Simulation of a mixer with a bidirectional rotational effect on material

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Abstract. The investigation of the mixer with bidirectional rotational impact on material is continued. The rotation of spherical mixing chamber is carried out by means of a drive using belting, chaining and beveling gears. The mixing of material in a chamber occurs relatively to two mutually perpendicular axes. The arising complex spatial movement of particles of a material can be regulated by a frequency converter and the corresponding elements of rotation gears. Preliminary experimental studies on the implemented laboratory facility are conducted. A digital model of the proposed device using the NX product is created. The analysis of the behavior of particles of mixed material, implemented using the EDEM package, is presented. The relevant conclusions are made.

1. Introduction

It is challenging to overestimate the importance of building materials industry as a driver for the economic development of various related branches, the objects of industrial and civil construction, etc.

Mixing equipment occupies an important place in the processing of various materials. An innovative alternative variant is a batch-type mixer implementing a bidirectional rotational effect on material in a mixing spherical chamber [1, 2].

The spherical form of a mixing chamber is appropriate to eliminate stagnant loading zones, increase the intensity of mixing, etc.

Bidirectional rotational impact on mixed material in a mixer with a spherical mixing chamber is realized by rotating the carrier with the chamber relative to the horizontal axis and the chamber relative to the second axis perpendicular to the first one.

The operation of a batch-type mixer implies the optimization of operating cycle, which begins with the loading of a mixing chamber through a hatch, the implementation of mixing process, and further shutdown of a chamber, its fixation and subsequent unloading. The construction features of the proposed mixer can contribute to the appearance of gyroscopic effect elements.

In previous research papers a specific mathematical apparatus was described concerning the behavior of material particles in a spherical mixing chamber with a bidirectional rotational impact on material [3, 4].

The kinematic scheme of the proposed device implementing a bidirectional rotational effect on material is presented in Figure 1.
Figure 1. The kinematic scheme of the device for mixing materials with chamber rotation relative to two mutually perpendicular axes: 1 - gear; 2 - rotating carrier; 3 - horizontal axis; 4 - belting; 5 - mixing chamber; 6 - loading hatch; 7 - second axis; 8 - beveling; 9 - chaining.

2. Methods
The technical orientation of the problem is the creation of an innovative device of non-infringement quality for mixing materials. It involves the use of modeling techniques. The combination of using physical and mathematical types of modeling will allow obtaining reliable results by adjusting the purposes, input parameters of the proposed mixer, as well as objective functions (output characteristics) [3].

During quantitative formulation of the purpose, the objective function accurately reflecting the most significant factors influencing the achievement of the purpose is obtained.

The experimental research methods involve conducting a computer experiment and obtaining empirical models.

The purpose of the experimental study is to obtain the extreme values of target function. The central composite orthogonal design (CCOD) of a fractional factorial experiment with four input parameters is chosen as the experiment design. For CCOD, the optimal criterion is the orthogonality of all the column vectors of planning matrix, ensuring the independence of the estimates of the coefficients of the regression equation. This means that the change in an estimate of any coefficient (the exclusion of a member from the regression equation) will not change the other estimates and their variances. For the experiments on the created original laboratory facility, the input parameters and the limits of their variation are taken: loading factor of a mixing chamber - 0.25÷0.3; chamber rotation frequency 3÷9 s⁻¹; particle size of loaded material 0.01÷0.02 м; t is the mixing time of loaded mixture, 30÷90 s. For example, the quality of mixing is chosen as the target function.

The creation of a digital model of the proposed device is an important step. Figure 2 shows a variant of the model of a mixer. The implementation of this model will allow analyzing the design features of the device and minimizing the errors of simulation stages.

In order to achieve this purpose it is proposed to use the NX product - one of the best “hard” solid-state 3D modeling systems. The digital model created during the development is presented in research works [4, 5, 6]. The exact three-dimensional model of the proposed innovative mixer is developed using the NX Modeling and Assembly modules, based on the complex of assembly units and parts, their configuration and relative position.
The analysis of the obtained digital model can be supplemented with regard to the use of the EDEM software package [7]. It is proposed to analyze the behavior of material particles inside a mixing chamber of spherical shape using the EDEM complex. The initial data for creating a load simulation in the EDEM software package include the parameters of the created laboratory facility, for example, the mixing chamber diameter equal to 0.5 m, etc. In addition, it is assumed that the material particles have a spherical shape, and the number of particles taken for analysis is 1500.

In order to determine the parameters of the interaction of mixed material particles with each other and the mixing chamber body, the values of the coefficient of restitution, the coefficient of static friction and the coefficient of rolling friction, etc. are set.

The functionality of EDEM allows combining mechanical, material and other physical properties in the process of modeling the molecular system of solid bodies. The proposed software package allows managing information on each particle separately (mass, temperature, speed, etc.), or their combination, as well as the forces acting on the particles of mixed material. For analyzing the process in the mixer, EDEM provides simulation data and 3D visualization of the particle flow. The core of the software package uses the physical model of contact interaction of elastic bodies of spherical shape, which determines how particles of the material act in the process of interaction with each other and with the body of the mixing chamber.

The analytical data is presented in different interpretations. For example, in Figures 3a and 3b, the diagrams of the distribution of the number of particles are presented depending on linear velocities after a certain time interval.
The diagram shown in Figure 3a characterizes the movement of particles in the mixer at time 30 s. Figure 3b shows the velocity distribution after mixing for 53.35 s. It can be seen that the largest number of particles have low linear velocities. Comparing the two velocity diagrams, it is possible to state that the number of particles with a low velocity (up to 0.2 m/s) decreases with mixing time from 97% to 93%. Over time, the maximum number of particles is placed to the right. If the speed is set below 0.2 m/s, higher percentage difference is obtained.

The analysis of the presented distribution indicates the possible use of an additional device (for
example, of a beveal shape) inside a spherical mixing chamber, which would promote greater contacting of the material particles.

The example of visualization of the particle flux after a certain time interval is presented in Figure 4.

![Figure 4](image)

**Figure 4.** The position of the material particles at the time of mixing $t = 53.35$ s

The analysis of the presented visual movement of particles in the mixer at time $t = 53.35$ (Figure 4) shows that 97% of the particles of material have a low speed, which can be changed by varying the rotation frequency of the spherical mixing chamber. At the same time, the disruption of particles of the material and rolling towards the center, the activation of mixing in the central part of the chamber are constantly observed.

The information obtained in the course of conducting virtual experiments (the speed of movement of particles of the material, kinetic and potential energy, the trajectories of movement of particles, etc.) will optimize the properties of the proposed mixer.

3. **Conclusion**

The simulation was actively used to create the original laboratory facility and further analysis to confirm the effectiveness of the proposed mixer, which implements a bidirectional rotational effect on the material. The experiments should be continued varying the particle size and characteristics of the load material, the size of the mixing chamber, etc.

The research is not only of practical importance, the proposed device demonstrates the features of the gyroscopic effect [8, 9]. The solution offered to production workers - a mixer located on a mobile portal and implementing a bidirectional rotational impact on the mixed material - can replace traditional gas concrete mixers used on production lines for gas-silicate products [10].

In addition, it is possible to use such mixers in paint-and-varnish industry, agriculture and similar light industries.

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