FLOW MODELING AND SIMULATION OF A SAND AND FAT TANK FROM A WASTEWATER TREATMENT STATION

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This paper studies the optimization of the process of separation of sand and fat from a wastewater tank. The optimal shape of the tank is obtained through modeling and simulation of the polyphasic fluid flow in reservoir. In fact, the tank has two compartments: a sand separator tank and a fat separation tank. The flow is studied within 48 hours, integrating the Navier-Stokes equations with ANSYS FLUENT 13.0 software with k-ε model and the finite volume method. The simulation results were compared with the actual ones obtained by experimental investigations from the mechanical stage of a wastewater treatment plant. Deviations less than 15 % are obtained, demonstrates validating the simulation model proposed by the authors.

Keywords: modeling, simulation, experimental validation, sand and grease tank

1. Introduction

The main objective of a wastewater treatment plant is the removal of suspended substances, colloid and in solution, toxic substances, micro-organisms, in order to protect the environment [1]. The changes that have taken place in recent years concerning the realization of technological processes related to the increasing complexity of tougher safety requirements and to improve performance as required, as well as reducing energy consumption have significant implications in the field of optimization of the operational processes and installations associated with them [2]. Existence is useful in technological scheme of a correctly sized equalization basin flows and smoothing of concentrations that allow a cleaning station with influential parameters always-constant [2], [3], [4].

The current state of research in this area confirms that the optimal shape of the sand and fat sedimentation tank can help by accelerating sedimentation and reducing consumables in the next stage of treatment [3].

The objectives of this article are: determination of the optimum geometry of the tank; the meshing of the flow domains; setting boundary conditions; solving

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equations of the flow model; also the analogy between theoretical results and experimental ones.

2. Proposal for research

This paper proposes a model for simulation the flow in a sand separation tank (big tank 2) and fat separation tank (small tank 1) of the mechanical stage of wastewater treatment. In the mechanical stage, the influent, which is a mixture of water, sand and fat enter by the rare gratings, then by fine gratings and then, in the sand and fat separation tanks.

The particles movement is characterized by different particles sedimentation rate. The sedimentation velocity is decomposed into two components, one horizontal and one output, depending on the direction of solids nature sedimentation.

The shape of the sand-fat separation tank is very important in this study of sedimentary particles flow process. This article aims to realize modelling and flow simulation in the sand and fat separation tanks using ANSYS FLUENT 13.0 software, in two steps: 1) for geometry, there were chosen two tanks, a small and a big one; 2) there was studied the flow in the small tank by choosing a flow model; 3) it continued the study with the big tank and repeated the modelling and simulation of the flow.

There was represented the graphical spectrum of the sedimentation of solids from wastewater by different plans and angles of analysis, which helped to choose the optimal shape of studied tanks as the best solution.

For the geometry of the sand separation tank and fat separation tank (Fig.1) there are the following dimensions: width of small tank- H_1 = 1.75 [m]; width of big tank, H_6 = 3.5 [m]; depth of tank, V_5 = 4.38 [m]; length of tanks, L = 35 [m].

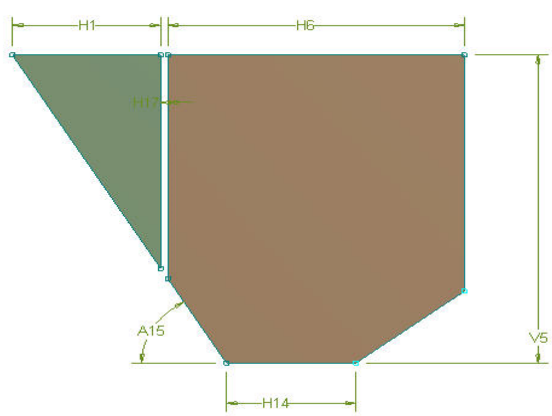

Fig. 1. The geometry of tank 1 and 2 - side view

After this, there was made the meshing of the domains. Uneven cell network made up of tetrahedrons, prisms and parallelepipeds. The small tank 1 has: 60,391 cells (1,406 prisms/wedges with 58,885 hexahedrons) with 70,096 nodes (Fig. 2).

