HYBRID MAGNETOSTATIC-HYDRODYNAMIC NUMERICAL MODEL OF CAPTURE EGDE IN OGMS SEPARATOR

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INTRODUCTION

The operating principle of the OGMS (Open Gradient Magnetic Separation) separator consists in the selective deflection of particles, according to their magnetic susceptibility, during their passage through a strong and nonhomogeneous magnetic field generated by superconducting magnet with an appropriate configuration of coils Janowski and Kozak (1). The OGMS separator should only deflect particles, but ferromagnetic ones can be captured on the inner wall of the separator. The ferromagnetic material on the wall influences magnetic and hydrodynamic circumstances in a working area. This can lead (in worst case) into the total blocking of a separation flow.

CLEANING WATER RESULTS

The superconducting OGMS separator for cleaning industrial water has been subjected to several tests made by Authors (1).

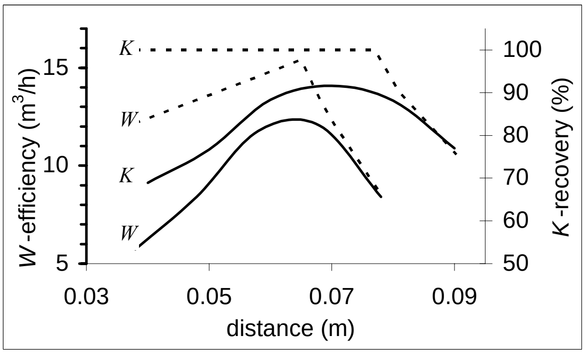

Figure 1: Efficiency and recovery vs. separator to cryostat distance (1), measured (solid lines) and computed (dotted lines)

Figure 1 presents the efficiency and the recovery as a function of the separator to cryostat distance. A comparison between computation results (numerical model of particle trajectories in which capturing effect is not taken into account Janowski and Kozak (2)) and experimental results shows that captured ferromagnetic material has significant influence on separation recovery and efficiency. The full elimination of this undesirable blocking effect is not possible but, as it can be seen during experiments, the OGMS separator can work properly with the recovery over 92% and the efficiency over 12 m^3/h at some ferromagnetic volume captured on the wall, when the parameters of separation are set correctly (1).

MATHEMATICAL MODEL OF CAPTURE EDGE

The ferromagnetic material captured on the inner wall of the separator decreases the effective separator cross-section and then the local medium velocity increases. This intensifies the fluid drag acting on the particles. The ferromagnetic material captured on the inner wall of the separator changes the magnetic field distribution in the separator and decreases the magnetic field acting on the particles. Under some conditions, this can lead to the equilibrium between the fluid drag and the magnetic force.

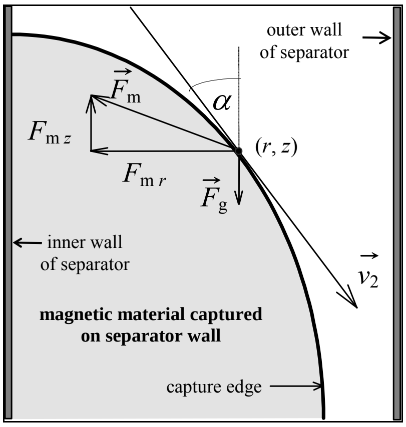

Figure 2: Forces and velocity directions on the capture edge

The equation 1, which describes the boundary conditions on the capture edge, is its mathematical model.

$$\begin{cases} f_{\mathrm{b}}(r,z) = f_{\mathrm{b\,m}}(r,z) - f_{\mathrm{b\,d}}(r,z) = 0 \\ f_{\mathrm{b\,d}}(r,z) = -\,6\pi \cdot R_{\mathrm{c}} \cdot \eta \cdot v_2 \\ f_{\mathrm{b\,m}}(r,z) = \sin\alpha \cdot F_{\mathrm{m}r} + \cos\alpha \cdot (F_{\mathrm{m}z} - F_{\mathrm{g}}) \\ \qquad - \tau\left(\cos\alpha \cdot F_{\mathrm{m}r} - \sin\alpha \cdot (F_{\mathrm{m}z} - F_{\mathrm{g}})\right) \end{cases} \tag{1}$$

where: $f_{\mathrm{b\,d}}$, $f_{\mathrm{b\,m}}$ – components of boundary equation depends on the flow and on the magnetic force, η– viscosity of the medium, v_2 – medium velocity, R_{c} – radius of the particle, τ – coefficient of friction, α– angle as shown in Figure 2, $F_{\mathrm{m}\,r}$, $F_{\mathrm{m}\,z}$ – radial and axial components of magnetic force, F_{g} – gravity.

