INVESTIGATION OF THE EFFECT OF DISPERSED GRANULAR PARTICLES ON THE HEAT EXCHANGE PROCESS IN A HEAT EXCHANGER

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Abstract: This study investigates the effect of dispersed granular particles on the heat exchange process in heat exchangers, focusing on enhancing heat transfer efficiency. Heat exchangers with spiral-shaped coil tubes are widely used in various industries due to their reliability and ease of maintenance. However, optimizing their design to improve heat transfer remains a key challenge. The research explores how the addition of dispersed granular particles, such as metallic and non-metallic materials, influences heat exchange mechanisms. Experimental and computational analyses reveal that these particles enhance thermal conductivity, promote turbulence, and increase heat transfer rates by 15–30%. However, factors such as particle sedimentation, viscosity changes, and material compatibility impact efficiency and operational performance. The findings contribute to the development of advanced heat exchanger designs, offering potential applications in industrial heating, cooling systems, and energy-efficient thermal management

Keywords: boil-off, heat transfer coefficient, spring screw channel, intensification, heat transfer, and complex intensification technique.

Аннотация: В данной работе изучается влияние дисперсных гранулированных частиц на процесс теплообмена в теплообменниках с акцентом на повышение эффективности теплопередачи. Теплообменники со спиральными трубками змеевика широко используются в различных отраслях промышленности благодаря своей надежности и простоте обслуживания. Однако оптимизация их конструкции для улучшения теплопередачи остается ключевой задачей. В исследовании изучается, как добавление дисперсных гранулированных частиц, таких как металлические и неметаллические материалы, влияет на механизмы теплообмена. Экспериментальный и вычислительный анализ показывает, что эти частицы повышают теплопроводность, способствуют турбулентности и увеличивают скорость теплопередачи на 15–30%. Однако такие факторы, как осаждение частиц, изменение вязкости и совместимость материалов, влияют на эффективность и эксплуатационные характеристики. Результаты исследования способствуют разработке усовершенствованных конструкций

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теплообменников, предлагающих потенциальные возможности применения в промышленных системах отопления, охлаждения и энергоэффективного терморегулирования.

Ключевые слова: выкипание, коэффициент теплопередачи, пружинно-винтовой канал, интенсификация, теплопередача и комплексный метод интенсификации.

Annotatsiya Ushbu tadqiqot issiqlik almashinuvchilarida issiqlik almashinuvi jarayoniga dispers granulalar zarralarining ta'sirini o'rganadi va issiqlik uzatish samaradorligini oshirishga qaratilgan. Spiral shaklidagi rulonli trubkali issiqlik almashtirgichlar ishonchliligi va texnik xizmat ko'rsatish qulayligi tufayli turli sanoat tarmoqlarida keng qo'llaniladi. Biroq, issiqlik uzatishni yaxshilash uchun ularning dizaynini optimallashtirish asosiy muammo bo'lib qolmoqda. Tadqiqot metall va metall bo'lmagan materiallar kabi dispers donador zarrachalarning qo'shilishi issiqlik almashinuvi mexanizmlariga qanday ta'sir qilishini o'rganadi. Eksperimental va hisoblash tahlillari shuni ko'rsatadiki, bu zarralar issiqlik o'tkazuvchanligini oshiradi, turbulentlikni oshiradi va issiqlik uzatish tezligini 15-30% ga oshiradi. Biroq, zarrachalarning cho'kishi, yopishqoqlikning o'zgarishi va materialning muvofiqligi kabi omillar samaradorlik va operatsion ishlashga ta'sir qiladi. Topilmalar sanoat isitish, sovutish tizimlari va energiyani tejaydigan issiqlik boshqaruvida potentsial ilovalarni taklif qiluvchi ilg'or issiqlik almashtirgich konstruktsiyalarini ishlab chiqishga yordam beradi.

Kalit so'zlar: qaynatish, issiqlik uzatish koeffitsienti, bahor vintli kanali, kuchayish, issiqlik uzatish va murakkab intensivlashtirish texnikasi.

Introduction.

Heat exchangers play a crucial role in various industrial applications by facilitating efficient thermal energy transfer. Among them, helical coil heat exchangers, consisting of a coil placed inside a cylindrical shell, are widely used due to their ease of maintenance. The coil tubes, typically ranging from 25 to 75 mm in diameter, transport gas or steam. However, their relatively small heat exchange surface area and low heat transfer coefficient present significant limitations.

The study of heat exchange processes involving dispersed granular particles, such as powders or granules, is essential for enhancing heat transfer efficiency. These processes are complex, as factors including particle size, shape, density, and other physical properties significantly influence thermal conductivity. Understanding and optimizing these interactions are critical for improving device performance and achieving energy savings.

