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Experimental Simulation of the Fouling in a Cylindrical Control by Milk

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Abstract: The present research is an experimental study intended to simulate the fouling of a solid wall by recombined milk. The objective is to study the influence of two essential parameters, the temperature of the solid wall and the rate of flow of the fluid, on the fouling of outside heated stainless steel cylindrical control. The results in particular showed fouling of an asymptotic type.

Key words: Fouling-heat exchanger-milk, simulation

INTRODUCTION

If technological researches of these last decades have improved the productivity in the various industrial processes, it does not remain about it less than major problems, such as fouling, appear and block the correct operation of the production equipment. Thus, the heat exchangers knew new applications in order to optimize the energy expenditure.

The fouling of such exchangers is the principal cause of the thermal loss of effectiveness during their use. This last constitutes an economic and technological problem major which utilizes complex physical phenomena. Accordingly, the expenditure of maintenance, induced by fouling via frequent pumping and cleaning is at the origin of significant economic losses.

For the milk industry, such losses often amount to million dollars. In France, for example, these losses were estimated at 1000 million French francs for the only year of 1991 (Chaudagne, 1991). More recently, a similar estimate of the expenses caused with the Nederland milk industry by the phenomenon of fouling, showed that not less than 40 million dollars were spent each year to thwart this plague (Grijspeerdt *et al*., 2003).

In the literature treating of this specific problem, it is allowed that when milk is brought up to a temperature exceeding 60°C, it is prone to a denaturising of called natural protein β-lactoglobuline which becomes very reactive. This denaturising is followed of an irreversible polymerization giving result to insoluble aggregates (Rosmaninho *et al*., 2007).

The kinetics of the various reactions are relatively well-known (Visser and Jeurnink, 1997). However, it is as recognized as fouling by salts exists in parallel but which it remains still underestimated (Petermeier *et al*., 2002). Several recent works was completed on the modelling of the phenomenon in question (Grijspeerdt *et al*., 2004; Nema and Datta, 2005; Rivero and Napolitano, 2004). However, the experimental studies remain very. A critical review of milk fouling in heat exchangers were reported by Bipan and Xiao (2006).

The present research is an experimental study intended to simulate the fouling of a solid wall by recombined milk. The objective is to study the influence of two essential parameters, the temperature of the solid wall and the rate of flow of the fluid, on the fouling of outside heated stainless steel cylindrical control. The results in particular showed fouling of an asymptotic type.

MATERIALS AND METHODS

This study was conducted during 2005-2007 in a laboratory of transfer phenomena with collaboration of manufactory of milk industry in Algiers (GIPLAIT).

Description of the unit: Figure 1 shows the total diagram of the used experimental unit. The latter is mainly made up of a section of test, a feeding system of the latter in fluid and of an adequate instrumentation. The section of test consists of a stainless steel tube of type 304, with a diameter 20/32 mm and length 400 mm. The tube is heated outside by the means of an electric resistance surrounding the tube. This last is thermically isolated by a layer from another and glass wool from cork. The feeding system of the section of test in fluid is made of a galvanized steel tank of 30 L. In order to maintain constant the temperature of the mass fluid at the entry of the section of test, a serpentine is plunged in the tank to allow the cooling of its contents by cold water current.

The preparation of the milk solutions with 90 g L^{-1} (industrial standard) is done in a second PVC reserve of

