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SEPARATION OF PETROLEUM RESIDUES USING THE VORTEX SEPARATION TECHNIQUE

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Refacerea solurilor afectate de scurgerile de petrol, recuperarea fracţiilor de petrol din depozitele de reziduuri, precum şi extracţia petrolului scurs în pânza de apă freatică din zona de mică adâncime sunt câteva dintre aspectele care stau în faţa specialiştilor din industria petrolului. Tehnica de separare cu vârtej permite o recuperare avansată reziduurilor petroliere în peliculă. Lucrarea prezintă posibilitatea utilizării unei instalaţii de separarea fazelor bazata pe tehnica centrifugării.

Restoring of soils affected by oil discharges, recovery oil of fractions from the deposits of residue and oil leaked into groundwater in the shallow area are some of the issues facing the oil industry specialists. Vortex separation technique allows a recovery of oil residues. This paper presents a method of oil separation, based on the vortex separation technique.

Keywords: phase separation, centrifugation, mathematical modeling, numerical simulation, slurry

1. Introduction

Water treatment in the oil industry began to use natural processes leading to phase separation. The newest methods allow recovery of petroleum constituent. The oil residues are recovered with an increased efficiency of extraction and processing, in this way the environment being protected.

The separation of film petroleum residues can be successfully accomplished by using the vortex separation technique, which allows an advanced recovery, with water percentage in the recovered phase being less than 4%. In this way, the recovered oil can be immediately introduced in the refinement process.

Today, the main problem of experts in the field, in the general context of efficient technologies, is to develop this process with low power consumption. This can be achieved by identifying ways to enhance and increase the recovery rate of the aqueous environment.

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The main objective of the present paper is to find a numerical solution for geometric dimensioning of an installation of waste oil recovery, which is based on vortex separation technique.

This paper studies the movement created by the forced vortex flow, with developed funnel and air suction, in a cylindrical tank with aperture – a bottom pipe located coaxial with the container. The study aims at determining the movement of free surface shape of the formed funnel, spectrum movement and velocities distribution.

2. Overview regarding vortex forming and developing

Applications of vortex movements (cyclone separation stages) are presented in theoretical and experimental researches in the scientific literature. In particular, vortex movements have found technical applications in water treatment or air, for the retention and disposal of dust and fats dispersed in the environment.

Fig. 1 shows the use of vortex for a separation process of oil residues from an aqueous environment. A rapid mixing equipment located on the float platform, creates a forced vortex that promotes separation of oil and water due to centrifugal forces action as an effect of phases density differences. Thus, the process is based on the extraction of large quantities of fat from water. Forced separation process, using vortex and the natural flotation, lead to high percentage of oil recovery from the effluent.

Researches have pursued the issue of forming and development of vortices, which can generate immiscible phase separation in polyphase systems. The necessity of vortex generation with a certain intensity, Γ, in specially designed tanks, appears in order to facilitate the oil separation from slurries.

Fig. 1. Detail of vortex forming

3. Numerical solutions for flows with forced vortex

One considers the case of a cylindrical container which has an aperture situated in the center of the installation, from which the oil can stream out the tank. The shape of the container, the central position of the aperture and the fluid height, have as a result the developing of a central vortex formed inside the tank. The movement is axially symmetric and thus it can be considered that the current lines are described by Laplace equation written as (1). Because the movement is in plane, for writing convenience Cartesian coordinates x, y, preferred instead of x, z. Therefore, Laplace's equation is written as:

$$\frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial y^2} - \frac{1}{x}\frac{\partial \psi}{\partial x} = 0 \tag{1}$$

with the coordinates *x* and *y*.

This equation can be numerically integrated using the program FlexPDE which enable the direct form of the current lines for constant values of current function, (ψ = constant).

The limit conditions are imposed as a Dirichlet form and they are given as values imposed on the area perimeter of the domain. Thus, on the axis of the container, on the free surface $\psi = 0$, will be imposed and from the bottom area to the aperture a constant value $\psi = \psi_0$ is given.

For the right vertical wall a linear variation is considered:

$$\psi = \frac{y}{H}\psi_0 . \tag{2}$$

Since this condition leads to the perturbation in the area situated far from the aperture, the form of the equation (2) was changed into

$$\psi = \psi_0 - \frac{y}{H}\psi_0 \tag{3}$$

In this way the current lines appeared normal and a correct distribution on the vertical axis of the tank was registered.

In the outlet area the effect of dense fluid flow through the aperture should be considered. This phenomenon is described by imposed condition written as:

$$\psi = \left(\frac{x}{x_0}\right)^2 \psi_0 . \tag{4}$$

In the following section are presented results of the processing the partial differential equation - Laplace equation - numerically solved under the limits described above.

