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Description of the test Stand for Developing of Technological Operation of nano-Dispersed Dust Preliminary Coagulation

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Abstract

Article describes the modeling, development and testing of a stand for coagulation nanosilica. For obtaining of nano-dispersed coagulated dust in IrNRTU test stand was designed and manufactured a for preliminary coagulation of nano-dispersed dust from gas purification silicon production. Presents the basic structural elements of the stand.

According to the studies conducted by different groups of scientists, the composition of the dust removed from the silicon furnaces is predominantly nanodispersed spherical silicon dioxide with a structure size of 100-500 nm. The concentration of SiO_2 in microsilica can reach up to 85% by weight. The second most concentrated substance in microsilica (up to 15%) is carbon. According to studies using electron and probe microscopy, the carbon part of microsilica consists of amorphous carbon and structured, fullerene-like nanostructures.

The distribution of the absolute total deformations (displacement) shows that the weakest point is the middle part of the upper mounting plate. The maximum displacements in the frame reach 0.36 mm. The resulting displacements did not exceed the permissible values [1 mm]. Thus, this structure has the necessary stiffness.

On the basis of calculations of the stand structure at the rigidity and strength it can be concluded that the structure in exploitation process will be operational.

Keywords: nanoparticles, coagulation, foam separation, nano-dispersed dust, nanocilica.

INTRODUCTION

To date, many factories in the metallurgical industry do not subject their waste to further processing capable of transferring waste into useful material, but prefer to dispose of waste by transporting waste to sludge fields. This method of waste disposal leads to environmental problems, as one ton of finished products of the plant is allocated up to a ton of dust products. For example, the amount of captured silicon plant dust can be 42 thousand tons per year, which inevitably leads to an increase in the size of sludge fields and ecosystem damage.

However, studies of dust removed from silicon furnaces suggest that this dust can be a convenient source for the production of various nanomodifiers and fillers. According to the studies conducted by different groups of scientists, the composition of the dust removed from the silicon furnaces is predominantly nanodispersed spherical silicon dioxide with a structure size of 100-500 nm. The concentration of SiO_2 in microsilica can reach up to 85% by weight [1-4]. The second most concentrated substance in microsilica (up to 15%) is carbon. According to studies using electron and probe microscopy, the carbon part of microsilica consists of amorphous carbon and structured, fullerene-like nanostructures [5-6].

Solving the problem of sludge fields could be the introduction of technology for processing dust removed from silicon furnaces. It is known that nanodispersed spherical silica with a mass fraction of up to 98% of SiO_2 is widely used in the production of construction concretes and high-strength composite alloyed metal alloys. In addition, it is used in the production of rubber products, and it is a filler in the manufacture of paints, ceramics, etc. [7-8]. Consequently, for further use of the dust of the silicon production furnaces, enrichment to a SiO2 content of not less than 98% is required. In the process of recycling microsilica, it is also possible to obtain a fraction of a pure carbon product with a high content of carbon nanostructures. Carbon nanostructured material is also widely used as modifying additives.

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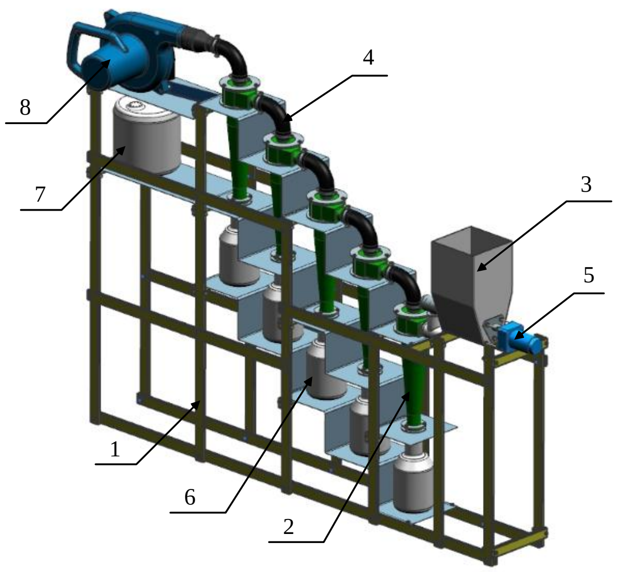
TEST STAND FOR DEVELOPING OF TO OF NANO-DISPERSED DUST PRELIMINARY COAGULATION

For obtaining of nano-dispersed coagulated dust in IrNRTU test stand was designed and manufactured a for preliminary coagulation of nano-dispersed dust from gas purification silicon production.

We considered the possibility of dry separation of microsilica on devices of gravitational centrifugal dust collection (cyclones). Carbon and silicon dioxide have a different density, therefore, provided that the particles have the same dimensions, they will be differently deposited in the cyclones. To test the hypothesis, a stand was constructed consisting of 5 successively mounted cyclones (Figure 1). The dusty stream was created with the help of a compressor and a dust-collecting device, including a screw feeder and a slotted shutter. As raw materials, dust of furnaces, caught in bag filters, was taken from a pipeline that carries a dust and gas stream from silicon furnaces.