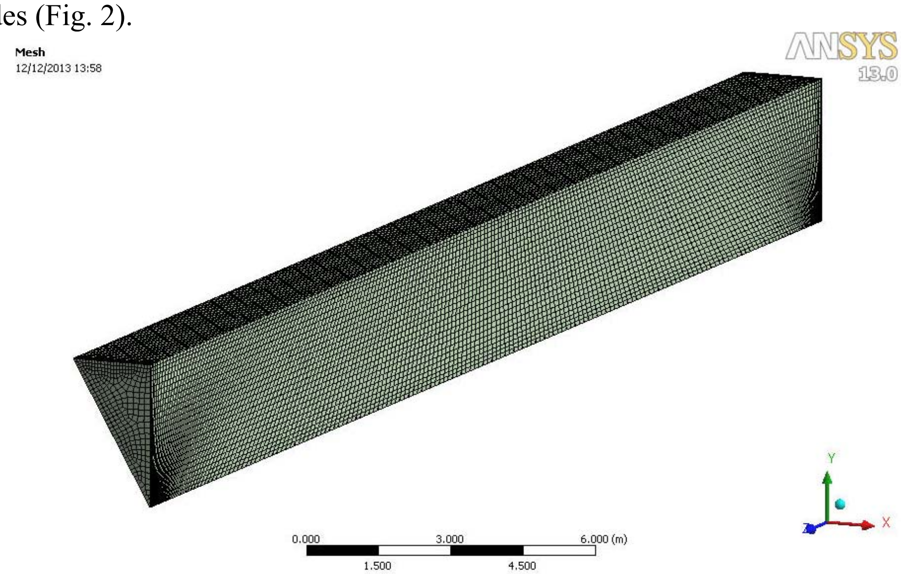

Fig. 2. The discretization of small tank 1.

The big tank 2 has: 140,800 cells (3,228 prisms with 137,572 hexahedrons) with 145,423 nodes (Fig. 3).

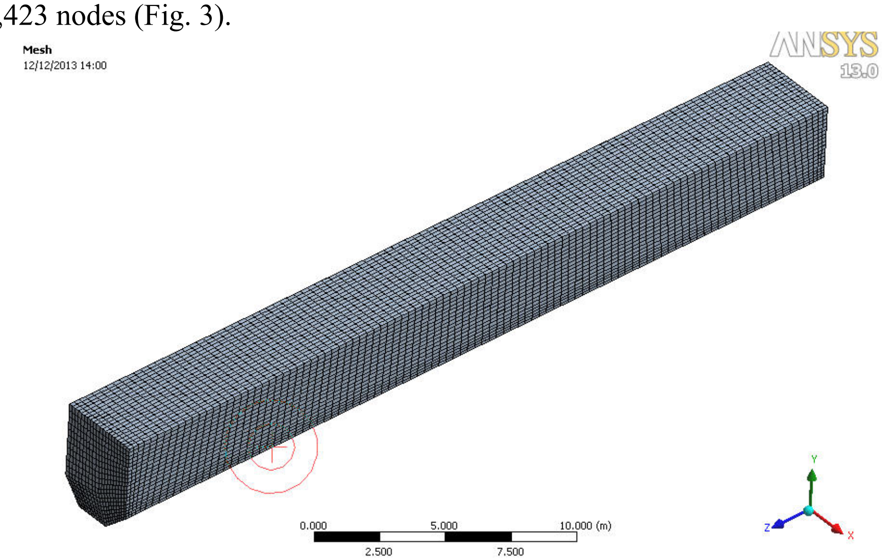

Fig. 3. The discretization of big tank 2

The boundary conditions were considered. The mixture is composed of 60% water with a density of 1000 kg/m^3, 25 % sand with a density of 1300 kg/m^3 and 15% fat with a density of 850 kg/m^3. Boundary conditions are as follows: mixture enters with a mass flow of 2.4 m^3/s which will impose a velocity around 0.2 m/s. The flow will separate itself in three zones due to gravity and density differences. The separated flow exits at atmospheric pressure.

