Application of hydrodynamic oscillations for activation of the hydrated lime slurry

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Abstract

Introduction. The purpose of this scientific work is to study the impact of the application of hydrodynamic oscillations for activation of the hydrated lime slurry in the production of sugar from sugar beets.

Materials and methods. General scientific methods, special methods, volume parametric imitation and visualization modelling methods, math modelling methods, optical microscopy, and ionometry were used for the researches.

Results and discussion. It is established that application of hydrodynamic oscillations for activation of the hydrated lime slurry in the production of sugar from sugar beets is very perspective.

It was established that the value of the linear speeds of a stream should be within 22 m/s for the first rotor and 24 m/s for the second rotor for intensification mass exchange processes between lime and water throughout the activating hydrated lime slurry.

The research studies demonstrated the increasing of the potential of hydrogen of the water prepared for the technology of the activating hydrated lime slurry for the processes of juice purification within 15%.

In general case was established that the decreasing of reduction-oxidation reaction which obtained throughout processing on an extent 210s, after that there is not large decreasing of the reduction-oxidation reaction.

The obtained data verify, that the lowest rank of reduction-oxidation reaction was observed in water which has been treating with application of the hydrodynamic oscillations. The common stage of decrease of reduction-oxidation reaction in evaluation with the initial makes 65%.

Conclusions. Application of hydrodynamic oscillations for activation of the hydrated lime slurry in the technological processes of purifying juice can greatly increase the capacity and replace the batch process for the continuous, can greatly reduce the duration of the process of activating mode, reduce power consumption

Introduction

Agriculture and food engineering are measured as one of the largest sectors worldwide with significant contribution to the economic development of the country.

The process for refining sugar beets consists of the dependable operations: washing, crushing, extraction, liming, carbonation, filtering, and addition of sulphur dioxide, concentrating, crystallizing and drying.

The most critical of these varieties of stages are:

- liming;
- carbonation;
- addition of sulphur dioxide.

Every of these stages have need of continuous control of potential of hydrogen, because it is important value which limits the velocity of the technological process of sugar production.

In recent years researches and technologists have turned their interest to employment of the innovative non-traditional technologies and methods in processing of the liquid mediums which consists of the water or water solutions.

Very actual to explain this setback is to use inexpensive methods that require commercial venture and allowing the use of existing reserves to reduce specific energy consumption of existing equipment due to the intensification of technological processes.

Analysis of scientific works

Sugar beet raw juice is polyconponent system that contains almost 99% of the original sugar and must be purified to eliminate the many other organics and minerals impurities that accompany it, so-called non-sugar particles [1].

Carbonation is the process in which remove impurities from the sugar solution of the sugar beet raw juice. The juice is purified using lime and carbonic acid.

Optimal purification is achieved through two stages of carbonation to avoid an uncontrollable form of rapid that can increase in single stage carbonation, but sometimes ccarbonation occurs in several stages. Secure pH control is necessary at each stage of the technological process to assure greatest removal of both impurities and calcium [2].

Strict process control, particularly of pH, must be maintained to avoid loss of sucrose in processing through its chemical hydrolysis to the unwanted sugars glucose and fructose [3].

.An adjunction of hydrated lime slurry into sugar beet raw juice coagulates colloid substances and precipitates non-soluble or hardly soluble substances [4].

The precipitate, called carbonation mud, contains fine crystals of $CaCO_3$ and aggregated or adsorbed non-sugars [5].

The chemical reaction is so high-speed. The process of carbonation has next form. For that reason, the sugar plants operate lime kilns where lime stone (calcium carbonate) is heated to create burnt lime (calcium oxide) and carbon dioxide.

$$CaCO_3 + \text{heat} \Rightarrow CaO + CO_2 \quad (1)$$

The lime is added to the sugar beet raw juice as lime milk or hydrated lime slurry. In the process, free calcium hydroxide precipitates are formed which connect the non-sugar particles.

$$CaO + H_2O \Rightarrow Ca(OH)_2 \quad (2)$$

Currently, the carbon dioxide is led into this mixture. The lime including the non-sugar particles stably precipitates and can be separated by filtration.

$$Ca(OH)_2 + CO_2 \Rightarrow CaCO3 + H_2O \quad (3)$$

This is the essence of carbonation. It is repeated in a second stage. Measurement of the electrical resistance of the solution indicates the residual lime content [6,7].

