FOR A CONTINUOUS WORKING OF THE VASILESCU-KARPEN'S CONCENTRATION PILE

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1. The imperious actuality of Vasilescu Karpen concentration pile.

The global warming in the two last centuries, due to the low efficiencies of the thermodynamical cycles, as well as the gas emission with green-house effect, followed in the last time of the important climate changes, manifested by strong storms and torrential rains, caused by the water vapor excess, resulted by burning, after 1850 years, also of the hydrocarbons too; will lead in the same time, in our opinion, at the situation that the Earth will lose gradually its seasons [1].

To avoid this effect, besides the arising of afforestated surfaces, on the first place of the technical proceedings the concentration pile of the famous Romanian scientist Nicolae Vasilescu Karpen [2]÷[7] situate as the only proceeding known by us, which will produce the electric energy by diminishing of electrolyte and consequently environment temperature.

2. Historical antecedents of the electrochemistry

Although the founder of the interdisciplinary science of the Electro-magneto-dynamics in 1831 and of the Electrochemistry in 1833 is the famous physicist and chemist Michael Faraday (1791-1867), galvanizing applications are known yet from the asiro-babilonian epoch, when the statues are gilded means by an electric pile.

In an previous paper [8] we tried to obtain the continuous working of the K pile, applying a magnetic field created by permanent magnets, in the aim to intensify the connective heat transfer between the electrolyte and the environment through the pile walls.

In this work we shall present a mathematical model of the K pile working in absence of magnetic field, but considering the *thermal-siphon effect* of the electrolyte density variation.

3. Two-dimensional mathematical model of the K pile and equation transformation

3.1. Electric field equations [9] with the component $J_Z = 0$ according with figure 1, are:

- **electric charge conservation equation**, unstable in the iterative numerical calculus, which can be identically verified by the introduction of the **electric current line function** $\cap(X,Y)$ = const. and which, with respect of the potential lines $\in(X,Y)$ are in the relations:

$$\mathrm{div}\vec{J} = \frac{\partial J_X}{\partial X} + \frac{\partial J_Y}{\partial Y} \equiv 0 \quad \rightarrow \quad J_X = \cap'_Y = \in'_X \quad \text{and} \quad J_Y = -\cap'_X = \in'_Y, \tag{1}$$

which permits the introduction of complex variable function

$$\Phi(Z) = \in(X,Y) + i\cap(X,Y), \tag{2}$$

whose real part, representing by the equation (1) verification, the harmonic potential,

$$\underset{X,Y}{\Delta} \in = \in''_{X^2} + \in''_{Y^2} = 0, \tag{3}$$

the imaginary part, representing the electric current line function

$$\frac{dX}{J_X}=\frac{dY}{J_Y} \;\rightarrow\; d\cap=\cap'_X dX+\cap'_Y dY=0 \;\rightarrow\; \cap(X,Y)=\text{const.}, \qquad (4)$$

supposing the spectral line orthogonality $\in(X,Y)=\text{const.}$ and $\cap(X,Y)=\text{const.}$

- **magnetic circuit law** in the case of quasistationary regime,

$$\mathrm{rot}\vec{H}=\vec{J}=\vec{i}J_X+\vec{j}J_Y+\vec{k}J_Z=\begin{vmatrix}\vec{i} & \vec{j} & \vec{k}\\ \frac{\partial}{\partial X} & \frac{\partial}{\partial Y} & \frac{\partial}{\partial Z}\\ H_X & H_Y & H_Z\end{vmatrix}=-\vec{i}\frac{\partial H_Y}{\partial Z}+\vec{j}\frac{\partial H_X}{\partial Z}+\vec{k}\left(\frac{\partial H_Y}{\partial X}-\frac{\partial H_X}{\partial Y}\right) \qquad (5)$$

and which, in the case of made hypothesis, one reduces of the equations:

$$J_X=\frac{\partial H_Z}{\partial Y}-\frac{\partial H_Y}{\partial Z}\cong-\frac{1}{\mu}\cdot\frac{\partial B_Y}{\partial Z},\; J_Y=\frac{\partial H_X}{\partial Z}-\frac{\partial H_Z}{\partial X}\cong\frac{1}{\mu}\cdot\frac{\partial B_X}{\partial Z},\; J_Z=\frac{\partial H_Y}{\partial X}-\frac{\partial H_X}{\partial Y}=0, \qquad (5')$$

the last of these equations demonstrating the two-dimensional magnetic field dependence on a scalar potential $\aleph(X,Y)$, in accordance with the equations:

$$\vec{H}(X,Y)=\vec{i}H_X+\vec{j}H_Y=\mathrm{grad}\,\aleph(X,Y)=\vec{i}\aleph'_X+\vec{j}\aleph'_Y \;\rightarrow\; H_X=\aleph'_X \;\text{ and }\; H_Y=\aleph'_Y, \qquad (5'')$$

