality and corrosion resistance by direct electrolysis. In this study, AISI 430 quality stainless steel was directly charged and cleaned by electrolysis in sulfuric acid solution and corrosion resistance, surface roughness, gloss and mass loss were investigated by Taguchi test method. Continuous and pulsed electrolysis were applied at different current densities to examine the effect of pulse in the electrolysis process.

INTRODUCTION

Stainless steel is a material that offers solutions to the needs of many sectors with its long service life and high mechanical properties, and therefore there are many different alloy qualities. It generally consists of austenitic, ferritic and martensitic, duplex grades. Available in cold rolled and hot rolled strip. Recrystallization and solution treatment in annealing furnaces is required before both hot and cold rolled strips which are reused or cold rolled again. Therefore, in the annealing process, high temperature oxides of spinal phases are formed on the surface [1]. Compared to carbon steel, the removal of high temperature oxides from the surface of stainless steels is more difficult and complex due to the high alloying element it contains. In addition, considering the increased diffusion rate and the diffusion character of the chromium element in the steel, the surface oxide contains high levels of chromium [2]. Chromium on the surface of the material is added to the oxide layer with the effect of high temperature. This significantly reduces the corrosion resistance by removing the passive layer of the material.

Stainless steel Process parameters are determined by considering continuous heat treatment lines, annealing time, annealing temperature, where descaling and pickling processes are parallel to the heat treatment time. When the desired descaling and pickling flexibility cannot be achieved, this situation causes over-etched, under-acidified and visually defective surfaces [3]. In the case of optimization of the relevant parameters, it can lead to serious, efficiency losses and extra processes. For this reason, many new methods have been developed to increase the production efficiency and surface quality of ferritic caliper stainless steels containing Fe-Cr [4].

In particular, electrolytic pickling lines provide significant flexibility, controllability and surface quality in terms of process controllability compared to old stainless-steel cleaning and passivation technologies. It is also advantageous for reducing acid consumption and avoiding the use of acids that are seriously harmful to the environment. The control parameter in these processes is electric current[5]. Electro-pickling is a surface treatment process that cleans the surface based on the anodic dissolution principle, where ions are removed from the surface of the material [6].

The foundations of electrochemical processes were first laid by Faraday in the nineteenth century. The foundations of the laws of electrolysis were established in 1833. The principles of electrolysis (Faraday's Law) are expressed as the polishing phenomenon, the elimination of roughness, the absence of crystallographic and grain boundary irregularities, and it is aimed to produce smooth, clean and shiny surfaces[7].

Typically, the workpiece is immersed in a temperature-controlled electrolyte bath and acts as an anode; is connected to the positive pole of an AC/DC power supply, where the negative polarity is connected to the cathode. The current passes from the anode to the cathode, where the metal or oxide on the surface is dissolved in the electrolyte. A reduction reaction occurs at the cathode surface, producing hydrogen. The important electrolyte is normally a concentrated acid medium with high viscosity, such as phosphoric acid, sulfuric acid and mixtures or solutions of perchloric acid, acetic acid. With increasing viscosity, the gloss increases. Electropolishing is widely applied in the metal coating industry because of its simplicity and can be used for polishing complex structures. Electropolishing technique has many different applications[8].

Electro-pickling provides a relatively rougher surface than electro-polishing. With the increase in the current value, the solubility on the surface also increases, so it is faster and gives a wide working range. The mass dissolution process proceeds at high anodic potential and the mechanism is like trans passive dissolution of stainless steels. The common feature of these mechanisms is that the rate of dissolution is greatly reduced when the mass on the surface is dissolved. In this way, there is almost no risk of excessive etching and excessive material loss. On the other hand, a final pickling with HNO3 and HF is usually required, as the base material is insoluble. mechanisms presented above[9].

This study was initiated to increase the knowledge of electrolytic pickling mechanism and kinetics required for the selection of pickling conditions and improvement of process control and equipment for different stainless-steel grades.

