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DESIGN OF A VACUUM SAUCE FILLING MACHINE FOR A FISH CANNING MANUFACTURING

Tanawat Maneesri, Paisan Kittisupakorn
Department of Chemical Engineering, Faculty of Engineering
Chulalongkorn University
Bangkok, Thailand

***Abstract*—A food canning is needed highly for the market, it is fish canning. Fish canning is a food process that produces the canned foods from some fish (e.g. tuna, mackerel, and sardines). Inspecting a canned foods factory found that sauce filling is a step of fish canning process that makes a lot of quantities of sauce loss. In-line gravity sauce filling equipment is used to filling sauce into cans with sardines. This type of sauce filler causes fluctuation of sauce flow rate into cans, which leads to the possibility of sauce overflow and deficit. This work focused on design a vacuum sauce filling machine for a fish canning manufacturing. Therefore, this work introduces an approach to reduce the quantities of sauce loss and increase the productivity of fish canning by using a vacuum sauce filling machine instead of the in-line gravity sauce filling equipment.**

***Index Terms*—filling, filling machine, fish canning, vacuum, sauce.**

I. INTRODUCTION

Canned foods affect currently lifestyle because having low price, various kinds, can be bought at any stores, convenient to carry and can be kept for a long time. As above, canned foods can respond to consumer demands nicely. Food canning is a food processing which produces canned food from some crops, some aquatic animals and some cooked foods. A food canning is needed highly for the market is fish canning [1], such as canned tuna, canned mackerel, and canned sardines. Therefore, fish canning factories were established in several areas of Thailand. Since the raw materials in fish canning are expensive, the production costs are increasing. The inefficient fish canning process causes sauce loss in the sauce filling step which will make the budgets highly and less profit. Therefore, the quantities of sauce loss in the filling step must be reduced. The inspection of a fish canning factory in Thailand found that the filling step using an in-line gravity sauce filling machine to fill sauce into cans with sardines and the sauce level in storage tank is not controlled. This filling method causes some cans are incompletely filled or overfilled, and consequently sauce is manually added or removed from the cans by using tablespoons. The filling method makes a lot of quantities of sauce loss which makes more loss of budget. Therefore, reducing quantities of sauce loss is required.

Liquid filling system has been developed by several researchers. A vacuum syrup filling machine that can positioning cans to expose their open ends to a filling head without enclosing them into a chamber, and while under automatic valve control the cans are vacuumized, filled and discharged as uniformly liquid filled cans [2]. An apparatus for metering and introducing a liquid into packaging containers has a liquid-introducing heads which are connect to a supply container via a distributor [3]. An apparatus for the simultaneous filling of precise quantities of viscous liquid material to a plurality of containers in a sanitary environment [4].

The purpose of this work is to improve the efficiency of the filling sauce system by design a vacuum sauce filling machine to minimize the quantity of sauce loss in the process and washing-up liquid in cleaning step.

II. FISH CANNING MANUFACTURING

Some standard manufacturing process of fish canning, for instance, fish preparation, canning, retorting and packaging. However, sardine canning and tuna canning have some different between them. For this work, only sardine canning process will be discussed. The sardine canning process, shown in Fig. 1, includes receiving, cutting, washing, can filling and pre-cooking, sauce filling, seaming, retorting and packaging [5]. In the sauce filling step, sauce can either be tomato sauce, tomato sauce with chili, brine, or oil.

Sauce is prepared in the sauce kettles previous to sauce filling. All ingredients are mixed and cooked for 1.5 to 2 hours at around 70 °C. Cooked sauce is pumped into the storage tank which is mounted on the top of the in-line gravity sauce filling machine. Sauce flows into cans with sardines in vertical by gravity force. Some of sauce falls to the bottom tank, and then they are returned to the storage tank via pump. Cans with sardines may be incompletely filled or overfilled, so manually removed or added into cans by using tablespoons are required. Moreover, the headspace of each can should have at least 6 mm to prevent bulging of seamed can due to overfilling.

