Using Material Balances to Improve the Design Of Electrolytic Degreasing Plants

By C.A. de Ritter and C. Coutin/Robert

A portion of an existing electrolytic degreasing section of a zinc electroplating plant is analyzed to determine the efficiency of the process. The results clearly show that conventional material balances can be used to improve the design of electrolytic degreasing plants. The use of material balances allows quantitative determination of the amount of organic and inorganic matter removed from the strip by the cleaning process. The method employed is based on solution measurements and can be performed at any time without upsetting production.

System Description

The steel strip coming from a continuous annealing plant is transported to the electrolytic degreasing section, where it is cleaned by emulsification, saponification, dispersion and the micro-scrubbing action of gas generated by water electrolysis. From the electrolytic degreasing section, the steel strip is moved to the activation section before plating.

Figure 1 shows the block flow diagram of the portion of the electrolytic degreasing section under study. A sodium hydroxide solution is continuously pumped from the electrolyte recycle tank (TK01) to the electrolytic degreasing unit (U01). In this unit, the steel strip passes through pairs of electrodes per face, where the polarity sequence is alternated. NaOH solution from this unit is recycled to the electrolyte recycle tank (TK01). The system is closed, except for an intermittent purge in the recycle tank. Manual additions of NaOH and water compensate for the solution loss caused by the purge. The NaOH solution in this tank is disposed of every three



Fig. 1—Block flow diagram, electrolytic degreasing section.

weeks, because experience has determined that after this period, the solution is no longer adequate, inasmuch as poor plating results.

Design Basis

Strip speed, 90 m/min

Strip width, 1.2 m

Mean surface iron on inlet strip, 100 mg/m²

Mean surface carbon on inlet strip, 20 mg/m²

- Maximum recommended surface iron on strip before plating, 10 mg/m²
- Maximum recommended surface carbon on strip before plating, 10 mg/m^2
- Total system volume, 22.8 m³

Procedure

The electrolyte recycle tank (TK01) was monitored every 24 hours for 13 days for iron content, total suspended solids (TSS) and percentage grease content. Figures 2 and 3 show the results for Fe and TSS in mg/L vs. time (hr), and Fig. 4, the percentage grease content vs. time (hr). The experimental data were fitted through linear regression, as shown in the figures. The results of the linear regression analysis are as listed in Table 1. The values of the R2 coefficient show that in Fig. 2 (Fe vs. time) 87.39 percent of the variability in Y is explained by the linear regression analysis and similarly for Figs. 3 and 4.¹ These values are considered sufficiently large to use the slope and intercept results to develop the materials balance of the unit.

Analytical Methods

- 1. Iron in solution: Measured in three steps: (a) sample dissolution, (b) reduction to the ferrous state with SnCl₂, and (c) titration with potassium dichromate.² Use of this procedure indicates that surface iron is present on the inlet strip as an oxidized coating.
- 2. Percentage grease content: 200 cm³ of sample are collected, heated to 80 °C, and 10 g NaF and 20 g NaCl are added. The resulting solution is transferred to a graduated vessel and 20 cm³ concentrated HCl are added. After heating for 8 hr, the volume of grease separated is measured and the percentage of grease content determined.

Table 1Results of Linear Regression Analysis

		R2	Slope	Intercept
Fig. 2	Fe vs. time	0.8739288	0.6909341	60.04396
Fig. 3	TSS vs. time	0.6003534	1.0907990	904.356500
Fig. 4	% grease vs. time	0.7332242	0.0002564	0.0730



Fig. 2—Iron content of electrolyte recycle tank during degreasing operations.

Table 2Materials Balance							
	1 Steel strip inlet	2 Accumulation TK01	3 Purge NaOH solution	4 Steel Strip outlet			
Flow, m ³ /hr			0.18				
Fe, kg/hr	0.65	0.016	0.03				
C, kg/hr	0.13	0.0001	0.0002				
MES, kg/hr		0.023	0.19				
Total, kg/hr	0.78	0.0391	0.2202	0.5207			

Nomenclature

R2: Percentage of the total variability in Y that is accounted for by using X to predict Y.¹

Materials Balance

The materials balance is developed based upon the following parameters:

1. The mean component concentration (Fe, TSS and percentage grease content) from Figs. 2, 3 and 4 during the 13-day period is used to calculate the kg/hr of each component at the outlet from the electrolyte recycle tank (stream 3 in Fig. 1).



Fig. 4—Grease content of electrolyte recycle tank during degreasing operations.



Fig. 3—Total suspended solids content of electrolyte recycle tank during degreasing operations.

- 2. The slope resulting from the linear regression analysis of Figs. 2, 3 and 4 and the total system volume are used to calculate the accumulation rate of each component in the system in kg/hr.
- 3. The available data do not allow determination of the composition of the total suspended solids; therefore, a global iron and carbon removal is calculated.
- 4. In order to develop the carbon balance, it is assumed that the percentage grease content corresponds to the carbon. This assumption is con-

sidered valid, even with the steel strip coming from an annealing operation, because there has been an analytical measurement of an increasing grease content with time in the electrolytic degreasing tank. This content, though weak, can come only from the steel strip surface. The result of the materials balance is shown in Table 2.

Results Analysis

Process efficiency is shown in Table 3.

Purge Flow

The actual purge flow of 0.18 m³/hr proves insufficient, because there is an accumulation of iron, carbon and suspended solids within the system.

Findings

The materials balance has enabled determination of the efficiency of the process. The total iron and carbon removal is 33 percent of the inlet iron and carbon pollution on the strip. It also represents 40 percent of the total removal required to attain the maximum recommended levels of pollution for the zinc plating process. The quantitative determination of the iron and carbon removal of the process is significant, because such information could not be obtained in the past without

Table 3 Process Efficiency						
		%	%			
	kg/hr	at inlet	recommended			
Fe + C removal	0.26	33	40			

going through the cumbersome procedure of stopping the unit and analyzing the outlet steel strip. The method employed here can be universally applied to any electrolytic degreasing unit. Its importance lies not only in its capability to determine the efficiency of the process, but on the usefulness of this determination in improving the design of the process. In this case, for instance, the findings show that there is an accumulation of organic and inorganic matter in the system. As a result, the system solution is no longer adequate after three weeks' use. To avoid this accumulation, it is necessary to increase the purge flow. A new purge flow could be calculated, based upon a nil accumulation rate of iron that is equivalent to fixing the initial concentration as the maximum concentration. The same could be done for the suspended solids and for the grease content. The largest of the flows would be the new adequate purge flow.

Increasing the purge flow alone, however, would not be sufficient to maintain a clean system solution. Whatever the total suspended solids concentration resulting from the increase in purge flow, if the tank design does not take into account the velocity of the settling particles, there will be a deposition of sludge. Therefore, a filtration or other separation unit should be included. A filtration unit would be designed taking into account the total accumulation rate of suspended solids and making an analysis of the particle size distribution of the solids.

Recommendations

For a more accurate development of the materials balance, the concentration measurements should be done with samples taken at the inlet and outlet of the electrolytic degreasing unit, and at the purge line. To be able to determine separately the iron and carbon removal of the process, it is necessary to analyze further the total suspended solids for organic and inorganic content.

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