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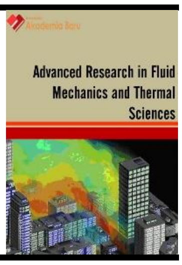

Design and Perfomance Evaluation of a Short Recycled Concentric Tube Heat Exchanger for Raw Milk Pastuerization

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ABSTRACT

The recycled concentric tube heat exchanger was designed with the principle of recycled heat transfer technique over a short concentric tube, which successfully constrained the heat transfer area of the conventionally long arranged or floating tubes to a reduced size in terms of cycles/minute. Validation was then carried out by experiment to ascertain its viability and the new concept was named cycle pasteurization following its success. The total head loss of both water and milk side of the heat exchanger were so negligible at 0.00002. The rate of heat, area, length, no of cycles, log mean temperature difference and effectiveness of the heat transfer were analyzed with respect to the pasteurizer and has exhibited very good characteristics which have kept the milk composition and it organoleptic properties safe for consumption. The most critical of the thermodynamic properties were coefficient of heat transfer of 1.411 and 4.2319 W/m^2 k and fouling factor of 0.7087 and 0.2363m^2 ℃/W at the beginning and end of tube heat transfer respectively, which are within the limits of pasteurization theory to keep the milk nutritive values safe for consumption. This valuable equipment with 2 litres capacity for home use and the concept of cycle pasteurization has effectiveness of 0.59 representing 98.3% efficiency of the system. Indeed, the pasteurizer will complement the existing conventional batch and flash pasteurization methods where arrangement of plates and floating long concentric pipes are used which is characterized with the challenge of micro-scale pasteurization.

Keywords:
Short concentric tube, heat exchanger, low temperature, long time, micro-scale and cycle pasteurization

1. Introduction

Heat Transfer has been an integral part of engineering development as engineering strives to improve on the efficient use of energy. This implies that heat transfer applications in both industrial and residual processes have affected the quality of eaten food, living and life style. As such, heat transfer is of particular importance in engineering field where understanding and control of heat flow through heat exchangers, thermal insulation and other supporting devices are used continuously to solve basic or fundamental human problems. Dairy products contain invaluable nutritional and health

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beneficial compounds. Hence, dairy processing is regarded as one of the most important sectors of the food industry and it is ranked the fifth among the most energy-intensive industries after oil, chemical, pulp and paper mill, and iron and steel making industries [1]. Heat exchangers have particularly become an essential component in the process lines of the liquid food industry for many years. In heat treatment processes, temperature control loops are often used with heat exchangers to maintain an accurate and stable temperature. Moreover, heat transfer enhancement in a heat exchanger system is carried out to actualize better performance [16]. Enhancement of heat transfer surface is used in many engineering application such as heat exchanger, air conditioning, chemical reactors and refrigeration systems [15]. In the case of heat treatment of milk, temperature is a critical parameter to health and product quality, since possible presence of pathogenic organisms legally requires that the milk is heated above certain temperature, whereas too high a temperature will affect product quality and increase the production cost. Milk is usually pasteurized to inactivate pathogenic and spoilage bacteria that may be present. During pasteurization, milk is heated from its storage temperature of less than 10 0C up to 72 0C, held at this temperature (pasteurizing) for 15s, and then cooled to a temperature. This is flash pasteurization.

Also, the hot milk heats the cold incoming milk, and the cold milk cools the hot pasteurized milk [2]. The application of heat exchanger in milk processing plant involves movement of liquid milk from one location to another which then becomes an essential or critical operation. The flow of liquid milk by a system is directly related to its properties, primarily viscosity and density. These will influence the power requirements for the liquids to flow as well as the flow characteristics within the pipeline. An understanding of the physical meaning associated with these properties is necessary in order to design or develop a new design from the existing designs with an optimization and sound method for measurement of its properties. Corrosion is also a major problem. Milk constitutes an important part of a balanced and healthy diet with its excellent nutritional properties. It is one of the most popular beverages where more than 6 billion people consume milk and milk products around the World. According to a recent study on the statistics from FAO (Food and Agriculture Organization) world total milk production is 703,996,079 tons/year [3]. Therefore, producing safe milk by pasteurization process is a vital issue for human health. Again, milk produced under hygiene conditions from a healthy animal should not contain more than 5 x 106 bacteria per ml [4]. The production of fluid milk requires crucial amounts of energy and raw materials. The main energy costs for dairy companies arise from their energy systems, the cleaning of the equipment and operating the machineries [3]. Thus, the effective design of the heat treatment or processing plant is major factors in determining its quality and cost of purchase from the producer. This is why "liquid milk equivalent" international prices or even imported factory prices are far more than the price paid for patronized locally fermented milk in Africa for the sole reason that more than 80% live below poverty line. This factor leads to persistent poor consumption of milk. Efforts by engineers should therefore be made to provide improvement for the local milk production at affordable cost with its desired quality.

For the prevalence of dairy food related diseases in developing countries, the safety of dairy products with respect to food borne diseases is of great concern. In developing countries many collection and preparation or treatment procedures for most dairy products are still traditional arts and the fermentations used is of uncontrolled starter cultures. Thus, exposes a wide variation in the quality and the stability of most fresh milk or locally fermented milk with respect to ideal standards which poses potential risk or hazard to consumers. Additionally, there is the potential that the diseases of cow such as tuberculosis, brucellosis and typhoid can be transmitted [5]. Thus, an intensified and tactical conceptual re-application of heat exchanger through enhancement of design factors remains the only platform to which pasteurization of milk can be made available and affordable in developing countries. Research have previously shown that cow milk fouling deposit is a Type A for the pasteurization process and is a white and voluminous deposit made up of protein (50-60%), minerals (30-35%) and fat (4-8%). The type A deposit starts to form when the temperature reaches about 700C [6]. The deposits are formed as the atom moves from atomic site to the other and eventually form the deposit at the surface of the exchanger [17]. The rate of food fouling is however a strong function of process variables, it is therefore important to understand the effects of variations in the system parameters on the rate of fouling. This research looked at the design and operating variables as part of the search for a heat exchanger with micro-scale capacity and cost effectiveness. To this end, the micro-scale milk pasteurization of milk leading to it readily accessibility and affordability in homes will be major step to provide a regulation for mandatory pasteurization of milk before consumption in Africa.

