Analysis of the Test Results of the Installation for Receiving the Foam Glass Continuous Tape and Suggestion for its Improvement

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Abstract
Based on the experience gained in the creation, experimentation and study of an equipment and a technology for the production of foam glass from household waste glass based on Bulgarian patents No 65718/24.11.2004 and No 65745 /26.05.2006, an idea was developed for a new device for which a patent application has also been filed and is now acknowledged. The basic operational concept of the previous device is preserved, but some deficiencies discovered during the experimentation have been corrected.

Keywords: Foam glass, device for the production of foam glass.

I. Introduction

Obtaining foam glass at the Institute of Metal Science, Equipment and Technologies “Acad. Angel Balevski” with Center of Hydro- and Aerodynamics at the Bulgarian Academy of Sciences (IMSETHC-BAS) [1] is related to the development of a new technology and an installation for the manufacturing of continuous band and blocks of foam glass using a vertical (Bulgarian) method which differs from the traditional methods for obtaining these products. The new installation was tested under a project entitled “Study of the technological processes in the production of thermal insulation material – foam glass obtained in a model of a frothing unit of a new vertical production device.” The project was funded by the Bulgarian Ministry of Education and Science within a program of the Bulgarian National Science Fund (BNSF) – Contract No DTK-02/72 of 17.12.2009, as well as under Bulgarian patents Nos. 65718/24.11.2004 and 65745/26.05.2006 “Model of a vertical installation for manufacturing of continuous band of foam glass”.

In Table 1 are shown the technical characteristics of the foam glass material produced using the new equipment.

The completed project tasks, as reflected in the literature [3,4,5] form the basis for the testing and analysis of an experimental device for the production of bands or blocks (at greater width of the band – up to 200 mm) of foam glass using household waste glass.

Table 1. Technical characteristics of the foam glass material produced in Bulgaria with the new equipment

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
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<tbody>
<tr>
<td>Density, kg/m³</td>
<td>from 120 to 300 and more (at the customer’s request)</td>
</tr>
<tr>
<td>Water absorption, %</td>
<td>max 3 (practically 0)</td>
</tr>
<tr>
<td>Thermal conductivity, W/m.K</td>
<td>from 0.032 to 0.093</td>
</tr>
<tr>
<td>Compressive strength, MPa</td>
<td>from 1.9 to 4.2 (up to 8 with modifiers)</td>
</tr>
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</table>
Due to the limited resources (reduction of the project budget for Stage 2 by BGN 100,000), the experimental program was not implemented as originally planned and the funds used for the implementation of the program up to that stage could not provide the return needed to generate sufficient experimental results for the required qualitative assessment.

II. Analysis of the test results for the device for the production of a continuous band of foam glass

1. Organizing the construction of the device and its installation on a test site

The development and the study of the vertical device for the production of band of foam glass, protected by Bulgarian patents [6,7], and the design of a technology for working with the device include several major tasks: organization of a test site, assembling and testing of the individual aggregates and nodes of the model device, wiring of the elements to form the heating system, building a control unit, putting the equipment into operation and running it for a certain amount of time to prove its functionality.

The tested device is shown in Fig. 1 and Fig. 2.

A test site of the required size was provided on the site of Promstroyproject Ltd. – Sofia. The firm was also the contractor for the mechanical structure of the device. The biggest difficulty was the shortage of funds for detailed testing and for the development of a working technology necessary to achieve product quality consistency (continuous band of foam glass). During the testing of the device it became clear that in order to ensure its proper and continuous operation, its construction required a number of modifications which could not be have been predicted in advance. Some deficiencies were eliminated while other changes requiring more funds were left for a later stage. The shortage of funds also affected the experimental work, especially the lack of funds for electricity costs and for the modification of some units of the system. Owing to this, the planned experiments involving the production of foam glass bands with varying thickness were curtailed.

Fig. 1. Diagram of the device  
(a) Longitudinal section of the device  
(b) Top view of the device  

Fig. 2. Picture of the device
Despite the difficulties, the model of the device, which is an 8-meter-high facility featuring 5 heating sections with a total of 43 heating elements and a furnace space capable of producing a continuous foam glass band, was launched and technological experiments were carried out. Experimental samples were obtained from which test samples were made in accordance with the requirements of the relevant standards and test procedures.

The mechanical structure of the device was tested off site after being manufactured, which ensures its correct operation when mounted on site. Subjected to testing were the most important units: the mechanical support frame; all basic units of the mechanical structure such as the batch supply system – the feed unit (Fig. 3), the system for shaping the ingot by means of metal strips – roller blocks with tension springs (Fig. 4), a pull-out mechanism for ensuring uniform drawing of the finished plate of foam glass, pressing and cooling rollers, a ratchet mechanism for driving the strips and other smaller elements. The following elements were also produced and then tested separately:

- The control unit (Fig. 5), which can control and test the important units of the device;
- The internal heater (Fig. 7 and Fig. 8) and the external heaters (Figures 6, 9 and 10) located along the height of the structure – a total of 16 heaters located on 4 levels; all heating elements are mounted in boxes isolated from the non-working area using wadding and cardboard made of ceramic fibers. The boxes contain the thermocouples.
controlling the temperature processes. The heating elements are wired using power and control wires, compensating wires and all other necessary operational elements;
– The hydro system located at the top of the device that drives all actuating mechanisms.