- **Ohm's law**, where σ is the electric conductivity and $\in(X,Y)$ the electric potential

$$\vec{J}=\vec{i}J_x+\vec{j}J_Y=\mathrm{grad}\in(X,Y)=\sigma\vec{E}=\sigma\left(\vec{i}E_X+\vec{j}E_Y\right), \rightarrow J_X=\in'_X=\sigma E_X,\; J_Y=\in'_Y=\sigma E_Y\;. \qquad (3)$$

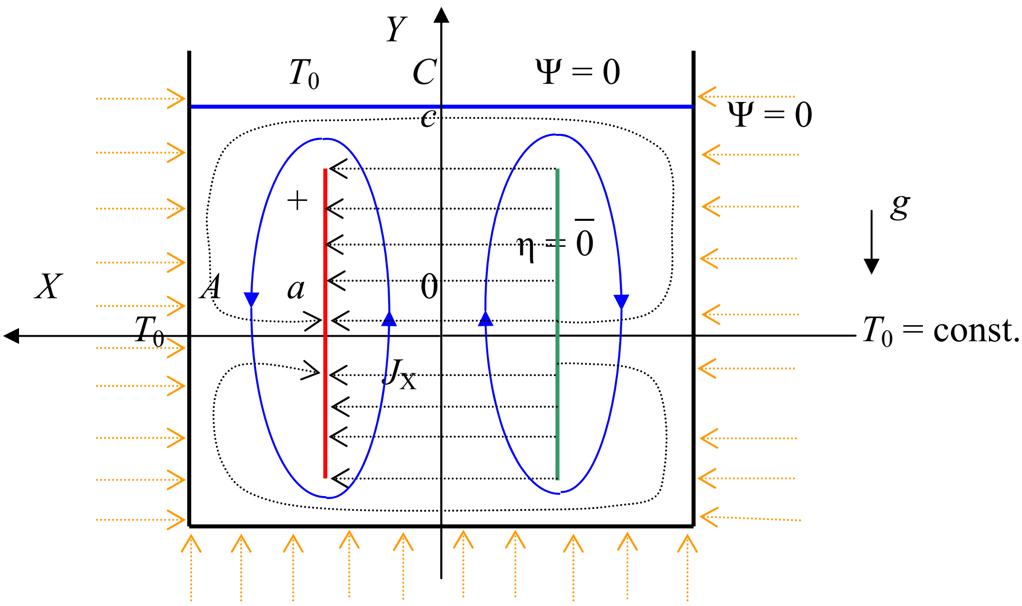


Fig. 1. Two-dimensional configuration of a K pile, boundary conditions and co-ordinate axes

3.2. The scalar temperature field equation, considering the heat connective transfer due to the K pile cooling in permanent regime, with the constant specific heat and thermal conduction coefficient, is

$$\rho(T)c\left(T'_X U+T'_Y V\right)=\lambda\left(T''_{X^2}+T''_{Y^2}\right)+R\left(J_X^2+J_Y^2\right)-K\left[J(X,Y)\right], \qquad (6)$$

- **liquid state equation** of variable density in accordance with the expression [10]

$$\rho(T)=\rho_0\left(1-\beta\cdot\delta T\right)=\rho_0-\rho_0\beta\left(T-T_0\right) \quad \text{with} \quad \rho'_{X,Y}=\rho'_T T'_{X,Y}=-\rho_0\beta T'_{X,Y}, \qquad (7)$$

where the influence of the relative volume variation δ*W*/*W* as function of the temperature variation,

$\beta = \frac{\delta W}{W} \Big/ \delta T = \frac{W_T - W_0}{W_0} \Big/ (T\text{-}T_0) = 3\alpha$ being the volume dilatation coefficient, three time greater than the linear coefficient $\alpha = \frac{\delta L}{L} \Big/ \delta T = \frac{L_T - L_0}{L_0} \Big/ (T - T_0)$.

