Influence of main factors on the quality of can cleaning in an immersion washer

A V Mayorov, G S Yunusov, D V Lukina, N V Yanukov and A S Kulalaeva
Mari State University, Yoshkar-Ola, Russia

E-mail: ao_maiorov@mail.ru

Abstract. Investigations of the influence of main factors on the quality of can cleaning in an immersion washer in the course of canning are quite relevant and very important in the food industry. Hence, a new design of a two-section washer is suggested. Experiments were performed on the washer under discussion. Results of experimental research of the quality of metal can surface cleaning are given. Based on the results of unifactor experiments with two-stage washing of can surface, relations were established between the can cleaning quality and wash liquor concentration at different wash liquor temperatures, also relations between the can surface cleaning quality and wash liquor temperature at different liquor concentrations by fixing the washer drive wheel’s rotation velocity. With increase of the washer drive wheel’s rotation velocity at constant wash liquor temperature its concentration at which the cleaning quality compliant with the standard is achieved falls down. At a velocity of 15 min\(^{-1}\), the wash liquor concentration is 3.5 g/l at 85 °C. The same quality of cleaning is achieved at wash liquor concentration equal to 1 g/l and its temperature equal to 85 °C at a velocity of 35 min\(^{-1}\). As the washer drive wheel’s rotation velocity increases at a constant concentration of the wash liquor, the temperature at which the cleaning quality compliant with the standard is achieved falls down. At a velocity of 30 min\(^{-1}\), the minimal temperature is 60 °C at 5 g/l concentration. The same quality of cleaning is achieved at a temperature of 48 °C in case of 5 g/l concentration at a velocity of 35 min\(^{-1}\). The quality of cleaning grows intensively at a concentration of 1 to 3 g/l. If the wash liquor concentration is further increased over 3 g/l, the quality of cleaning improves insignificantly. The optimal temperature providing good-quality cleaning of can surface that would comply with the standard is within 65…85 °C regardless of the washer drive wheel’s rotation velocity.

1. Introduction
Demand for good-quality preservatives is increasing from year to year all over the world and increasing quantities and types of food are canned. Convenient storage, transportation, sale, product acceptability, absence of strict requirements to storage, and a number of other advantages of canned food over natural – all this indicates necessity of further improvement of manufacture of this type foodstuff.

Canning allows preserving food in a tight package for a long period; therefore, the canning industry plays an important role in supplying population with foodstuff.

Agricultural businesses of this country are major consumers of fuel and energy resources, which evidences that even a small improvement of the process equipment operation efficiency is extremely important because on the sector scale it results in large savings of energy resources.

That is why investigations aimed at improvement of the process of washing filled cylinder cans in
the course of canning are quite relevant and very important in the food industry. Significance of such work is supported, for instance, by the fact that the cost of energy carriers is growing every day and affects considerably the cost of finished products [1-3].

For the criterion of specific energy cost per unit of cleaned surface, it was found to be equal for high-pressure jet cleaning to 0.1…0.3 kW·hr./m², for low-pressure jet cleaning – 2.2…6 kW·hr./m², for immersion cleaning – 0.2…1.8 kW·hr./m². Перспективным является применение High-pressure and immersion cleaning are most promising as less energy-intensive [4-7].

In the canning industry, jet can washers are widely used, which use incompletely efficient wash liquors with high content of surfactants; are limited in working temperature by cavitation phenomena in transporting and booster pumps; have a complex design and are difficult to maintain; utilize a narrow range of intensification techniques [8-10].

The existent immersion washers used mostly at repair businesses to remove difficult contaminations from irregularly shaped parts have a complex design and are intermittently operated apparatuses.

It is uneconomic to use the above washers in the food industry for washing the outer surface of metal cans because cleaning with their help is highly energy-intensive, metal-intensive and costly.

Creating fluid agitation by installation of multiple various parts around the object of cleaning makes the washer design even more complex and increases the energy-intensity and cost of product cleaning. However, such streams of wash liquor can be created easier and more efficiently by coercing planetary movement to the object itself and activating the liquor by air bubbling on its outer side. This is the principle the immersion washer developed in the Mari State University is based on [11].

2. Experimental part
For investigation of the process of can washing, an experimental washer performing the work process following a two-step cycle was fabricated.

The design and process block diagram of the washer developed for filled metal cylinder cans is shown on figure 1a, b.