The simplest electrolysis system is an electrochemical cell consisting of an anode, cathode, and electrolyte. The part to be cleaned or polished is connected to the positive voltage at the power source as the anode. The counter electrode works as the cathode electrode and is connected to the negative voltage. With the power supply turned on, electrons move from the anode surface to the cathode surface. The anode loses electrons and is oxidized. Metal atoms on the material surface are dissolved in the electrolyte solution, which is a material transfer process. The cathode gains electrons and is reduced. In a normal electrolysis process, hydrogen is released from the cathodic surface due to the reduction reaction.

The dissolution of the material in the electrolyte depends on the material's properties, electrolyte composition, electrolysis time, temperature, etc. Among these process parameters, current density and electrolysis time are the most effective ones. These parameters directly affect the surface roughness and therefore its brightness.

EXPERIMENTAL PROSEDURE

The stainless steels used are EN 1.4016 (AISI 430). The chemical composition of AISI 430 quality stainless steel is given in Table 1. Samples are 50mm, 10mm and 500mm. All samples were processed in order given in Table 2. The samples were cut with the help of laser from 0.6 mm thick sheets, which underwent 77% deformation.

TABLE 1. AISI 430 Stainless Steel Chemical Properties

Grade	C	Mn	P	S	Si	Cr	Ni
430 (1.4016)	0.12 max	1.0	0.045 max	0.03 max	1.0 max	16.0-18.0	0.75 max

All experiments are constructed by one-to-one modification according to taguchi experimental method. All samples were picked up at different heat treatment times and temperatures selected at the same deformation rate and thickness. Surface properties after annealing are examined. Descaling and Electro-Pickling procedures were then applied so that all samples were linked to heat treatment time. Electro-pickling variables: Current density is

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determined as pulse count and pickling time. All electrolysis procedures were performed with a 15% sulfuric acid solution by mass.

FIGURE 1. Design of Experimental Tabel

The heat treatment parameters of the samples are determined to show a feature within the limits of mechanical properties. Heat treatment temperatures were 750 °C, 775 °C, 800 °C, and heat treatment times were 100 s, 120 s. and 140 s. Current power is kept constant and current ranges are determined as full-time semi pulse and intense pulse. The samples were given the same currents in total for the same periods.

All parameters are determined according to the continuous plate heat treatment and pickling line at Trinox Metal INC's Ergene factory.