4. Results

Equation (1) was introduced in FlexPDE program which conducted to a series of numerical simulations. Some of these are presented below. It was initially considered a cylindrical tank with 40 m diameter, 5 m height and aperture diameter of 2 m. The numerical simulations were realized for only a half of the vessel, because the flow is symmetrical inside the basin.

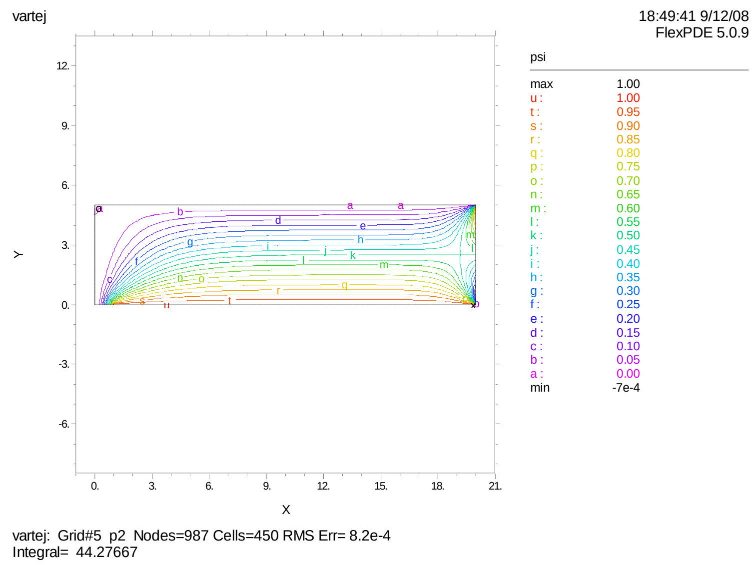

Fig. 2. Current lines fo r ψ = constant.

In Fig. 2 the concentration of current lines of evacuation hole can be observed. For the following numerical simulations some parameters were changed. For example, in Fig. 3, the high of the tank was increased up to 10 m. The values for other parameters were not changed.

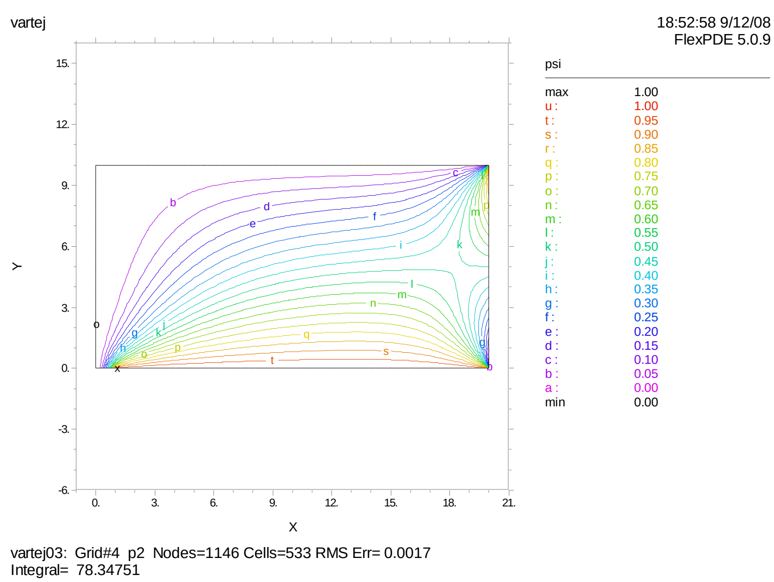

Fig. 3. Current lines for a deeper tank

In both of the two cases the formed vortex can be easily observed. The funnel formed by the vortex is larger for the second case, where the height was increased. In Fig. 4, the aperture diameter was modified, from 2 m to 0.4 m. The current lines are presented below.