The following equations were used: the flow equations (Navier-Stokes equations), turbulent model k-epsilon equations and volume fraction method.

The equations of Navier-Stokes were also used for flowing liquids.

For turbulent model k-epsilon: the equation for turbulent kinetic energy k (1) was used and, dissipation epsilon, also. (2):

$$\frac{\partial}{\partial t}(\rho_m k)+\nabla\cdot\left(\rho_m \bar{v}_m k\right)= \nabla\cdot\left(\frac{\mu_{t,m}}{\sigma_k}\nabla k\right)+G_{k,m}-\rho_m\varepsilon\,, \tag{1}$$

$$\frac{\partial}{\partial t}(\rho_m \varepsilon)+\nabla\cdot\left(\rho_m \bar{v}_m \varepsilon\right)= \nabla\cdot\left(\frac{\mu_{t,m}}{\sigma_\varepsilon}\nabla \varepsilon\right)+\frac{\varepsilon}{k}\left(C_{1\varepsilon}G_{k,m}-C_{2\varepsilon}\rho\varepsilon\right), \tag{2}$$

where:

$$\rho_m=\sum_{i=1}^{N}\alpha_i\rho_i\,, \tag{3}$$

$$\bar{v}_m=\frac{\sum_{i=1}^{N}\alpha_i\rho_i\bar{v}_i}{\sum_{i=1}^{N}\alpha_i\rho_i}\,, \tag{4}$$

$$\mu_{t,m}=\rho_m C_\mu\frac{k^2}{\varepsilon}\,, \tag{5}$$

$$G_{k,m}=\mu_{t,m}\left(\nabla\bar{v}_m+\left(\nabla\bar{v}_m\right)^T\right):\nabla\bar{v}_m\,. \tag{6}$$

Also, to calculate the three-phase transportation (water, sand and fat) it was used the volume fraction method. The volume fraction method relies on the fact that two or more fluids have a density ration closer to 1. For each additional phase added to the model, a variable was introduced: the volume fraction of the phase in the computational cell. In each control volume, the volume fraction of all phases sum to unity. Thus, the variables and properties in any given cell are either purely representative of one of the phases, or representative of a mixture of the phases, depending upon the volume fraction values,

$$\frac{1}{\rho_q}\left[\frac{\partial}{\partial t}\left(\alpha_q\rho_q\right)+\nabla\cdot\left(\alpha_q\rho_q\right)=S_{\alpha_q}+\sum_{p=1}^{n}\left(\dot{m}_{qp}-\dot{m}_{pq}\right)\right], \tag{7}$$

where: $\dot{m}_{qp}$ is the mass transfer from phase q to phase p, and $\dot{m}_{pq}$ is the mass transfer from phase p to phase q; α_q is the volume fraction of the phase q and S_{α_q} is a specific constant.

3. Results and interpretations

After running over 10,000 iterations, the solution still not convergences. After the scenarios, the calculation model and approach were changed, it was found that the results are good. But this time the solution depends on the elapsed time; the solution was only physically reaching 1/3 of the length of the small tank.

To observe what is going on, the program was allowed to run for 48 hours. After 48 hours, there were observed the following: input tank velocity is 0.25 m/s, and the maximum attainable is 0.6 m/s. There were studied the density variation in different planes, from different angles (Fig. 4) and one can observe the movement of sand particles, namely, the delimitation of sedimentation lines of sand particles, which are pushed from entry to exit.