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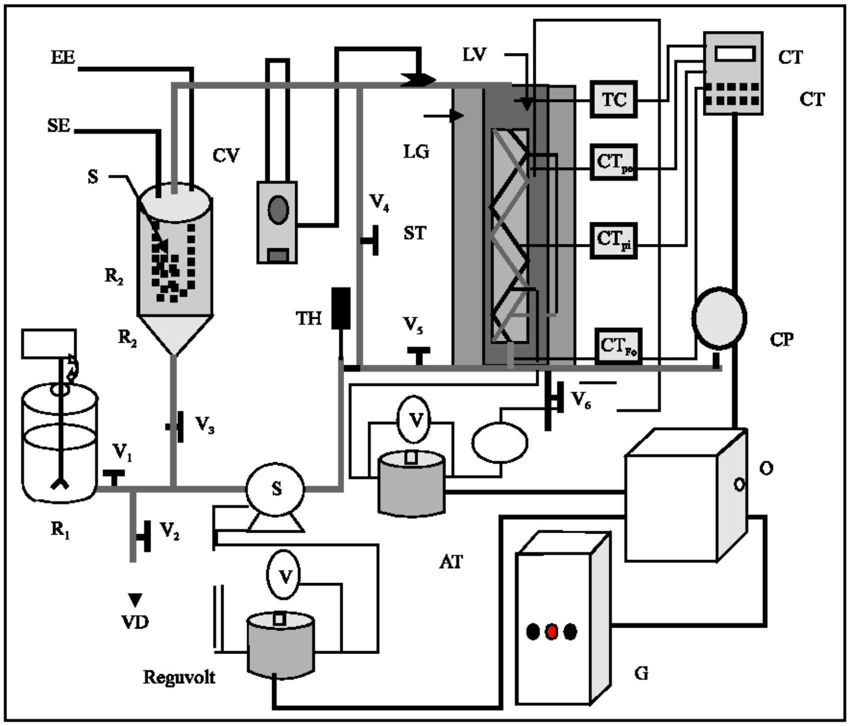

Fig. 1: Diagram of the experimental installation, AT: Auto transformer of flow, CP: Pressure pick-up, CT: Temperature gauge, CV : Velocity pick-up, EE: Entry of water, G: Generator; LG: Cork, LV: Glass wool, O: Inverter, P: Pump, R_1, R_2: The tanks, S: Serpentine, SE: Exit water, ST: Section of test, T: Thermometer, V: Vann and VD: The dra

30 capacity litres comprising a mechanical agitator. A centrifugal pump is used to feed the section of test in fluid with a maximum capacity of 0.66 L sec^{-1}. The intermediate conduits connecting the various parts of the installation are out of galvanized steel of diameter 20/27 or 15/21 with an adequate site of multiple valves.

The instrumentation is made up of measuring apparatus of temperature, pressure, speed and current and electric tension. Four thermocouples of the type K make it possible to measure and the exit inlet temperatures of the fluid in the section of test as well as the temperatures of the walls internal and external of the heated tube. The temperature of the internal wall is regarded as being the temperature of surface in contact with the fluid. The temperatures are indicated by a digital reader of Philips mark of precision ±1°C. A pressure gauge indicates the pressure loss of the fluid in the drain.

The speed of the fluid is measured by a flow-meter with ultrasounds placed on control carrying out the fluid towards the section of test. An autotransformer is used to vary electrically the flow of the fluid. The power of heating of the section of test is fixed by a regulator of power of the Reguvolt type supplied with a source of alternating voltage (220 V, 50 Hz). A voltmeter and an ammeter of precision 0.25 V and 0.2 Ä measure the tension and the intensity of the current feeding heating resistance, respectively.

Procedure: The protocol followed for the achievement of an experiment aiming to the measurement of the resistance of fouling by milk is as follows:

- Fill the tank (R_1) with 15 L of water to which one adds 1350 g of dried milk to obtain a concentration with 90 g L^{-1}. Agitate the mixture until obtaining a homogeneous solution.
- Open the valves V_1 and V_4 and to start the pump in order to fill the tank (R_2) from (R_1) by maintaining the valves V_2, V_3 and V_5 closed.
- Stop the pump and the agitation when the quantity of milk completely passed in the tank (R_2).
- Close the valves V_1 and V_4 and to open the valves V_3 and V_5.
- Start the pump and to regulate using the car transformer of the flow the speed of the fluid read on the velocity pick-up.
- Start the regulator of power and fix the value of the heat flow desired. This power is obtained by

multiplying the intensity of the current I read on the ammeter by the voltage V read on the voltmeter. These values are immediately fixed when the initial moment (t = 0) corresponds to the first passage of the fluid in the section of test. The catch of the 4 temperatures of interest starts as from this moment, noted t = 0.

