www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(8): 99-102

www.thepharmajournal.com
Received: 02-06-2022
Accepted: 07-07-2022

Bhagat PN
Dairy Engineering Division, Karnal, ICAR-National Dairy Research Institute, Karnal, Haryana, India

Barnwal P
Dairy Engineering Division, Karnal, ICAR-National Dairy Research Institute, Karnal, Haryana, India

Deep A
Dairy Engineering Division, Karnal, ICAR-National Dairy Research Institute, Karnal, Haryana, India

Ranveer SA
Dairy Microbiology Division, Karnal, ICAR-National Dairy Research Institute, Karnal, Haryana, India

Chavhan BB
Dairy Engineering Division, Karnal, ICAR-National Dairy Research Institute, Karnal, Haryana, India

Manoj KN
Dairy Engineering Division, Karnal, ICAR-National Dairy Research Institute, Karnal, Haryana, India

Corresponding Author
Bhagat PN
Dairy Engineering Division, Karnal, ICAR-National Dairy Research Institute, Karnal, Haryana, India

Determination of hold up volume for three stage scraped surface heat exchanger

Bhagat PN, Barnwal P, Deep A, Ranveer SA, Chavhan BB and Manoj KN

Abstract
Scraped Surface Heat Exchangers (SSHE) are widely used industrially for the processing of food products with high viscosity, However, their complex geometry and the presence of seals for the rotating shaft, the food product entry and exit as well as the blade shaft connections make cleaning difficult. The fluid is subjected to a high friction force inside the SSHE itself due to the mixing provided by the scraping blades, inducing fluid stagnation, due to the weakness of flow dynamics in closed areas. The experiments were conducted to determine the hold-up volume for TSSSHE at fixed parameters i.e. steam pressure, flow rate and scrapper speed for water as a process fluid. It was found as 5 to 10 litres for operating parameter range (scrapper speed 200, 175, 40 rpm; flow rates 350 to 528 kg/h and steam pressures 3.5, 2.5 and 1 kgf/cm^2 for first, second and third stage respectively).

Keywords: SSHE, volume, heat transfer, khoa

1. Introduction

A scraped surface heat exchanger (SSHE) is a device that comprises of a cylindrical rotor and stator in an annular gap. Scraping is the act of removing fluid from a surface. This improves heat transport by rupturing the thermal and hydrodynamic boundary layers at the surface. High-viscous fluids are specifically thermally treated using SSHEs. SSHE is frequently used in the food industry to sterilise or cool very viscous fluids including ice cream, peanut butter, mayonnaise, and cream cheese. Due to the highly viscous nature of the treated fluids in SSHE, fouling issues could arise and severely lower the thermal efficiency of SSHE. By having moving blades in the annulus, it is feasible to prevent the potential fouling issue on the heat exchanger surface and enhance the product's heat transfer treatment. SSHE could be very effectively used for continuous manufacture of Indigenous milk products [1]. The rate of the fluid entering the exchanger, revolution velocity of the rotor shape, numbers of the blade and mechanism of applying flux (fixed of variable to the exchanger are the factors of their heat transfer aspects investigated). SSHE design has been improved to enhance their specific application, whether for use as heat transfer units, crystallizers, and chemical reactors [2].