It relates to continuously operated machines. Here, the object of cleaning goes via guides 4 and 5 of bath sections 1 and 2, making a planetary movement in the wash liquor thanks to elastically rimmed drive wheels 7 and 11 having diameter $D = 0.71$ m. Making such movement, the object is exposed both to friction against fluid and to its pressure.

Besides, powerful unsettled turbulent streams of fluid arise around the object, rendering hydromechanics effects on contaminated surfaces. Complex combined effect of surface tangential and frontal forces of resistance to fluid on contaminations takes place. Hydrodynamic studies have shown that surface tangential and frontal forces have a complex nature because they are variable both in value and in direction.

So, rather complex ‘staggering’ and ‘scraping’ mechanic effects are rendered on contaminations of the object of cleaning. Besides, such efficient mechanic effect promotes the influence of thermophysical and chemical properties of wash liquors.

Installation of perforated pipelines 14 to supply air (bubblers) to the guides on two lateral sides provides wash liquor activation near can surfaces. Wash liquor movement near washed surfaces accelerates physical and chemical interaction. In this region, multiple bubbles form, which bust upon collision with the object of cleaning, creating high pressures on contaminated surfaces, thus, assisting higher intensity of the cleaning process.

The number of holes in the bubbler, their diameter and space between their centers have been determined based on mixing intensity. The number of holes on the arch-shaped bubbler was substantiated as 36 and, correspondingly, the hole diameter as 2.5 mm and space between their centers as 21.5 mm. The minimal pressure in the air feed system for bubbling at which all holes on the arch-shaped bubbler are used amounted to 0.5 MPa.
Figure 1. Design and process block diagram of the washer for filled metal cylinder cans, where a is overall view; b is washer in operation; 1, 2 are washing baths; 3 is partition; 4, 5 are guides; 6 are shafts; 7 is drive wheel; 8 is gear motor; 9 is coupling; 10 is hub; 11 is driven wheel; 12 is V-belt transmission; 13 is bearing shell; 14 is bubbler; 15 is overflow nozzle; 16 are drain nozzles.

At the exit onto domed arch-shaped section $D$ of the transfer from one bath to the other (figure 1 b), used wash liquor of the first bath 1 streams down carrying particles of contaminations. Besides, on surfaces of removed objects, film currents are forming, which are characterized by high tangential friction stresses promoting intensification of the cleaning processes.

To heat the wash liquor with hot steam, radiators connected to a steam line are installed in baths. All above-listed hydromechanics effects, combined with physical and chemical properties of wash liquors, ensure intensive even and high-quality cleaning of the outer surface of cylinder cans.

Implementation of kinematic connection between the wheels of the first 1 and second 2 baths as a V-belt transmission 12 with reduction ratio 0.86 ensures higher productive rate of the second bath 2 than that of the first bath 1, precludes can jams, and provides uninterruptible operation of the process line.
For smooth stepless control of rotation rate of the shaft of washer electric motor adjustable to line throughout, the gear motor is equipped with frequency converter Altivar 31 of Telemecanique brand. As studies have shown, the following factors render substantial influence on the quality of cleaning and process intensity in the washer developed: temperature, wash liquor (type, concentration), drive wheel’s rotation velocity (this is the factor which kinematic parameters are connected with – linear and angular velocities and accelerations of the object of cleaning), process duration, activation of the fluid by air bubbling on the outer side of washed objects, wash liquor kinematic and dynamic viscosities, the shape and size of the bath for that liquor; type, composition, level, and strength of contaminations. However, in the investigation of the process of washing surfaces of tin cylinder cans using a two-step immersion washer with a planetary movement of the object of cleaning, unrelated to each other factors that affect the process mostly, such as wash liquor temperature and concentration, drive wheel’s rotation velocity, were most interesting and were studied by us during in-process testing of the washer. All other factors either depend on the said three ones or insignificant and in some cases render no influence on the washing process at all.

To study the influence of drive wheel’s rotation velocity, liquor temperature and liquor concentration separately on the quality of can outer surface cleaning, unifactor experiments were performed, when at fixed rotation velocities of the washer’s drive wheel, the wash liquor temperature and concentration was varied.

The experimental studies were conducted with wash liquor bubbling. In the system feeding air for bubbling, pressure was maintained constant, its mean value being 0.5 MPa. The diameter of holes on the arch-shaped bubbler was 2.5 mm. The experiments were performed in three replicates.