In view of attending to the problem of micro-scale pasteurization of milk [7], performed numerical and experimental studies of double pipe helical heat exchanger; the experimental stride of double pipe helical heat transfer and hydrodynamic characteristics was carried out. The objective was to determine the effects of these fluid properties on the heat transfer and pressure drop in the heat exchanger. The method was developed based on the concept of heat treatment to estimate the heating/cooling uniformity. The new design is required to limit the possible dead zone and to change the geometry to something that is easier to characterize. Thus, a double pipe helical heat exchanger for fluid to fluid flow was developed as shown Figure 1. The achievement gave way for little economy of space but the problems of cost effectiveness persist.

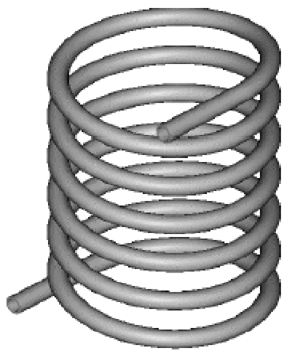

Fig. 1. Coiled Double Pipe Helical Heat Exchanger [7]

Rahat *et al.,* [8], fabricated a solar milk pasteurizer (SMP) (Figure 2) to investigate the potential of using solar energy to pasteurize natural milk. The milk samples from different animals were collected and were used for the inactivation of microbes. This experimentation was done on temperature ranging from 65°C to 75°C. During the research the maximum ambient air temperature was 40°C .The base and inner space temperature were recorded and they were found to have values 85°C and 75°C respectively. It provides a practical, low-cost milk pasteurizer for the improvement of drinking milk quality in developing countries like Pakistan. The deficiency of the Solar Milk Pasteurizer is that of space economy, long duration of pasteurization and availability of Sun light at a time.

Fig. 2. Solar milk pasteurizer [8]

As milk often contains solid matter such as dirt particles, it must be clarified. Since pasteurization is less likely to be effective if bacteria are hidden in lumps and particles in the milk, clarification must take place upstream of heating. Milk can be clarified in a filter or more effectively, in a centrifugal clarifier. The process takes place in a heat exchanger and is called regenerative heat exchange or more commonly, heat recovery. Correct heat treatment requires that the milk is held for a specified time at pasteurization temperature, milk is then cooled and then heat regenerated. Holding is done in an external holding cell. Accurate control of the flow rate is essential because the holding equipment is dimensioned for a specified holding time at a given flow rate [9]. Holding sections built into the heat exchanger were used earlier, but external holding cells are used almost exclusively nowadays [10].

2. Governing Equations of pasteurizer Development

For designing or predicting the performance of a heat exchanger, it is necessary that the total heat transfer may be related to its governing parameters: (i) U (overall heat transfer coefficient) due to various modes of heat transfer (ii) A total surface area of the heat transfer and (iii) t_1, t_2 (the inlet and outlet fluid temperatures) Figure 3 shows the overall energy balance in a heat exchanger.

Let M = Mass flow rate, kg/s
Cp = Specific heat of fluid of constant pressure, J/kgK
T = Temperature of fluid ^{0}C and
Δt = Temperature drop or rise of a fluid across the heat exchanger

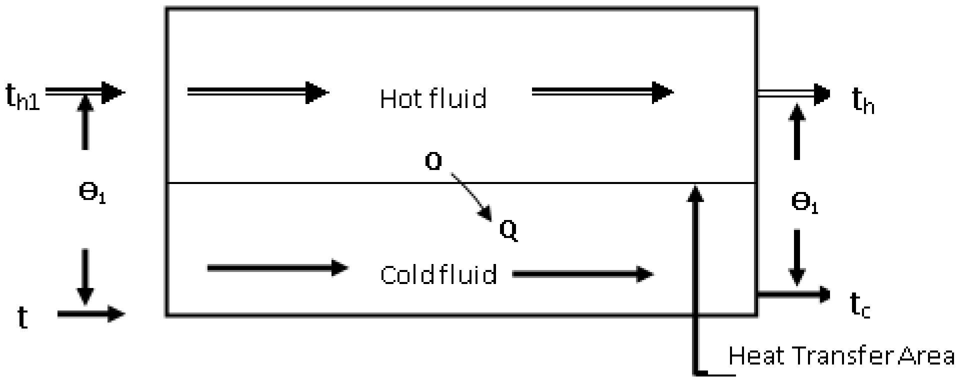

Fig. 3. Overall energy balance in heat exchanger

Subscript h and c refer to the hot and cold fluid respectively; subscript 1 and 2 correspond to the inlet and outlet conditions respectively. Assuming that there is no heat loss to the surroundings and potential and kinetic energy charges are negligible, from the energy balance in a heat exchanger, we have

Heat given up by the hot fluid

$$Q = M_h C_{ph}(t_{h1} - t_{h2}) \quad (1)$$

Heat picked up by the cold fluid

$$Q = M_c C_{pc}(t_{c1} - t_{c2}) \quad (2)$$

Total heat transfer rate in the heat exchanger

$$Q = UA\theta_m \quad (3)$$

where, U = Overall heat transfer coefficient between the two fluids
A = Effective heat transfer area and
θ_m = Appropriate mean value of temperature difference or logarithmic mean temperature difference (LMTD) [11]

Summary of governing equations include

$$Q = UA \cdot \theta_m$$

$$\theta_m = \frac{\theta_2 - \theta_1}{\ln\left(\theta_2/\theta_1\right)} = \frac{\theta_1 - \theta_2}{\ln\left(\theta_2/\theta_1\right)}$$