2. Organizing experimental work and conducting technological experiments.

The organization of the experimental work of the model of the device for the production of bands of foam glass includes manufacturing and assembly of the different units and elements of the system, preparation of the feedstock, glass granules in this case, mobilizing human resources for the fulfillment of all tasks, and creating a precise plan, i.e. a scenario for carrying out the experimental work.

![Fig. 7. Diagram of the internal heater](image1)
![Fig. 8. Picture of the internal heater](image2)

The technological process includes the following sequence of operations:

2.1. Processing of the necessary basic and auxiliary materials for the production of foam glass from household glass waste.

The preparation of the feedstock for the device (Fig. 11 and Fig. 12) comprises grinding the glass waste in a large 2-ton ball mill with non-metallic insulation, micro granulation (with a size from 0.3 to 0.6 mm) of the grounded and homogenized waste glass with the addition of a foamer consisting of 1% glycerin and 3% water glass, granulation of the obtained raw material to pellets with a size from 5 to 9 mm using a specialized granulator, hardening the granules obtained in a drying oven at 100-120 °C for 1-2 hours and sifting the granules using two types of sieves to separate them into two fractions with dimensions respectively up to 0.3 mm and up to 10 mm.
Due to the limited resources (reduction of the project budget for Stage 2 by BGN 100,000), the experimental program could not be implemented as originally planned.

2.2. Conducting of the technological experiments: putting the device into working mode

Successive industrial experiments were conducted after the preparation of the various mechanisms and of the feedstock in order to obtain bands with a thickness of 60 mm and 160 mm. Test reports were issued for these experiments. From the material obtained from these experiments, samples were made and tested (Fig. 13) at the Department of Silicate Materials at the University of Chemical Technology and Metallurgy in Sofia, Partner No 1 in the Project, and at the Department of Building Materials and Insulations at the University of Architecture, Civil Engineering and Geodesy in Sofia, Partner No 2 in the project.
3. Analysis of the technological tasks and of the construction as a whole.

The program of the project includes the fulfillment of the following tasks:

- Preparation of the feedstock in the form of granules (not in powder form, as in the case of the conventional production of foam glass) – accomplished.
- Exploration of the speed of movement (the ingot residence time in the different technological zones). This task requires extensive tests with different speeds of movement of the foam glass ingot towards the mechanism which cuts it into separate plates – partially accomplished.
- Developing of technological procedures for different types of foam glass (for plates of various thicknesses: 60, 100, 160 and 200 mm) – accomplished.
- Evaluation of the results of the planned technological experiments, conclusions and determination of the parameters for a future industrial model using the theory of similarity. In this task, it was intended to made adjustments to the documentation and to make a new constructive assignment for a following industrial model of the device – accomplished.
- Study of the physical and mechanical properties of the obtained samples of foam glass such as compressive strength, bending strength, density, apparent porosity, thermal expansion coefficient, heat resistance and others – accomplished.
- Conducting of climate tests, examination of the coefficient of heat conduction and sound insulation in order to assess the product’s ability to fulfill its intended purpose, which is the rehabilitation of buildings and the construction of supporting partition walls – partially accomplished.
- Preparation of a standardization document for the release of the product on the market using the laboratories of the Department of Building Materials and Insulations at the University of Architecture, Civil Engineering and Geodesy in Sofia, and of the Building Research Institute in Sofia or of another authorized body (the Bulgarian branches of LLOYD England or Germany) – not accomplished.

The fulfillment of each of the above-mentioned tasks was analyzed precisely, the results were summed up and conclusions were drawn. Particular attention was paid to analyzing the effectiveness of the technological and constructive solutions. The tasks were divided into 2 groups: qualitative and quantitative. The results from the analysis were presented using a special methodology with a ten-point scale for each technological and constructive task:

For the first group – qualitative tasks:

- efficient utilization of glass waste – 10;
- effective heating of the granule shaped batch material in order to froth it – 6;
- obtaining a quality exterior surface and a different color range of the finished product (ingot of foam glass), by moving the forming surfaces (metal strips) and coating them to avoid contact between them and the foam glass band, without scrap and losses – 8.

For the second group – quantitative tasks:

- Creating of formulations (recipes) for a batch made of waste glass and production of granules of specified sizes – 10;
- Investigation of the process of pore growth and testing of various foaming agents to determine the quantitative balance for optimal frothing according to the type of glass waste and the size of the granules – 10;
– Study of the thermal balance of the frothing process and creation of different thermal modes for the production of foam materials of various density – 8;
– Determination of the heating and cooling speeds in the frothing area and in the stabilization zone – 8;

Fig. 13. Test samples obtained from a 160 mm thick band

– Determination of the motion modes of the metal strips to obtain a quality ingot of foam glass – 8;
– Determination of the type and thickness of the coating on the boundary between the ingot and the metal surface, as well as the optimal intervals of coating to obtain a quality surface of the ingot – 8 (6).

