Investigation of the pressure drop on the filtration and protective baffles of a hydrodynamic vibration filter using ANSYS CFX

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Abstract. This paper considers the relationship of the pressure drop at the filtration baffle of a hydrodynamic vibration filter with and without protective baffle for different operation parameters like baffle flowrate and filtration baffle rotation speed. The simulations were done using ANSYS CFX and nonlinear Darcy’s law.

In different areas of the industry, removal of mechanical impurities from fluids. Filters utilizing vibration, hydrodynamic and centrifugal forces with conventional filtration methods using a porous filtration baffle for removing impurities reduce the loads on the baffle and extend the filter life service time in general [1]. A filter with this construction can also be used as an alternative means of separating fluids with different densities [2–4], especially for small filter flowrate. This paper conducts computer simulation of a filter utilizing hydrodynamic and centrifugal forces for purifying liquids, i.e., a hydrodynamic vibration filter (HVF) [5].

The aim of the simulation is to obtain the relationship of the baffle pressure drop vs. the following factors rotation speed of the porous filtration baffle, baffle flowrate for two different filter layouts. Modeling was done using ANSYS CFX. The model did not take into account the increase of the baffle resistance due to the precipitation of impurities. In the model, the working body was water.

For simulations, a simplified geometrical model of the HVF was used. Figure 1, 2 show a geometrical and mesh model of the considered filter of two constructions [6].
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For simulation, a free tetrahedral mesh was built [7]. The maximum cell size was 3.5 mm. In the models of a filter without and with a protective baffle, there were 154337 and 279944 tetrahedral cells, accordingly.

In a filter, a liquid goes through a bottom tube (1), then passes through a filtration baffle (2), and then the purified water leaves through the outlet tube (3), while some of the fluid is bypassed via the upper tube (4). The working principle of a filter with a protective baffle is the same, but there is a perforated protective baffle with a diameter greater than the filtration baffle.

The total HVF flow rate was constant in the simulation studies. In the studies, the bypass fluid volume ratio and filtration baffle rotation speed were varied. The total HVF flow rate was 0.54 m$^3$/h, the bypass ratio was varied from 5 to 26%, and the filtration baffle rotation speed was varied from 0 to 2000 rpm with a step of 100 rpm. In total, 210 simulations were conducted. The coefficient of hydraulic resistance varied as a function of the flowrate over the baffle. For simulating a filtration baffle, nonlinear filtration Darcy’s law was used. For theoretical studies of this filter, one can use vortex theories [8] and theories of mass transfer [9, 10].

The mathematical model of the filtration baffle was described in depth in [11, 12]. In the model, the main parameters of the filtration baffle were as follows: pore diameter – 150 μm, porosity – 0.6, baffle area – 0.024 m$^2$ (construction without a protective baffle), 0.018 (construction with a protective baffle).
The parameters of the protective baffle were as follows: pore diameter – 500 \( \mu \)m, porosity – 0.36, baffle area – 0.024 m\(^2\).

Based on this data, the average fluid flow in the media was calculated:

\[ v = \frac{Q_{fp}}{S_{fp} \varepsilon} \]  

(1)

where \( Q_{fp} \) is the filtration baffle flowrate, m\(^3\)/s; \( S_{fp} \) is the baffle area, m\(^2\); \( \varepsilon \) is porosity.

Having calculated the average fluid velocity, one should calculate the Reynolds number Re given by:

\[ Re = \frac{\rho v D}{\mu} \]  

(2)

where \( D \) is the characteristic channel diameter, m; \( \rho \) is the fluid density, kg/m\(^3\); \( \mu \) is the dynamic viscosity of the fluid, Pas. For simulating baffle, the simulation program introduces porosity and the coefficient \( \alpha \) (kg/m\(^4\)) given by:

\[ \alpha = \frac{64 P Re^{-1}}{2 \varepsilon^3 A} \]  

(3)

where \( P \) is the perimeter of the wetted area, m; \( A \) is the cross-section of the channel of the porous media, m\(^2\). The calculated value of the coefficient is put in a corresponding form of simulation software. As seen from the formulas, the coefficient of resistance \( \alpha \) varies with the change of the baffle flowrate. For calculating the coefficient, MathCad 15 was used.

For calculating the static pressure drop, at the end of the simulation, the values of the static pressure before the filtration baffle and after it averaged for the whole baffle length were output. Simulation results are shown in figure 3-4.

![Pressure drop vs. filtration baffle rotation speed for different flow rates](image)

**Figure 3.** Simulation results for a filter without a protective baffle.
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From the simulation results, one can conclude that the pressure drop is a power function of the baffle rotation speed. The filter with a protective baffle enjoys a pressure drop up to 3-4 times greater than that of a filter without a protective baffle. Whether it is justified to use such a construction is to be determined by its efficiency of removing impurities compared to the filter without a protective baffle.

As seen from figure 5, the pressure drop is a linear function of flowrate, and it is weakly dependent upon the bypass parameter because the ultimate contribution to the pressure drop is made by the baffle rotation speed, and the bypass ratio is to be selected based on other criteria (efficient, the amount of concentrate).

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