With respect to temperature notations as ΔT_m, we have

$$Q = UA \cdot \Delta T_m$$

$$\Delta T_m = \frac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1/\Delta T_2)} \quad (4)$$

Evaluation of ΔT_1 and ΔT_2 depends on the heat exchanger type (Figure 4 and 5)

For both Parallel and Counter Flow Heat Exchanger

$T_{h,\ inlet} = T_{h1}$; $\qquad T_{c,\ inlet} = T_{c1}$

$T_{h,\ exit} = T_{h2}$; $\qquad T_{c,\ exit} = T_{c2}$

Hence,

$$\Delta T_1 = T_{h1} - T_{c1} \qquad \Delta T_2 = T_{h2} - T_{c2}$$

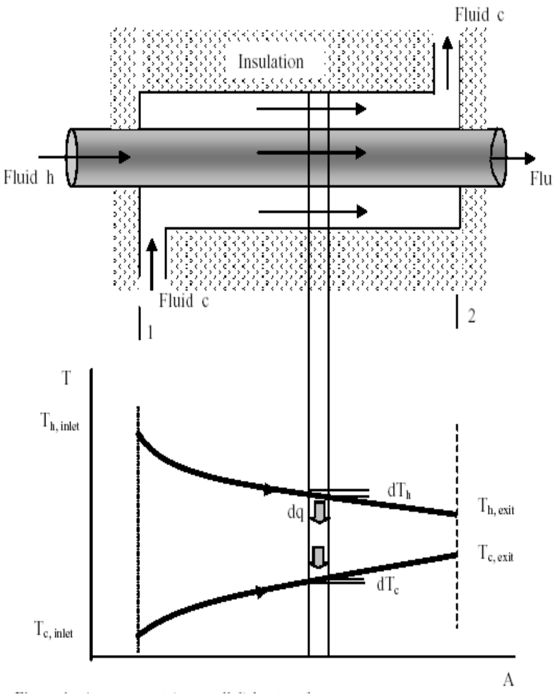

Fig. 4. A co-current heat exchanger

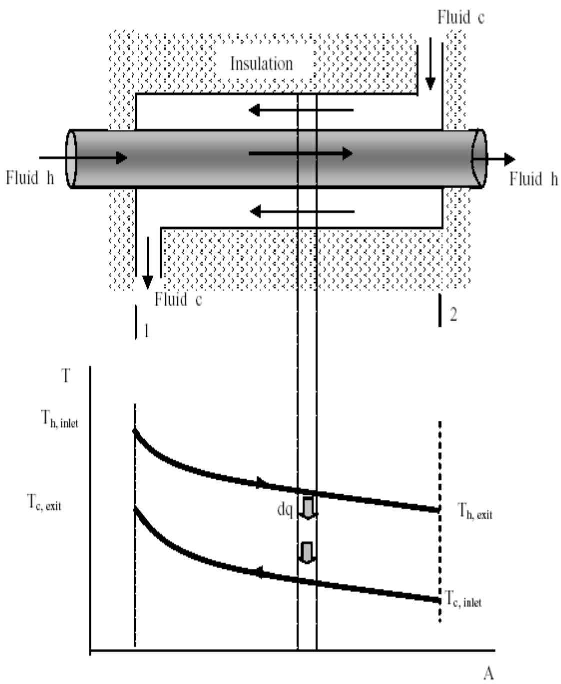

Fig. 5. A counter current heat exchanger

2.1 Heat Loss or Gain by the Milk and Temperature Values

In the first step, heat transferred from the heating medium to the cold fluid is determined using the specific heat equation for either fluid
For concurrent flow

$$Q_h = m_h C_{ph}(T_{h1} - T_{h2}) \quad (5a)$$

$$Q_c = m_c C_{pc}(T_{c1} - T_{c2}) \quad (5b)$$

For counter flow

$$Q_h = m_h C_{ph}(T_{h2} - T_{h1}) \quad (6a)$$

$$Q_c = m_c C_{pc}(T_{c2} - T_{c1}) \quad (6b)$$

In Eq. (5) and (6) Q_h is equal to Q_c because the heat lost by the heating medium is equal to the heat gained by the cold fluid. Let us designate this heat flow as Q. While calculating Q with a specific heat equation, we remain on either the hot or the cold fluid side. For this calculation, both inlet and outlet temperature values for one of the fluids are needed, which may likely be the case in size determination calculations. For example, for pasteurization of milk, both the temperature of raw milk at inlet and of the pasteurized milk at the outlet will be known. Thus, Q_c can be calculated. If pasteurization is performed using hot water entering the heat exchanger at a given temperature, the exit temperature of water can be calculated by using the equation for Q_h and equating it to the Q_c value. In summary, the above equations will yield heat flow and all four temperature values.

2.2 Determination of the Overall Heat Transfer Coefficient

For concentric tube heat exchanger, the inner and outer curved surface areas of the cylindrical tube are different. Its overall heat transfer coefficient is based upon the selected area value;

$$U_i A_i = U_o A_o = \frac{1}{R_t} = \frac{1}{\frac{1}{h_i A_i} + \frac{\ln\left(\frac{R_O}{R_i}\right)}{2\pi k L} + \frac{1}{h_O A_O}} \tag{7}$$

Both U_i and Uo will yield similar results in further calculations as long as the corresponding areas are used. Heat transfer coefficient calculation may require greatest amount of effort on a given application. The surface heat transfer coefficient (U) values in equation above depends upon the fluids thermal properties (Prandtl number) flow properties (Newtonian or non-Newtonian) nature, viscosity, power – law parameters etc.
Reynolds and Prandtl numbers are given by

$$Re = \frac{\Delta CP}{\mu} \tag{8}$$

$$\mathrm{Pr} = \frac{CP_{\mu}}{k} \tag{9}$$

The equations above indicate that the U value increases with increase in fluid velocity. Therefore, a high velocity during turbulence causes a significantly greater heat transfer.

