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PRELIMINARY ASSESSMENT OF THE PERFORMANCE OF NOVEL DESIGN OF THE SPACER FOR THE MEMBRANE MODULE

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Abstract
In the current work, the results of the assessment of the effectiveness of the novel design of the spacer for the spiral wound membrane module using computational fluid dynamics methods were represented. The feature of the new design of the spacer is the shape of the filament, which has a triangle shape of cross-section. The results of the simulation have demonstrated that this shape of filament allowed for decrease the number of the stagnant zones in comparison with the conventional spacer design (filament with round cross-section). Also, in the considered range of conditions, a decrease of the pressure drop by 12-18% is observed in the channels with the novel design of spacer.

Key words: *membrane, module, spacer, simulation, computational fluid dynamics, pressure drop.*

Introduction

The pressure driven membrane processes are widely used in the purification of industrial wastewaters [1]. The suitable design of the membrane module is an important factor for the effective membrane performance. In particular, in the spiral wound membrane modules, which are the most widely used design, the spacer is the key element [2]. For the increase of the effectivity of the performance of such modules, a significant number of novel spacer designs were proposed [3-5]. The simulations using the computational fluid dynamics methods demonstrated the high effectiveness of such design, however, there are some doubts about the possibility of manufacturing some complex designs, in particular, the ones proposed in work [5]. Therefore, of novel designs of spacers, which would be able to increase the effectiveness of the membrane module and would be suitable for the manufacturing in large scale, is still relevant. The working hypothesis is that the spacer with a triangle cross-section of the filament allows a decrease in the number of stagnant zones, which in turn allow to decrease the risk of fouling.

Purpose of work

The purpose of the work is to test the effectiveness of the spacer with the triangle-shaped filament, in particular in comparison with the conventional spacer design.

Research methodology

The research is carried out using computational fluid dynamics methods, and the simulations were realized on the program package OpenFOAM-v2212, which was applied in the previous investigation [6]. The geometry of the system under investigation was created in the program FreeCAD 1.0.0, and the visualizations of the results were realized with the aid of the program package ParaView 5.10.1.

Results and discussion

The set of simulations of the flow in the channels with the novel spacer design and the conventional spacer design with round filament was carried out for testing the effectiveness of the first one. The simulations were realized under the conditions of a constant volumetric flow rate on the inlet surface, the conditions of the static pressure on the outlet surface, the wall (non-slip) conditions on the side surface, and the spacer filaments. The simulations were carried out in the range of the volumetric flow rate 0.2-1.0 l/h, which corresponds to the experimental data obtained in work [7-8] (with recalculation relative to the cross-section area).

The visualization of the flow in the channels with the spacers is represented in Figure 1. From this figure is clearly seen that the regions with the low velocity (which is denoted by the blue color) in the channel with the triangle spacer are significantly lower, at least in zones before filaments. These results prove the working hypothesis.

Figure 2 demonstrates the dependence of the pressure drop expressed in the form of the kinematic pressure (pressure to the density ratio) from the volumetric flow rate for both channels under investigation.

