Calculation of geometrical parameters of the cossettes scalder

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Keywords:

Scalding
Beet
Foam
Gas
Extract

Article history:

Received 16.09.2013
Received in revised form 24.11.2013
Accepted 23.12.2013

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ABSTRACT

Introduction. The process of cossettes scalding are examined. The exploration objective is the development of calculation methods for the parameters of the countercurrent cossettes scalders.

Materials and methods. The research techniques are based on physicochemical laws of constitutional changes and on industrial data processing.

Results and discussions. The basic stages of cossettes scalding are: preliminary heating of cossette, final heating of cossette, separation of blood and scalder mixture and foam, defoaming. The formulas for calculation of scalder diameter, the length of countercurrent and mixing parts, as well as the diameter of defoamer are proposed reasoning from optimum hydrodynamic conditions in a scalder.The basic dimensions for the scalders of different productivity are adduced. The obtained results can be used for designing the scalders for diffusion plants of columnar, rotating and twin screw type.

Introduction

At present, the overwhelming majority of extraction plants in beet sugar industry worldwide is armed by horizontal tandem countercurrent cossettes scalders with the system of forced defoaming. Those scalders were developed for fitting-out the diffusion towers produced by BMA and Buckau-Wolf [1], but then they came into in use for fitting-out the rotary and inclined double-screw plants.

There are the following technological and thermotechnical requirements for a process of scadling in sugar industry:

- cell membranes denaturation by thermal action (~70 ° C) during the period of about 10 minutes;
- heat recovery of diffusion juice by counterflow heat exchange with the beet cossettes coming in the cossettes scadler;
- defoaming in blood and scalder mixture;
- preparation of homogeneous blood and scalder mixture for its swap by centrifugal pumps;
- minimization of mechanic damages of beet cossettes.

The processes of different nature (mechanical, hydrodynamic, thermal, biochemical, diffusion, etc) occur during the work of a scalder. They are interrelated and therefore all factors, character and force of their influence should be taken into account during their projection.

Different aspects of scalders operation have been studied by native explorers. Lysianskyi V.M. elaborated the theory of heat and mass exchange processes calculation. However, the methods of the geometrical parameters calculation of scalders, taking into account hydrodynamic processes and processes of formation of foam during scalding, have not been sufficiently developed.

The available scalders have no system of forced defoaming. This drawback should be eliminated while the development of new scalders. The crucial task is an elaboration of modern scalders producing 4 – 6 thousands tons of beets in a day.

Goal of research: development of methods of geometrical dimension calculation of counter-flow scalder for the extraction plants of different types.

Materials and methods

The research techniques are based on physicochemical laws of constitutional changes and on industrial data processing.

Mathematic simulation based on physico-chemical laws of phase changes.

Processing of information concerning structure and behavior of the equivalent equipment produced by leading companies.

Results and discussions

The process of scalding in a counterflow scalder has the following stages:

1. The preliminary heating of cossettes to ~60°C at the counterflow area of a scalder. At such temperature, the gas emission is insufficient. On this area, the essential foaming can happen when failed to confirm with the standard operating procedure. That is, having low juice level, unripe beet processing, intense microbiologic activity, pump aeration, etc. In such cases, the antiseptic and defoaming agents are used and the process conditions are being corrected.
2. The final heating of cossettes to 70…75°C at the area of mixing. Here, the foam formation is a regular process caused by gas bubbles leaving the beet cossettes. The resulting foam is removed from the scalder, as well as the defoamant circulation circuit.
3. Defoaming takes place in the anti-foam vessel. Defoamed juice is returned to the scalder.

During the design calculation of a scalder it is necessary to determine the frame diameter, the counterflow part and the mixture part length. The base for calculation is the regularity of main processes.

The frame diameter of a scalder has an influence on the speed of diffusion juice flow in the intercossette space. It has an optimal meaning determined by interaction of both factors:

- heat transfer from juice to cossettes surface;
- compression of the cossettes layer caused by hydrodynamic friction.

4. When the speed slows down, the flow turbulence intensity descends and the heat irradiation goes down, therefore a big working volume of the counterflow part is necessary for the process. The increase in speed stimulates pressure and compacting of the cossettes layers right up to values when the selection of the adjusted juice quantity from the scalder becomes impossible.