NUMERICAL MODEL OF CAPTURE EDGE

Hybrid numerical model was used to solve coupled magnetistatic and hydrodynamic problem of capture edge computations Kozak (3). This numerical model consists of system of author's programmes (Figure 3) controlling magnetostatic parameters computations by PC-OPERA. These parameters, saved into **f.xxx** file, are used in main, magnetostatic and hydrodynamic computations by auhtor's (C++) programme **OP_GRAD4.EXE**.

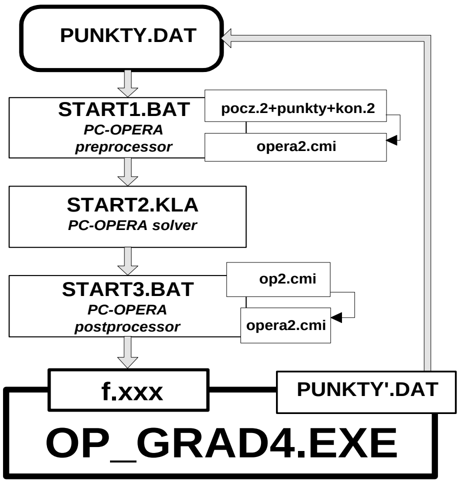

Figure 3: Algorithm of hybrid numerical model for capture edge computations

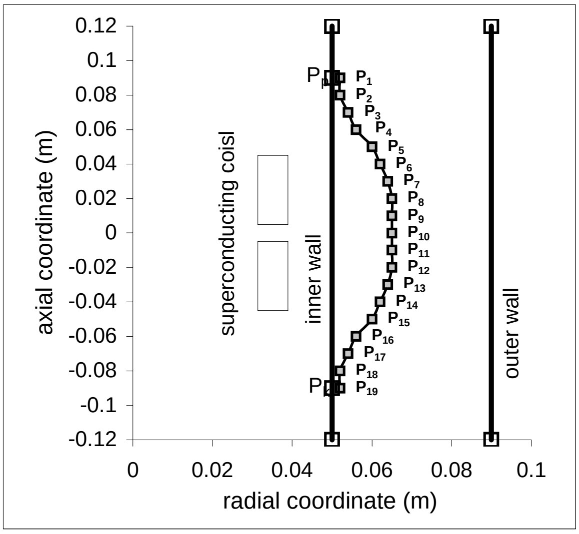

Figure 4: Geometry of capture edge

PUNKTY.DAT collects the coordinates of vertex points (from P_1 to P_{19}, Figure 4) of capture edge open polygon. **OP_GRAD4.EXE** calculates and analyses $f_{\mathrm{b\,m}}$ and $f_{\mathrm{b\,d}}$ components of the boundary equation 2 in every point from P_1 to P_{19}, changes the geometry (if necessary) of the capture edge and creates the temporary **PUNKTY'.DAT** file of coordinates. If appropriate coordinates of every point in the **PUNKTY.DAT** and **PUNKTY'.DAT** files are almost equal (with satisfied precision), then the computation is stopped.

$$\begin{cases} f_{\mathrm{b\,m}}(\mathrm{P}_1) = f_{\mathrm{b\,d}}(\mathrm{P}_1) \\ f_{\mathrm{b\,m}}(\mathrm{P}_2) = f_{\mathrm{b\,d}}(\mathrm{P}_2) \\ \dots\dots\dots\dots\dots\dots\dots\dots \\ f_{\mathrm{b\,m}}(\mathrm{P}_{19}) = f_{\mathrm{b\,d}}(\mathrm{P}_{19}) \end{cases} \tag{2}$$

Figure 5 shows the maximal thickness of captured material and blocking factor vs. current density of magnet. If the current density of magnet increases then the more magnetic material is captured in the separator. This effect was observed during experiments (1).

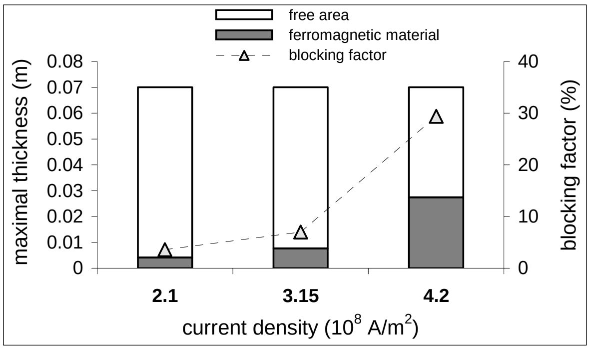

Figure 5: Maximal thickness of captured material and blocking factor vs. current density of magnet (3)

SUMMARY

Presented numerical model can be used to research for the influence of the parameters of superconducting magnet on the capture edge shape in OGMS separator. If capturing of magnetic material during OGMS separator operation is predicted as unavoidable, it will be possible to search for the separator and magnet geometry that minimise the influence of that undesirable effect on the separator efficiency and recovery under defined separation conditions.

REFERENCE

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3. Kozak,S. 2001, J.Technical Physics, 42, 53-83