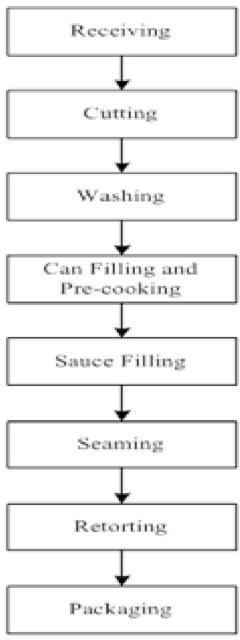

Fig. 1. **Sardine canning process flow diagram.**

III. Mathematical Models

There are mathematical models are used to solve the problems in the application of fluid mechanics. The most useful models are based on the principles of mass balance or continuity, the momentum balance, and the mechanical energy balance [6]. The efflux time of liquid drainage of large open storage tanks can be predicted by the derived models, which are based on principles of mass balance, and energy balance [7].

The mass balance equation for an incompressible fluid in the tank flows out the pipe [1] can be written as:

$$\frac{dV}{dt} = Q_{in} - Q_{out} = v_a A_a - v_b A_b \qquad (1)$$

Where V is the volume of the liquid in the tank, Q_{in} is the volumetric flow rate of the liquid flows into the tank, Q_{out} is the volumetric flow rate of the liquid flows out of the tank, v_a is the velocity of the liquid in the tank, v_b is the velocity of the liquid in the pipe, A_a is the cross-sectional area of the tank, and A_b is the cross-sectional area of the pipe.

The Bernoulli equation is a useful equation that describes the energy conservation in a flowing fluid. The equation is obtained from deriving the equation of motion. The Bernoulli equation states the sum of the flow, kinetic, and potential energies of a fluid particle along a streamline is constant [8]. At any two points on the same streamline, The Bernoulli equation can be written in the head form as:

$$\frac{P_a}{\rho g} + \frac{v_a^2}{2g} + Z_a = \frac{P_b}{\rho g} + \frac{v_b^2}{2g} + Z_b \qquad (2)$$

Where P is the pressure, v is the velocity of the liquid, Z is the elevation from a chosen datum, ρ is the density of the liquid, and g is the gravitational acceleration. The three terms on each side of this equation are pressure head, velocity head, and elevation head, respectively. a refers to the point at the top of fluid head, and b refers to the point at the outlet of the pipe.

A. Model of the Gravity Sauce Filling

The surveyed canned food factory uses gravity sauce filling in the sardines canning. Sauce was contained in the storage tank of the sauce filler, and then it flows out of the tank into the cans with sardines. The storage tank of the sauce filler is shown in Fig. 2. The dynamic model [9] of the gravity sauce filling is based on the following hypotheses.

- The physical properties of liquid are constant.
- The liquid flow is unidirectional.
- Pipe is smooth, Friction loss are neglected.

According to the above hypotheses, the dynamic model can be written as:

$$\frac{dh}{dt} = \frac{1}{A}(-Q) \qquad (3)$$

From the mass balance and the Bernoulli equation,

$$Q = A_{out}\sqrt{2gh} \qquad (5)$$

Where $h(t)$ = the level of the sauce in the tank (m)

$Q(t)$ = the flow rate of the sauce at the outlet (m^3/s)

A = the cross-sectional area of the tank (m^2)

A_{out} = the cross-sectional area of the outlet (m^2)

g = the gravitational acceleration (m/s^2)

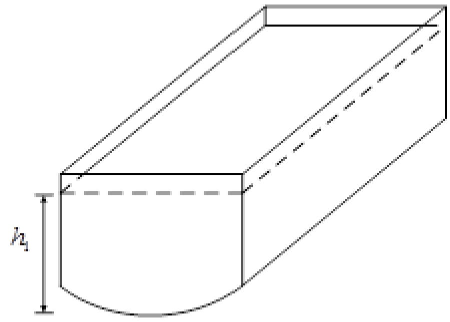

Fig. 2. Storage of the gravity sauce filler.

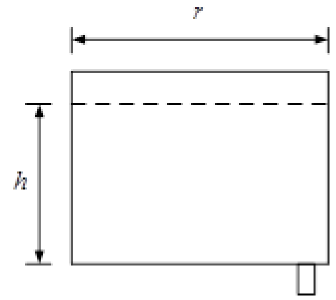

Fig. 3. Storage tank of the vacuum sauce filler

B. Model of the Vacuum Sauce Filling

The behavior of sauce flow rate of the vacuum sauce filling as a function of time must be studied. Figure 3 shows the apparatus consisting of cylindrical tank. The dynamic model is made according to the following hypotheses.