RESULT AND DISCCUSSION

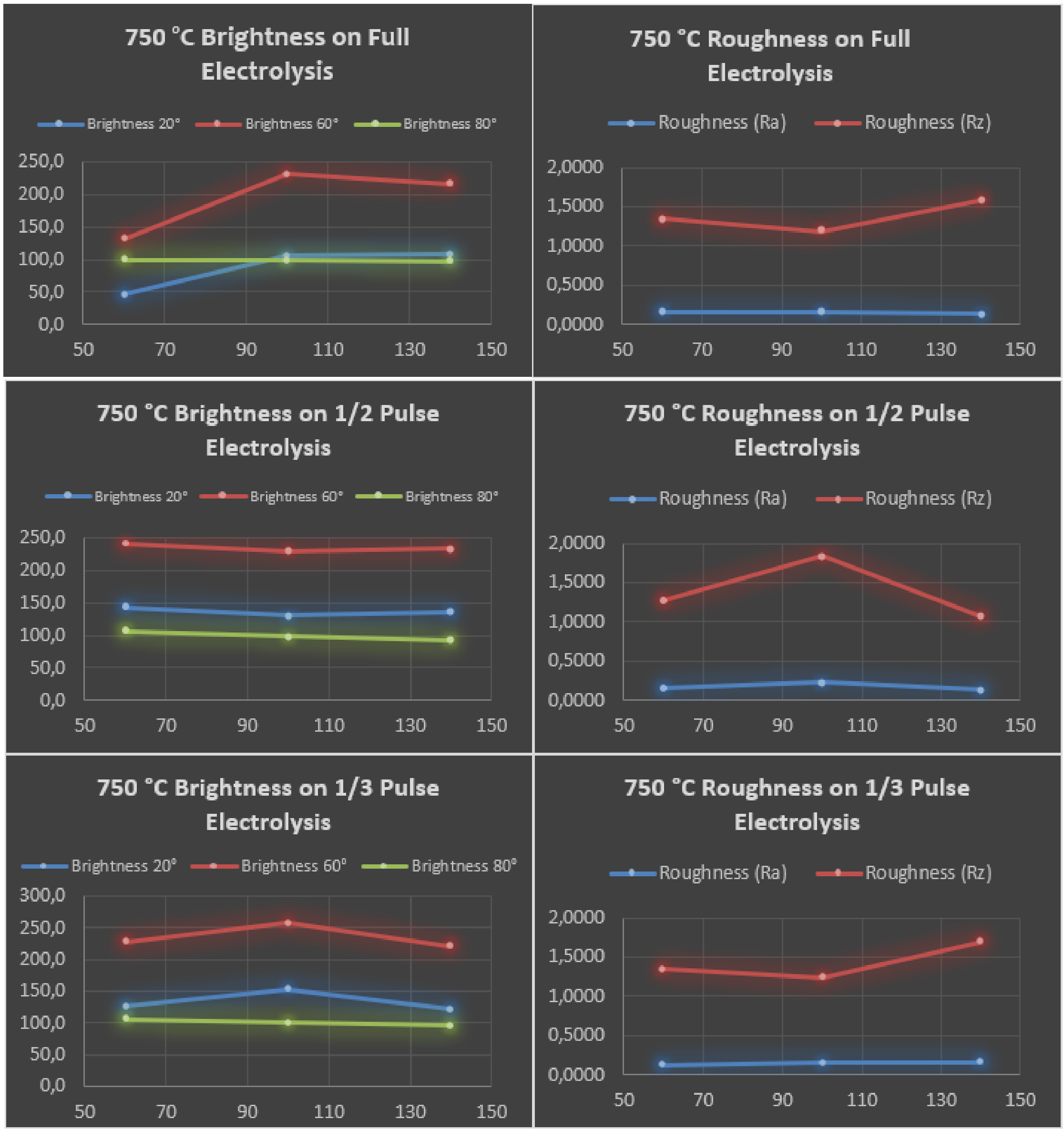

FIGURE 2. Variation of roughness and brightness at 750 °C degrees due to different heat treatment times and electrolysis types

When the triblockic properties of increased heat treatment time and electrolysis time at 750 °C are examined according to variable electrolysis types, surface brightness has increased at this temperature in general during increasing periods. Surface brightness was observed to increase in the samples that were applied with intense pulse. It is understood that the brightness decreases with the increased Rz value and disperses when the light is reflected. It is understood that 60° brightness gives more accurate results in AISI 430 alloy. Accordingly, all samples can be selected. The increase in surface roughness negatively affected the brightness.

