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APPLICATION OF DYNAMIC AND AERODYNAMIC FOAM GENERATORS. (The use of dynamic foam generators in integrated technologies for water purification, regeneration, and recirculation, including their application in greenhouse facilities and hydroponic systems)

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Abstract

This work examines modern technologies for water purification and regeneration, as well as the range of materials, including composite ones, used in these processes. It highlights that selecting the optimal technological solution is complicated by scale-dependent factors and varying operational conditions. Special attention is given to recent engineering findings: studies have revealed unique properties of gripping mechanisms in specialized robotics. The injection of compressed air from a vacuum gripping device operating on the Bernoulli principle into a liquid enables effective foaming, opening new prospects for applying such mechanisms in innovative water treatment methods.

Keywords: *Foam generator; Aerodynamic foam generator; Optimal compressed gas pressure; Scale factor; Foam load-bearing capacity; Technical specifications; Vacuum level; Required purification quality level*

Introduction

There are many different basic technologies for the purification and regeneration of water and aqueous process solutions. The market offers a wide variety of materials, including composite ones, for the same purpose. However, when it comes to making a final decision on the selection of a specific technology and material for a particular case, difficulties arise in performing a comparative analysis.

The latest technological concepts in this and related fields encounter significant challenges during implementation due to the substantial influence of the scale factor on the results of various water treatment, purification, and regeneration operations.

During the initial experiments, it was discovered that the prototype of the future foam generator, due to the fact that the air flow thickness does not exceed a few microns, can control the diameter of air bubbles in the foam by adjusting the gap between the membrane and the housing.

This indicator and technical parameter turned out to be particularly important, as it provided flexibility and a wide range of possibilities for foam generation processes based on a new principle.

In addition, the load-bearing capacity of the foam obtained in this way turned out to be significantly higher than that of conventional foam.

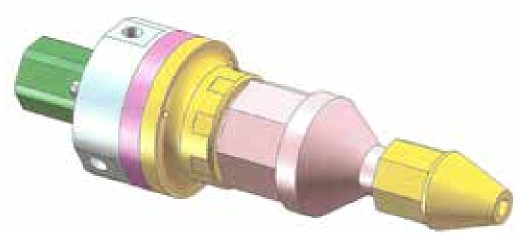
Figure 1. *Dynamic foam generator*

Figure 2. *Foam produced using a dynamic foam generator*

The ease and precision of adjusting the diameter of air bubbles in the foam are demonstrated in the following photograph. It shows how the structure of the foam within the same liquid and the same container can change when the gap between the membrane and the housing is adjusted.

It is necessary to emphasize the exceptional importance of applying the innovative developments and publications of the well-known specialist and highly qualified expert **Nikolai Seriukov**. In his research and designs, he successfully integrated the most effective technical solutions, enabling confident achievement of the ideal final result in accordance with the **Theory of Inventive Problem Solving (TRIZ)** and the **Algorithm for Inventive Problem Solving (ARIZ)**, which he masters to perfection. At the same time, the required level of structural simplicity is maintained – positively influencing the reliability of the system.

Figure 3. *Foam generator*



This simplicity is achieved through the exceptionally simple design of the foam generator.

Figure 4. *Composition of the foam generator*

As shown in the photograph, the dynamic foam generator consists of three parts, none of which are movable.

Additional technical conditions for planning water treatment equipment using foam generators based on the aerodynamic effect

Several variants of the foam generator's scale factor and design features are considered. Foam generator with optimal dimensions and optimally selected compressed gas pressure. The overall dimensions of the foam generator and the compressed gas pressure determine the quantity and size of the bubbles that form the foam, which accumulates contaminants and carries them to the surface of the liquid within the module. In addition, as mentioned earlier, the most critical factor determining the foam type and the overall efficiency of the foam generator is the thickness of the gap between the membrane and the generator housing.

Foam generator with optimal dimensions and reduced compressed gas pressure relative to the optimal level

A reduction in compressed gas pressure relative to the nominal or optimal pressure (8 atmospheres) decreases the rate of bubble formation, reduces the number of bubbles, and lowers the efficiency of contaminant fraction separation in the water. Proportional enlargement of the foam generator dimensions, while maintaining the compressed gas pressure and key operational characteristics, leads to increased gas consumption and a greater number of generated bubbles.

At this point, the author proposes to pause the description of technical conditions and turn to one of the practical applications of the foam generator.

Figure 5. *Foam layer obtained using a foam generator on wastewater from modern butter production*

All major contaminants of fatty and organic origin are present in this foam layer, which forms a relatively isolated layer that can be easily separated from the remaining liquid. The liquid, once freed from fats and other organic impurities, can then be effectively treated using electrochemical technologies.