- The physical properties of liquid are constant.
- The liquid flow is unidirectional.
- Pipe is smooth, Friction loss are neglected.

$$\frac{dh}{dt} = \frac{1}{A}(-Q) \qquad (7)$$

From the mass balance and the Bernoulli equation,

$$Q = A_{out}\sqrt{2\left(\frac{P_1 - P_2}{\rho}\right) + 2gh} \qquad (8)$$

Where $h(t)$ = the level of the sauce in the tank (m)

$Q(t)$ = the flow rate of the sauce in the tank (m^3/s)

A = the cross-sectional area of the tank (m^2)

A_{out} = the cross-sectional area of the outlet (m^2)

P_1 = the pressure at the top of the sauce head (Pa)

P_2 = the pressure at the outlet of the pipe (Pa)

ρ = the density of the sauce (kg/m^3)

g = the gravitational acceleration (m/s^2)

IV. Design of Vacuum Filling Machine

The present sauce filling method is the in-line gravity sauce filling, shown in Fig 4. It makes a lot of the sauce loss, thus the canned factory would like to use the vacuum sauce filling in place of the gravity sauce filling. The quantity of sauce loss from gravity filling is 0.78 g/can or 2,102.60 kg/year.

The design of vacuum filling machine consists of a 199.43 L stainless steel cylindrical tank, 18 sauce filler heads, and rotary cans conveyer. Figure 5 shows some parts of the vacuum filling machine that are creating in the factory

V. Result and Discussions

From the simulation of the gravity sauce filling, the sauce level in the storage tank (h) versus time (t) plot is shown in Fig. 6. The result represents the sauce level in the tank was slow decreasing when the time increasing. This means the production will be slowed.

Fig. 4. The used in-line gravity sauce filling equipment

Fig. 5. Some parts of the vacuum filling machine

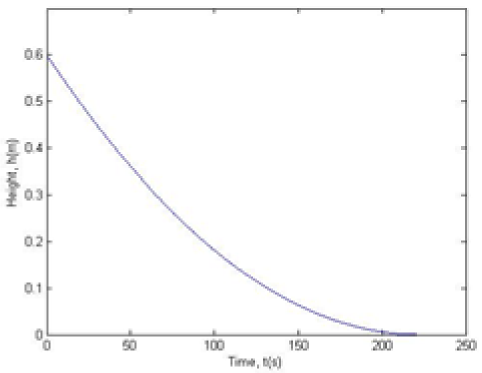

Fig. 6. Relation between height versus time of the gravity sauce filling

Figure 7, the time increasing, the height of sauce level in the storage tank (h) of the vacuum sauce filler was decreasing. However, the results show that the sauce flow rate of the vacuum filling is more than the sauce flow rate of the gravity filling, because of the decreasing of the sauce level of the

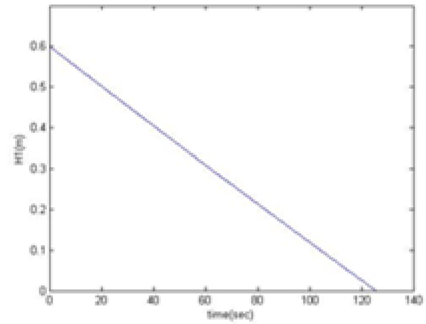

Fig. 7. Relation between height versus time of the vacuum sauce filling

vacuum filler is faster than the decreasing of sauce level of the gravity filler. Consequently, the vacuum filler possibly produce the canned fish more than the gravity filler.