- From this moment, the various temperatures are recorded every 5 min then with intervals of larger times and this, until appearance of an asymptotic value in the value of the resistance of fouling.
- After stop of the pump and system of heating, one carries out the draining of the system by opening all the valves.
- Lastly, is carried out to the cleaning of all the circuit while following the method cleaning in place the process of cleaning is based in 6 stages and shown in Table 1.

Data processing: The data obtained relate to mainly the temperatures initial and periodically recorded in the time of the internal wall of the section of test as well as heat flow imposed on the latter. The resistance of deposit is then calculated by the relation:

$$Rd = (\frac{T_i - T_{i0}}{\Phi}) \quad (1)$$

Where:

R_d : Resistance of fouling ($m^2.K/W^{-1}$)
T : Temperature (K)
I : Relating to the internal wall
0 : Relative à t = 0)
Φ : Heat flow, $W.m^{-2}$

The results are adapted to the model of Kern and Seaton given by the relation:

$$R_d = R_d^*(1-e^{-Bt}) \quad (2)$$

Table 1: Process of cleaning of the type cleaning in place

Stages	Stage of clearing	Duration (min)	Objectives
Stage 1	Rinsing with water of city	10	Eliminate the large particles
Stage 2	Cleaning with NaOH solution of 2% with T = 80°C	20	Eliminate all the fat content by the reaction from saponification
Stage 3	Rinsing with water of city	10	Eliminate NaOH
Stage 4	Cleaning with the nitric acid of 1% in T = 70°C	20	Eliminate the rock salt generated by the drainage duct
Stage 5	Rinsing with water of city	10	Avoid the contact between two different products
Stage 6	Rinsing with chlorinated water	10	Disinfection

Where:

R_d^* : Resistance of fouling ($m^2.K/W^{-1}$) (*asymptotic value)
B : Constant
t : Time (sec)

RESULTS AND DISCUSSION

The experimental plan consisted in varying the heat flow imposed by keeping the flow of constant fluid then to vary this last by keeping the flow constant. For that, five values were selected for each one of these two parameters. It is necessary to note that the variation of the heat flow imposed on the section of test returns in fact to impose the internal temperature of the wall heated in contact with the fluid.

Figure 2 shows the results obtained at variable flow and for a milk flow equal to 0.21 L sec^{-1}. A first observation shows that the shape of the curves obtained is of exponential type with an asymptote obtained after a certain time in conformity with the simple model of Kern and Seaton. In addition, it appears as clearly as fouling is all the more significant, as the power of heating, there fore the temperature of the solid wall in contact with milk, is higher. The actual values in the resistance of fouling are relatively significant compared to those observed in other applicability. For each curve obtained, Table 2 shows the values of constant B and asymptotic resistance, R_D^*, appearing in the equation of the model of Kern and Seaton (Eq. 2).

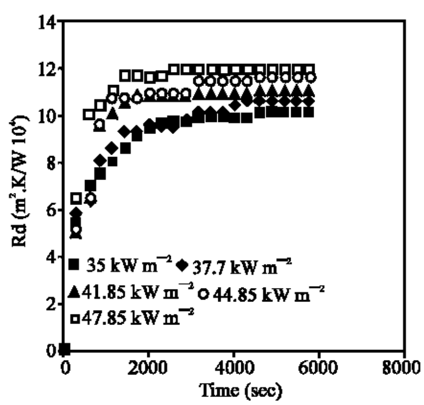

Fig. 2: Evolution of the resistance of fouling in time for 5 values of power of heating

Table 2: Adaptation of the results to the exponential model

Φ ($kW.m^{-2}$)	35.00	37.70	41.85	44.85	47.85
R_d^*. 10^{-4}	10.00	10.08	10.94	11.59	11.91
B. 10^{-3}	1.83	1.93	1.53	1.47	1.81