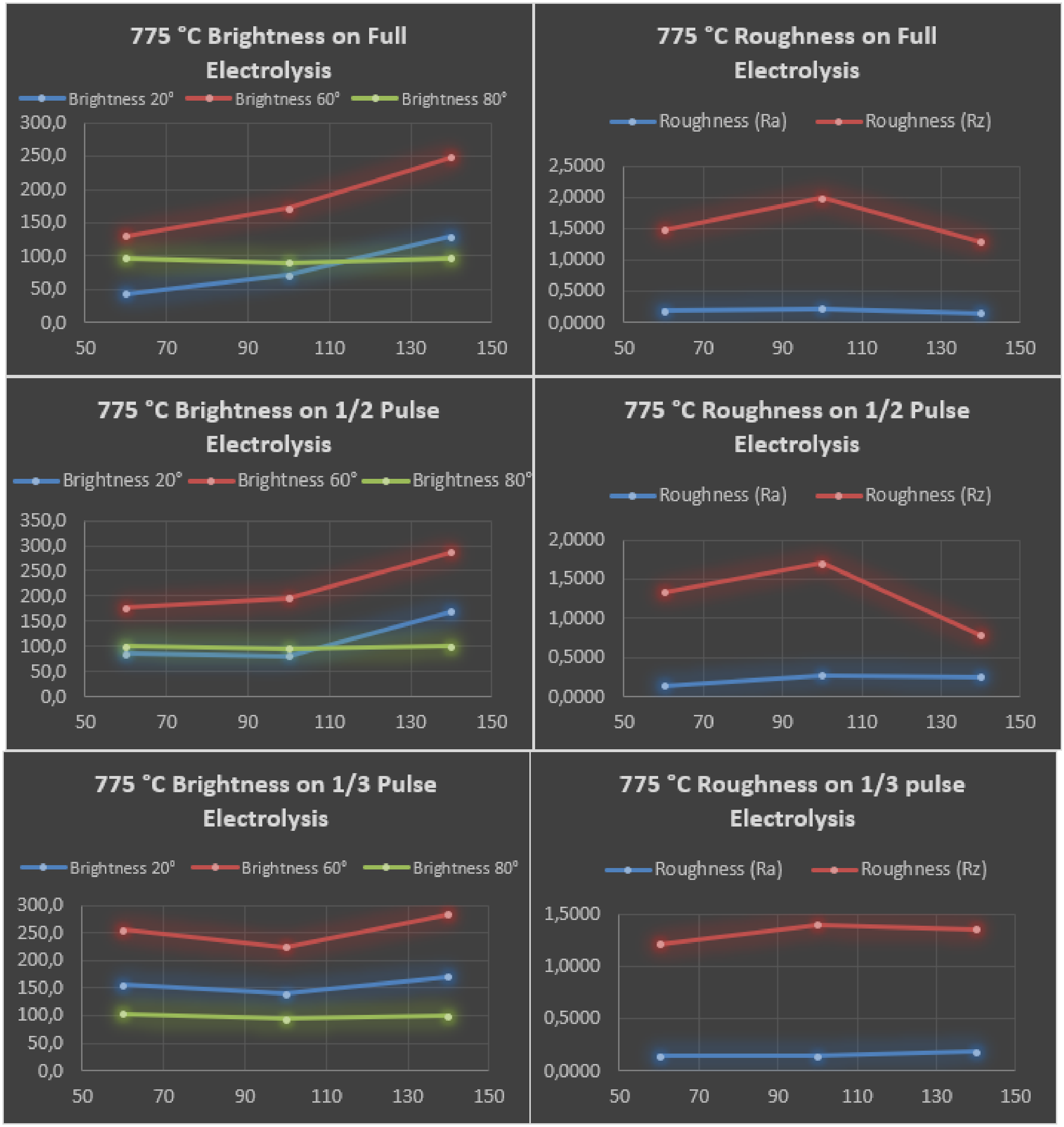

FIGURE 3. 1 Variation of roughness and brightness at 775 °C degrees due to different heat treatment times and electrolysis types

Surface oxides that become unstable during increased heat treatment and electrolysis times in 775 °C heat treatment have been shown to negatively affect surface brightness even though they do not increase surface roughness very much during low electrolysis times. As the pulse intensity increases at this temperature, it is understood that the roughness decreases and the brightness increases significantly. In addition, the dependence of surface properties on duration has increased. Especially in the periods of 140 sec heat treatment and electrolysis, brightness has increased significantly and roughness has decreased. According to the design of the experiment, the electrolysis time is proportional to the heat treatment time. With the increase in heat treatment time, the increased oxide can be removed from the surface.