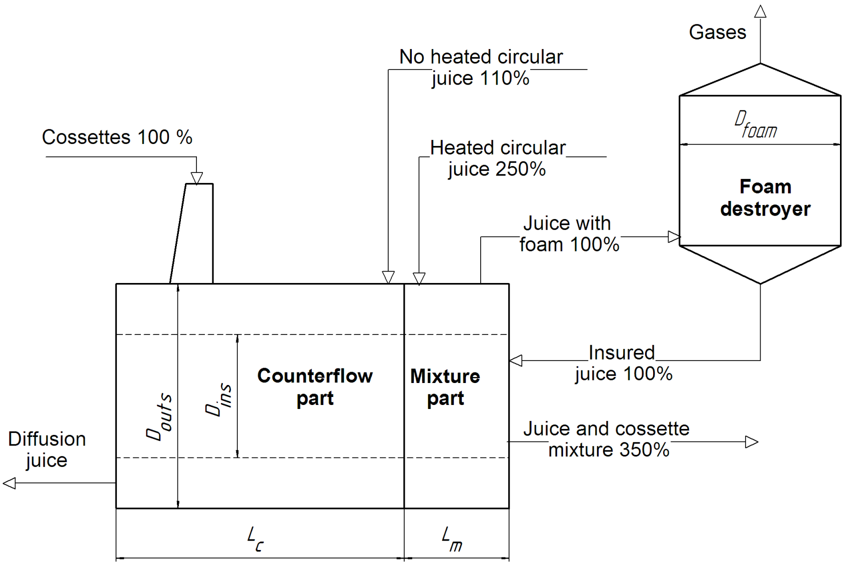

Fig. 1. Scheme of a counterflow scalder

Grebeniuk S.M. determined the value of this critical speed for cossettes obtained from the beets of different quality: 0.027 m/s for fresh beets, 0.021 m/s for frost-bitten and 0,016 for frozen ones. In the counterflow part of scalder the cossette is subjected to supplementary pressing between screw and counter-blades of transporting and mixing system. Considerable part of the scalder cross-section is surpassed by transporting paddles and screw belts. The design speed of the juice flow in space among cossettes equals 0.008 m/s.

The diffusion juice flow rate taken from the scalder is determined from the formula, m^3/s:

$$q = \frac{A}{24 \times 3600} \times \frac{\alpha}{100} \times \frac{1000}{\rho}, \qquad (1)$$

where A – design capacity of scalred, t/day; α – diffusion juice extraction, % to beet weight; ρ – diffusion juice density, kg/m^3.

The computed value of total cross-section area between cossettes is determined from the formula, m^2:

$$F = \frac{\pi}{4} \times \left(D_{ins}^2 - D_{outs}^2\right) \times \frac{\left(1000 - \gamma_c\right)}{1000}, \qquad (2)$$

where D_{ins} – bore diameter of scalder frame, m; D_{outs} – full diameter, m; γ_c – specific loading of working place of counterflow part by cossettes, kg/m^3.

The juice flow speed in the space among cossettes equals, m/s:

$$v_{fl} = \frac{q}{F} \tag{3}$$

There are other values for design calculation of a scalder: v_{fl} = 0.008 m/s; α = 110 % to beet weight; ρ = 1060 kg/m^3; D_{outs} = 0.385 D_{ins}; γ_c = 500 kg/m^3. Substituting those values in formulas (1), (2) and (3), we have obtained the relation for the value of the inside diameter of the case,m:

$$D_{ins} = 0,0671 \cdot \sqrt{A}. \tag{4}$$

The heat transfer duration is determined by the counterflow part length. Its increase provides better thermotechnical index. However, an area, where the temperature of juice cossettes mixture is 35-36°C, extends, and sugar actively decomposes on ferments and microorganisms. The exploitation of scalders of different types has shown that good thermotechnical results under acceptable values of sugar loss from decomposition are obtained when the counterflow heat transfer continues 600-900 s.

The counterflow heat transfer duration is determined from the formula, s:

$$\tau_c = \frac{\pi\left(D_{ins}^2 - D_{outs}^2\right)L_c}{4} \times \frac{\gamma_c}{1000} \times \frac{24 \times 3600}{A} \times \frac{\rho}{1000} \tag{5}$$

where L_C – scalder counterflow part length, m.

$$L_c = 0,00725\tau_c \tag{6}$$

For design calculation of scalder τ_c = 720 s, accordingly L_c = 5.22 m.

Air is the source of gas bubbles in the intercellular spaces and pores of the beet tissue, as well as gases exhaling from the enchylema by virtue of diminution of their solubility during the heating. Mechanical stimulation of cossettes speeds up the air outlet.

The process of gas outlet is caused by gas expansion and compression of beet tissue during scalding. The experimental evidence shows that during the beet cossettes heating to 70 °C, it strongly expanses during 2-3 minutes. This is the time of gas outlet. The bubbles of different diameter are formed in the process of gas outlet from the beet tissue capillaries. The time of the bubble gas dilution in the diffusion juice is determined from the formula:

$$\tau_{dil} = \frac{r^2}{2D_{gas}\left(C_S - C\right)} \tag{7}$$

where r – bubble radius, m; D_{gas} – gas diffusion coefficient in solution, m^2/s; C_s – gas dilution in solution, m^3/m^3; C – gas content in solution, m^3/m^3.

The speed of gas bubble floating-up is determined from the formula, s:

$$v_{fl} = \frac{2 \cdot \rho \cdot g \cdot r^2}{9\mu} \tag{8}$$

where μ – liquid viscosity, Pa·s, g – gravitational acceleration, m/s^2.

