Research Journal of Engineering Sciences ISSN 2278 – 9472
Vol. **2(1),** 5-10, January **(2013)** *Res. J. Engineering Sci.*

To Study the Fouling of Corrugated Plate Type Heat Exchanger in the Dairy Industry

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Available online at: www.isca.in
Received 20th December 2012, revised 17th January 2013, accepted 15th January 2013

Abstract

Fouling is a major severe problem both technically and economically in the corrugated plate type heat exchanger from dairy industry. Thermal treatment of milk represents major unit operations. It should be considered that products microbiologic safety and shelf-life increase. But during the thermal treatment of such sensible fluids in a corrugated plate type heat exchanger, proteins are denaturized and aggregate reaction takes place. Finally formation of fouling affect's the treatment's efficiency and overall heat transfer efficiency. The relative amount of denaturated and aggregated proteins depends upon a number of factors such as milk quality, presence of micro organism, Operating condition, design and type of heat exchangers and heat transfer surface properties. In this present work fouling factors consider the change in a process condition. Pre-heating of test fluid and cleaning of corrugated plate surface provides controlling of fouling and enhances the rate of heat transfer and increase the treatment efficiency (pasteurization, sterilization process) of milk products.

Key words: Fouling, corrugated plate type heat exchanger, heat transfer coefficient, cleaning.

Introduction

Plate Type Heat Exchangers have a number of applications in the pharmaceutical, petrochemical, chemical, power, and dairy, food & beverage industry. In the recent past plate type heat exchangers are commonly used when compared to other types of heat exchangers such as shell and tube type in the process of heat transfer. This is with respect to their compactness, ease of production, sensitivity and efficiency. Corrugated Plate type Heat Exchangers (PHEs) are very common in dairy industries. This is due to their ease of maintenance and cleaning, their compact design and their excellent heat transfer coefficient characteristics required for thermal sterilization/pasteurization purposes. However Sandu and Lund et al[1] fouling of plate type heat exchanger is a severe problem both technically and economically. It significantly increases its capital and operating costs. Frequent cleaning of the plant is needed for both microbiological reasons and to restore PHE heat transfer characteristics, i.e. to remove the additional heat resistance of the fouling layer and to reduce the pressure drop in the process plant.

Christian, Changani and Fryer et al.[2] investigated the overall cleaning times and cleaning rates, under standard conditions which were dependant on the deposit composition. There is a lack of knowledge concerning the influence of deposit structure and kinetics of deposit mass upon the cleaning efficiency to get rid off the total mass deposit.

Müller-Steinhagen and Zhao et al. [3] investigated the influence of SiF4 + ion implanted stainless steel, which significantly reduces CaSO4 scale formation during pool boiling.

Kück and Hartmannet et al.[4] observed the application of nano-coatings with anti-adhesion effect which reduces the buildup of deposits on the surface of heat exchanger plates. Due to the reduction of adhesive forces, the operation efficiency of the plant can be significantly improved and the general hygienic situation of the product can be increased. Additionally, intensity and frequency of cleaning can be substantially reduced to achieve the desired degree of product quality.

Sandu et al.[5] presents a considerable amount of work on milk fouling, in plate heat exchangers. He developed a detailed physic mathematical model where fouling kinetics and dynamics were de"ned based on experimental results.

Bansal et al.[6] shows that the investigated the formation of CaSO4 deposit generated by a combination of crystallization and particulate fouling.

Beuf and Rizzo et al.[7] studied the fouling of dairy product on modified stainless steel surfaces in a plate and frame heat exchanger. Different surface modifications, such as coatings (diamond like carbon [DLC], silica, SiOX, Ni-P-PTFE, Excalibur, and Xylan) and ion implantation (SiF+, MoS2) were analyzed. No significant difference was found between the modified stainless steels and the unmodified one.

Premathilaka et al.[8] have been studied for the fouling behavior of whey protein solutions on modified stainless steel (SS) surfaces coated with diamond-like carbon (DLC) and titanium nitride (TiN).