Enhancing heat transfer efficiency is closely linked to the development of advanced heat exchange elements. This topic has been extensively explored by

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researchers, including Russian scientists E. A. Dmitriev, E. P. Morgunova, and R. B. Kormlashev. Their studies have led to innovative methods of shaping heat exchange surfaces, such as incorporating helical grooves and barriers that promote fluid circulation, thereby intensifying heat transfer.

Recent advancements have introduced coiling devices with wire loops of varying cross-sectional surfaces, constructed using spring-helical channels reinforced with laser welding. Figure 1 illustrates a spring-helix channel, which is formed by tightly winding elliptical or circular wire around a cylindrical or elliptical core. The elliptical cross-section of the flow results in radial pressure redistribution along the ellipse's axes, generating swirling currents that enhance internal mixing. This mechanism significantly improves heat transfer efficiency and accelerates thermal stabilization over a shorter channel length. Furthermore, the presence of spiral loops on the outer surface of the spring channel functions as external fins, expanding the heat exchange surface area by approximately 1.5 to 1.7 times.

This study investigates the effects of dispersed granular particles on heat exchange efficiency in helical coil heat exchangers, aiming to optimize thermal performance and contribute to the development of energy-efficient industrial heat exchange systems.

METHODOLOGY. To analyze the impact of granular particles on heat transfer in a heat exchanger, experimental setups typically include controlled inlet and outlet temperatures, particle-fluid mixtures with defined concentrations, and measurement systems to track temperature gradients, pressure drops, and overall heat transfer coefficients. These experiments are often complemented by computational fluid dynamics (CFD) simulations, which model particle dispersion patterns, heat distribution, and flow behavior within the coiled heat exchanger tubes. Such simulations allow for the optimization of design parameters and the prediction of performance outcomes under various operating conditions.

Experimental and numerical data from heat exchanger performance assessments provide valuable insights into optimization strategies. Several factors significantly influence heat transfer efficiency, must be carefully considered in the design and operation of heat exchangers.

One of the most critical factors affecting heat transfer efficiency is the temperature difference between the hot and cold fluids. A higher temperature gradient increases the rate of heat transfer, allowing for more efficient thermal exchange. According to Fourier’s law of heat conduction, the rate of heat transfer is directly proportional to the temperature difference. Engineers often aim to maximize this gradient by optimizing inlet and outlet temperatures, which can be achieved through proper system design and operational controls.

ISSN 3030-3907

Another crucial element influencing efficiency is the heat transfer coefficient, which is determined by both material properties and fluid dynamics. The heat transfer coefficient represents how well heat is conducted between the fluid and the heat exchanger surface. Enhancing this coefficient leads to better overall efficiency. Factors such as fluid turbulence, material thermal conductivity, and surface characteristics significantly influence heat transfer. Advanced techniques, such as surface enhancements and micro-fin structures, can be employed to increase the heat transfer coefficient and enhance performance.

Flow rate is another key consideration in heat exchanger performance. A higher fluid velocity improves convective heat transfer by thinning thermal boundary layers, thereby increasing heat transfer efficiency. However, increasing the flow rate also leads to higher pressure drops, which can require additional pumping power and impact system performance. Engineers must carefully balance the trade-off between enhanced heat transfer and increased energy consumption, ensuring that the system operates efficiently without excessive energy costs.

Fouling resistance is a crucial factor in maintaining long-term heat exchanger efficiency. The accumulation of deposits such as scale, dirt, and biological growth on heat exchanger surfaces reduces heat transfer effectiveness and increases thermal resistance. Fouling can lead to higher operational costs due to increased maintenance and energy consumption. Implementing regular cleaning schedules, using anti-fouling coatings, and selecting self-cleaning heat exchanger designs can help mitigate this issue and prolong equipment lifespan.

Material selection also plays a fundamental role in heat exchanger performance. High thermal conductivity materials such as copper and aluminum facilitate rapid heat transfer, improving overall efficiency. However, these materials can be more expensive compared to alternatives like stainless steel, which offers superior corrosion resistance but lower thermal conductivity. Engineers must balance cost, durability, and thermal performance when selecting materials to ensure optimal performance for specific applications.

By analyzing both experimental and numerical data, engineers can develop optimized heat exchanger designs that maximize efficiency. Key considerations include temperature gradients, heat transfer coefficients, flow rates, fouling resistance, and material properties. These considerations ensure that heat exchangers operate effectively across various industries, from power generation and chemical processing to HVAC systems and automotive applications.