2.3 Calculation of Long Mean Temperature Difference and Size of Heat Exchanger.

The temperature difference between hot and cold fluid is continuously changing, therefore, an effective difference needs to be calculated to determine heat flow through separating the two fluids. This effective temperature difference is termed as LMTD (ΔT_m).

$$\Delta T_m = \frac{\Delta T_1 - \Delta T_2}{\ln\left(\frac{\Delta T_1}{\Delta T_2}\right)} \tag{10}$$

where ln is the natural Log and ΔT_1 and ΔT_2 are the temperature differences between the hot and the cold fluids calculated at inlet and outlet.

The equation assumes that the specific heat (C_P) of the fluid does not vary with temperature and the heat transfer coefficients are constant along the length of the heat exchanger. The second assumption is more serious because the heat transfer coefficient of a fluid is a function of its viscosity, density, specific heats and thermal conductivity which changes continuously as a function of temperature.

Changing fluid properties cannot easily be accounted for by using simple design calculations and require more sophisticated computer based solution. Despite these assumptions, ΔTm based calculations are commonly performed for designing heat exchangers.
The heat transfer equation involving overall heat transfer coefficient (U) and ΔT_m is

$$Q = UA\,\Delta T_m. \tag{11}$$

Rearranging leads to the following expressions for the heat exchange surface area:

$$A = \frac{Q}{U \Delta T_m} \tag{12}$$

The size of a heat exchanger can be easily obtained by dividing the area with the inner cylinders circumference which yields the tube length needed for a concentric tube heat exchanger [12].

3. Working Principle of the Pasteurizer

The process flow design and the schematics are depicted in the figure 6 below in accordance with the literature requirement. All process requirement of pasteurization is sequentially represented.

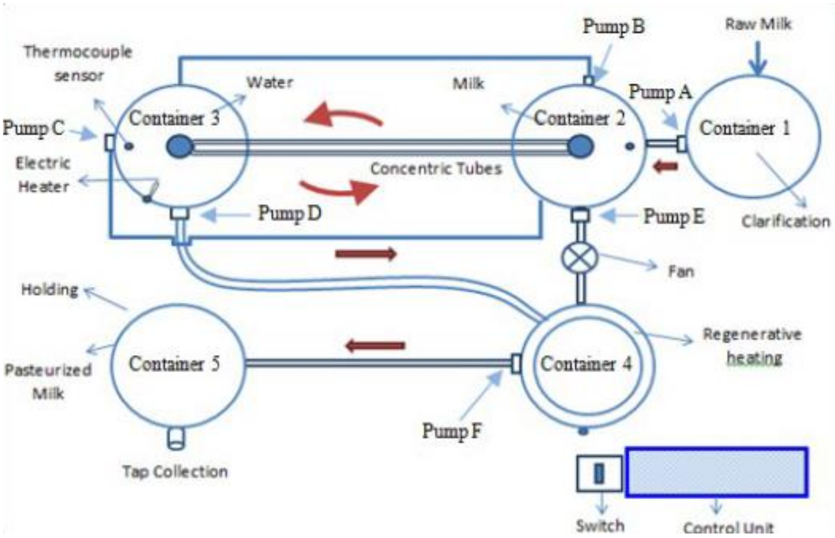

Fig. 6. Schematic of the process flow design

3.1 Components of the Pasteurizer and Specifications

The component of heat exchanger includes: Concentric tubes, pumps, Containers, Digital Temperature recorder, control panel, boiling ring, thermometer, rollers, ply-wood base and it frame and Sensors.

i- Water pump - The water pump selected is a single phase and has a constant torque. The design as calculated is safe for 0.5hp water pump.
ii- The concentric tube - This is simply where the heat exchange between the milk and water takes place. It is made of stainless-steel pipes of one within the other. It is 0.3 meters long.
iii- The containers - The containers are of equal sizes which are fabricated to contain 2 liters volume of milk or water at a time, except the 5th container which has additional surrounded jacket to contain water for regenerative heating.
iv- The switches - The switches are incorporated in the panel for the heater elements and each of the six water pumps.
v- The Digital Temperature recorder - The digital recorded is incorporated to ensure reading and control of the pasteurization. The pasteurization requires treatment of milk to 63ºC for 30 minutes. The operating pumps are them switched off.
vi- The boiling ring - The boiling ring water heater of 1000W power is selected because of its efficiency in water heating at a reduced time of the heating.

vii- The thermometer - The thermometer is to serve as a means of temperature confirmation in the containers, so as to ensure that pasteurization process is correctly going on.
viii-The ply-wood base and frame - The plywood is selected to provide a smooth base for all components. It is also a means of incorporating the frame. The size is (1.5 by 0.7) m.
ix- The rollers - The rollers are to serve as a means of providing movement from one place to another. The choice of rollers (about 6 of them) compared to other methods such as lifts or seating is to ensure ease of movement and eight of them to ensure good moving position in all turns or draws.

3.2 Design Calculations and Fabrication
3.2.1 Selection of electric heater and heating time

The aim of the process of pasteurization is to minimize time especially for the whole process to be completed in 30 minutes or less.

i. Highest Volume of liquid milk = 2 litres = $0.002m^3$
ii. Specific heat capacity of water = 4200J/kgK
iii. Density of water = $1000g/m^3$
iv. Required temperature range= $90^oC - 27^oC = 63^oC$
v. Voltage = 220volts
vi. Electric heater = 1000watts

$$Energy, E = MC\theta \tag{13}$$

where m = mass of substance (kg)
C = Specific heat capacity of substance
θ = Temperature required (^oC)

