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THE INFLUENCE OF CONSTRUCTIVE SIZE OF EQUIPMENT ON THE CARBONATION PROCESS IN SUGAR PRODUCTION

The paper studies influence of the size of equipment for saturation in crude juice purifying process in sugar production. Parametric diagrams and a mathematical model for calculation of carbonation process are developed. It is established that theoretical size of saturator is smaller than the size of machines used in sugar factories. Saturation of carbonation gas with carbon dioxide has negative impact on its utilization rate.

Key words: *calculations optimization, crude juice purifying, sugar production.*

Робота присвячена дослідженню впливу розміру обладнання для сатурації в процесі очищення дифузійного соку в цукровому виробництві. Розроблена математична модель і параметричні схеми для розрахунку процесу карбонізації. Встановлено, що теоретичний розмір сатуратора менше тих апаратів, що використовуються на цукрових заводах. Насичення сатураційного газу діоксидом вуглецю негативно впливає на коефіцієнт його використання.

The main task of crude juice purifying by limewater and carbonation gas is the maximum possible removal of nonsugars and obtaining of sludge with high sedimentation filtration rates.

The most widespread in factory practice are technological schemes of cold (warm) and hot purifying of crude juice, which include preliming and combined cold (warm) and hot main liming.

In this case high quality of semi-products is achieved due to the presence of the cold (warm) stage in main liming, on which with decreasing of temperature of sugar-containing solution solubility of lime increases, and direction of reactions of reducing substances dissolution changes towards the formation of little colored substances. These substances are well-absorbed in the first saturation process, their chromaticity decreases while intensive decomposition of chromophore systems in dye molecules happens, and in case of cold crude juice heating, due to reducing of lime solubility, forms supersaturated sugar-lime solution, which with further saturation passes through the stage of gel that has high adsorption properties.

Nevertheless, purifying of crude juice using the scheme of cold- (warm-) hot main defecation doesn’t always give high quality and high sedimentation filtration rates at the same time.

One of the radical methods of improvement of sedimentation and filtration properties of sludge is presaturation processing. Therefore, in industrial practice, especially in foreign countries, purifying schemes, where to get sludge with good sedimentation and filtration properties used predefecosaturation or previous defecation in combination with predefecosaturation, are very popular. As the result, macromolecular substances and substance of colloidal dispersion coagulate with simultaneous dehydration and get adsorbed on the surface of the formed crystals of calcium carbonate.

Perspective ways of crude juice purifying, not only with maximum purification effect, but also with formation of good sedimentation and filtration properties of sludge, are schemes with separation of the main mass of nonsugars coagulate till the main liming. Increase of purification efficiency based on preventing of sludge dissolution during the main liming, and increasing of efficiency of the first saturation conducting on clean sludge of calcium carbonate.

At sugar factories recommended for wide implementation technological scheme of crude juice purifying with progressive preliming, combined main defecation, defecation before the second saturation with recirculation of the whole thickened suspension of the second saturation juice together with a part of the first saturation unfiltered juice on preliming.

The Department of Informatics (NUFT, Kyiv) worked on optimization of the calculation process of the equipment intended for absorption of carbon dioxide with the purpose of neutralization of calcium hydroxide during the crude juice purifying in sugar production.

With this aim was developed a mathematic model for calculation of technological process of saturation, parametric scheme of which is shown on pic. 2. On the first saturation with participation of calcium carbonate finishes formation of sludge with necessary for its separation sedimentation and filtration properties.

Quantity of removed from the juice on the first saturation by adsorption and cocrystallization nonsugars is much influenced not only by lime expenses, but also by the following parameters:

- calcium hydroxide content in the juice during the crystallization of calcium carbonate;
- temperature;
- carbon dioxide absorption speed;
- surface area and amount of charge of calcium carbonate particles;
- linear speed of calcium carbonate crystallization, etc.

High index of using of carbon dioxide prevents factory work from overspendings of lime, fuel and energy, and significantly improves management of first saturation.

Degree of utilization of carbon dioxide is influenced by the following parameters:

- calcium hydroxide content in the juice, that is in the saturator;
- interface between gas and juice;
- intensity if juice mixing, etc.

The ultimate goal of this work was achievement of optimal value of the saturator diameter depending on carbon dioxide content in the carbonation gas.

It has been found that when the amount of carbon dioxide in the carbonation gas reduces to 20% extent of absorption increases approximately to 70%.

During optimization was taken into account interconnection of the mentioned process parameters and a control calculation was made. From the table data were obtained equations used in the mathematical model [1].

