**Electrochemical Pickling of Steel for Industrial Applications: Modelling**

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**Introduction:** The present work is aimed at simulating the steel electrochemical pickling process by means of experimental investigation in industrial field and the development of a mathematical model. The reference system is characterized by a cell in which an electrolyte is present. A group of electrodes (cathodes and anodes) is immersed in the electrolytic bath. A steel strip, to be submitted to the pickling treatment, is interposed between the electrodes.

![Figure 1. Industrial electrolytic pickling cell](Image)

**Computational Methods:** A reliable, flexible and robust 3D model has been made for simulating the steel strip electrochemical pickling. This process is modeled like a multiphysics system for the current control.

![Figure 2. Geometric model of the electrolytic pickling cell](Image)

The physics of the problem is described by the following equations system:

\[
\begin{align*}
\nabla i_t &= Q_t \quad (1.1) \\
\nabla i_s &= Q_s \quad (2.1) \\

i_t &= -\sigma \nabla \Phi_t \quad (1.2) \\
i_s &= -\sigma \nabla \Phi_s \quad (2.2)
\end{align*}
\]

the equations system is completed by the next set:

- the boundary conditions of the current which develops on both the electrodes (Anode-Cathode) and the strip surfaces :

\[
\eta_A = \eta_A = \Phi_s - \Phi_t - E_{eq} \quad (3.1)
\]

\[
i_k = i_0 \left[ e^{\frac{akFq}{RT}} - e^{-\frac{akFq}{RT}} \right] \quad \forall k = 1, ..., N \quad (3.2)
\]

- the initial condition for the potential in the electrolyte, the electrodes and the steel strip:

\[
\Phi_s = V_{s0} \quad (4.1) \\
\Phi_t = V_{l0} \quad (4.2)
\]

where the equations:

- 1.1 and 2.1 are obtained by the combination of the mass conservation law with the Nernst-Plank's law and Faraday's one in the steady case and applied in the electrolyte, in the electrodes (Anode-Cathode) and in the steel strip

- 1.2 and 2.2 represent the Ohm's law in differential form

- 3.1 represents the secondary current distribution calculated according to the second Kirkoff's law of the equivalent electric circuit

- 3.2 is the empirical Tafel's law for each ionic specie

- 4.1 and 4.2 are the initial potential values in the cell

**Results:** The obtained model allows to estimate, evaluate and verify the operating conditions of a cell dedicated to the industrial electrochemical pickling process. According to the results of management of industrial plants, the total current is the "driving-control" variable. Then it is possible to evaluate:

- the potential distribution in the cell
- the current density distribution in the steel strip
- the geometric effect on the current density distribution
- the voltage-current characteristic curve.

![Figure 3. Initial potential distribution in the cell](Image)

![Figure 4. Steel strip current density distribution](Image)

**Conclusions:** The system is an excellent tool to use during feasibility study, plants analysis and design, testing and maintenance in the electrolytic pickling plant. The model results were compared and validated with real process data. Different pickling cells/plants will be simulated in the future. The system will be upgraded with additional physics (e.g. electrolysis gas modelling), as well.

**References:**


