STUDY OF TRANSIANT FLOWS OF MICROPARTICLES SUSPENSION BY USE OF THE TANGENTIAL MICROFILTRATION PROCESS.

Rachid MIRI *, Régis JOULIÉ ** and Gilbert Marcel RIOS **
* Mechanical Dept Engineering
USTHB, BP32, Bab Ezzouar El-Alia 16111 ALGIERS
Faxes:(021)90.16.54- 90.15.60 **E-mail: mirirachid@yahoo.fr**
** L.M.P.M. Equipe Génie des procédés UMII
34000 MONTPELLIER France

ABSTRACT

In industry, when an operation of separation, concentration, purification or sterilisation is necessary, the membrane processes can be applied. Into the food industry, the tangential process is used for many sectors (milk, gelatine, vinegar, juice, wine...)
Other fields are also concerned with these processes among which, master of suspension concentration before an evaporation or drying stage, the recycling of fluids (worn water), the treatment of the fluids for the recovery of particle products (pigments)…etc.
This work is a contribution to the study of the tangential micro filtration of the suspensions and the protein solutions on the one hand and, adsorption solid/liquid phenomenon, on the other hand.

The flow of a solvent through a porous environment as during an operation of filtration is generally modeled by the Darcy law [2]:

$$\frac{Q_p}{S_F} = J = \frac{P_{T.M}}{\mu_P . R_m} \qquad (1)$$

where Q_P is the flow of filtration, S_F filter surface, J the density flux of filtration (also called speed of permeation), P_{TM} the trans-membrane pressure, μ p the viscosity of the permeat and Rm the intrinsic hydraulic resistance of the membrane. In the case of a solution or a suspension equation (1) is replaced by [1,6,7]:

$$J = \frac{P_{TM}}{\mu . Rh}$$

with Rh = Rm + Rc

where Rh is the hydraulic resistance (or total) of the filtering ambient, .i.e. the sum of the membrane resistance Rm, and the resistances to the transfer Rc which is due to various mechanisms implying a reduction of the perméat_flow, following the introduction of solutions, which can be defined as follows [8,9]: Rc = Rg + Rs + IH
with

Rg: gel resistance (concentration polarization) [m^{-1}]
Rs: resistance due to particles deposition on the membrane surface.
IH: resistance due to particles deposition inside the pores

The value of Rh, in a tangential filtration, depends also on: the speed, the size of the particles, the trans-membrane pressure, the physicochemical ambient (pH, ionic force)…. etc.
In a first approach, the retention rate should depend essentially on the relative size on the molecules and pores. For a cylindrical membrane and a Newtonian fluid in a turbulent mode, the transfer coefficient K at the membrane-solution interface is estimated in general starting from the number of Sherwood. Several correlations are proposed for its determination [14,15]. The simplest Deissler

relation let to write:

$$Sh = \frac{K.d_h}{D} = \frac{d_h}{\delta} = 0{,}023\ Re^{0{,}875}\ Sc^{0{,}25}$$

In the film theory, the overestimation of the concentration at the level of the boundary layer Cm [16], show filtration flows lower than in reality. The use of the Nakao relation enables us to have more correct evaluation of the K coefficient, and consequently of the limit filtration flow Jlim.
Cm can be calculated by the following relation:

$$\frac{C_m - C_F}{C_0 - C_F} = \exp\left(\frac{J_{lim}}{K}\right)$$

where, C_F and C_o are the solution concentrations in the permeat and the in the main solution.

The micro filtration installation is represented on figure 1, and is composed essentially of a volumetric pump with membranes Hydra-Cell (Wanner), which provides a proportional flow to the rotation speed. At the exit of this element, a stainless steel membrane holder is found (M), followed by a valve punch (NV) to allow precise adjustment of the trans-membrane pressure. A storage tank containing the liquid to be filtered, is used on one hand to supply the pump and on the other hand to collect the retentat and possibly the filtrate. The tank contains a cooling coil of the liquid to work under isothermal conditions. At the exit of the pump, the installation is composed of a safety valve (SV), to limit the pressure in case of obstruction or bad control of the punch valve.