3. Results and Discussion
Based on the results of unifactor experiments during two-step washing of can surfaces, dependencies of the quality of can surface cleaning on the wash liquor concentration at different wash liquor temperatures were established, as well as dependencies of the quality of can surface cleaning on the wash liquor temperature at different liquor concentrations at fixed rotation velocity of the washer’s drive wheel. On the figures, dashed horizontal line shows the quality of cleaning compliant with the standard $K \geq 93\%$ [1-4].

Analysis of diagrams obtained (figure 2 and 3) shows the following relations:

- as the rotation velocity of the washer’s drive wheel increases at a constant temperature of the wash liquor, its concentration at which the quality of cleaning compliant with the standard is achieved decreases (figure 2). At velocity equal to 15 min$^{-1}$, the wash liquor concentration is 3.5 g/l at 85 °C. The same quality of cleaning is achieved at wash liquor concentration 1 g/l and 85 °C temperature at velocity 35 min$^{-1}$.
Figure 2. Dependencies of the quality of can surface cleaning on the wash liquor concentration at different temperatures t (a – washer drive wheel’s rotation velocity $n_1=15 \text{ min}^{-1}$; b - $n_1=20 \text{ min}^{-1}$; c - $n_1=25 \text{ min}^{-1}$; d - $n_1=30 \text{ min}^{-1}$; e - $n_1=35 \text{ min}^{-1}$): 1 – $t=45 ^\circ \text{C}$; 2 – $t=55 ^\circ \text{C}$; 3 – $t=65 ^\circ \text{C}$; 4 – $t=75 ^\circ \text{C}$; 5 – $t=85 ^\circ \text{C}$.

- as the rotation velocity of washer’s drive wheel increases at a constant concentration of the wash liquor, the temperature at which the quality of cleaning compliant with the standard is achieved lowers (figure 3). At velocity $30 \text{ min}^{-1}$, the minimal temperature is $60 ^\circ \text{C}$ at concentration equal to 5 g/l. The same quality of cleaning is achieved at $48 ^\circ \text{C}$ with concentration equal to 5 g/l at $35 \text{ min}^{-1}$ velocity.
- the quality of cleaning intensively grows at a concentration between 1 and 3 g/l. Further increase of wash liquor concentration over 3 g/l is associated with quite insignificant improvement of the quality of cleaning;
- the optimal temperature providing high-quality cleaning of can surface compliant with the standard is within the range of 65…85 $^\circ \text{C}$ regardless of the washer drive wheel’s rotation velocity.
Figure 3. Dependencies of the quality of can surface cleaning on the wash liquor temperature at different concentrations of liquor c (a – washer drive wheel’s rotation velocity $n_1$=15 min$^{-1}$; b - $n_1$=20 min$^{-1}$; c - $n_1$=25 min$^{-1}$; d - $n_1$=30 min$^{-1}$; e - $n_1$=35 min$^{-1}$): 1 – $c$=1 g/l; 2 – $c$=2 g/l; 3 – $c$=3 g/l; 4 – $c$=4 g/l; 5 – $c$=5 g/l

4. Summary
Based on the results of investigations performed, the following optimal parameters were obtained:

- the quality of cleaning grows intensively at a concentration of 1 to 3 g/l. Further increase of wash liquor concentration over 3 g/l is associated with quite insignificant improvement of the quality of cleaning;
- the optimal temperature providing high-quality cleaning of can surface compliant with the standard is within the range of 65 to 85 °C;
- according to the investigations performed, the optimal rotation velocity of the washer’s drive wheel is 20 to 35 min$^{-1}$.

References
[1] Jain S V and Patel R N 2014 Renew Sust Energ Rev 30 841–68
[2] Akikur R K et al 2013 Renew Sust Energ Rev 27 738-52
[3] Plappally A K and Lienhard V J H 2012 Renew Sustain Energy Rev 16(7) 4818–48
[4] Tadesse M G et al 2017 Smart Mater Struct 26 065016
[5] Eze V C et al 2017 Chem Eng J 322 205-14
[6] McDonough J R et al 2015 Chem Eng J 265 10-121
[7] Zhang J et al 2011 Bioresour Technol 102 7407-14
[8] Mohayeji M et al 2016 J TAIWAN INST CHEM E 60 76-82
[9] Chen Z et al 2015 Chem Eng Sci 130 254-63
[10] Hodgkinson J and Tatam R P 2013 Meas Sci Technol 24(1)
[11] Mayorov A V et al 2014 Vestnik of the Mari State University 1 (13) 48–53