Also

$$Electrical\ Energy, = I^2Rt = IVt \tag{14}$$

where I = Current (amperes)
R = Resistance (Ω)
V = voltage (volts)
t = time (sec)

$$Volume, V = \frac{m}{\rho} \tag{15}$$

$m = v\rho$, where ρ = density of water

$$Electrical\ Energy = IVt$$

Put $Power = IV$

$$I = \frac{Power}{V}$$

3.2.2 Selection of pump power

Mean velocity $\mathcal{V}_m = 0.0572m/s$
Density of water $\rho = 1095g/m^3$
Density of milk $\rho = 1250g/m^3$
Diameter of pipe for water $D_1 = 0.009375m$
Diameter of pipe for milk $D_2 = 0.00625m$
Dynamic viscosity of water $\mu = 0.0009$
Dynamic viscosity of milk $\mu = 0.003$
Specific heat capacity of water = 4200 J/kgk
Specific heat capacity of milk = 3900 J/kgk
From;

Volume flow rate $\dot{v} = \mathcal{V}_m A$ (16)

Reynolds number $Re = \frac{\rho \mathcal{V} D}{\mu}$ (17)

To check friction between the fluid and the partition, we apply Corel Brook equation derived in equation.

$$\frac{1}{\sqrt{f}} = -2.0 \log\left(\frac{\frac{\varepsilon}{D}}{3.7}\right) \quad (18)$$

$$\Delta P = \Delta P_L = f \frac{L}{D} \frac{\rho v^2}{2g} \quad (19)$$

F
or major losses, $h_L = \frac{\Delta P_L}{\rho g}$

For minor loses, $h_L = K_L \frac{\mathcal{V}^2}{\rho g}$, where $K_L = \frac{\Delta P_L}{\frac{1}{2}\rho \mathcal{V}^2}$

Total head loss, $h_L = major + minor \approx 0.00002$

From

$$\dot{v} = \frac{3600 \times P}{\rho c \Delta T}$$

$$P = \frac{\dot{v} \rho c \Delta T}{3600} \quad (20)$$

$= 0.4hp$

However, the nearest standard rating of 0.5hp pump was selected [13]

3.3 Estimation of the Thickness of Stainless Steel Material

Consider the sketch (Figure 7)

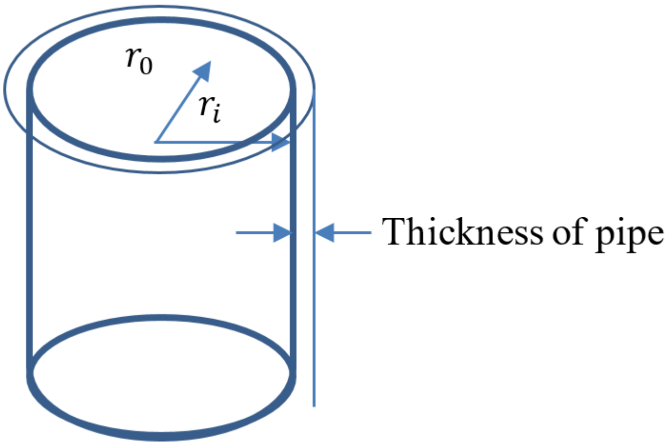

Fig. 7. Depiction of pipe parameters

Data

T_i = maximum possible temperature of hot water = 90°C
t_m = Thickness of the material (stainless steel) = x=?
k_m = Thermal conductivity of stainless steel (316) = 16.2w/mk [14]
T_o= Minimum possible temperature of hot water to be used = 80°C
hs_∞= Surface heat transfer coefficient of stainless steel = 16.2w/m^2
V = Volume of milk to be used= 2litres = 0.002m^3
L = Length of pipe to be used = 0.3 meters
r_i = 0.046875m
r_0 = 0.046785 + x
Q_r = Estimated heat transfer rate = 1000W

from

$$Q_r = \frac{2\pi l k_m (T_0 - T_i)}{\ln\left(\frac{r_0}{r_i}\right)} \approx 2mm$$

The specifications and working parameters used for thermal calculations of the heat exchanger are as follows

i. Thermal conductivity of stainless steel tube = 60W/m^{2}k
ii. Specific heat of the milk Cp_c = 3900J/kgK
iii. Specific heat of water Cp_w = 4200J/KgK
iv. Heat Transfer Coefficient on the milk side = 500 W/m^{2}k
v. Heat Transfer Coefficient on the water side = 900 W/m^{2}k
vi. Mass flow rate of milk $\dot{m}_c$ = 0.0022Kg/s
vii. Mass flow rate of water $\dot{m}_c$ = 0.0043Kg/s

The container 1 (Figure 8) is filled up with 2 litres of raw milk which passes through a wire mesh for filtration and clarification. Pump 1 will then be switch on to draw the raw milk to container 2 where it is ready for pasteurization process. Container 3 is then filled with 2 litres of water where it will be heated to the required temperature. With pump 2 on and the ball valve opened, to the heated water is recycled from the container and back to the container through it path for the heat exchange. With pump 3 and it ball valve also opened, the raw milk is recycled from the container back to the container through it path for the heat exchange. The digital temperature reading of the pasteurization process will be noted and the system is switched off when it is 63^{o}C milk temperature before it is been hold for 30 minutes. The water temperature after pasteurization at 63^{o}C is then confirmed with the aid of thermometer. Pump 4 is switched on to draw milk pass the cooling fan for cooling to the regenerating heat container. Pump 5 is also switched on to draw hot water to the regenerating heat container for the 5 minutes regenerative heating. Pump 6 is switched on to draw milk from the regenerating heat container to the holding container, where it is held for another period of 8 minutes. The pasteurized milk is then collected through the tap attached to the holding container. Final samples of milk at 63^{o}C pasteurization milk temperature for 84^{o}C, 86^{o}C, 88^{o}C, 90^{o}C, and 92^{o}C water temperatures are collected.