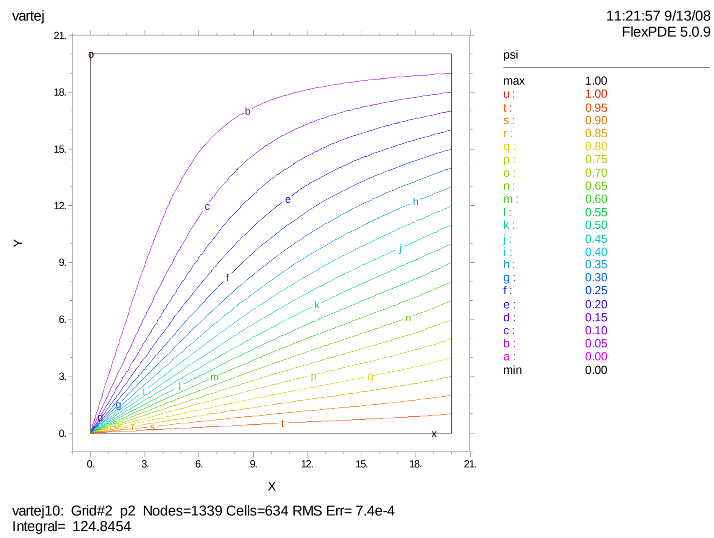

Fig. 4. Current lines for a aperture of 0.4 m diameter

In order to validate the numerical models an experimental setup for phase separation was realized. This equipment was tested and several measurements were realized. In figure 5 is represented the vortex formed inside the experimental installation. The shape of the funnel is marked with red color. A comparison between the theoretical and experimental results is presented in Figs. 5 and 6.

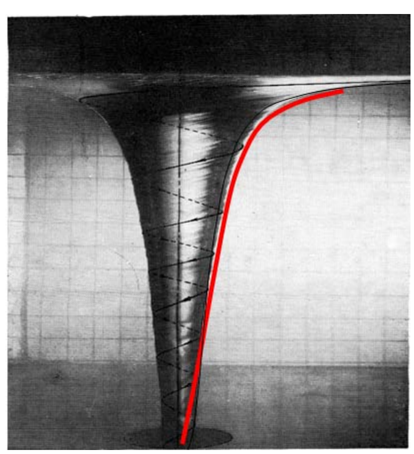

Fig. 5. The funnel shape for the experimental installation

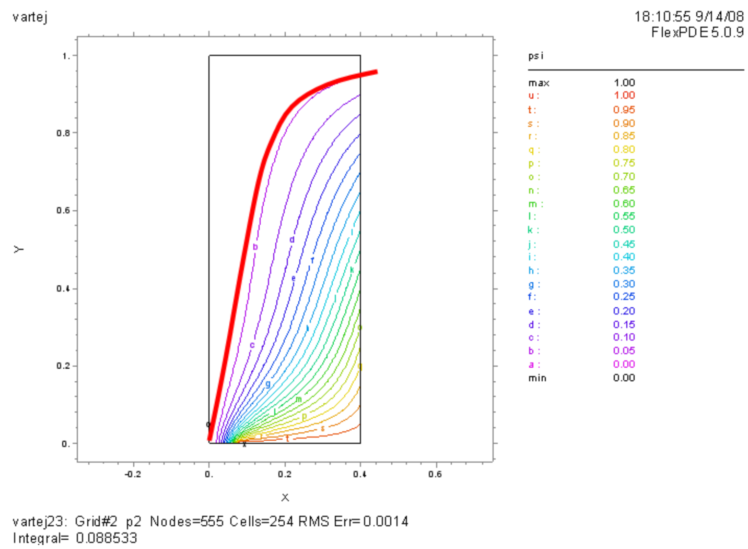

Fig. 6. The funnel shape for the theoretical researches

Comparing the two figures, it can be observed that the mathematical model applied in FlexPDE program is correct and the simulations can be validated.

The model below was a numerical integration of Laplace equation for the vortex case tested in the laboratory. The shape of the forced vortex induced in installation was photographed. The vortex was created due to the way which water was introduced inside the tank. The numerical simulations continued with the determination of velocities values inside the tank The two following figures present the form of lines for constant velocities.