Zhao and Liu et al.[9] experimental results of showed that the surface free energy of the Ni–P–PTFE coating had a significant influence on the adhesion of bacterial, protein and mineral deposits. The Ni–P–PTFE coating reduced the adhesion of these deposits significantly.

If the following literature[10-11] analysis for the flow field and heat transfer characteristics within fully developed region of corrugated channels were analyzed numerically and the predicted pressure drop within the corrugated channel was in good agreement with experimental observations.

Murugesan M.P. and Balasubramanian et al[12] deals with the effect of mass flow rate and heat transfer characteristics of a corrugated plate heat exchanger were studied for increase of mass flow rate with subsequent increase in the flow velocity has led to an increase in the overall heat exchanger coefficient as well as the individual heat transfer coefficient. Its providing corrugated (or) embossed patterns is to import high turbulence to the fluids which result in high heat transfer co efficient as high as 2-5 times of those obtainable in shell and tube heat exchanger for similar duties.

In this present research work can be investigate the fouling of heat exchanger from dairy industry. Milk sterilization and pasteurization heat treatment operations are varying of process and operating conditions with cleaning and surface coating in the corrugated plate type heat exchanger.

Material and Methods

Experimental setup: A schematic diagram of the experimental apparatus and the sharp edge version of the corrugated duct used in the heat transfer experiments are presented in figure 1. The channel configuration is characterized by the corrugated channel height, the respective values of 10 mm. In the plate type heat exchanger designed for 25^{O} corrugation angle and 31 mm plate pack length with $100^{O}C$ work temperature and design pressure 6 kg/cm^2. The heat exchanger was constructed using 316 stainless steel plates. It should be giving of higher heat transfer efficiency of pasteurization and sterilization process. The plate heat exchanger had a height of 304 mm and a plate thickness of 1mm. The total heat transfer area of $2.24m^2$. Plate had a gap between the plate is 10mm. A pump was used to provide flow to the cold fluid side. The flow rate was controlled by a calibrated area flow meter, allowing flows to be controlled and measured between 0.42 kg/s. In the corrugated plate type heat exchanger plate surfaces can be coated for silica and SiO_X, material used for minimizing of fouling in a heat treatment process. The test fluid inlet pipe is connected to the bottom of the corrugated plate type heat exchanger and the outlet is taken from another end top of the heat exchanger. The hot fluid is heated by pumping the steam from the boiler to the temperature of about $75\text{-}93^{o}$ C and connected to hot fluid reservoir, and then the hot solution is pumped to heat exchanger using a pump. The hot fluid inlet pipe is connected at the top of the corrugated plate type heat exchanger and the outlet pipe is taken from bottom of the heat exchanger. The flow rate for the hot fluid was controlled by an identical flow meter as it was done for the cold fluid flow. Thermocouples were inserted into the pipe to measure the inlet and the outlet temperatures for both fluids.

