Next generation membranes by additive manufacturing

Energy consumption, the next challenge to improve CTFF efficiency

The first challenge in the history of Ceramic Tangential Flow Filtration (CTFF) was to increase the filtration area per filter element without changing the hydraulic diameter of the membranes. This challenge was overcome by TAMI Industries in the '90s, by the development of non-circular channel membranes that became even more efficient in the last decade.

Today, energy efficiency is one of the most important factors for environmental protection and TAMI Industries has accepted the new challenge: to reduce the energy consumption of CTFF by creating the next generation of ceramic membranes.

The theory behind CTFF and energy consumption

In CTFF, the feed solution is recirculated continuously inside the channels of ceramic membranes. This allows the feed solution to keep the surface of the membranes free of solid materials for longer than in frontal flow filtration (FFF), which results in less frequent membrane cleanings and the possibility of filtering solutions with higher solid concentrations.

This "auto-cleaning" effect in CTFF can be explained by the fact that when a feed solution travels inside the channel and parallel to the surface of the membrane, it exerts a force on this surface, also known as the Wall Shear Stress (WSS). In summary, the stronger this force, more powerful will be the "sweeping" effect of the feed solution in reducing the concentration polarization and the fouling on the surface of the membrane.

However, the great advantages of CTFF come at a cost: energy is required to maintain the feed solution at constant movement. In fluid mechanics, one of the simplest ways to increase WSS is to generate turbulence by making the liquid travel faster. This means demanding more from the pump and consequently consuming more energy. If the opposite is done, energy consumption is reduced but it causes an adverse effect on the performance of the membrane such as decreased flux and faster membrane fouling.

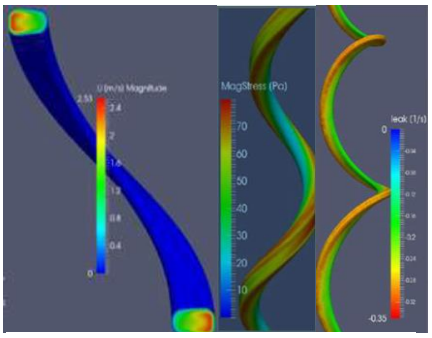
Therefore, the question to be answered to reduce energy consumption without affecting performance is: "*How to increase WSS without consuming more energy?*"

And this was the question that pushed the R&D team of TAMI Industries to once again combine its extensive knowledge in fluid mechanics, ceramic material handling and CTFF to come up with a world-class innovative solution.

How to increase wall shear stress without increasing energy consumption?

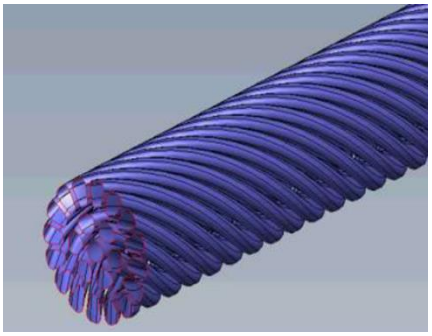
The solution and a new problem: helical channels

After discarding the option of increasing velocity to increase WSS (which would also increase energy consumption) and the option of adding fluid promoters (which would increase fouling), TAMI Industries focused on Computational Fluid Dynamics (CFD) to start from zero and investigate all possible options.



Computational Fluid Dynamics.

This work resulted in the understanding that changing the shape of the membrane channels would provide the highest WSS. Among different shapes tested, it was observed that the helix (spiral) was the best one in terms of elevated and even WSS across the membrane.



23-channel membrane with helical channels.

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The problem? Extrusion, the traditional manufacturing technology of ceramic membranes, cannot produce channels with helical shapes. No relevant cases were found in the industry or the literature to guide the production of such ceramic membranes at industrial scale.

Additive manufacturing, the solution with a steep learning curve

After researching different manufacturing technologies, TAMI Industries' R&D team selected additive manufacturing as the best manufacturing technology to produce the new generation of ceramic membranes with helical channels. The novelty of this solution in ceramic membrane manufacturing presented the need of developing both the hardware and the software necessary to produce them. This fact obliged TAMI Industries to invest additional years in learning the theory related to additive manufacturing and mastering its use in ceramic membranes.

Promising results

In June 2018, TAMI Industries presented the initial progresses made in the development of the new generation of ceramic membranes at ICIM (International Conference on Inorganic Membranes, Dresden – Germany). At the time, TAMI Industries had just finished the production of the first batch of ceramic membranes with helical channels.

Results of the comparative tests between the first batch of new generation vs. current generation membranes are presented in Figure 1.

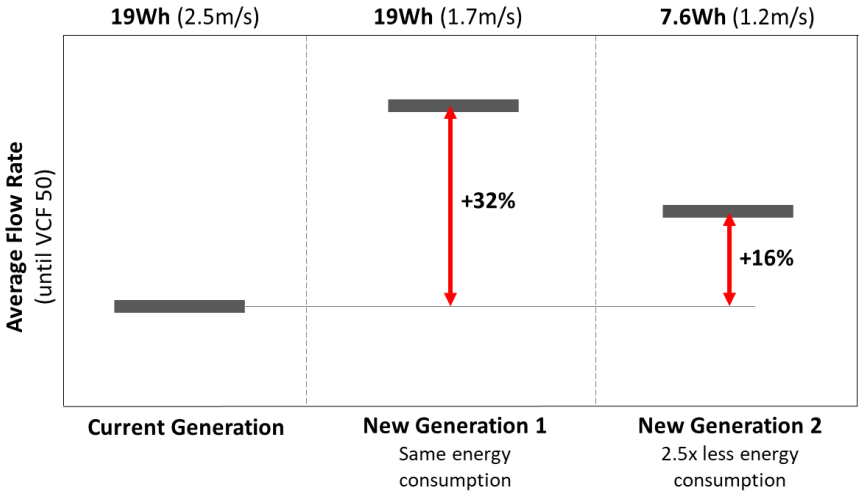

Figure 1: average permeate flowrates during tests with the current generation and the new generation membranes in red wine filtration. 23-channel, 0.2µm membranes.

This test was conducted with red wine in a batch filtration until reaching Volumetric Concentration Factor (VCF) 50, comparing the performances of membranes at the same level of energy consumption and at 2.5 times less energy consumption. Preliminary results demonstrated that the new generation membrane is 32% more productive at the same level of energy consumption. In the following test, even after reducing energy consumption by 2.5 times, the new generation membrane was still 16% more productive than the current generation membrane.

The work continues, the new generation membranes are arriving soon

Since the promising initial results obtained in 2018, the R&D team of TAMI Industries has been focused on developing efficient additive printing techniques, hardware and software to produce the new generation ceramic membranes at industrial scale. The team has also been working on protecting with international patents the groundbreaking progresses made.

The new generation of ceramic membranes are expected to be launched in phases. The first phase will be the release of a range of laboratory products. The easiness of conducting relatively quick tests in large quantities will allow TAMI Industries to gather precious feedback from customers. The laboratory products will also allow customers to confirm the concept before moving to scale-up. The second phase will be the release of a vast range of industrial products.

Related articles:

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