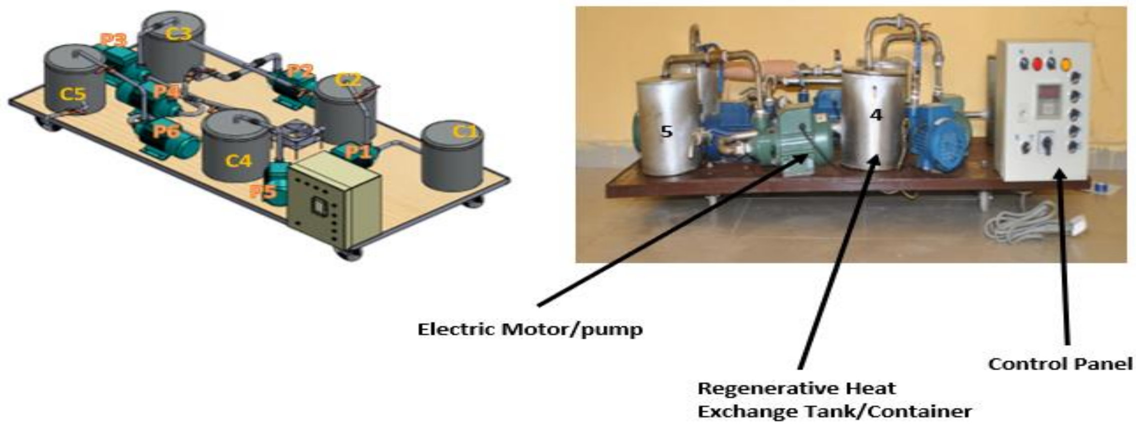

Fig. 8. Isometric view and the fabricated pasteurizer

The containers can be removed for cleaning through the union connectors. Detergent is passed through the concentric tube chambers continuously over a long period of time and water is then passed to ensure cleaning is correctly done. The pumps can also be removed through the unions when repair is required. All joints, unions and all components should be handled with care to ensure safety of the system.

3.4 Maintenance and Safety

i. The containers can be removed for cleaning through the union connectors.
ii. Detergent is passed through the concentric tube chambers continuously over a long period of time and water is then passed to ensure cleaning is correctly done.
iii. The pumps can also be removed through the unions when repair is required.
iv. All joints, unions and all components should be handled with care to ensure safety of the system.

Table 1

Thermodynamic Property Analysis of Experimental Calculations

S/No	Parameters/length	Water / Milk	0.1	0.15	0.2	0.25	0.3
1	Coeff. of Heat Transfer	Water /Milk side	1.411	2.116	3.712	3.981	4.2319
2	Fouling factor	Water/Milk side	0.7087	0.4725	0.2694	0.2512	0.2363

Table 2
Thermal Analysis of Experimental Heat Transfer

S/N	Parameter/temperature	84	86	88	90	92
1	Water Temperature at t_{h2}°C	66.9	69.9	70.9	72.9	74.9
2	No. of cycles per minute	21	22	23	29	47
3	Effectiveness	0.63	0.61	0.59	0.57	0.55

4. Results and Discussion of the Heat Exchanger Analysis

From the graph in Figure 9, it shows that as the initial hot water required for an experiment is increased so also the remaining temperature of water increases at the end of experiment. It is a measure of uniform heat transfer provided by the service media to the milk. The temperatures obtained were 66.9°C, 69.9°C, 70.9°C, 72.9°C and 74.9°C at 84°C, 86°C, 88°C, 90°C and 92°C experiments respectively. As water temperatures after experiment increases, it demonstrates poor homogeneity of heat transfer depicting that milk properties are better safe at 88°C and 70.9°C initial and final water temperatures of experiment.

As shown in Figure in 10, the number of cycles/minute obtained by the experiment for the heat transfer increases as the initial temperature of hot water used for the experiment increases from 84°C, 86°C, 88°C,90°C and 92°C. This implies that temperature also determines the number of cycles/minute to be obtained for a heat transfer in cycle pasteurization. In this case, the thermal analysis for 2 litres of raw milk at hot water temperature at 84°C, 21 cycles/minute was obtained while at 92°C, 47 cycles/minute was obtained to complete heat transfer to milk at 63°C in each case. This result implies that the time of experiment in faster with increase in temperature which at a stage potent danger to the required pasteurization process. If the time of the experiment is excessively fast, the tendencies that some portion of the milk will be overheated while other portion will not have sufficient heat i.e. non-homogeneity of heat transfer is certain. Thus, it means that the probability of excessive fouling will occur. The graph in the figure clearly shows that experiment at 88°C provides the better heat transfer of pasteurization process as it is from 88°C experiment that number of cycles/number rapidly increases.

The required effectiveness of heat transfer in pasteurization process is 0.6 which provide a medium for saving its composited properties. The Figure 11 shows that as initial water temperature of experiment increases, the effectiveness of heat transfer decreases. Essentially what this means is that even if the number of cycles/minute increases very fast, the effectiveness of heat transfer decreases. Thus, the milk may not be pasteurized as needed after all. Therefore, the experiment which was carried out at 88°C where 0.59 effectiveness was obtained provided better pasteurization experiment.

These parameter is the proportionality coefficient between the heat flux and it driving forces as heat is been transferred between service media and the product. It is essential that this coefficient is administered in such away as not to destroy the nutritive value or keeping the nutritive values intact for consumption. As depicted in Figure 12, the coefficient of heat transfer representing both of water and milk side shows that at hydrodynamic entrance region, the milk gain heat so that it's density and viscosity is reduced for efficient heat transfer, these coefficient of heat transfer increases rapidly and up to a time, that the viscosity and density will heavily stretched. The coefficient of heat transfer is then reduced through the remaining number of cycles/minute of the experiment to keep the milk's nutritive values safe for consumption.