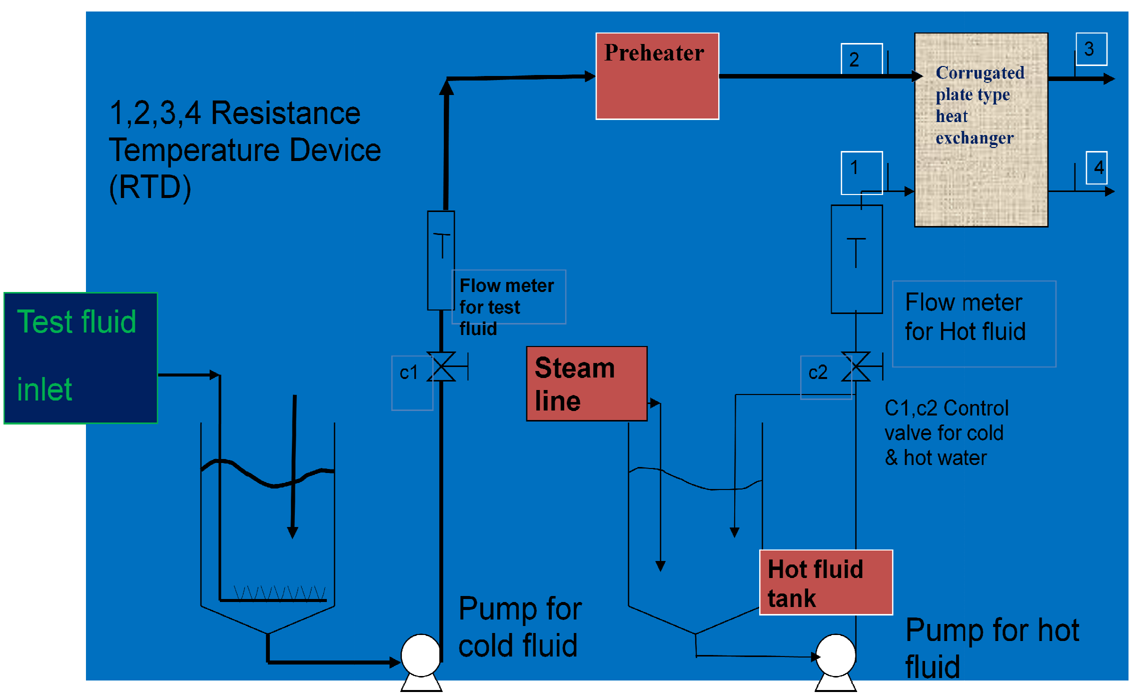

Figure 1
Schematic of Experiment set up

Experimental Procedure: Pasteurization and sterilization process is one of the major heat treatment for dairy products. If the treatment destroys all microorganisms and enhanced product microbiologic safety with increase shelf time of products. The heat transfer and fouling of test fluid were tested in corrugated plate type heat exchanger as shown in figure 1. Water used as the hot fluid. The inlet hot fluid flow rate is kept constant and the inlet cold test fluid flow rate is varied using of control valve. In this present work maintaining of preheating process on 63-65^{0}C temperature for before passing of heat exchanger. The preheating of hot and cold fluid flow rate is varied using control valves, C1 and C2 respectively. Thermocouples T1 and T2 were used to measure outlet temperature of hot and test fluids respectively; T3 and T4 were used to measure the inlet temperature of hot and test fluids respectively. Pasteurization process is maintained for 70-75^{0}c within 15 to 20 seconds time periods. For that time destroys all microorganisms and formation of protein denaturation and aggregation reaction. Finally takes place for precipitate materials in a corrugated plate surfaces and reducing of treatment efficiency. It should be consider that maintaining of preheating of test fluid and lowering the surface temperature and increasing the flow velocity and to reduce fouling.

Factors affecting for milk fouling: Fouling depends upon various parameters such as heat transfer method, operating conditions, heat transfer surface characteristics, hydraulic and thermal conditions and quality of milk. These factors can be broadly classified in to five major categories are milk composition, operating conditions in plate type heat exchangers type and characteristics of heat exchangers, presences of micro organisms, and location of fouling.