The calcium carbonate precipitate, including the impurities, is now removed in a pressure filtration stage using polypropylene filter cloth as supporting media and utilizing the calcium carbonate as a filter aid [8].

For coagulation to occur, the medium must be alkaline and produced by the medium or by the presence of alkalinizing agents such as calcium oxide (quick lime), calcium hydroxide sodium hydroxide, or sodium carbonate [9, 10].

These reagents and components are modifying the potential of hydrogen of the sugar beet raw juice.

There are many methods and processes of water treatment to obtain water and water solutions with necessary physical and chemical parameters and properties which require for the manufacturing.

They are including: acoustic treatment, the electromagnetic pulse effect of the low-frequency field, cavitations processing, emitting treatment (ultraviolet, ionizing, infrared), hydrodynamic effects.

The method of discrete-pulsed input of energy can power structural transformations in difficult liquid systems on micro- and nanolevel and gives possibility to initiate physical and chemical transformations in these complex systems.

The main effects of the discrete-pulsed input of energy are effects which connected with increase of velocity of association of a continuous phase, power of pressure of shift, cavitations, the effect of explosive boiling, collective effects in assembly of vials, crossness of an interphase surface in gas-liquid bubbly medium, action of hydrodynamic oscillations, alternating impulses of pressure.

A great number of mass industrial processes such as: crushing, dispersion, mixing, emulsification, homogenization, activating, etc. are exhausted in rotary pulse apparatus of cylindrical type.

In these types of apparatus the main effects of the discrete-pulsed input of energy are realise.

The purpose of this scientific work is to research the impact of the application of hydrodynamic oscillations for activation of the hydrated lime slurry using reagent-free method of treatment in the production of sugar from sugar beets.

Materials and methods

Materials

Water, water systems, carbon dioxide and hydrated lime slurry were used for experiments. The proportion of the hydrated lime slurry was wide-ranging by the technological regulations of the productions sugar from the sugar beets.

Experimental installation

The most important element of the pilot unit is a rotary pulsed apparatus in which liquids treat by hydrodynamic oscillations [11].

Sample preparation

Water and water solutions and hydrated lime slurry were prepared using the standard methods which described in [12]. Water, carbon dioxide and lime milk was used for activating of the hydrated lime slurry.

Water and lime milk gave in to processing by hydrodynamic oscillations previous to the industrial procedure of receiving of the hydrated lime slurry. Water treatment and activating of the hydrated lime slurry was spent in rotary pulse apparatus [13].

Liquid water solutions and hydrated lime slurry were passed throughout turning coaxial cylinders with cuts on a surface and small clearances between them, which reach $(500–100)\cdot10^{-6}$m instantaneously that permitted to spend this process by continuous approach.

Methods

General scientific methods and special methods were used for the analyzing of the results of research work.

The volume parametric imitation and visualization, modelling methods, math modelling methods were used for the prognosis of the physical and chemical parameters of the hydrated lime slurry and water solutions.

The ionometry and optical microscopy method were used for the researches.

Experimental investigations of liquid samples were carried out with using standard laboratory measurement procedure.

For the description of physical and chemical parameters of liquid samples of water and hydrated lime slurry which obtained throughout the experimental investigations, standard methods described in singular literature are used [14].

The scrutiny of change of potential of hydrogen and the potential of reduction-oxidation reaction of liquid samples of the hydrated lime slurry is carried out with use analogue pH-meter-millivoltmeter pH-150 M with special electrodes.

For the reception related data, liquid samples of water and hydrated lime slurry were analyzed not less than three times with the following statistical processing.

Results and discussion

The power of introductory processing of water with appliance of the hydrodynamic oscillations for activating hydrated lime slurry in the technology of production sugar from sugar beets was studied.