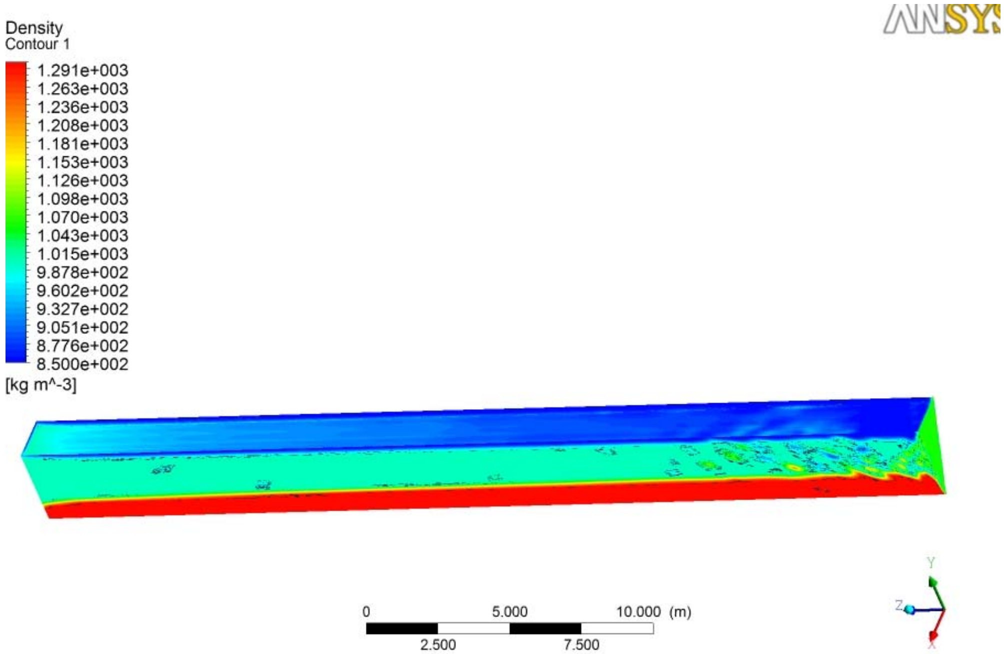

Fig. 4. Density variation in 3D

The variation of velocity and static pressure were also studied (Fig. 5, Fig. 6):

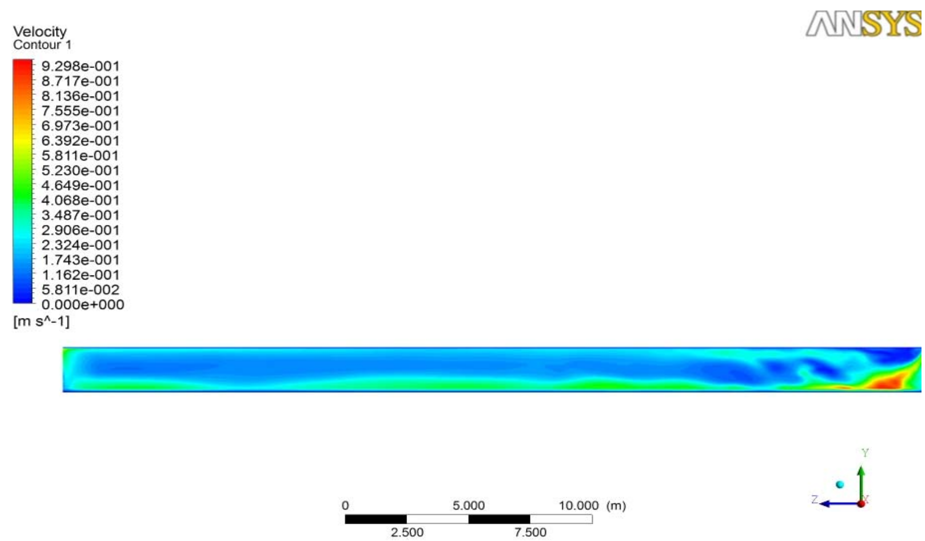

Fig. 5. Velocity variation.