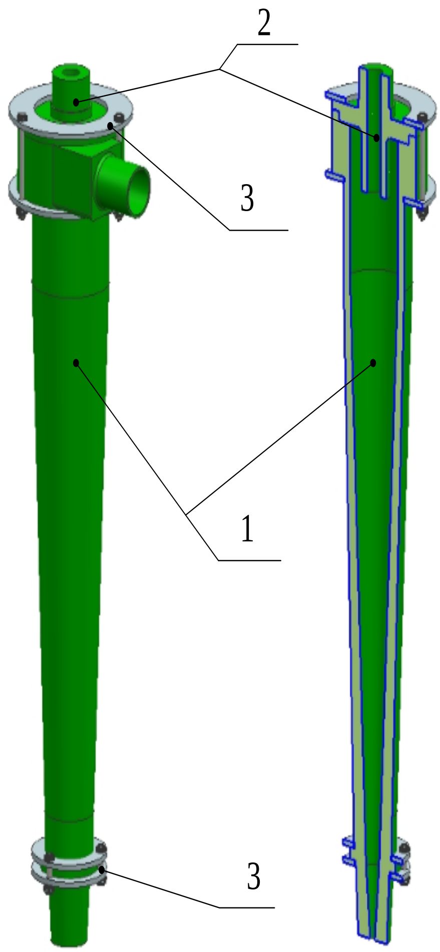
1 - frame; 2 - coagulant; 3 – loading hopper; 4 - flexible outlet; 5 – motor without collector with reducer (type FL86BLS98); 6 - container; 7 - container for collecting dust after blower; 8 - the electric blower (such as Makita UB1101).

Figure 1: Test stand for developing of TO of nano-dispersed dust preliminary coagulation

All elements of the frame stand design are made in-house, and finished goods (coagulant, flexible outlet, clamps, screw, blowers) are purchased from suppliers.

The stand frame is made of rectangular profile 40x20x1,5 according to GOST R 54157-2010, St.2 material. Bolted attachment M8x40 GOST 7808-70 (30 pcs.), M6x40 GOST 7808-70 (6 pcs.). Mounting plates are made of sheet semi-finished St.3sp GOST 8568-77 - Steel sheets with rhombic and lentil corrugation, thickness S = 2.5 mm. Mounting plates are fastened with screws 4,2 x 13 Din 7504 (40 pcs.).

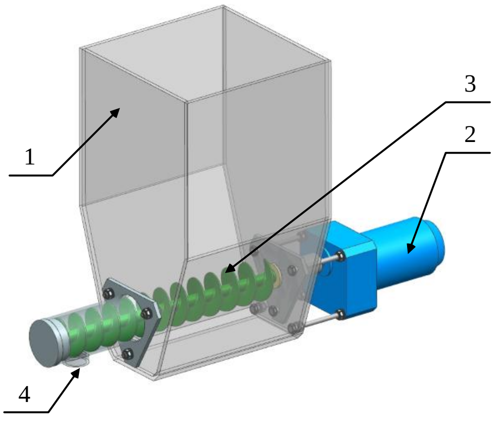
The main "working" part of the stand is a coagulant, whose design is shown in Figure 2.



1 - body; 2 - cover; 3 - installation / mounting plates.

Figure 2: Coagulator

The coagulator is made of non-metallic material with 2 parts, connected together by means of mounting plates. In the upper part of the coagulator body feedstock is fed using retraction of air jet, heavy elements sink and settle at the bottom of the coagulator through a hole 8 mm in diameter, lighter particles enter the upper part of the body and move on the next stage of coagulation.



1 - bunker; 2 - motor without collector with reducer (type FL86BLS98); 3 - screw; 4 - feed box.

Figure 3: Bunker download

Loading hopper of feedstock is made from plexiglass by soldering on the junction of the walls coupling. With the end of the hopper by bolted attachment the engine is mounted, to which the feed screw is fixed.

Calculation of the stiffness and strength of the stand structure is carried out with the aim to find out the greatest deformation of the stand frame as of the weight of all the elements that are hung on the frame, and of its own weight. The requirements for stiffness and strength of the stand design at work impose their mark when making design decisions. To substantiate a constructive solution, it is necessary to analyze the stiffness and strength of the structural elements of the stand. The traditional method of such analysis is a method based on the knowledges of the resistance of materials subject. However, this method requires special training of the designer in the field of knowledge on the resistance of materials. In addition, the traditional method is less productive compared to the modern method.