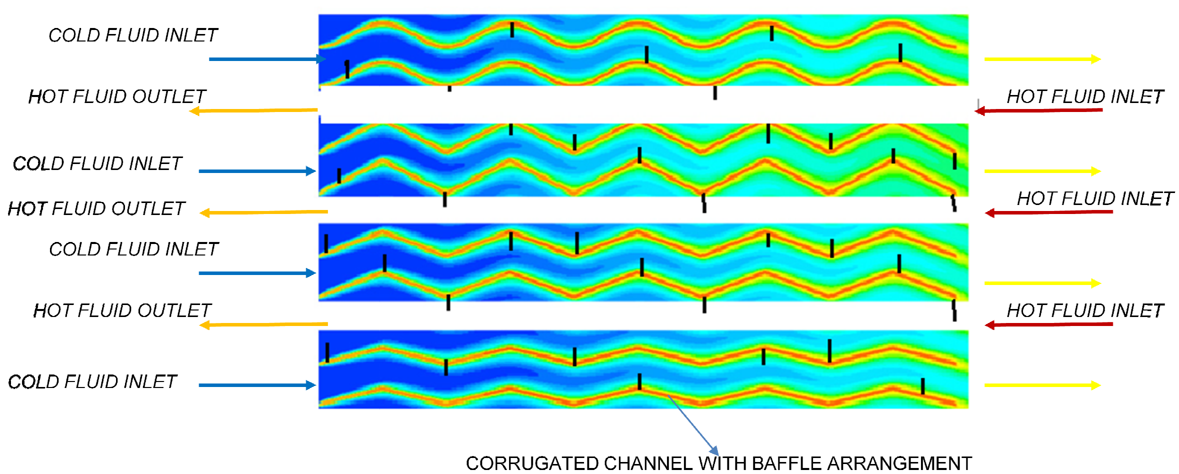

Figure 2
Schematic diagram before fouling for plate surfaces

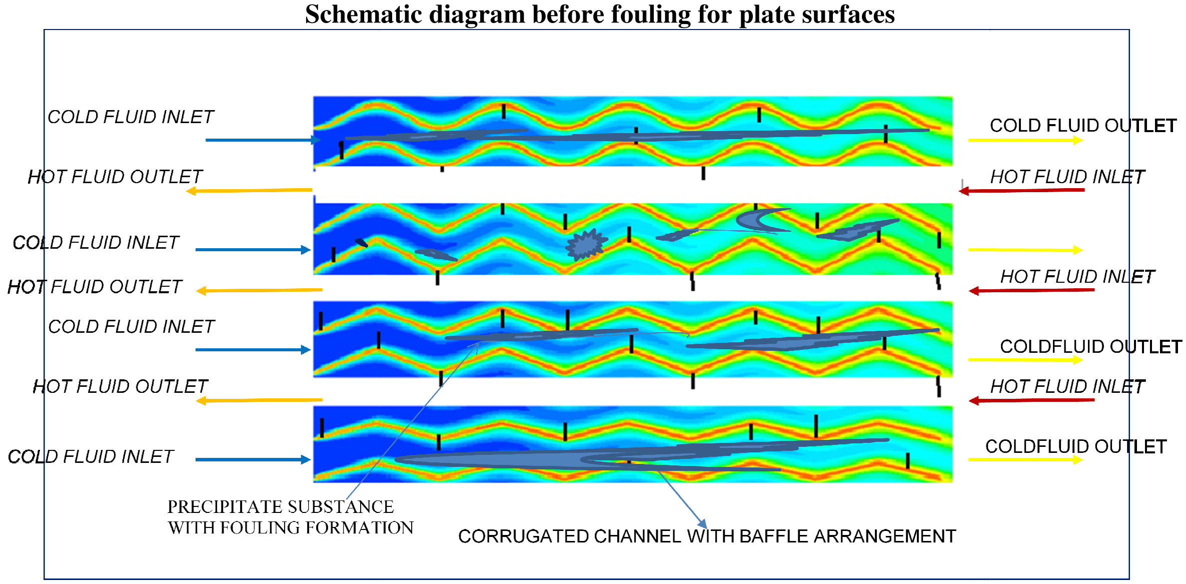

Figure-3
Schematic diagram after fouling for plate surfaces

Results and Discussion

Reducing of fouling: Surface modification: In this experimental study, Nano-composite coatings were used to reducing of fouling an inside the corrugated plate heat exchangers. It should be involved in pasteurization and sterilization of milk. An antifouling coating with low surface energy and reduce the precipitate formation. The main goal of the project work is done for application of new surface coatings (nanotechnology) to avoid fouling and improve treatment efficiency, simplify cleaning processes with lesser resources and chemical use, and increase the product quality.

The test used for the investigation of milk adhesion and the stability of the coatings on corrugated plates. A number of coatings and surface treatments were tested. Heat exchanger plates coated with different nano-composites as well as electro polished plates installed in the heating section of the pasteurizer were tested. Significant differences were observed between coated and uncoated plates. The coated plates showed that reduced deposit buildup in comparison with the uncoated stainless steel plates. The time required for cleaning place with the coated plates was reduced by 75% compared to standard stainless steel plates.