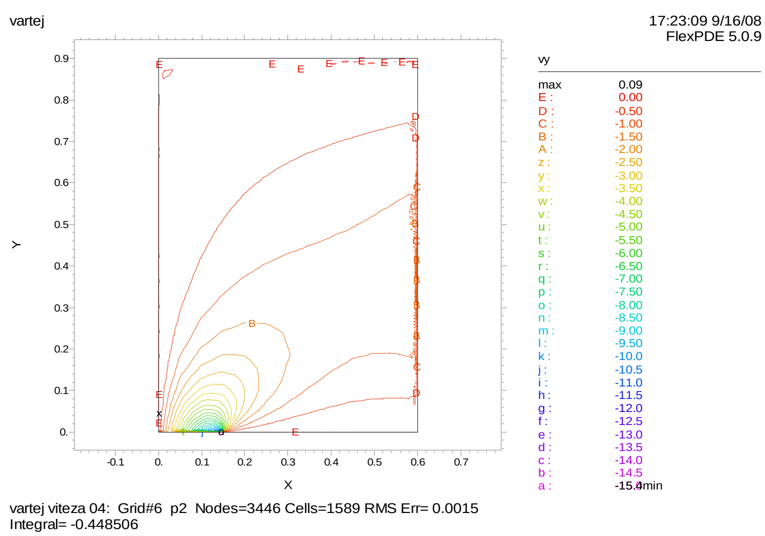

Fig. 7. Distribution of velocity v_y

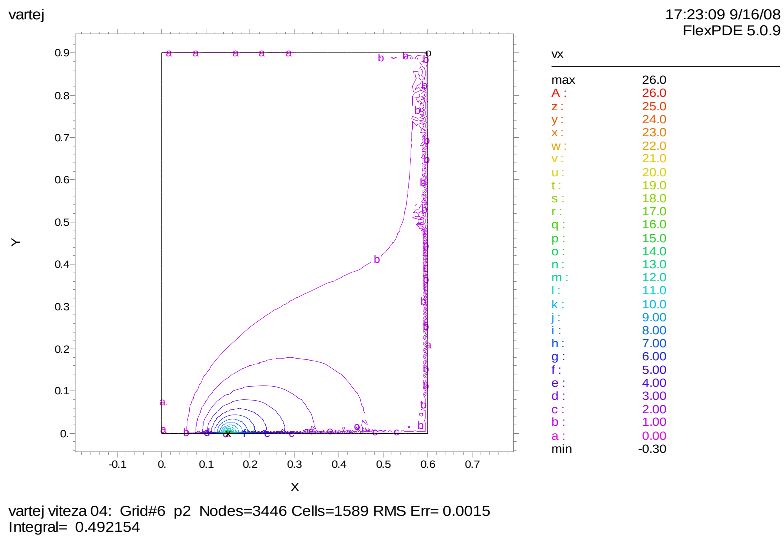

Fig. 8. Distribution of velocity v_x

5. Conclusins

Study of flow with vortex is a very complicated problem because the motion is 3D and it is dependent on many factors as the shape and size of tank and physical properties of the fluid. Following the technical literature several papers and work addressed to this topic can be identified but they are not able to give a general valid solution for all types of vortex movements. Therefore any theoretical development that leads to solving a concrete problem is important and significant.

In this paper the practical problem of a forced vortex motion was solved and shape and dimension of the created funnel was determined. In this way, the correct area to place a pump in order to capture the oil evacuated from installation can be indicated. It was demonstrated that is possible (to separate) of water-oil phase by generating a vortex movement. From the aperture situated at the bottom part of the installation, oil can be eliminated.

The model developed allows the determination of shape for the fluid free surface that is discharged through the aperture. Numerical simulations show that the shape of the curves for current lines is identical to the one obtained experimentally.

Simulations of fluid flow phenomena, with vortex movement, through the bottom aperture were made of different diameters for both container and central pipe. The model developed is original and may therefore be used for any separation tank and orifice sizes.

REFERENCES

[1]. *R. R.Bharvani,* Hydrocarbon Precessing, 2002

[2]. *A. A. Cristu,* Investment – Efficiency – Environmental Protection In Romanian Oil Industry, The 15th International Symposium Alternative Economic Strategies, November 25, 2003

[3]. *R,B. Miller, A. Macris, A,R. Gentry*, Petoleum Technology Quarterly, 2001

[4]. *Diana Robescu, D. Robescu, Raluca Mocanu, Ioana Corina Moga*, Modeling of attached growth biological wastewater treatment processes, Scientific Bulletin, U. P. B.,Sci. Bull., Series C Electrical Engineering, vol. 64, number 4, ISSN 1454-234x, pag. 593 - 598, 2007

[5]. *M. Dinu,* Teoria rotației sistemelor fluide, (Theory of rotation of fluid systems) Editura ştiinţifică şi enciclopedică, Bucureşti 1983 (in Romanian)

[6]. *S.I. Green,* Fluid Vortices*.* Fluid mechanics and its applications, Kluwer Academic Publishers, London, 1995

[7]. *Anca Gabriela Ilie*, Consideratii generale privind piata mondiala a petrolului (General considerations regarding oil market), Murzacova, Angela Editura A.S.E., Bucuresti, 2003 (in Romanian)

[8]. *Sanda Visan, A. Angelescu, Cristina Alpopi*, Mediul inconjurator. Poluare si protectie, (Environment. Pollution and protection), Editura Economica, Bucuresti, 2000 (in Romanian)

[9]. *M. T. Clift,* Reduce storage tank emissions, Hydrocarbon Processing*,* no. 5, 1997