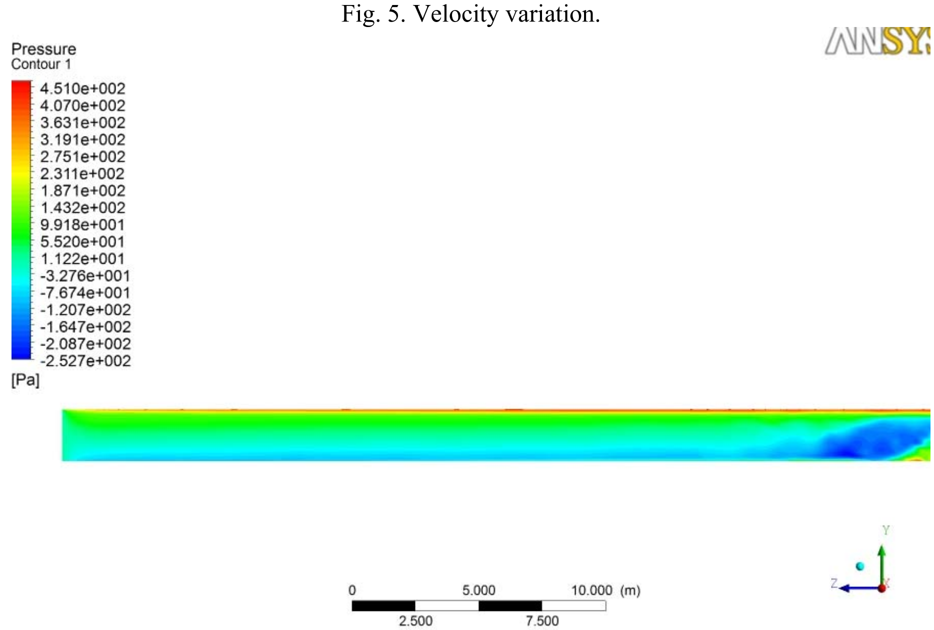

Fig. 6. The static pressure variation.

The study continued with the same steps for the big tank and the results were obtained for: density variation, velocity variation and static pressure variation (Fig. 7, Fig. 8, Fig. 9) [5]:

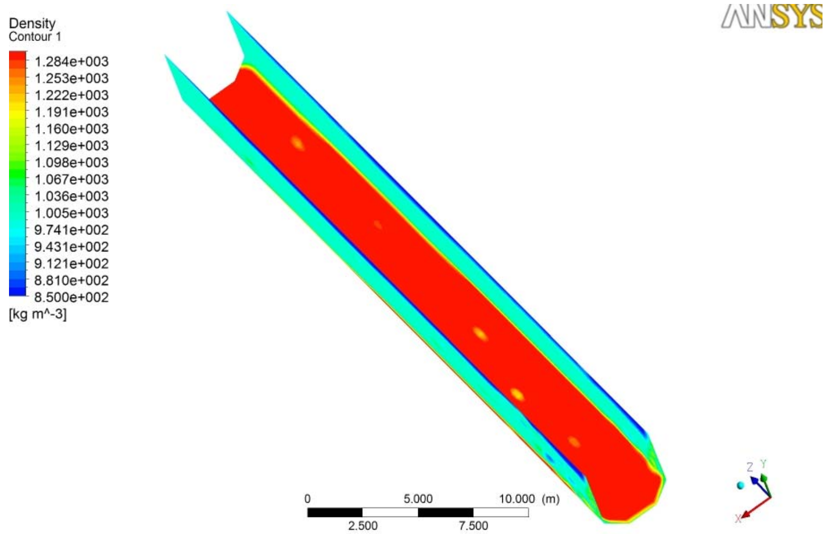

Fig. 7. The big tank density variation - top view.