Preheating: Normally the desired processing temperature are reducing directly after pasteurization, but sometimes it is necessary to cool and store the temporarily, before the final processing is done. Milk can be preheated before the heat treatment operations. It should be enhanced heat transfer efficiency and reduce fouling and also required for minimum time consumptions.

Cleaning: Cleaning process is must in milk pasteurization and sterilization process in the corrugated plate type heat exchanger from a dairy industry. In this process is done by circulating of detergents in a plate surfaces. To achieve efficient cleaning, the corrugated plate type heat exchanger must be designed not only to meet the required temperature program, but also with cleaning in mind. If some passages in the heat exchanger are very wide range several parallel channels, the turbulence during cleaning may not be enough to remove fouling deposits efficiency. It has been consider that maintaining of cleaning process in the milk heat treatment operations in a corrugated plate type heat exchanger.

Log Mean Temperature Difference: The log mean difference temperature was defined as the "average" driving temperature difference between the hot and cold streams for heat transfer calculations. For heat exchangers, the use of the log mean difference temperature makes the calculation of the heat transfer coefficient more accurate. For counter current flow, it is defined as

$$\Delta T = \frac{(T_1 - T_4) - (T_2 - T_3)}{\ln\{(T_1 - T_4)/(T_2 - T_3)\}}$$

Overall heat transfer coefficient

$$\frac{1}{U} = \frac{1}{h_{hs}} + \frac{1}{h_{cs}} + \frac{\Delta x}{k} + Rf$$

The milk pasteurization and sterilization process are maintaining of without surface coating, preheating, cleaning of corrugated plate type heat exchanger. For that time proteins are denaturation and aggregation reaction takes place. Finally produce fouling that affect the treatment efficiency and overall heat transfer a efficiency. It should be explained for graphical representation in figure 4 and 5.

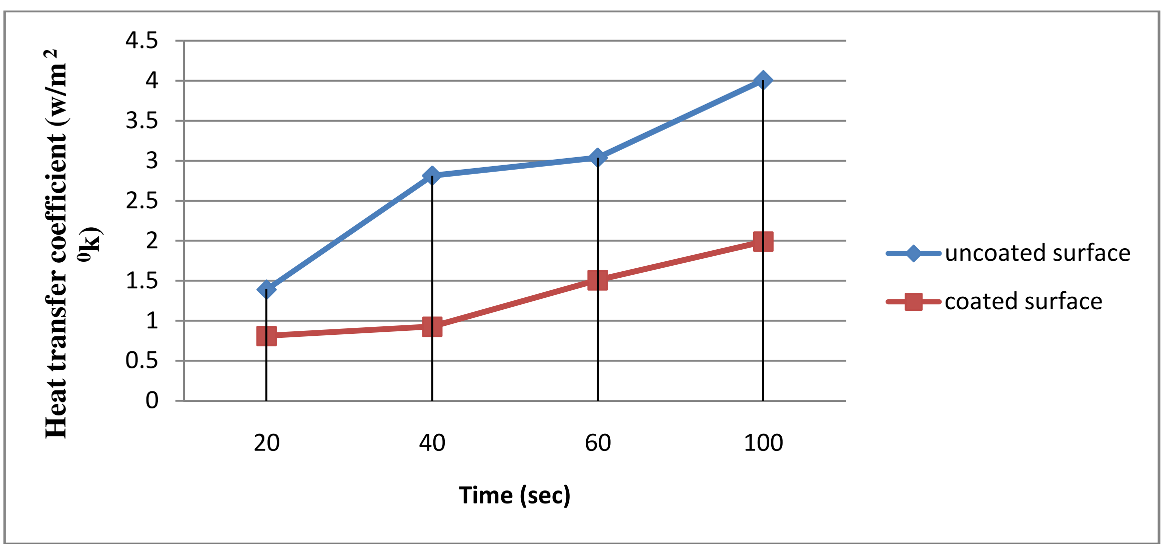

Figure-4
Effect of fouling in Heat transfer co efficient (coated and uncoated surfaces)