Throughout water treatment by hydrodynamic oscillations the potential of hydrogen and reactionary ability of water, calcium oxide and carbon dioxide varies.

All through the processing of water and activating hydrated lime slurry in the conditions of hydrodynamic oscillations characterized $\Delta P = 350$ kPa near an outside surface of an interior spinning rotor; $\Delta P = 250$ kPa near an outside stator surface; $\Delta P = 150$

kPa near an interior stator surface; ΔP = 200 kPa near an interior surface of an outside spinning rotor.

By the volume three-dimensional parametric imitation visualization modelling processes, mathematical and numerical modelling was found that the value of the linear speeds of a stream should be within 22 m/s for the first rotor and 24 m/s, for the second rotor, Figure 1.

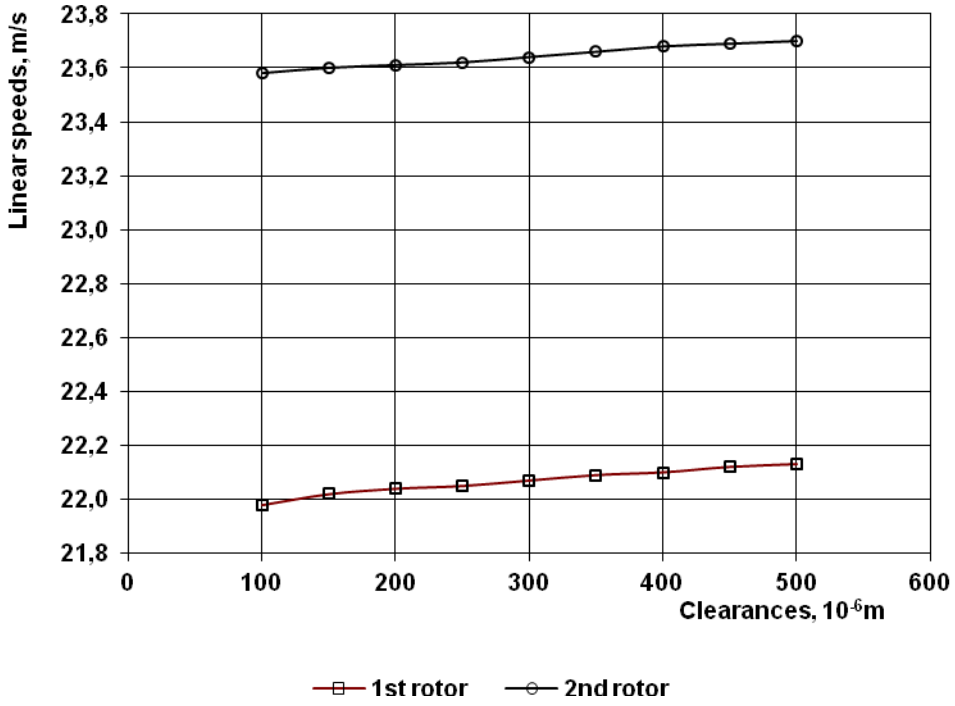

Figure 1. Profile of changes linear speeds of a stream from the clearances between coaxial cylinders

It was established that speeds of shift of a stream should be equal to $2{,}0 \cdot 10^5 s^{-1}$ for the first rotor and $2{,}5 \cdot 10^5 s^{-1}$ for the second rotor Figure 2. Such values of the speeds of shift of a stream provide intensive particle movement of the carbon dioxide in continuous phase – water.

The value of pressure of shift of a stream must be 220Pa for the first rotor and 230Pa, for the second rotor Figure 3.