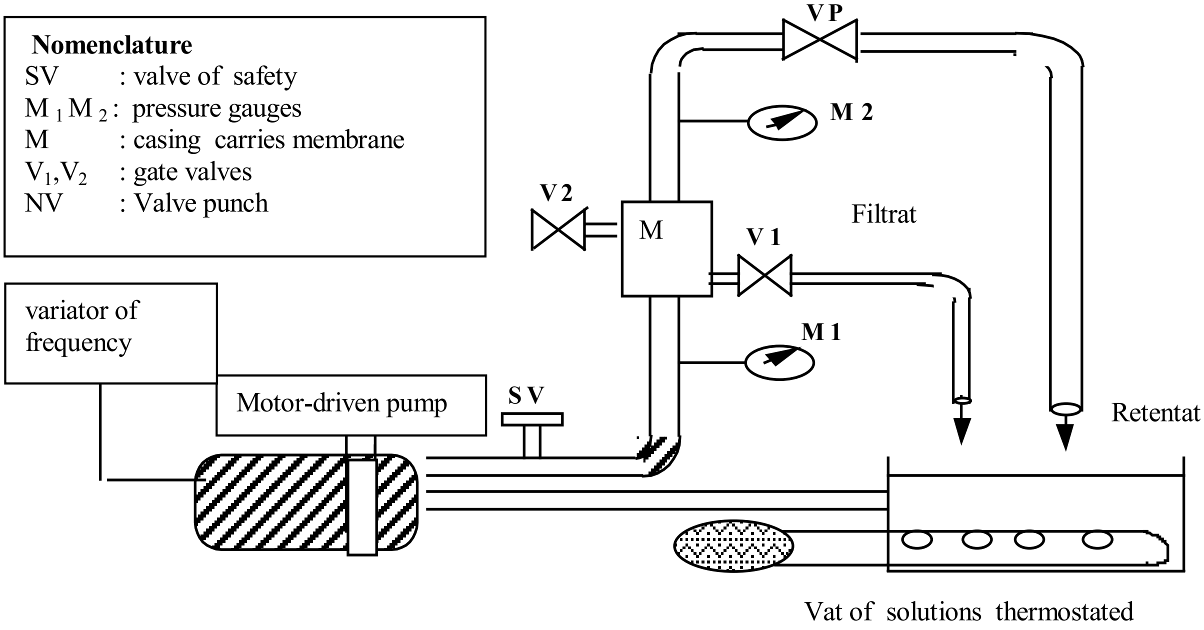

Figure 1: Unit controls micro filtration

A mineral membrane of diameter of pore 0,2 μm porous diameter was used, a protein solution (β-lactoglobuline 10mg/l concentration) and a suspension of active coal which variable concentration.
The micro filtration of products alone (ultra pure water, activated coal, protein) has lead to a better understanding of the role of each component in the process of separation. The adsorption of proteins with an active coal powder has been studied afterwards in a micro filtration loop in an agitated cell.
Experimental studies of the influence of the hydrodynamic parameters (trans-membrane pressures, tangential speed), composition of the suspension and/or solution (concentration) were necessary to determine the performances and the effectiveness of the operation.

Globally, the results obtained show the importance of the ionic force in the fluid and the existence of strong interactions between membrane and solvent on the one hand, and membrane and protein, on the other hand.

The application of models for the formation of filling phenomenon opposed to the transfer of material and the isotherm adsorption are proposed. The conformity of the test results with classical laws (tangential filtration) predictions confirm the validity of the models and the established experimental protocol.

The study of the filtration of the suspension of active coal has shown that the main cause of the flow fall is the instantaneous filling deposition (cake). The total resistance of material transfer is the sum of the external, the polarization and the proper membrane resistances.

The micro filtration tests with the β-lactoglobuline solution increase quickly the internal and the external filling via the deposition of a gel layer on the membrane walls. The over estimation of the concentration limit led us to the application of the Nakao equation in order to have a better idea on the theoretical transfer coefficient. The obtained results were close to the experimental values, which were determined by the graphic method (film theory).

Bibliography

[1] Porter M.C. Ultrafiltration of colloidal suspensions, AIChE Symposium Series, 68 (1972) 21-30.
[2] Svarovsky L. Filtration fundamentals. In Solid liquid separation, second edition, ed. Svarovsky, Butterworth, (1981) 242-264.
[3] Evans E.W. and Glover F.A. Basic principles of reverse osmosis and Ultrafiltration, J.Soc.Dayry Tech., 27, (1974) 111-120.
[4] Field R.W., Transport processes in membranes systems, in 'Membranes in bioprocessing, theory and applications, Howells, Sanchez Eds, Blackie Acad.&Prof. London (1993) 111-120.
[5] Rivet P., Guide de la séparation liquide-solide; Idexpo Eds, SFF, Paris (1981).
[6]Lojkine M.H., Field R.W. and Howell J.A., Crossflow microfiltration of cell suspensions:a review of models with emphasis on particle size effects, Trans IChemE. partC,70 (1992)149-164.
[7] Porter M.C., Membrane filtration. In : Handbook of separation techniques for chemical Ed. Schweitzer, McGraw-Hill, Inc. (1979), ch2.1, 2.3-2.105.
[8]Meireles M.and Co, Les techniques à membranes: micro et ultrafiltration. Biofutur.N°111,(1992).
[9] Bennasar M.and Co, Model of the filling mechanism and the working of a mineral membrane in tangential filtration. Sci.Alim.7, (1989), 647-655).
[10] De Balman H.and Sanchez V., Membrane partition and mass transfert in ultrafiltration, Sep. Sci. Technol., 25 (1990) 507-534.
[11] Brun J.P., Procédés de séparation par membrane, Masson, Paris, (1988).
[12] Field R.W., Transport processes in membrane systems, in Membranes in bioprocessing, theory and applications, Howell, Field Eds, Blackie Acad.&Prof. London (1993) 55-112.
[13] Ferry J.D., Ultrafilter membranes and Ultrafiltration, Chem Rev.,18 (1936) 373-455.
[14] Gegas V. and Hallstrom B., Mass transfer in the membrane concentration polarization layer under turbulent cross flow. I Critical literature review and adaptation of existing Sherwood correlation to membrane operations, J. Membrane Sci., 30 (1987) 153-170.
[15] Nakao S., Nomura T. and Kimura S., Characteristics of macromolecular gel layer formed on ultrafiltration tubular membrane. Aiche J., 25 (11), 615-622.
[16] Tarteron E.S. and Wakerman R.J., Understanding flux decline in Crossflow microfiltration,Part II. Effects of process parameters Trans. I. Chem. E, Part A, 72, (1994)431-440.
[17] Barnier H., Filling problem in membrane, 5 th Word filtration Congress, Nice, France,June5-8.
[18] Freund P., Rios G.M., Etude des phénomènes de transfert en ultrafiltration et électrofiltration sur membranes minérales de solutions protéiques modèles, Thèse USTL, Montpellier, (1989).