To form and generate the foam, only a foam generator and a compressor are required – no additional chemical reagents are needed.

It should be noted that in current industrial practice, similar processes typically rely on chemical reagents, the cost of which can reach hundreds of thousands of dollars per month, not to mention the need to protect the final products from the harmful effects of these chemicals. Eliminating the adverse impact of chemical reagents and their residues in process water used for food and dairy production is both complex and extremely expensive. Therefore, achieving the same technological effect through aerodynamic action – using only compressed air – provides the technology of aerodynamic foam formation with significant **economic** and **environmental** advantages.

Figure 6. *Liquid treated using an aerodynamic foam generator*

Liquid treatment using aerodynamic foam generators makes it possible to achieve the required level of purification quality at relatively low process costs, without the need for investments in the development of soy graphene production. After this brief digression, it is appropriate to return to the discussion of additional technical conditions.

Foam generator with reduced dimensions and optimal compressed gas pressure

Reducing the dimensions of the foam generator while maintaining optimal pressure leads to lower compressed gas consumption and a reduction in the number of generated bubbles.

Foam generator with increased dimensions and increased compressed gas pressure relative to the optimal level

In this case, if the increase is proportional across all parameters, there is a linear rise in compressed gas consumption and, accordingly, in the number of formed bubbles, while maintaining their energy characteristics.

Foam generator with reduced dimensions and increased compressed gas pressure relative to the optimal level

Here, the amount of compressed gas and the number of generated bubbles do not decrease, but their energy intensity increases.

Variants and parameter ratios of the module for aerodynamic flotation Increased module column capacity with a constant optimal number of foam generators

Increasing the column capacity while maintaining the optimal number of foam generators reduces the flotation module's productivity.

Increased module column capacity with an increased number of foam generators

In this case, the productivity of the module increases, but so do the energy costs of its operation.The design of the foam generator is so universal and simple that it can be manufactured from a wide variety of structural materials, including all types of plastics and composite materials.The following photographs show foam generators made of aluminum alloys and stainless steel. The author draws attention to the **shape of the membrane combined with the conical reflector**, which allows the establishment of a minimal gap regardless of the construction material and its rigidity.

Figure 8. *Shape of the membrane combined with the conical reflector*

Applications of Foam Generators

There are many known applications of foam generators, two of which are worth discussing in detail for comparison – one in **greenhouse environments**, and the other in **systems designed for cleaning oil from the sea surface**.

System for Cleaning Oil from the Sea Surface

The device for separating oil from seawater is mounted on a specially equipped vessel. This separation apparatus must be installed on a ship equipped with all necessary systems and modules where oil is separated from seawater through **aerodynamic treatment** using foam generators. The ship must also include diesel generators (powered by the same oil-water mixture), compressors (powered by those diesel generators), pipelines, pumps, tanks for contaminated water, oil collectors, and reservoirs for purified seawater.

General Specifications of the Apparatus

- **Productivity**
- **Occupied operational area**
- **Compressed air consumption**
- **Duration of one purification cycle**
- **Number of modules per ship**

The **expected purification efficiency** of seawater should be **at least 99.97%**, with a **residual oil concentration** not exceeding **3 mg per liter** of purified seawater.

- Compressed air consumption at 4 bar: no more than **0.8 liters per second per foam generator**.
- Productivity per module: at least **20 gallons of water per minute**.

- Total compressed air consumption for one module: **19.2 liters per second (1152 liters/min, or 40.7 cubic feet/min at 4 bar)**.
- Power consumption per module (using screw compressors): not more than **5 kW (6.7 horsepower)**.

Advantages of the Proposed Method and Apparatus

- The system has a **modular design**, enhancing overall reliability.
- **Productivity** can be increased by adding more modules (each occupying ≤ 6 m^2). A full-scale system of 125 modules occupies about **750 m^2**.
- The entire purification complex, including all cleaning stages, can be installed on a ship with a **deck area of 1000 m^2**.
- Modules can be arranged in **two or more tiers**, allowing capacity to double or triple without changing ship type.
- The system can be expanded with additional purification units.
- The ship and its purification modules are **fully autonomous**, generating energy from the oil–water mixture itself, eliminating the need for external fuel deliveries to spill zones.
- Thanks to its modular architecture, the system offers **high flexibility, interchangeability, reliability, and maintainability**.

Conclusion

As evident from the above, the proposed **dynamic foam generation technology** has a **wide range of applications**, offering **significant technical and economic advantages** while maintaining **low investment costs**.

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