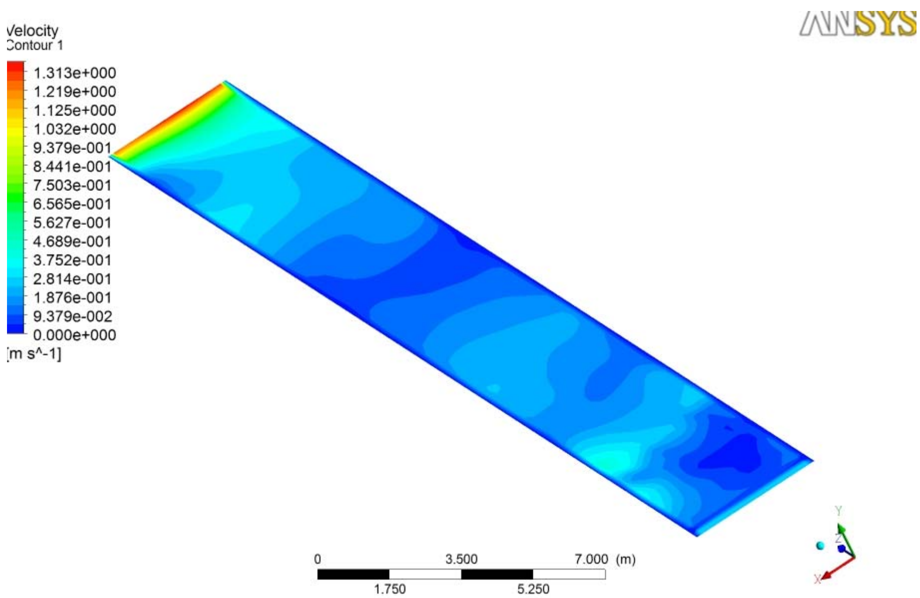

Fig. 8. The big tank velocity variation - top view on the water mirror.

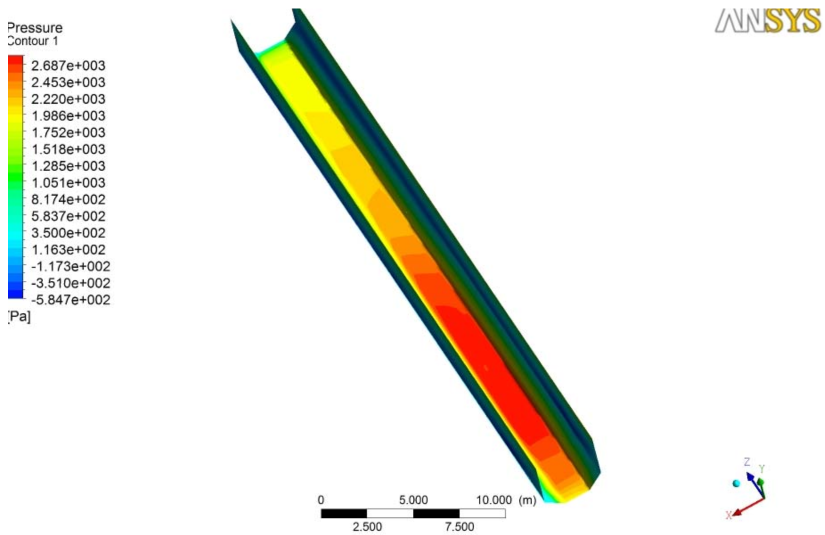

Fig. 9. The big tank pressure variation - top view.

These results are used in the comparative study.

4. Comparative study between theoretical and experimental results

In the scientific literature concerning sand separation tank [4], there are represented the following quantities: density - 1.2 - 1.6 kg/l; horizontal velocity - 0.2 m/s; recirculation velocity - 0.3 m/s. The following experimental data were obtained for these parameters (Fig. 10, Fig. 11, Fig. 12) therefore in the end it was concluded with the comparative study (Table 1):