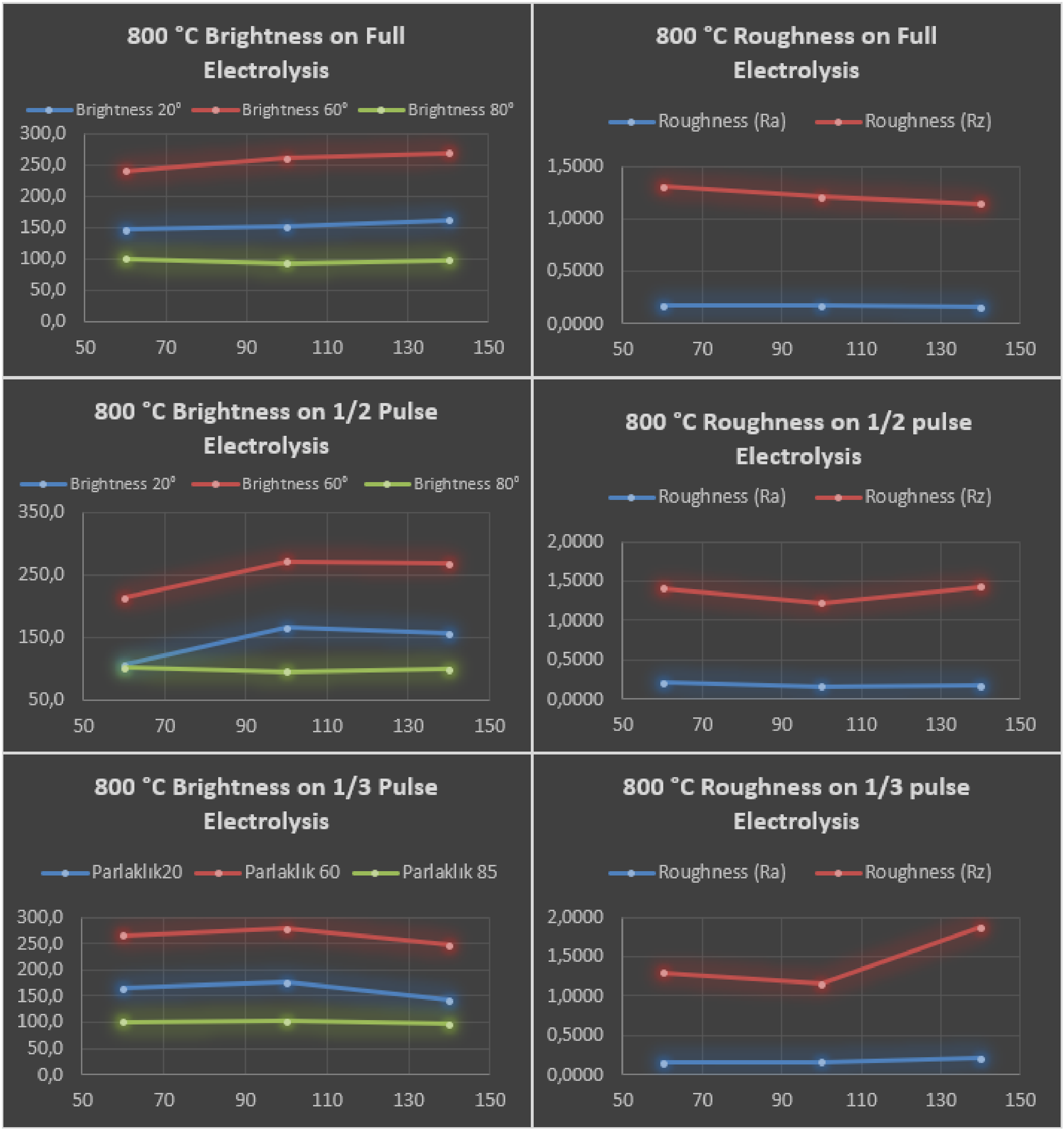

FIGURE 4. Variation of roughness and brightness at 800 °C degrees due to different heat treatment times and electrolysis types

With increasing temperatures at 800 °C, the instability of oxide forms increased and near-each other surface brightness was measured even under the same electrolysis conditions. In this direction, increased surface roughness partially affected the surface brightness.

The relationship between surface roughness and brightness continued at this heat treatment temperature. In samples that were pulsed for half a period, the effect of time on tribological characteristics was greater. It is more effective at high temperatures for intense pulse electro-pickling.

CONCLUSION

- AISI 430 quality stainless steel direct electrolizer applied to the surface pickling.
- Surface roughness and brightness can be controlled in the electrolysis process and there is a general inverse ratio between them
- Although the electocliz current increased to high heat treatment temperatures, it did not show any significant effect on brightness.
- Pulse current has generally shown better surface properties in the same electrical forces.
- Stainless steel can be used directly for electrolysis surface treatments in flat product production.
- Electrolysis is an ideal method for surface roughness control.

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