The constructional solutions of the frothing system of the device have also been analyzed and evaluated and methodologies have been developed to test them. This includes a block diagram of the system, constructive solutions for the different system units implementing specific technological functions and development of test methods for the different units. The evaluations for the different units are as follows:
– The feedstock installation supplying the device with granular material – 10;
– The unit for heating the batch to frothing temperature combined with a process monitoring and controlling system – 6;
– The unit for fixation of the foamed structure – 8;
– The unit for stabilization and subsequent cooling of the foamed material -8;
– The driving unit for the ingot – 6;
– The system for synchronization and control of the technological parameters of frothing, fixing and stabilization of the speed of movement of the side strips, and hence of the ingot of foam glass – 10.

4. Summary of the results of the implementation of the project "Study of the technological processes in the production of thermal insulation material – foam glass obtained in a model of a frothing unit of a new vertical production device”.

The work that was carried out was complex and considerable. It covers a variety of creative activities: formulating conceptual solutions, implementing them through specific constructions and technologies, organizational activities and using research methods and analytical assessments to solve diverse complex tasks. Despite the cutting of the project budget, the results are very good. Further work is still to be done to turn the model into an operating facility suitable for commercialization.

III. Solutions for improving the construction of the existing device by creating a new one with improved performance

The main improvements of the existing and tested device are as follows:
1. In the existing device (Fig. 1) the quality of the middle layer of the monolithic ingot is not quite satisfactory due to the adherence of the foamed material to the housing of the heating unit since the batch frothing takes place at the lower end of the wedge-shaped heating unit which has ribs on its outer surface. The purpose of this positioning of the heating unit was to maximize the use of froth-forming energy by supplying it in the middle of the band or block being processed. This hinders the technological process and the finished product does not achieve the desired quality.

In the new device (Fig. 14) [8] the concept for the internal heater has changed. The adhesion to the surface of the inner heater is eliminated by moving the heaters to the upper part of the ingot which is formed by accumulating granules so that the contact of the ingot with the walls and the ribs of the heater is minimal. In the new installation the lower surface of the vertical inner prismatic heating block is the heating roof of a rectangular furnace with a homogeneous temperature. Additionally, during the construction stage the inner wall of the rectangular furnace will be required to have minimal contact with the softened batch. Also, minimal clearance must be sustained between the inclined wall of the rectangular furnace and the movable metal strips which form the side walls of the foam glass band.

2. In the existing installation the metal strips which get expanded by the temperature and due to the pulling of the propelling rollers located at the top of the device. This affects adversely the performance of the device.

In the new solution the propelling of the metal strips will be carried out by the lower rollers of the installation, designated in Fig. 14 as both driving and pulling. This allows the metal strips to stay tightened. As a result, the working efficiency of the device improves considerably.

![Fig. 14. Scheme of the new system – Bulgarian patent 66903/19.12.2014](image.png)

3. In order to obtain better homogenization of the temperature field, the width of the narrower heaters in the thermal heating zones is symmetrically extended from 200 mm to 350 mm and the additional expansion space is filled with insulating wool. The overlapping thus obtained
provides for the closing of the joints (left for free movement of the metal strips) which causes heat loss, as a result of which the frothing at the corners of the forming foam band is improved.

4. It was planned to investigate the possibility to use a composition of a coating that would prevent the foam glass material sticking to the walls of the internal heater, but because of the cuts in the project budget this task was not implemented. The new solution minimizes the contact of the frothed granules to the cooler metal surfaces. Only the well-heated walls of the furnace that have a minimum area of contact remain. It is desirable to seek a metal alloy with water glass dampness for these walls and with good insulation. The metal strips are coated each time before entering the heating zone, so that with them the problem of sticking does not occur.

Conclusions

An experimental study and an analysis of the working technology and the constructive solution of the installation for the production of foam glass band has been carried out. In order to avoid some shortcomings, a new construction of the device is proposed for which a patent application has also been filed and is now acknowledged. The following conclusions are derived:

1. With the help of the new and improved technical solution, an important optimization task is solved – the efficiency of the system is improved.
2. The proposed new construction for the frothing unit of the installation for forming a continuous band of foam glass in a vertical manner guarantees low energy consumption and avoids the problem of the material sticking to the inner heater by means of moving the inner heater to the upper part of the frothing section of the device.
3. The main goal is achieved – the heating and the frothing of the feedstock and the obtaining of a quality product.
4. The technological decision for the type of feedstock – in the form of granules – remains unchanged.

References

1. Project NF-00-92 / 05.05.2005 for a preliminary study on the topic “Study for the development of technology and equipment for introduction in the production of energy-saving insulation (foam glass) from waste glass”.
2. NSF – MES “Study of the technological processes in the production of heat insulating material – a foam glass obtained in a model of a frothing section of a new vertical production installation” under the contract with MES No DTK-02/72.

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