Theoretical aspects and engineering approaches to energy-saving liquid atomization technologies

CM& LTP 2025

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Abstract

The development of energy-saving liquid atomization technology is one of the most promising areas in the field of engineering and industrial processes. Over the past decades, much attention has been paid to the search and implementation of new atomization methods that not only increase the efficiency of heat and mass transfer and reaction processes, but also reduce energy costs for production. Given the global problems associated with energy resources and environmental challenges, the creation of energy-efficient and environmentally friendly technologies has become an important goal for scientists and engineers in many industrial fields. In this regard, the need to develop and implement energy-saving technologies for atomizing liquids is becoming increasingly relevant. The search for new approaches that can significantly reduce energy consumption without losing the quality of processes is an important part of modern research. The development of efficient atomizers that use minimal energy costs is becoming an important area in the modernization of existing technologies. Special attention is drawn to the analysis of the liquid state and its influence on the atomization processes. Theoretical understanding of these properties makes it possible to optimize the design of sprayers and increase the efficiency of heat and mass transfer in liquid-gas systems. Increasing energy efficiency in liquid atomization processes is an important step towards reducing energy costs and reducing the environmental impact of industrial production. To do this, it is necessary to introduce the latest technologies that contribute to reducing energy consumption while maintaining high process efficiency. One of such solutions is the use of thin-film technologies, which allow significantly increasing the surface area of the liquid and accelerating the evaporation process. This allows reducing energy costs, while simultaneously increasing atomization efficiency and reducing the time required to achieve the necessary physicochemical changes.

General theoretical fluid models

- structurally heterogeneous - shows the model of the liquid as a cluster of many ultramicroscopic significantly deformed aggregates - "crystalline islands", separated by regions of chaotic arrangement of particles;
- structurally homogeneous - it is based on a model that shows that each molecule in a liquid is surrounded by neighboring molecules that are located around it in almost the same way as they are located in a crystal of the same substance.
- hole - proceeds from the main important differences - of the liquid state from the gaseous one: fluids and a free surface are manifested in liquids. The fluidity of liquid media is manifested in their ability to change their shape with minimal effort without changing the total volume;
- - quasicrystalline - the liquid exhibits the properties of long-range order, which is characteristic of crystals. According to this model, the liquid is a set of temporary microcrystals (quasicrystals), which periodically collapse and reappear inside the liquid.

Heat and mass transfeer liquid-gas phases

Heat and mass transfer between liquid and gas phases is one of the main processes in technologies related to liquid atomization. This process involves the transfer of heat and mass from the liquid to the gas phase or vice versa, which is important for such industrial applications as cooling, air purification, chemical processing and others.
Thermal conductivity is one of the main mechanisms of heat and mass transfer, describing the transfer of heat through materials without macroscopic particle motion. In liquid-gas systems, thermal conductivity is determined by the ability of a liquid to transfer heat due to collisions of molecules.
Convection is the process of heat or mass transfer through the movement of a liquid or gas. It can be natural or forced. In the case of liquid atomization, convection occurs when the gas surrounding the liquid droplets moves and picks up the heat transferred from the liquid phase. Convection is important for increasing the efficiency of the heat and mass transfer process because it allows heat to be distributed over a large area.
Evaporation is an important mechanism of heat and mass transfer, when a liquid turns into a steam, absorbing heat from the environment. This process is of great importance in technologies involving liquid atomization, as it contributes to lowering the temperature of the liquid, which increases the cooling efficiency.