1.1 Application of scraped surface heat exchangers

Products are processed in jacketed compartments or containers in the dairy and food industries to highlight issues with the design and management of heat exchangers [3]. (SSHE) are typically used in mechanical settings that involve continuous boiling of liquids and solids that resemble liquids. These are designed to handle the problems that arise while handling really sticky materials. For the mechanical preparation of particularly viscous food products, SSHE are widely used. However, due to their complex design, close proximity to seals for rotating the shaft, sustenance item entry and departure, and sharp shaft connections, cleaning is difficult [4]. The sharp blades have two functions: (a) they lightly scrape the stator's inner surface, and (b) they increase the liquid's speed and create turbulence to boost heat exchange rates [5]. The heating surface of the apparatus is continually scraped in the scrapped surface heat exchanger. By using this method, the slow-moving product layer near the heating surface that hinders heat transmission is swiftly eliminated and blended with the liquid bulk. The scraping is simultaneously accomplished by a series of moving blades. Due to the turbulence, they produce and the liquid they push into the system, blade motion improves heat and mass transmission. The horizontal arrangement can be adopted to increase the rate of heat transfer from condensing steam. The semi-continuous *Khoa* manufacturing system [6] was developed by Banerjee *et al.* in 1968 and has since undergone various modifications. The equipment consists of an SSHE for pre-concentrating milk and an open semi-jacketed container with spring-loaded scrubbers for continuous *Khoa* production. The milk in this machine, which has a total solids content of 12–13%, was warmed, taken in SSHE to a solids content of 30-35%, and then further heated and concentrated to a final solids content of 50–55%. The heating surface of the apparatus is continually scraped in the scrapped surface heat exchanger. By using this method, the slow-moving product layer near the heating surface that hinders heat transmission is swiftly eliminated and blended with the liquid bulk. As the scraper rotates, the bulk product is thus brought into touch with the equipment's surface. The scraping is simultaneously accomplished by a series of spinning blades. Due to the turbulence, they produce and the liquid they push into the system, blade motion improves heat and mass transmission. The horizontal arrangement can be adopted to increase the rate of heat transfer from condensing steam. The equipment consists of an SSHE for pre-concentrating milk and an open semi-jacketed container with spring-loaded scrubbers for continuous *Khoa* production. The milk in this machine, which has a total solids content of 12–13%, was warmed, taken in SSHE to a solids content of 30-35%, and then further heated and concentrated to a final solids content of 50–55%. The results showed that maintaining a heating temperature of 121°C and a scraper speed of 28 rpm is the ideal operating environment for milk evaporation. Items that are sticky, include particles, and have a propensity to frame and store films on the heat exchange surface are handled by SSHE. For the food processing industry in particular, operational flexibility makes SSHE desirable [7]. SSHE are turbulent film heat exchangers that are mechanically supported. The versatility of an SSHE also resides in the use of diverse heat exchange media, such as water, salt water, steam, Freon, and alkali, for the materials that need incredibly unique treatment, such as blending, emulsification, and whipping.

1.2 Some of the distinctive performance parameters of SSHE include

The materials stays in the hot area for a few seconds precisely. Therefore, it makes sense to use this type of heat exchanger when working with heat-sensitive materials. There is a high rate of heat transfer and heat fluxes because of the product's thin layer and the turbulence the rotor produces. As a result, very viscous material that tends to scale may be processed easily. Less negative reactions and product degradation occur with a shorter residence time, increasing yield. The hold-up volume is very tiny compared to batch processing, when the loss would be complete, because the product is limited and a thin coating on the heating surface tends to minimise loss due to spoiling inside the heat exchanger. The device can handle even semi-solid products without heating them up. Outflow to inlet viscosity ratios of 1000 or more are possible. The majority of automated cleaning systems can use it. Working in an entirely contained space guarantees the cleanliness of the operation Operators of machines face little physical strain. A modest number of valves simply need to be opened or closed. Product quality is constant because of the on-going production process. Process zone product performance is subpar. After processing is finished, top-to-bottom splits may reach a maximum of 99:1. There is very little pressure loss. The capacity to decline is also highly regarded. Hardly any surface fouling liquids with a propensity to foam can be handled easily. It is better to control and enhance the process.

1.3 Investigations of heat transfer in SSHE

SSHE are typically employed with products that have a viscous consistency. Thin film operation is utilised for evaporation, when process liquid travels as a thin film along the heat transfer surface. The best benefits of SSHE are for heating or cooling, specifically the continuous removal of the hard film near to the wall and the resulting increase in heat transfer coefficients and decrease in fouling at the wall. The mechanisms of heat transmission occurring in SSHE during evaporation were also investigated.
A study focused on the primary element that [8] came to the conclusion that heat transfer happens by conduction over the vapour films along with evaporation of the more volatile element at the film's surface. Gravity and peripheral forces are the main rotation-induced forces acting on the fluid film during evaporation in the SSHE.
By using a two-bladed rotator of the SSHE type and the penetration theory, [9] arrived at an empirical connection for the Nusselt number with the restriction of heat transfer on the viscosity and velocity of liquid through the exchanger.