3.3. The equation system of the velocity hydrodynamic field, composed by:
- **motion equations** on the two directions, of a liquid with constant viscosity

$$\left(UU'_X + VU'_Y\right)\cdot\rho(T) + P'_X = \upsilon\left(U''_{X^2} + U''_{Y^2}\right)\cdot\rho(T), \tag{8}$$

$$\left(UV'_X + VV'_Y\right)\cdot\rho(T) + P'_Y = \left[\upsilon\left(V''_{X^2} + V''_{Y^2}\right) - g\right]\cdot\rho(T), \tag{9}$$

- electrolyte **mass conservation equation**, unstable in the iterative numerical calculus, is according the estimation from [10]

$$(\rho U)'_X + (\rho V)'_Y = -\beta\left(T'_X U + T'_Y V\right) + \left[1 - \beta(T - T_0)\right]\left(U'_X + V'_Y\right) = 0, \tag{10}$$

but identically verified, introducing the streamline function $\Psi\,(X,Y) = \text{CT.}$ by the relations:

$$U(X,Y) = \frac{1}{\rho\left[T(X,Y)\right]}\Psi'_Y,\ V(X,Y) = -\frac{1}{\rho\left[T(X,Y)\right]}\Psi'_X. \tag{11}$$

By introduction of the **thermal-current line function** and pressure function elimination in virtue of Schwarz's relation, of second order mixed derivative commutativity $P''_{X,Y} = P''_{Y,X}$, one obtains a nonlinear with partial differential equation up to 4th order for thermal-current line function and up to 2nd order for temperature function.

4. The equation system transformation for the numerical treatment

For more generality of the numerical solving, we shall use the dimensionless variables and functions, denoting by:

$$x = \frac{X}{A},\quad y = \frac{Y}{A} \text{ and } u = \frac{U}{U_m},\quad v = \frac{V}{U_m},\quad \psi = \frac{\Psi}{U_m A},\quad \theta = \frac{T}{T_0},\quad j = \frac{J}{J_0},\quad \varepsilon = \frac{\in}{\in_0},\ \eta = \frac{\cap}{\cap_0}, \tag{12}$$

with which the relation (2) becomes in dimensionless form $\varphi(z) = \varepsilon(x,y) + i\,\eta(x,y)$.

4.1. The electric charge conservation equation, replacing the partial differentials with the expressions in finite differences, in the case of a quadratic grid $\delta y = \delta x = \delta$, becomes

$$\underset{x,y}{\Delta}\varepsilon = \varepsilon''_{x^2} + \varepsilon''_{y^2} = 0, \quad \rightarrow \quad \frac{\varepsilon_1 - 2\varepsilon_0 + \varepsilon_3}{\delta^2} + \frac{\varepsilon_2 - 2\varepsilon_0 + \varepsilon_4}{\delta^2} = 0, \tag{13}$$

Thus, the solving of the algebraic relation (13) makes the calculation of the harmonic electric potential

$$\varepsilon_0 = \frac{1}{4}\sum_{i=1}^{4}\varepsilon_i, \tag{13'}$$

associated to the equation with partial differentials (13), representing the very known formula of the mean value.

The numerical solution stability is assured always by the error propagation relation in any both calculus directions in the considered domain [11]

$$\delta\varepsilon_{n+1}^{\pm x,y} = \frac{1}{4}\delta\varepsilon_n. \tag{14}$$

4.2. Temperature field equation, utilizing the (11) relations, becomes in dimensionless form

$$\psi'_y\theta'_x - \psi'_x\theta'_y = \frac{1}{\text{Pé}}\left(\theta''_{x^2} + \theta''_{y^2}\right) + \Im\text{o}\left(j_x^2 + j_y^2\right) - \text{Ka}\sqrt{j_x^2 + j_y^2}, \tag{15}$$

in which one denoted the similitude numbers Péclet, Joule and Karpen of the specific thermal-electric considered phenomenon, by the expressions:

$$\text{Pé} = \frac{U_m A}{a T_0 \rho_0}\ , \ \Im\text{o} = \frac{R J_0^2 A}{c\, U_m},\ \text{Ka} = \frac{K\, A\, J_0}{c\, U_m}. \tag{16}$$