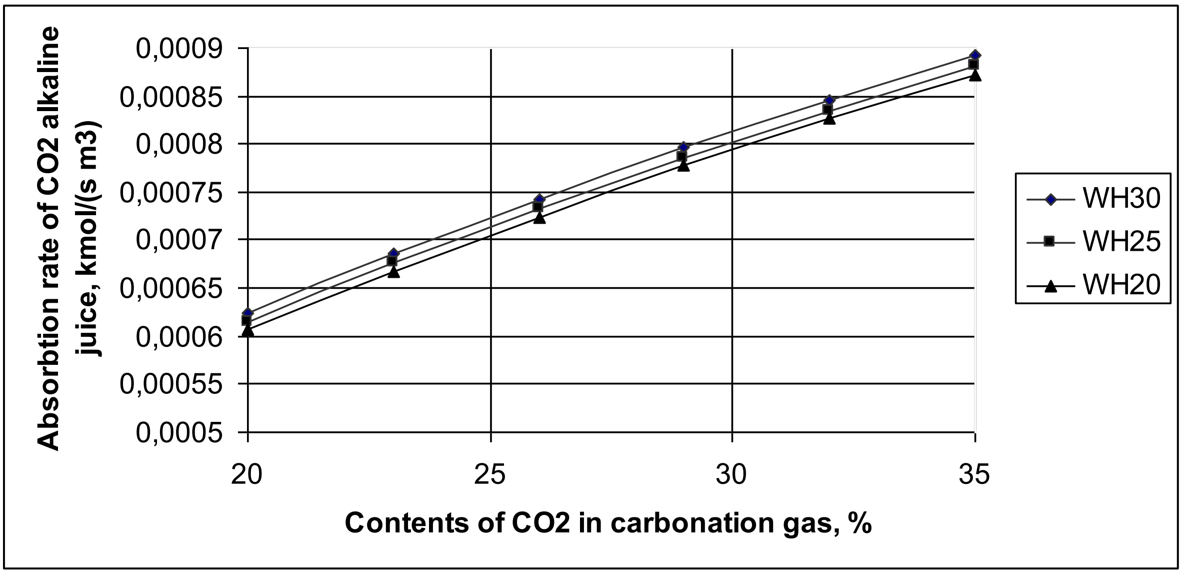

Fig. 1. Dependence of CO_2 absorption speed on its content in carbonation gas and the machine diameter (WH30 – 3 м; WH25 – 2,5 м; WH20 – 2 м).

This is Henry constant for the temperature within 20 – 90 °C, which defined by the formula obtained using the method of least squares with absolute deviation only $\delta^2 = 1,6 \cdot 10^{-2}$

$$\mathrm{He} = 1,654 \cdot 10^{-4} t^2 - 9,162 \cdot 10^{-3} t + 0,157 \qquad (1)$$