$$Nu = 1.6\, Re^{0.5}(Pr)^{0.5} \quad (1.0)$$

In their directed evaporation studies, [10] demonstrated that the scraped heat transfer heat transfer coefficient declined as T increased at constant rotor speed, low flow rate, and higher T estimation. The relationship that goes along with it was seen.

$$h_s = 437\ (N)^{0.33}\ \rho K/\mu \quad (1.1)$$

The dimensional analysis to establish empirical correlations for heat transfer coefficients in the late 1950s and early 1960s. These correlations were then modified by adding variables like the effect of rotation, the number of blades, and physical characteristics in the regime between fully turbulent flow and laminar flow.

$$Nu = 4.9\ (Re)^{1.0}\ (\mathrm{Pr})^{0.96}(DNr/Vz)^{0.62}(Ds/s)^{0.55}(B)^{0.53} \quad (1.2)$$

In a thin film evaporator with a variety of fixed clearance blades [11] investigated the relationship between blade clearance and heat transfer. The experiment showed that when clearance was doubled, the heat exchange coefficient decreased by 20% and increased by 20% when clearance was reduced by 80%.

2. Material and Methods

2.1 Procedure Conducted for Holdup Volume

Procedure followed for determination of the holdup volume
First upon all the parameters of SSHE were fixed i.e. steam pressure, flow rate. Then the feed pump was kept at the high flow rate (528kg/h). After that the Initial height of the balance tank was noted (H_i). When the water started to come from the outlet of TSSSHE the final height of balance tank was noted (H_f). Put the level difference i. e. Initial and final reading in the formula which is given below.

$$V = \frac{\pi\, d^2 \times (H_i - H_f)}{4} \quad (2.1)$$

$$= \frac{\pi \times (69.075)^2 \times (24 - 11.75)}{4}$$

(V) = 45906 cm^3

Calculated hold up volume V = 45.906 lit

$$Volumetric\ flow\ rate = \frac{volume}{(T_f - T_i)} \quad (2.2)$$

$$= \frac{45.906}{(5-0)}$$

$$= 9.1812\ lit/min$$

The water holding or hold up properties of the SSHE was calculated by the Balance tank of TSSSHE and plastic crate. The dimension of both utensils is given in Table 1.1.

Table 1: Dimension for Crate and Balance tank

Dimensions (cm)	Crate	Balance Tank
Length (cm)	60	-
Height (cm)	30	75
Width (cm)	39.2	-
Diameter (cm)	69.075	69.075
Volume (cm^3)	70560	280303.875

3. Results and Discussion

For modelling the design, certain experiments trials were conducted to analyse the hold-up volume for TSSSHE by holding the required fixed parameters which includes steam pressure, flow rate and scrapper speed. The combination of the parameters of flow rate ranging from 350 to 528 kg/hr, Steam Pressure in first stage was ranged from 3.5, second stage steam pressure 2.5 and third stage was 1 kgf/cm^2 along with the scraper speed 200, 175 and 40 RPM respectively with replication. The fixed parameters (Table 1.2) were determined on the basis of conducted experimental trials which during the study.

3.1 Fixed Parameters SSHE

Table 2: Fixed Parameters for SSHE kept during holdup volume studies

SSHE stages	Steam Pressure (kg/cm^2)	Scraper Speed (RPM)
First stage	3.5	200
Second stage	2.5	175
Third stage	1.0	40