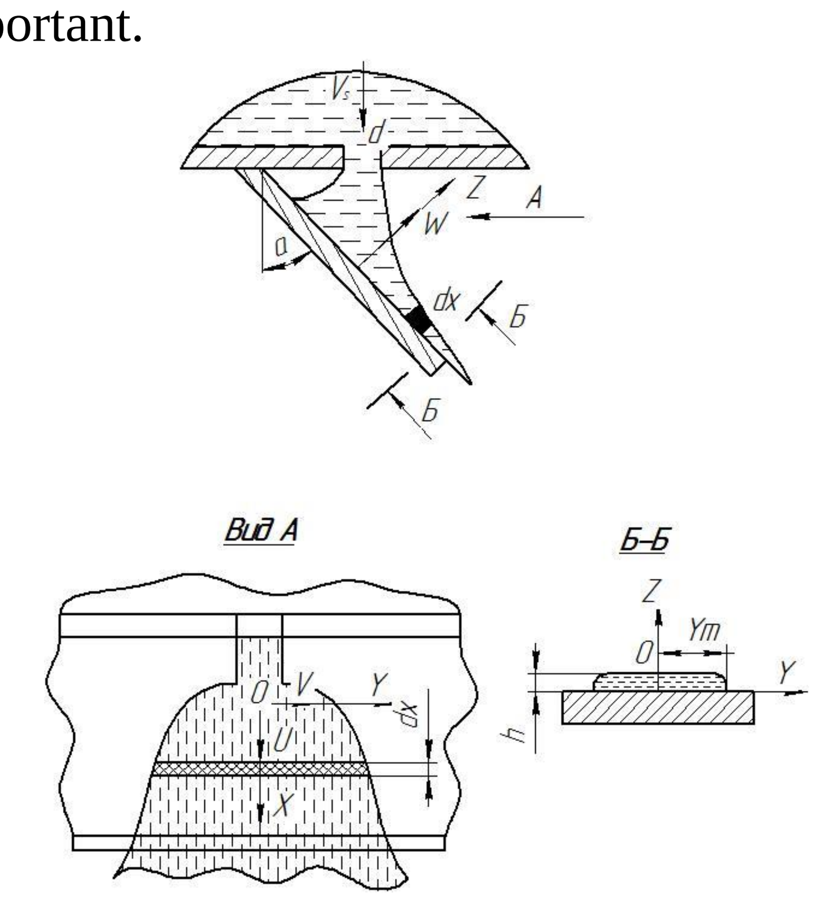
Liquid atomizing methods

The process of atomizing liquids is an important step in many industrial processes, as it provides the necessary dispersion of the liquid for effective heat and mass transfer, mixing, chemical reaction or cooling. There are different methods of atomizing liquids, and each of them has its own specific advantages depending on the technological requirements and process parameters.

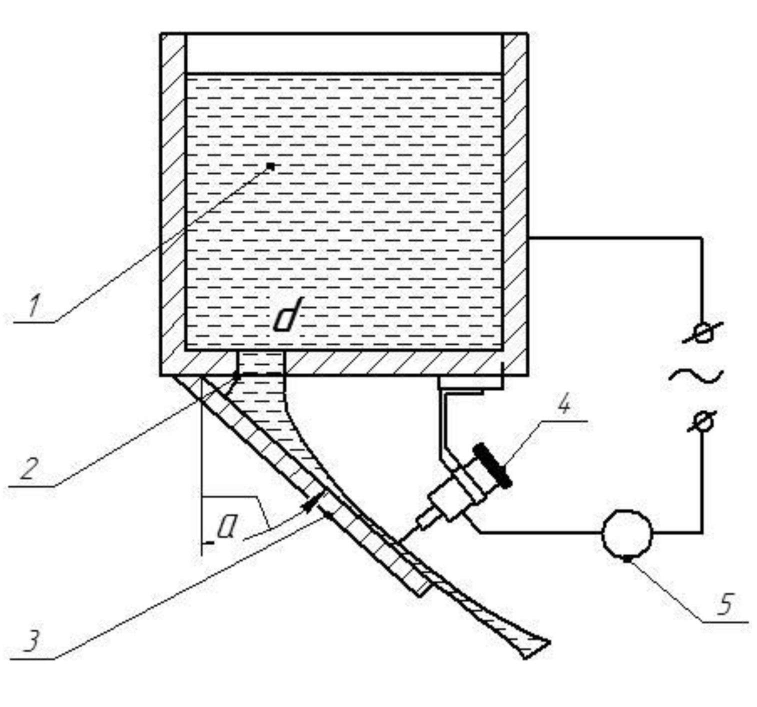
- **Static sprayers;**
- **Centrifugal atomizers**;
- **Pneumatic sprayers;**
- **Mechanical sprayers;**
- **Laser and ultrasonic atomization.**

Static sprayers

Static sprayers are a type of device that uses a mechanism that does not require moving parts to spray a liquid. They operate on the basis of the pressure difference between the liquid and the environment surrounding the sprayer, creating a thin film or fine droplets. Static sprayers are simple in design and are mostly effective for processes where energy savings and minimal mechanical complexity are important.