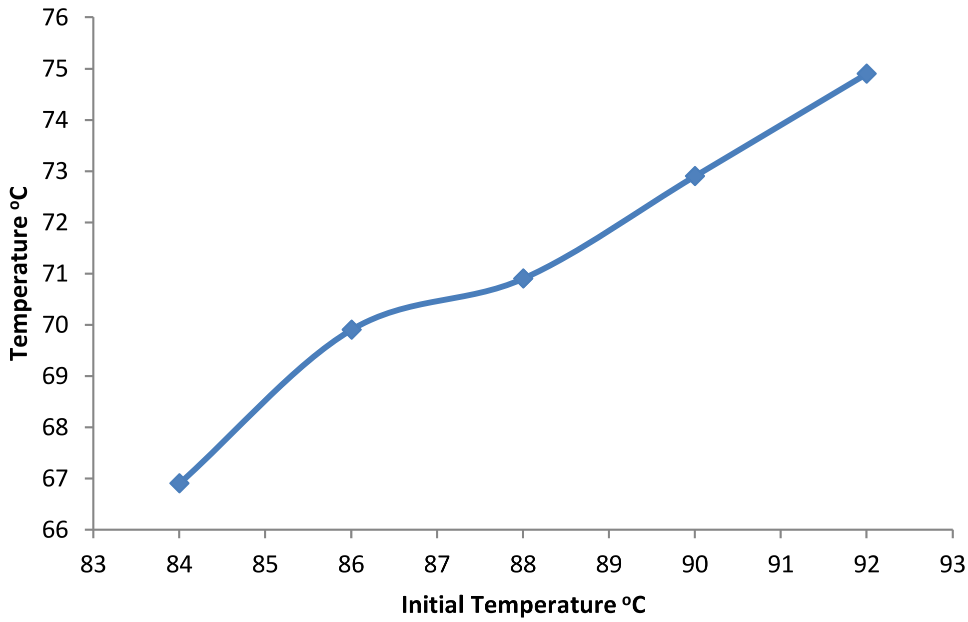

Fig. 9. Water temperatures at the end of the experiment against initial temperatures

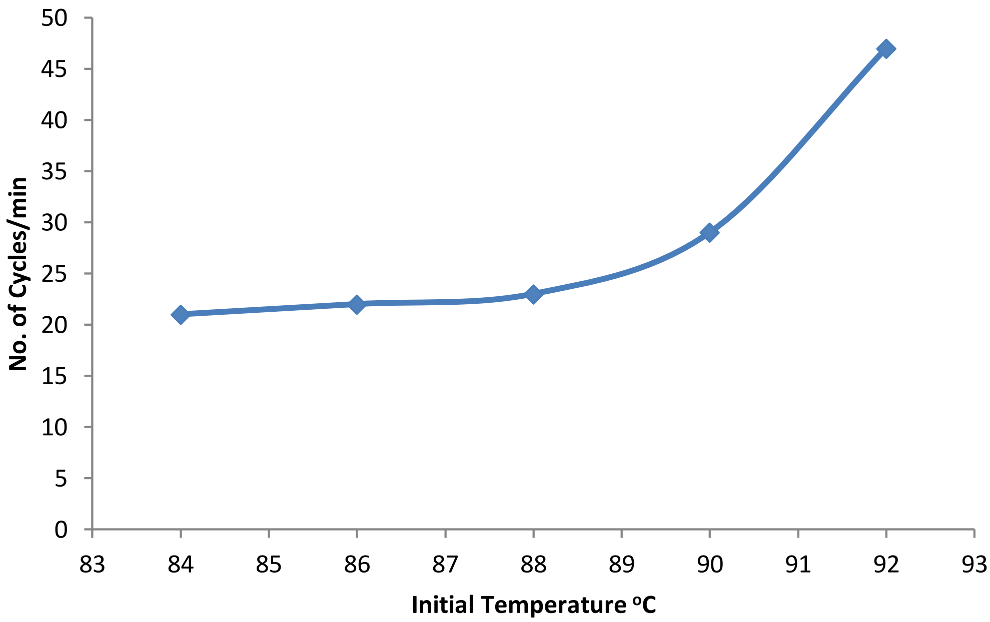

Fig. 10. No. of Cycles/Minute against Initial Temperature.

The fouling factor represents resistance to heat flow or transfer due to build up large amount of dirt or other factors. As shown in Figure 13, at the hydrodynamic entrance region, the fouling drops rapidly because at that time the density and viscosity of the liquids are still high and as such, the tendency for fouling is high. When the viscosity and density is essentially stretched, the fouling factor then reduced gradually through remaining number of cycles/minute of the experiment. The essence is to keep the milk nutritive values and the heat exchanger cleaned at the beginning and at the end of cycles/minute of the experiment and hence, better heat transfer.