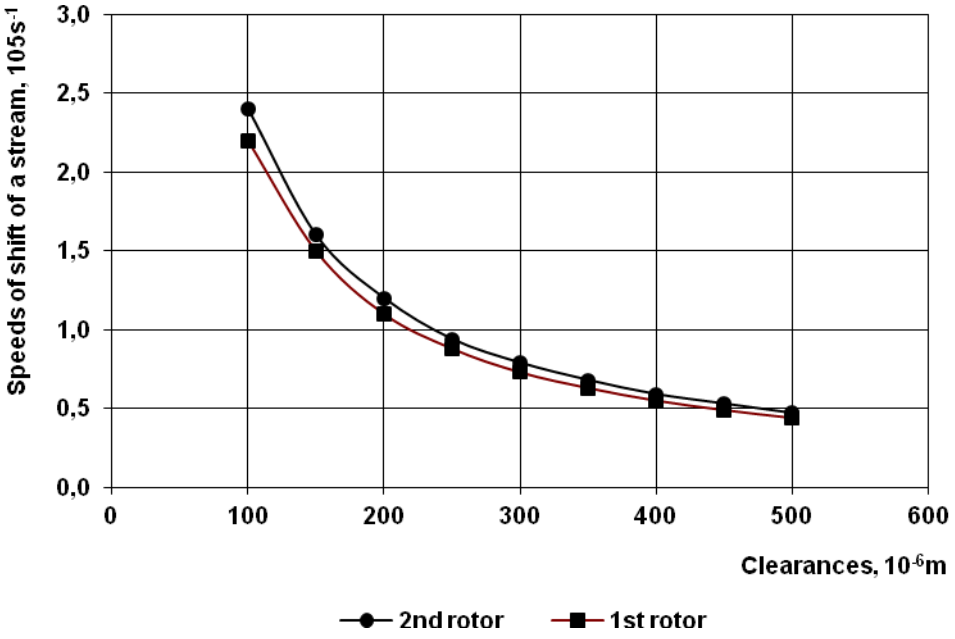

Figure 2. The profile of changes of speeds of shift of a stream from the clearances between coaxial cylinders

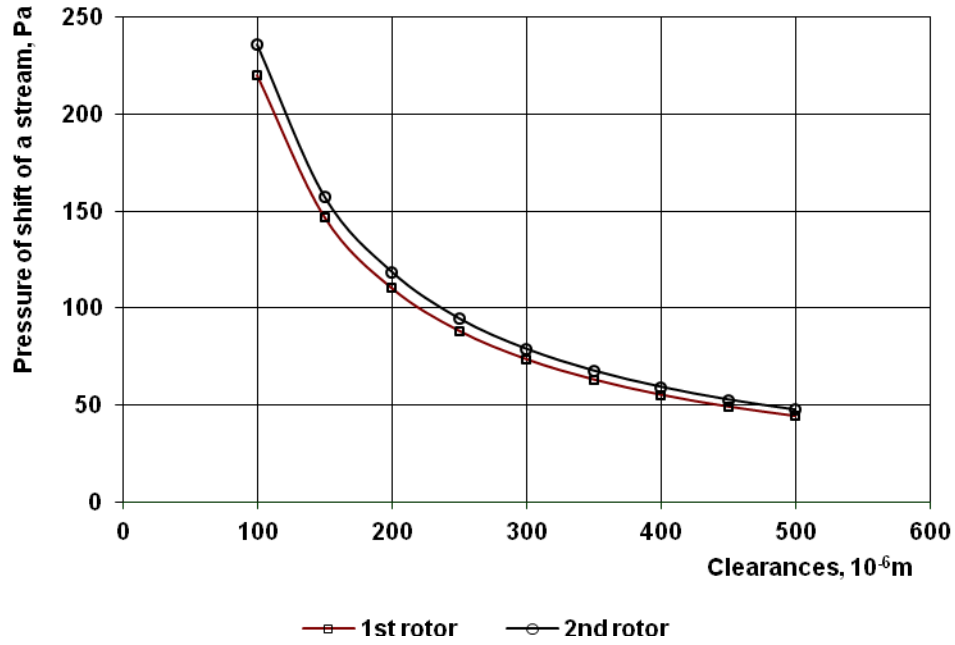

Figure 3. The profile of changes pressure of shift of a stream from the clearances between coaxial cylinders

These demanding hydrodynamic conditions give the possibility to treat water and water solutions with the initialization of the formation of structure and intermolecular interacting such as forming three-dimensional framework from the hydrogen bonds.