Modern approach to perform engineering analysis of stiffness and strength of the developed construction is the use of special software for the structural analysis of mechanisms. The calculation of stiffness and strength of the stand frame is performed in this project. The calculations are performed by the finite elements method of Ansys WorkBench v.14 system resources.

The stand frame is designed as a volumetric structure of rectangular profile. On the frame, there are mounting plates, by use of which the spatial positioning of the coagulators in the stand is made.

From the working conditions of this design it can be seen that the entire load of the elements is evenly distributed throughout the stand frame.

Current loads for the upper and lower plates are defined as weight of coagulators, now let’s define the magnitude of these loads for later use in a Design simulation module. Application plate is a surface of mounting holes.

The boundary conditions of finite-element model include fixing conditions and applied loads. Fixing conditions - rigid sealing of the lower surface of the stand frame.

Thus, there are introduced little assumptions about the boundary conditions, that reduce time of calculation, and calculation error is not more than 5%.

To perform the analysis, the model's body was divided into finite elements net. The total number of tetra elements - 91643. The model uses tetra and hexa elements, depending on the geometry of the geometric model of each body.

Now let us analyze the results.

The stress distribution is shown in Figure 4, the deformation distribution is shown in Figure 5. On curve the stresses are given in MPa. The stress distribution shows that the maximum stresses are 29.924 MPa.

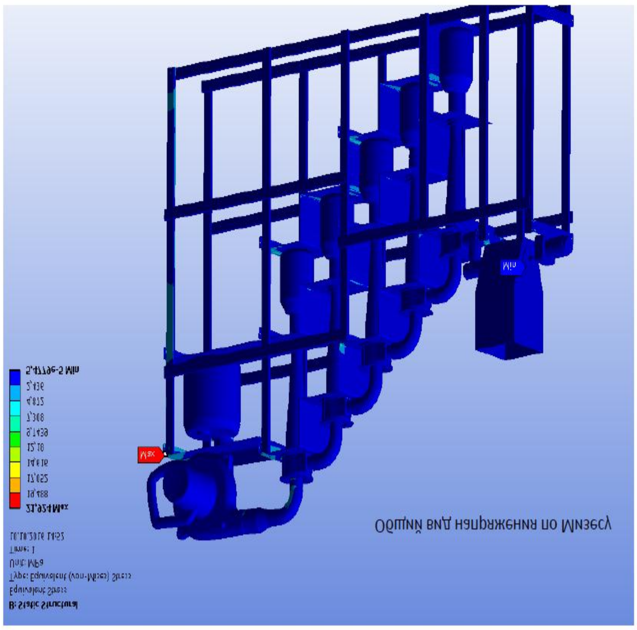


Figure 4: Curve of stresses on the Von-Mises in stand design, MPa (21.924 MPa max.)

When analyzing the stiffness, total deformation was determined (displacement).

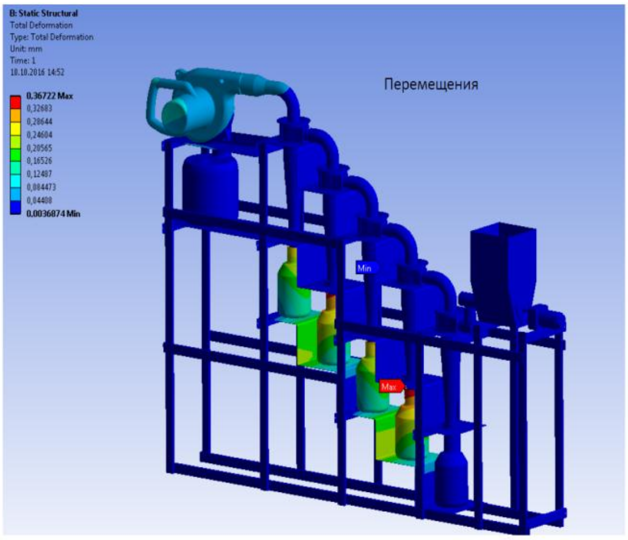


Figure 5: Curve of deformations in the stand design, mm (max 0,36mm.)

CONCLUSION

Thus, the strength is ensured. The distribution of the absolute total deformations (displacement) shows that the weakest point is the middle part of the upper mounting plate. The maximum displacements in the frame reach 0.36 mm. The resulting displacements did not exceed the permissible values [1 mm]. Thus, this structure has the necessary stiffness.

On the basis of calculations of the stand structure at the rigidity and strength it can be concluded that the structure in exploitation process will be operational.

As a result of series of tests, it was possible to increase the concentration of microsilica from 85% to 93% with a yield of up to 50%. It was possible to achieve an increase in the concentration of the carbon fraction from 14% to 45% with a yield of 10%. Mathematical calculations and results of mathematical modeling testify to the possibility of increasing the separation characteristics of the installation, in the event of a change in the geometric dimensions of the dust-collecting devices.

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