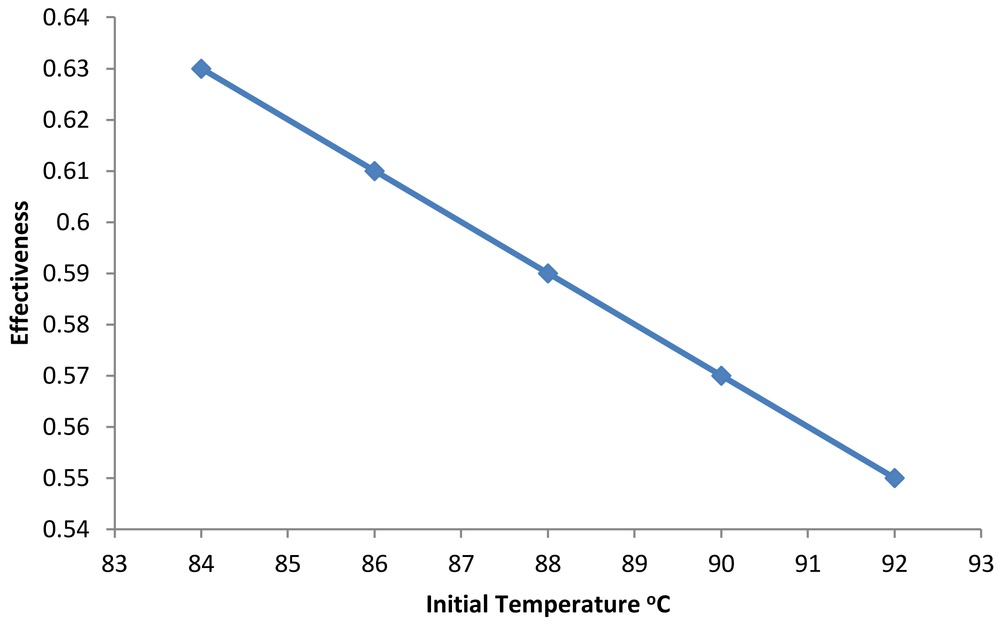

Fig. 11. Effectiveness value against initial water temperature

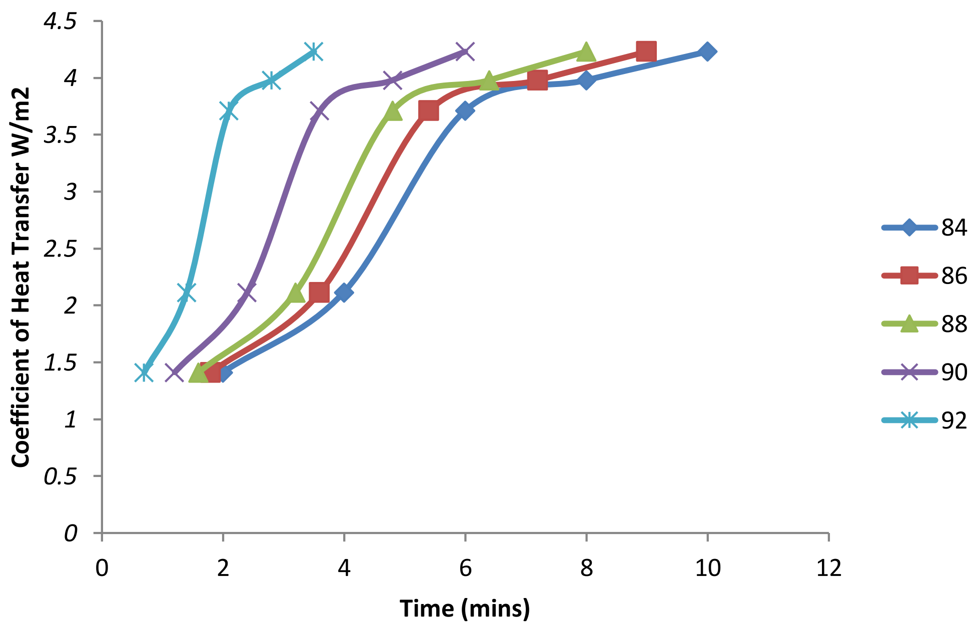

Fig. 12. Coefficient of heat transfer against time for water /milk side

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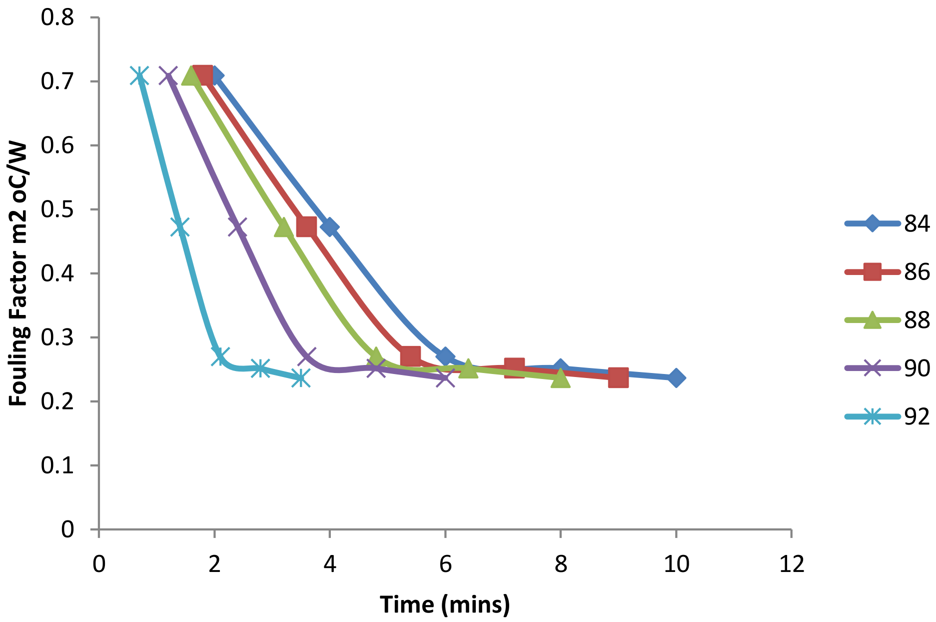

Fig. 13. Fouling factor for water /milk side

5. Conclusion

Recycled heat transfer over short tube concentric tube was modeled and designed to solve the problem of portability, micro-scale production and cost effectiveness, and has demonstrated to be appreciably efficient with tremendous thermodynamic properties and performance evaluation based on experimental results. Thus, cycle pasteurization technique used to pasteurized two litres of raw milk is a giant step for enhancement of technology with a view to providing accessibility of pasteurized milk and enhancing hygienic consumption of milk by homes, thereby leading to the elimination of zoonotic diseases. Overall, the results obtained indicated that the milk values of nutrients will not be destroyed at the beginning and towards the end of the experiments where high heat transfer coefficient poses the danger of losing them. This is the significance of figrecycling in pasteurization heat transfer process. Fouling of the milk was avoided due to recycling which prevent the milk from sticking or forming scum to the surrounding walls of the heat exchanger which demonstrated that fouling was reduced to the barest minimum towards the end of cycles per minute to have longer time of production cycle before cleaning.

Thus, it is concluded based on the findings of this study on cycle pasteurization system that

i. The uniform turbulence flow of the milk in the system had been realized and fouling of the milk to form scum is eliminated without stirring the system.
ii. The recycled heat transfer system has been able to redefine essential parameters at critical intervals of cycles/minute between the hydrodynamic entrance region, and when density and viscosity is stretched to keep the composition of the milk safe for consumption.
iii. The design has the advantage of temperature selection to soot a particular kind of need or if affected by environmental conditions.
iv. The effectiveness of the heat exchanger was thermally calculated as 0.59 which represent 98.3% efficiency of the system.

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