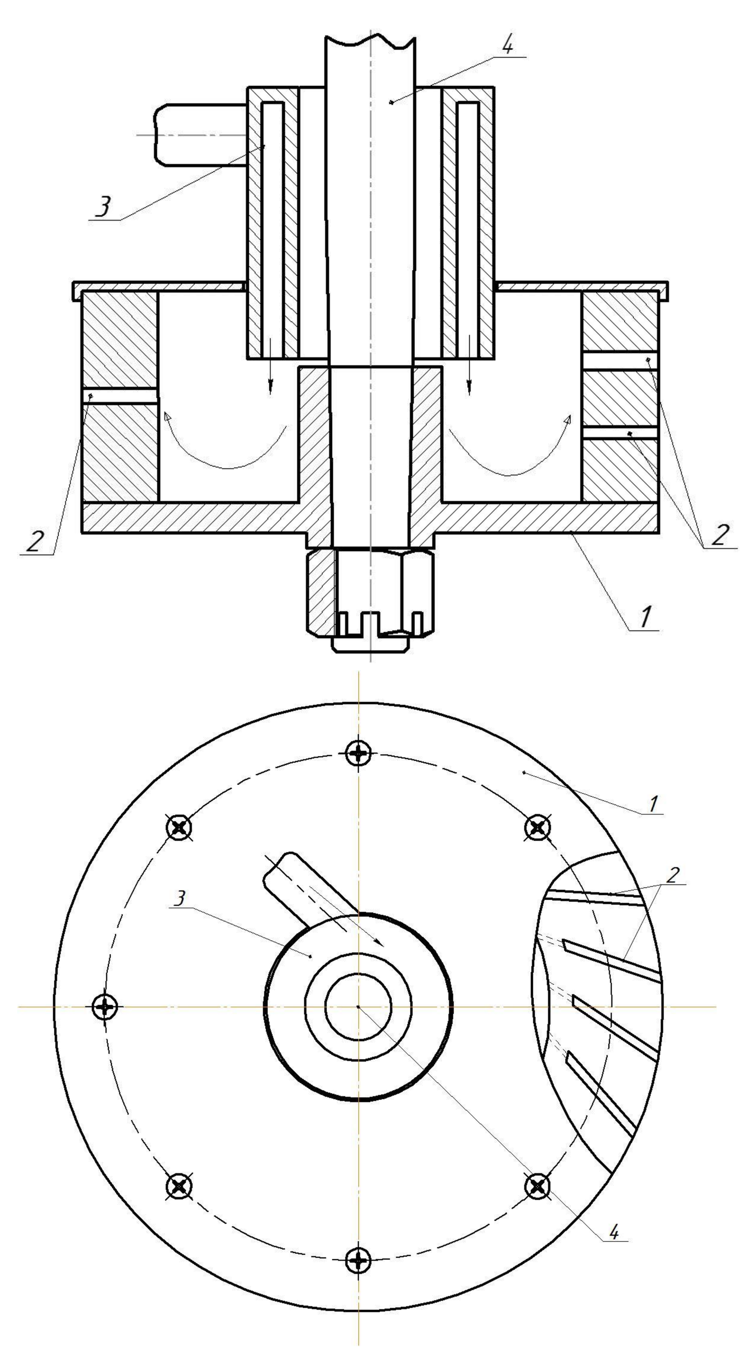


Scheme for calculating the parameters of a single film formed on a static film former.



Centrifugal atomizers

Centrifugal atomizers use the principle of operation based on the creation of a high speed of rotation of the liquid in rotating elements. As a result, the liquid is dispersed into small droplets, which can have a wide range of sizes. This type of atomizer provides high performance and allows to create very small droplets, which is important for processes where intensive heat transfer or high reactivity is required. Centrifugal atomizers usually consist of a disk or rotor that rotates at high speeds, creating centrifugal force that ejects the liquid into the surrounding space in the form of small droplets. These atomizers are used in systems where it is necessary to create a homogeneous and finely dispersed suspension.



Schematic diagram of the design of a vane centrifugal atomizer

Energy-saving prospects

Increasing energy efficiency in liquid atomization processes is an important step towards reducing energy costs and reducing the environmental impact of industrial production. To do this, it is necessary to introduce the latest technologies that contribute to reducing energy consumption while maintaining high process efficiency. One of such solutions is the use of thin-film technologies, which allow significantly increasing the surface area of the liquid and accelerating the evaporation process. This allows reducing energy costs, while simultaneously increasing atomization efficiency and reducing the time required to achieve the necessary physicochemical changes.
The use of such innovative atomization methods allows to achieve not only economic advantages, but also significantly improve the environmental efficiency of production processes. In the future, the development of energy-saving technologies in the field of liquid atomization will ensure a more sustainable development of industrial processes, allowing to reduce their energy consumption and environmental impact. Research in this direction will undoubtedly contribute to the creation of new, more effective solutions for energy saving and improving productivity in various industries.

Conclusions

The use of such innovative atomization methods allows to achieve not only economic advantages, but also significantly improve the environmental efficiency of production processes. In the future, the development of energy-saving technologies in the field of liquid atomization will ensure a more sustainable development of industrial processes, allowing to reduce their energy consumption and environmental impact. Research in this direction will undoubtedly contribute to the creation of new, more effective solutions for energy saving and improving productivity in various industries.
The research is based on an analysis of contemporary literature, physical and technical models and experimental data. The importance of considering the specific properties of liquids in the development of new atomizer designs, as well as the necessity of an interdisciplinary approach to optimizing process is emphasized. The obtained results indicate the prospects of further research in the field of energy-saving technologies for liquid atomization. This will ensure that industrial processes are both economically beneficial and environmentally sustainable.