Table 3: Variable Table: Variable observation for hold up volume for TSSSHE

#	Flow Rate	Steam Pressure __ Stage			Scraper Speed __ Stage			Replication	Time taken		Balance Tank level		Temperature		Crate height	
		I^{st}	II^{nd}	III^{rd}	I^{st}	II^{nd}	III^{rd}		T_i	T_f	H_i	H_f	Inlet	Outlet	H_i	H_f
Units→	(kg/hr)	kgf/cm^2	kgf/cm^2	kgf/cm^2	RPM	RPM	RPM		s	s	cm	cm	°C	°C	cm	cm
1	350	3.5	2.5	1.0	200	175	40	1	0	5	64	57	30	83	0	3.5
2	350	3.5	2.5	1.0	200	175	40	2	0	5	53	46	30	82.4	0	3.6
3	450	3.5	2.5	1.0	200	175	40	1	0	5	69	58	30	84	0	8.6
4	450	3.5	2.5	1.0	200	175	40	2	0	5	53	43.5	30	86	0	8.5
5	528	3.5	2.5	1.0	200	175	40	1	0	5	32	19.5	30	84	0	11
6	528	3.4	2.5	1.0	200	175	40	2	0	5	16	4	30	84	0	11.4

Where,
H_i -Initial height of balance tank
H_f- Final height of balance tank
T_i -Initial time taken
T_f- Final time taken

Table 4: Hold up volume calculation

Total Volume			Volumetric Flow Rate		
Inlet	Outlet	Evaporated	Inlet	Outlet	Evaporated
l	l	l	l/min	l/min	l/min
26.23	8.16	18.06	5.24	1.63	3.61
26.23	8.39	17.83	5.24	1.67	3.56
26.23	8.28	17.95	5.24	1.65	3.59
41.22	20.05	21.16	8.24	4.01	4.23
35.60	19.82	15.77	7.12	3.96	3.15
38.41	19.94	18.46	7.68	3.98	3.69
46.84	25.65	21.18	9.36	5.13	4.23
44.96	26.58	18.37	8.99	5.31	3.67
45.90	26.12	19.78	9.18	5.22	3.95

4. Conclusion

In dairy Industry, scraped surface heat exchangers (SSHE) are widely used in the industrial settings where the continuous processing of fluids and fluid-like materials are involved. Scraped surface heat exchanger (SSHE) is one of the equipment where high heat transfer rates at high temperature, pressure and flow rate of product co-exist during processing operations/conditions. Calculated hold up volume for TSSSHE was 45.883 at the volumetric flow rate 9.1812 l/min litres by keeping the parameters fixed i.e. scraper speed 200 rpm, flow rate 528 kg/h and steam pressure utilized was higher value for first stage followed by lowest value for third stage and subsequently intermediate value for second stage respectively.

5. References

1. Abhichandani H. Heat transfer correlation for mechanically formed thin film heat exchanger. Ph.D. Thesis, Kurukshetra University, Kurukshetra, Haryana, 1985.
2. Harrod M. Scraped surface heat exchangers: A literature survey of flow patterns, mixing effects, residence time distribution, heat transfer, and power requirements. Journal of Food Process Engineering. 1986;9:1-62.
3. Timperley DA, Smeuders CNM. Cleaning of dairy HTST plate heat exchangers: Optimization of the single- stage procedure. International journal of Dairy Technology. 1988;41(1):4-7.
4. Blel W. Cleanability study of a Scraped Surface Heat Exchanger. Food and Bio products processing. 2013;91:95-102.
5. D'Addio, Carotenuto C, Di Natale F, Nigro R. A new arrangement of blades in scraped surface heat exchangers for food pastes. Journal of Food Engineering. 2012;108(1):143-149.
6. Banerjee AK, Verma IS, Bagchi B. Pilot plant for continuous manufacture of *khoa*. Indian Dairyman. 1968;20:81-86.
7. Darlington R. Heat transfer and heat exchangers [in the

food industry].Food Manufacture. 1972;47:33-34.
8. Kramers H, Van Cappelle AET, Van DE Schraff. De Ingenieur. 1955;8:9.
9. Lateinen GA. Discussion of correlation of scraped film heat transfer in the rotator. Chem Eng. Sci. 1958;9:263.
10. Kirschbaum E, Dieter K. Heat Transfer and Partial Distillation in Thin-Layer Evaporators. Chemie-Ingenieur Technik, 1958;(11):715-720.
11. Reay WH. Recent advances in thin film evaporators. Chemistry and Industry. 1963;39:293-297.