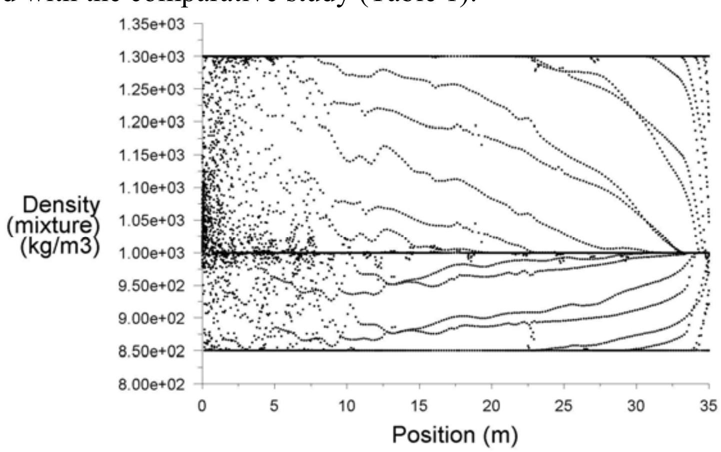

Fig. 10. The density variation for mixture.

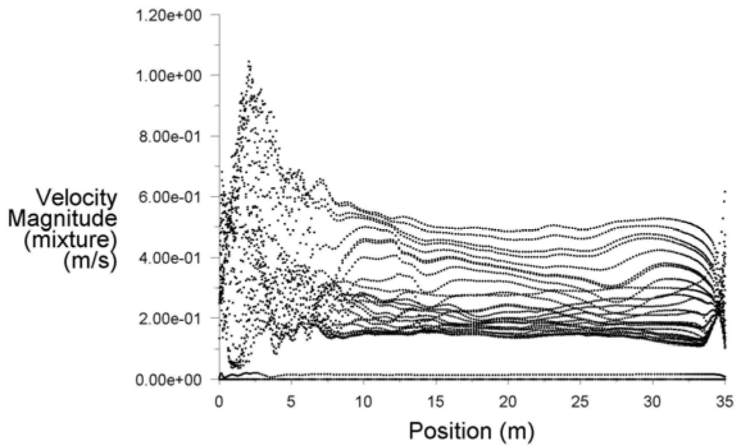

Fig. 11. The velocity variation for mixture.

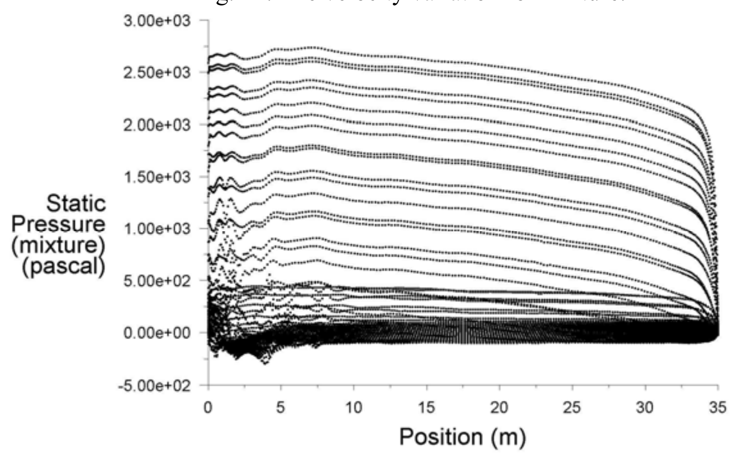

Fig. 12. The pressure variation

Table 1

Experimental and theoretical results

Experimental values	Theoretical values	Deviation[%]
Density, kg/m^3 800...1350 **Velocity**, m/s 0....1.2 **Pressure**, Pa 500....3000	**Density**, kg/m^3 881...1208 **Velocity**, m/s $15.17.10^{-2}$.....$8.34.10^{-1}$ 25.272...451.3	8.94...11.01 0........6.95 5.054....15.033

6. Conclusions

The flow modelling and simulation in adequate boundaries conditions for horizontal sand sedimentation tank gave the curves for solid particles at different values of the concentration of solid - fluid mixture [6]. In this way it is possible to establish the optimum dimensions [7] of the sand sedimentation tank.

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