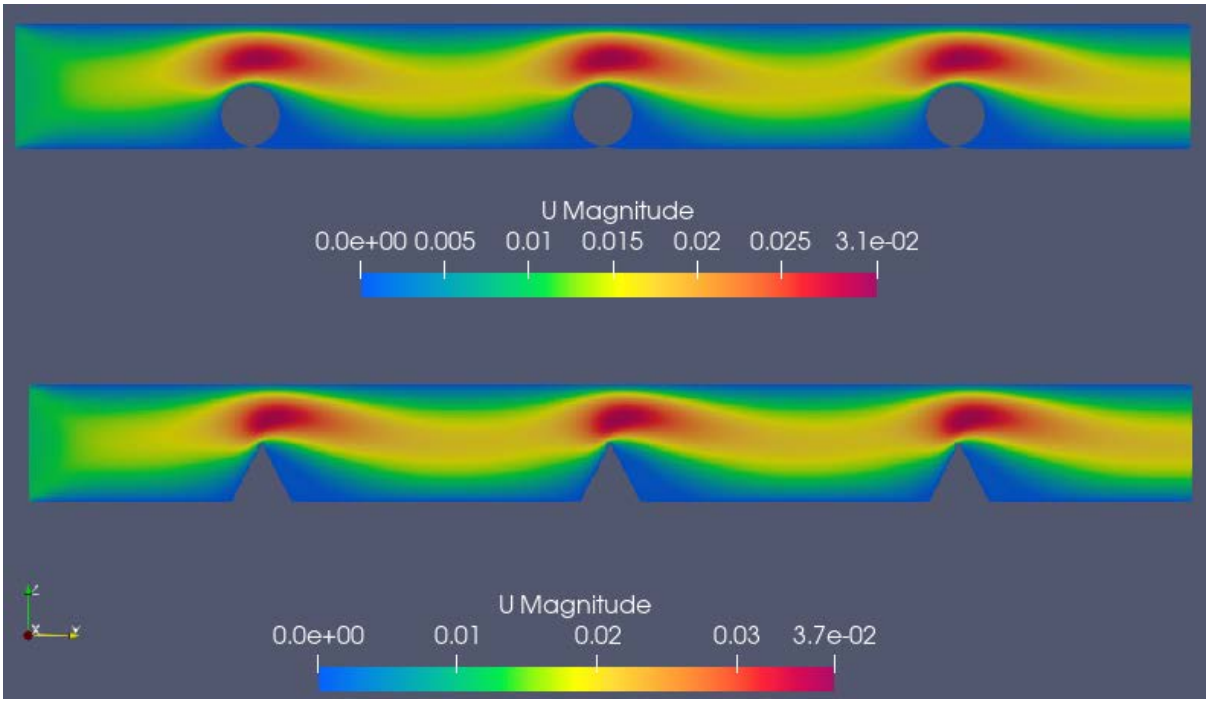

Fig. 1. *The visualizations of the in the channel with the spacers of the round and triangle shape*

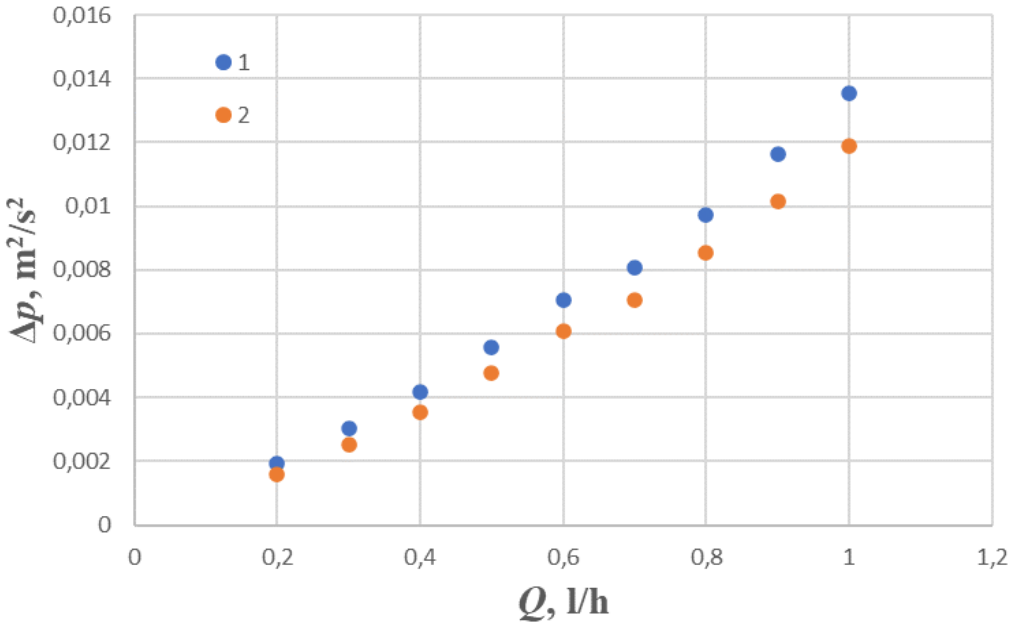

Fig. 2. *The relationship of the pressure drop (kinematic pressure) from the volumetric flow rate for the channels with the spacer round (1) and triangle (2) shapes*

The obtained results show that the pressure drop in the channels increases with volumetric flow rate, with a slight deviation from linearity. The approximation of data showed that for both shapes of the spacer, the pressure drop is proportional to the flow rate raised to the power 1.2, which indicates the presence of a slight level of turbulence. At the same time, the pressure drop in the channels with the spacer with the triangle filaments is lower in comparison with the conventional design by 12-18%/ Taking into account conclusions made in work [6], this decrease of the pressure drop can be considered as significant. The visualization of the flow (Figure 1) allows to make conclusion that new design of spacer decrease the length of the narrow sites in the channel, thereby the length of the sites with the maximal velocity is decreased (in the Figure 1 this is appears in a form of decreasing length of the red colored sites).

Conclusions

The obtained results of the simulations showed that the proposed design of the spacer allows for increasing the effectiveness of the membrane module performance via decreasing the number of stagnant zones, and also allows for decreasing the pressure drop in the membrane module channel.

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ПОПЕРЕДНЯ ОЦІНКА НОВОЇ КОНСТРУКЦІЇ СПЕЙСЕРА МЕМБРАННОГО МОДУЛЯ

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Анотація

В роботі представлені оцінки ефективності нової конструкції спейсера для спіральних мембранних модулів зв використанням моделювання методами обчислювальної гідродинаміки. Особливістю нової конструкції є форма ниток, які в поперечному перерізі мають трикутну форму. Результати моделювання показують, що така форма конструкції дозволяє знизити кількість застійних зон в області перед ниткою спесера, порівняно з традиційною конструкцією спейсера (нитки з круглим поперечним перерізом). Також, в розглядуваному діапазоні умов моделювання спостерігається зменшення гідравлічного опору в каналі з новою конструкцією спейсера на 12-18%.

Ключові слова: мембрана, модуль, спейсер, моделювання, обчислювальна гідродинаміка, гідравлічний опір.