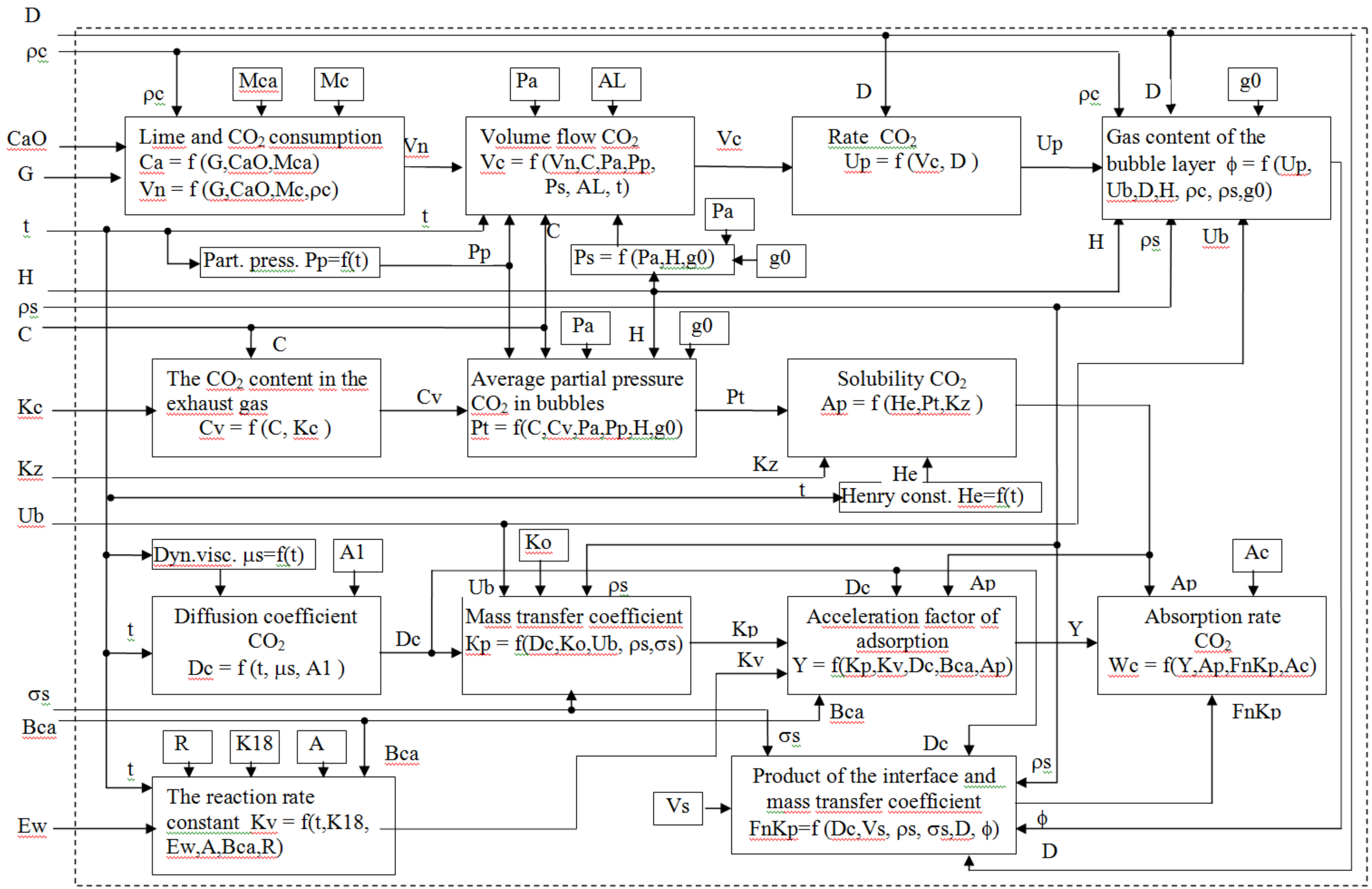

Fig. 2. Parametric diagram of mathematical model for calculating the rate of absorption of CO_2 in the saturator

where D – saturator diameter, m; H – level of juice in the apparatus, m; Gz – plant capacity, ton/day; t – temperature of the process, ^0C; S – sugar content of juice, %; CaO – lime consumption for cleaning, % to the mass of beet; C – content of CO_2 in carbonation gas, %; Кc – degree of CO_2 utilization; Ac – initial concentration of CO_2; ρs – juice density, kg/m^3; ρc – density of CO_2, kg/m^3; νs – kinematic viscosity of juice, m^2/s; σs – surface tension on a phase-separation surface, N/m; Ub – rate of gas bubbles floating, m/s; Ew – activation energy, J/mol; Bca – concentration of calcium hydroxide in juice, kmol/m^3; Кo – coefficient of resistance during mass transfer; Кz – coefficient of sugar content; g0 – acceleration of gravity; Mca – molecular mass of CaO; Mc – molecular mass of CO_2; К18 – reaction rate constant at temperature of 18 ^0C; α - expansion coefficient; Pa – atmospheric pressure; R – universal gas constant; A, A1 – coefficients; G – plant capacity, kg/s; μs – dynamic viscosity of juice, (N·s)/m^2; He – Henry's constant; Pp – partial pressure of water vapour, mPa; Ca – lime consumption, kmol/s; Vn – quantity of CO_2 for lime neutralization, m^3/s; Vc – volumetric carbonation gas consumption, considering the temperature, pressure, and juice layer squeezing, m^3/s; Dc – coefficient of carbon dioxide diffusion in juice, m^2/s; Кp – mass transfer coefficient, m/s; Ap – solubility of CO_2 in aqueous solution of sucrose, kmol/m^3; Wc – rate of CO_2 absorption by alkaline juice, kmol/m^3.

Value of the equilibrium partial pressure of water vapour, determined by the equation, obtained with absolute accuracy $\delta^2 = 4.818 \cdot 10^{-3}$

$$P = 2{,}48 \cdot 10^{-4} t^2 - 2{,}0613 \cdot 10^{-2} t + 0{,}5252 \tag{2}$$

and value of the dynamic viscosity of juice, obtained by the approximate formula, with mean square error $\delta^2 = 5{,}38 \cdot 10^{-10}$

$$\mu = 2 \cdot 10^{-7} t^2 - 3{,}8 \cdot 10^{-5} t + 2{,}27 \cdot 10^{-3} \tag{3}$$

Conclusions. The result of the work is the determination that theoretical size of the saturator is smaller than the size of machines used on sugar factories, and it changes from 2,5 to 2,1 metres with increasing of content of carbon dioxide in carbonated gas. Saturation of carbonation gas with carbon dioxide has negative influence on its utilization rate. With two times increase of CO_2 content in the gas its efficiency of use decreases for 25% (fig. 1).

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