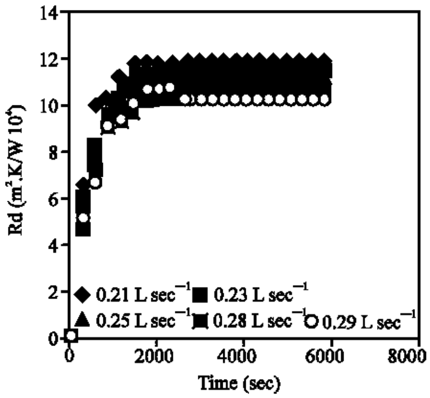

Fig. 3: Evolution of the resistance of fouling in time for 5 values of the flow

Figure 3 shows the results obtained with variable flow and heat flow maintained constant to 47.85 K/W.m $^{-2}$. As previously, the shape of the curves also follows the exponential law with existence of asymptotic values at relatively high times. However, the effect of the increase in the flow of fluid, therefore its speed, seems to affect the phenomenon of deposit differently, compared to heat flow.

Indeed, it seems that strong flows tend to decrease the fouling of the heated wall, which is in agreement with the results of several authors. In addition, no time of induction generally preceding the beginning by the deposition was observed in all the experiments realized. Lastly, it should be noted that a calculation of the experimental deviations obtained showed that these last did not exceed 5%.

The obtained results are in concordance with those reported by literature Mahdi and All (2005).

CONCLUSIONS

An experimental study was undertaken to evaluate the fouling of a tubular exchanger by recombined milk starting from a powder of known origin. The effect of two significant operational parameters, namely the temperature of the hot wall via the flow of heating as well as the flow of fluid was of interest. The results showed an exponential shape of the curves of the resistance of deposit in time with presence of asymptotic values in all the studied cases. In addition, it was observed that the power of heating increased the fouling of the exchanger, where as the flow decreased it appreciably.

REFERENCES

Bipan, B. and D.C. Xiao, 2006. A critical review of milk fouling in heat exchangers. Comp. Rev. Food Sci. Food Safety, 5 (2): 27-33.

Chaudagne, D., 1991. Fouling Costs in the Field of Heat Exchange Equipment in the French Market. In: Fouling Mechanisms: Theoretical and Practical Aspects, Bohnet, M., T.R. Bott, A.J. Karabelas, P.A. Pilavachi, R. Séméria and R. Vidil (Eds.). European Edn. Thermics and Industry, Paris, France, pp: 21-25.

Grijspeerdt, K., B. Harazika and D. Vucinic, 2003. Application of computational fluid dynamics to model the hydrodynamics of plate heat exchangers for milk processing. J. Food Eng., 57 (3): 237-242.

Grijspeerdt, K., L. Mortier, J. De Block and R.V. Renterghem, 2004. Applications of modelling to optimize ultra high temperature milk heat exchangers with respect to fouling. Food Control, 15: 117-130.

Mahdi, Y. and All, 2005. Numericalsimulation of fouling in heat exchangers by milk. 7th Colloque Interunersitary Franco-Quebecois in Thermic-System, St Malo France.

Nema, P.K. and A.K. Datta, 2005. A computer based solution to check the drop in milk outlet temperature due to fouling in a tubular heat exchanger. J. Food Eng., 71 (5): 141-156.

Petermeier, H., R. Benning, A. Delgado, U. Kulozik, J. Hinrichs and T. Becker, 2002. Hybrid model of the fouling process in tubular heat exchangers for the dairy industry. J. Food Eng., 55 (1): 9-17.

Rivero, C. and V. Napolitano, 2004. Estimation of fouling in a plate heat exchanger through the application of neural networks. J. Chem. Technol. Biotechnol., 80 (7): 594-600.

Rosmaninho, R., O. Sontos, T. Nylander and M. Paulsson, 2007. Modified stainless steel surface targeted to reduce fouling-evaluation of fouling by milk components. J. Food Eng., 80 (4): 1176-1187.

Visser, J. and T.J.M. Jeurnink, 1997. Fouling of heat exchangers in the dairy industry. Exp. Thermal Fluid Sci., 14 (4): 407-424.