The time of gas bubble floating-up from the scalder bottom is determined from the formula:

$$\tau_{fl} = \frac{9 \cdot \mu \cdot D_{ins}}{2 \cdot \rho \cdot g \cdot r^2} \quad (9)$$

At the area of mixing the juice cossettes misture usually has the temperature of 70 °C. The condenseds are used as extragents. The diffusion juice in the column diffusion tower does not contact with an air, thereupon, the diffusion juice has little air incorporation.

There are another values for design calculation of a scalder: $D_{gas} = 2.9 \cdot 10^{-9}$ m^2/s; C_s = 0.0116 m^3/m^3 ; C = 0.00116 m^3/m^3; μ = 0.859×10^{-3} Pa·s, g = 9.81 m/s^2.

Plugging (4) in (9) and setting to (9), we value of some characteristic bubble radius r_{char} is determined, (image 2):

$$r_{char} = 68,8 \cdot \sqrt[4]{A} \quad (10)$$

The rise rate V_{char} corresponds to bubble radius r_{char} according to the formula (8) and the ascent time τ_{char} according to the formula (9). In period τ_{char} all bubbles, for which $r < r_{char}$, dissolve, and bubbles, for which $r > r_{char}$, reach the sieve and output from the scalder. For design calculation of a scalder, the hold-up time for the juice cossettes mixture should be no less than 1.25τ_{char}. The length of the mixing part of a scalder is determined from the formula (4) and (5) and the value of the specific inflation of mixing part is γ_m = 286 kg/m^3:

$$L_m = 0,0159\tau_{char} \quad (11)$$

The cross-section area of foam destroyer should have such value that the speed of descending current of juice should be less than 0.5V_{char}

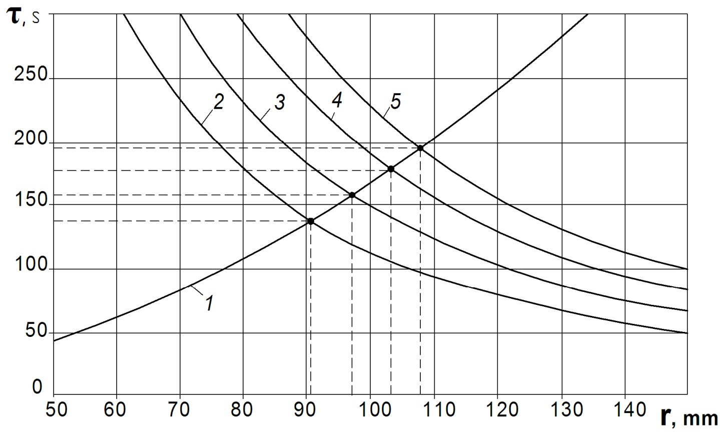

Fig. 2. The dependence of bubble dilution time value (curve 1) on bubble radius and on time of bubble floating-up for the scalders having
D_{ins} is 3; 4; 5; 6 m (curves 2; 3; 4; 5 respectively)

The diameter of foam destroyer is determined from the formula:

$$D_{f.d} = \sqrt{\frac{A}{24 \cdot 3600} \times \frac{1000}{\rho} \times \frac{4}{0,5 \cdot \pi \cdot V_{char}}}, \quad (12)$$

The results of calculation of main parameters for the scalders of different standard sizes are represented in a table.

Table 1

The main parameters of counterflow scalders of beet cossettes

Parameter	Parameter value						
A, tpd	2000	3000	4000	5000	6000	7000	8000
D_{ins}, m	3.00	3.68	4.24	4.74	5.20	5.61	6.00
D_{outs}, m	1.16	1.41	1.63	1.83	2.00	2.16	2.31
L_c, m	5.22	5.22	5.22	5.22	5.22	5.22	5.22
r_{char}, µm	90.6	95.3	98.7	101.5	103.9	105.9	107.7
V_{char}, m/s	0.022	0.024	0.026	0.028	0.029	0.030	0.031
τ_{char}, s	136	151	162	171	179	186	192
L_m, m	2.16	2.39	2.57	2.71	2.84	2.95	3.05
$D_{f.d}$, m	1.59	1.85	2.06	2.24	2.40	2.54	2.67

The formulas for the calculation of beet cossettes scalders are proposed, their use secures the optimum hydrodynamic conditions for juice and cossette countercurrent movement and heat transfer.

Conclusions

The methods of main geometric parameters calculation of the countercurrent cossettes scalders are elaborated. The calculation formulas are based on the empirical evidence of processes in diffusion plants, namely in hydrodynamic, heat-exchange and diffusion ones. The results of the optimal sizes calculation for scalders of different productivity are given. The obtained results can be used for designing the scalders for diffusion plants of columnar, rotating and twin screw type.

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