The nature and velocity of many physical and chemical processes which take place in such water systems transforms.

Besides, the activity of the water depends from the transformations and hydrogen bonds which can form between molecules. It is important for activation of the hydrated lime slurry

For shipping out of process of activation of water for the carbonating process hydrated lime slurry gave in to action during special time from 1s to 300s. The change of pH value during the processing by hydrodynamic oscillations is shown on the Figure 4.

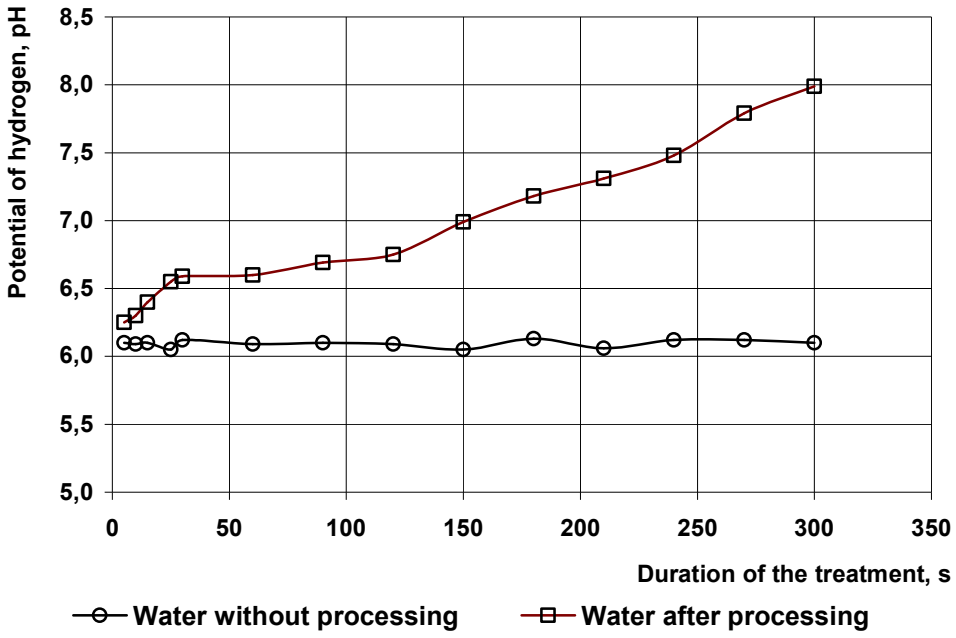

Figure 4. Change of potential of hydrogen during water processing by the hydrodynamic oscillations

The potential of hydrogen is shows concentration of free ions of hydrogen in water and water solutions and it is one of the major operational indicators of quality of water, in many compliments describes nature of chemical and another process which take place in water and in hydrated lime slurry.

The research studies demonstrated the increasing of the pH of the water prepared for the technology of the activating hydrated lime slurry for the processes of juice purification within 15%.

The significance of the potential of reduction-oxidation reaction is depending of the potential of hydrogen. It is the interrelated quantities of the water and hydrated lime slurry.

The potential of reduction-oxidation reaction depends from activity of oxidized form of material.

In this research employment the results of the investigation of the change of the potential of reduction-oxidation reaction is presented.

The decreasing of the potential of reduction-oxidation reaction of water in technological process of liming throughout experimental treatment in rotary pulse apparatus is shown on Figure 5.