VI. Conclusion

The in-line gravity sauce filling is the filling system that was used by the inspected fish canning factory. The gravity filling equipment consists of main three parts such as a pump, a sauce storage tank, and a bottom tank. This filling method causes the oscillation of sauce flow rate into cans, which leads to the possibility of sauce overflow or deficit. This filling method causes some cans are incompletely filled or overfilled, and consequently sauce is manually added or removed from the cans by using tablespoons. The filling method makes a lot of quantities of sauce loss. This work focused on design a vacuum sauce filling machine for use in the canning process instead of the gravity sauce filling machine. From simulation, the results show that the vacuum sauce filling machine has more productivity when compares with the in-line gravity sauce filling machine

Acknowledgment

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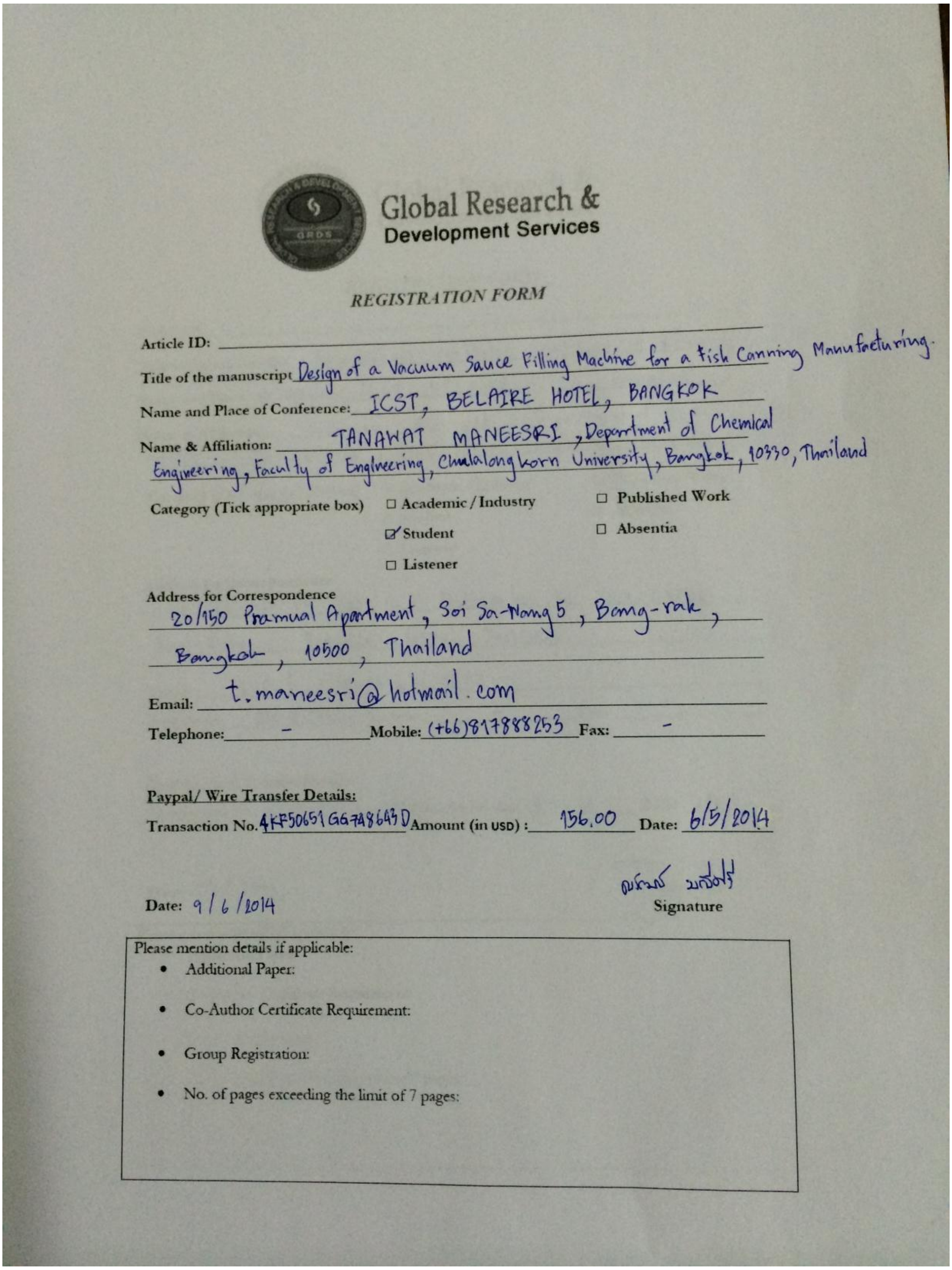

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Address for Correspondence: 20/150 Pramual Apartment, Soi Sa-Nang 5, Bang-rak, Bangkok, 10500, Thailand

Email: t.maneesri@hotmail.com

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