Replacing in (15) the expressions of partial differentials, deduced by the finite difference method and expliciting the θ_0 value from the linear part, one obtain the associate algebraic relation

$$\theta_0 = \frac{1}{4}\sum_{i=1}^{4}\theta_i + \frac{\text{Pé}}{16}\left[(\psi_1-\psi_3)(\theta_2-\theta_4)-(\psi_2-\psi_4)(\theta_1-\theta_3)\right] + \frac{\text{Pé}\,\Im\text{o}\,\delta^2}{4} j_0^2 - \frac{\text{Pé}\,\text{Ka}\,\delta^2}{4} j_0, \tag{17}$$

from which we can deduce the error propagation relation, for instance on the calculus direction $\pm x$

$$\delta\theta_{n+1}^{\pm x} = \left(\frac{1}{4} \pm \frac{\text{Pé}(\psi_2\text{-}\psi_4)}{16}\right)\delta\theta_n \mp \frac{\text{Pé}(\theta_2\text{-}\theta_4)}{16}\delta\psi_n + \frac{\text{Pé}\,\Im\text{o}\,\delta^2}{4}\delta j_{n+1}^2 - \frac{\text{Pé}\,\Im\text{o}\,\delta^2}{4}\delta j_{n+1}, \tag{18}$$

which assure **numerical solution stability** in the conditions:

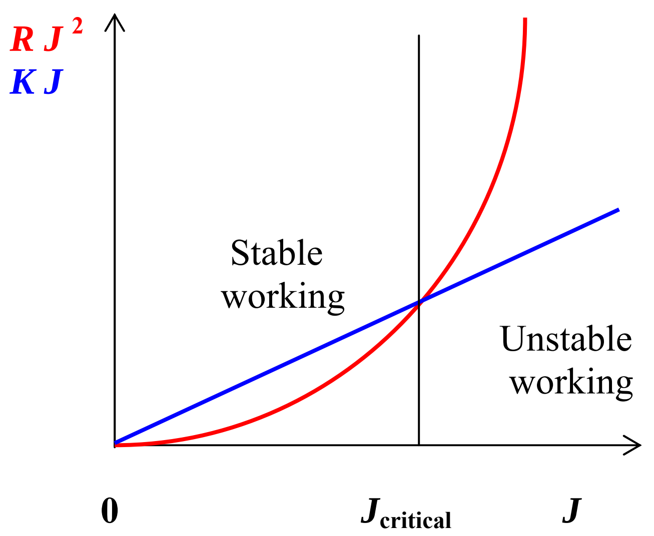
$$\left(\frac{1}{4} \pm \frac{\text{Pé}(\psi_2\text{-}\psi_4)}{16}\right) \prec 1,\quad \text{Pé}(\theta_2\text{-}\theta_4) \prec 16,\quad \text{Pé}\,\Im\text{o}\,\delta^2 \prec 4 \quad \text{and} \quad \text{Pé}\,\Im\text{o}\,\delta^2 \prec 4. \tag{19}$$

5. The specific boundary conditions of the studied problem in the case of steady state:

5.1. For the **hydrodynamic field**, $\Psi_C = 0$ on the whole vessel outline containing the electrolyte, inclusive at its free surface and on the electrode axis, with unknown values $\pm\,\Psi_E$ on the two electrodes, which will result follows the iterative numerical calculus and of the electric current resulted by closing of the circuit on the exterior charge resistor.

5.2. For the **thermal field**, $T_C = T_0$ = the environment temperature, on the whole vessel outline supposed as thermal perfect conductor, inclusive at the electrolyte free surface, with unknown but constant values T_E = const. on the two electrodes, good thermal conductors and depending of the pile working regime intensity,

5.3. For the **electric field**, on the axis perpendicularly on the two electrodes $\eta_{A\perp E} = 0$ and with unknown values $\pm\,\eta_C$ at their two ends, with the boundary conditions on electrodes face $J|_{FE} = J_{FE}(Y)$ and back $J|_{BE} = J_{BE}(Y)$, resulted by the relation (14) and solving in the boundary conditions concerning to the voltage values on the both electrodes $\pm\varepsilon_E$.



6. A final observation

The calculus program being for the moment in course of elaboration, we shall permit only a consideration to explain the experimental result of the electrode polarization in the situation of a intense working of the Vasilescu Karpen pile, considering the graphic representation (fig.2) of the thermal energy functions of pile heating and cooling respectively, given by the equation (17), limiting the two zones of continuous working, stable of physical point of view and specific of pile reduced charge, with respect of the intense one, when the developed energy by heating overtakes, by our estimation, its cooling one, resulting by the normal working.

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