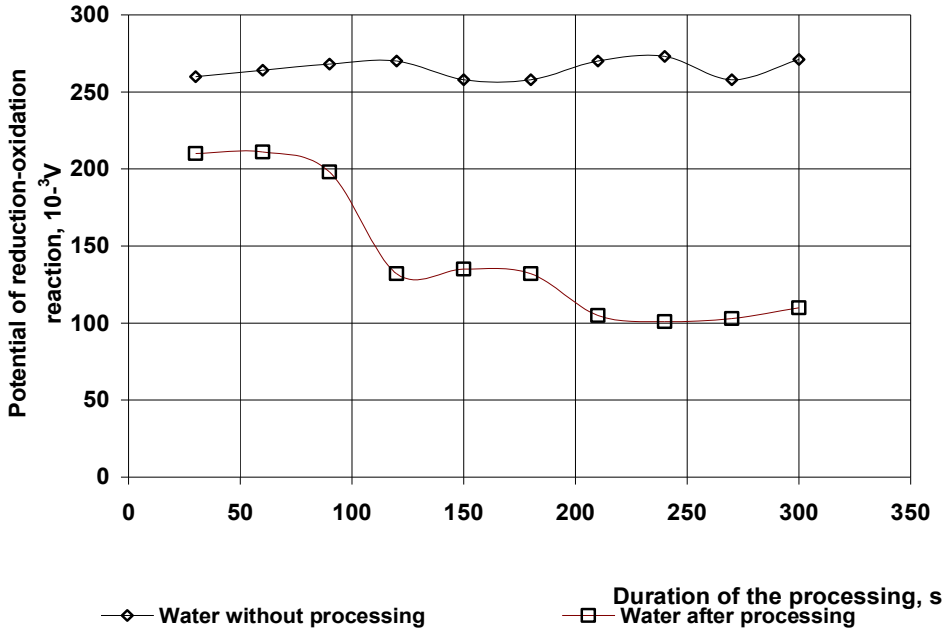

Figure 5. Investigation of the potential of reduction-oxidation reaction during the experimental water processing

A significance of reduction-oxidation reaction in the itinerary of processing with the appliance of the hydrodynamic oscillations depends from the duration of the processing and decreases on 25-65%.

During the activating hydrated lime slurry in the technology of production sugar from sugar beets the great value has change of a potential of hydrogen significance to initial value to processing.

The potential of hydrogen can greatly verify the velocity of itinerary of chemical reactions.

Appliance of the hydrodynamic oscillations in the technology of the production of sugar from sugar beets allow receiving the activated water and hydrated lime slurry with the definite substantial properties and parameters, assured value of a pH.

The alteration of physical and chemical properties and parameters of pure water and water solutions has been established during the processing with appliance of hydrodynamic oscillation.

It gives the possibilities to explain change of reactionary capability, outstanding to beginning of carrying over of a H^+ in associated liquids such as water and water solutions and configuration of a three-dimensional grating which formed by hydrogen bonds which in turn influences to the structural framework and a formation.

The experimental researches of the liquid examples of water solutions and hydrated lime slurry were carried out by research microscope system Zeiss Axio Imager Vario.

The samples were analyzed in automatic mode in straight light which passes through the examples of water solutions of the different types of water and hydrated lime slurry. Some of the examples were received by traditional technology and another was activated by the hydrodynamic oscillation in which water was exposed to processing and was not exposed to processing.

A significance of the reduction-oxidation reaction in the route of treatment in the conditions of hydrodynamic oscillations depends on dispensation duration.

In general case was established that the decreasing of reduction-oxidation reaction which obtained throughout processing on an extent 210s has been noted Figure 5, after that there is not large decreasing of the reduction-oxidation reaction.

The obtained data verify, that the lowest rank of reduction-oxidation reaction was observed in water which has been treating with application of the hydrodynamic oscillations. The common stage of decrease of reduction-oxidation reaction in evaluation with the initial makes 65%.

Conclusions

As a result of research, it was found that the application of hydrodynamic oscillations for activation of the hydrated lime slurry in the technological processes of purifying juice can greatly increase the capacity and replace the batch process for the continuous, can greatly reduce the duration of the process of activating mode, reduce power consumption.

The experimental and analytical studies have shown that activation of the hydrated lime slurry in rotary pulsed apparatus may be suitable for processing in food engineering especially for production sugar from sugar beets, where hydrodynamic oscillations are found to be a substitute to traditional tanks activating.

A complete study of experimental data showed that the use of hydrodynamic oscillations in the treatment of water and preparation hydrated lime slurry allows obtaining solutions with improved physical and chemical parameters.

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