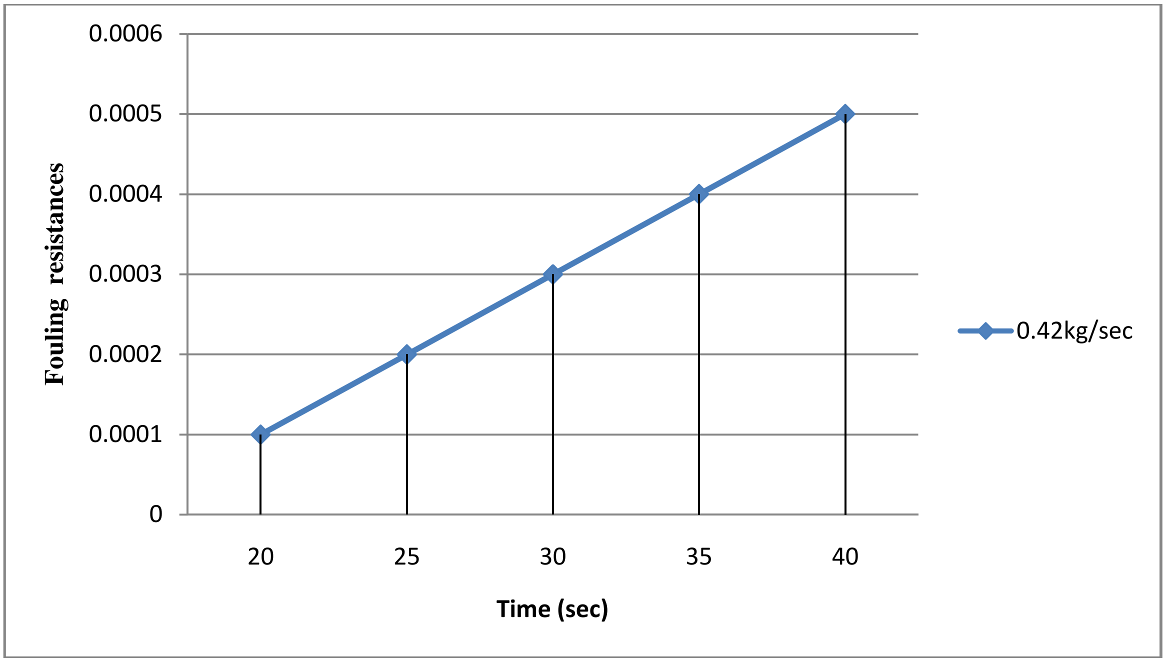

Figure-5
Effect of fouling resistance vs time

Conclusion

Experiments were conducted in the corrugated plate type Heat Exchanger in the dairy industry. Although there is an established link between protein denaturation and fouling, the relative impact of the denatured and aggregated proteins on the deposit formation is not clear. In general, it is believed that fouling is controlled by the aggregation reaction of proteins and the formation of protein aggregates reduces fouling. The mass transfer of proteins between the fluid and heat transfer surface also plays an important role. It may not be possible to completely eliminate fouling in heat exchangers simply due to the fact that denaturation and aggregation reactions initiate as soon as milk is subjected to heating. Fouling, however, can be controlled and mitigated by selecting appropriate thermal and hydraulic conditions. Both increasing the flow rate, decreasing the temperature and proper cleaning process in done for reduce the fouling. In this experimental work used for three mechanism used for reducing of fouling as well as surface coating, preheating, cleaning of corrugated plate surfaces. It's provides higher heat treatment efficiency and controlling of fouling.

Nomenclature: Abbreviations: PHE plate heat exchangers, PHEs plate heat exchangers, LMTD log mean temperature difference,

Symbols: T1 = Temperature inlet – hot side, T 2 = Temperature outlet – hot side, T 3 = Temperature inlet – cold side, T 4 = Temperature outlet – cold side, Hhs =the heat transfer coefficient between the medium and the heat transfer surface (W/m^2 °C), Hcs =the heat transfer coefficient between the heat transfer surface and the cold medium (W/m^{2}°C), Δx = the thickness of the heat transfer surface (m), Rf = The fouling factor (m^2 °C/W), k = the thermal conductivity of the material Separating the Medias (W/m °C).

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