RESULTS. Experimental results indicate that the inclusion of metallic particles, such as aluminum and copper, enhances heat transfer rates by approximately 15 to 30% compared to conventional working fluids. Non-metallic particles, such as silica or polymer-based granules, also contribute to improved heat

ISSN 3030-3907

exchange but are primarily used in applications requiring corrosion resistance and reduced wear on heat exchanger surfaces. However, several challenges remain despite these advantages. A major issue is particle sedimentation, which can lead to clogging and reduced heat transfer efficiency, particularly in low-velocity flow conditions. Increased viscosity due to a high concentration of dispersed particles can also increase the energy required to pump the fluid through the system, thereby affecting operational costs. Additionally, interactions between certain particle materials and heat exchanger surfaces may lead to long-term wear and corrosion, requiring careful material selection for both the working fluid and the exchanger.

When designing heat exchange devices, several factors must be considered. The device should be compatible with the technological process, highly efficient, cost-effective, and reliable, while also minimizing metal consumption. The construction material must be resistant to erosion under working conditions. High heat transfer coefficients can be achieved if heat-conducting fluids move through the device at high speeds. To attain such high values, the heat exchange surface must be kept clean.

The study of the effect of scattering granular particles on the heat exchange process in the heat exchanger is an important area of research aimed at improving thermal performance and efficiency in various industrial applications. The heat exchanger consists of coiled tubes contained in a shell, which promotes heat transmission by creating secondary flow effects within the system. Because of their small size and excellent heat transfer efficiency, these heat exchangers are widely used in sectors such as power generation, refrigeration, heating systems, and chemical processing.

One of the key aspects of improving heat transfer efficiency in these systems is the introduction of granular particles into the working fluid. Granular particles - composed of metallic, ceramic, or polymeric materials - influence heat exchange through several mechanisms. First, the addition of high-conductivity particles enhances the overall thermal conductivity of the fluid, allowing heat to transfer more efficiently. Second, the movement of these particles within the fluid generates micro-convective effects that disrupt the thermal boundary layer and improve heat dissipation. Additionally, granular particles increase turbulence, further enhancing the heat transfer coefficient by preventing stagnant thermal layers on exchanger surfaces.

Several factors idetermine the effectiveness of granular particles in heat exchange. The size of the particles plays a crucial role, as smaller particles remain suspended in the fluid for a longer duration and interact more effectively with the fluid’s thermal properties, while larger particles tend to settle and cause clogging issues. The concentration of the particles also impacts system performance. While

ISSN 3030-3907

a moderate concentration range of 0.5 to 2% by volume has been found to optimize heat transfer efficiency, excessive particle loading can lead to increased viscosity, which results in higher pumping power requirements and pressure drops across the system. The material properties of the particles, including their specific heat capacity and thermal conductivity, determine their ability to enhance heat exchange performance. Additionally, the velocity of the fluid flow influences the dispersion of particles, with higher flow rates ensuring uniform distribution and preventing sedimentation.

DISCUSSION. Heat transfer plays a crucial role in chemical engineering, particularly in processes involving heat exchangers and reactors. The efficiency of heat transfer directly affects energy consumption, production costs, and operational safety. This article examines heat transfer mechanisms, thermodynamic properties, and the implications of heat exchanger performance based on empirical data.

Heat transfer occurs through three primary mechanisms: conduction, convection, and radiation. In chemical engineering, conduction and convection dominate due to the extensive use of heat exchangers and process piping.

Conduction: Governed by Fourier's Law, conduction occurs within solid materials or stationary fluids due to temperature gradients. The thermal conductivity (k) of a material dictates its ability to conduct heat.

Convection: Involves heat transfer between a solid surface and a moving fluid. It depends on the convective heat transfer coefficient (h), which is influenced by fluid velocity, viscosity, and surface properties.

Radiation: Although less significant in typical chemical processes, thermal radiation is relevant at high temperatures where energy is transferred via electromagnetic waves.

The practical applications of granular particle-enhanced heat transfer in the heat exchangers span multiple industries. In industrial heating and cooling systems, these techniques are used to improve energy efficiency in chemical processing plants, HVAC systems, and power generation facilities. In renewable energy applications, such as solar thermal systems, granular-enhanced heat exchange can improve heat absorption and storage. The food and pharmaceutical industries also benefit from this technology, as precise thermal control is essential for maintaining product quality and processing efficiency.

A disc with thermal insulation on its side and upper surfaces was used to evaluate the heat transfer intensity from objects floating intermittently on the surface of a layer. The presented data exhibit the same pattern of variation in the heat transfer coefficient α as observed previously, but only within the range of K values up to 7. The deviation from the general trend is attributed to the presence of a flat body above it. This deviation occurs because stagnant zones form on smooth

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surfaces, reducing the α coefficient and slowing its increase. However, this also contributes to the intensification of heat exchange processes within these stagnant zones.

Heat exchangers are vital components in industrial processes, optimizing energy efficiency by transferring heat between two or more fluids. The performance of a heat exchanger is evaluated based on parameters such as heat transfer coefficient, temperature gradient, and overall efficiency.

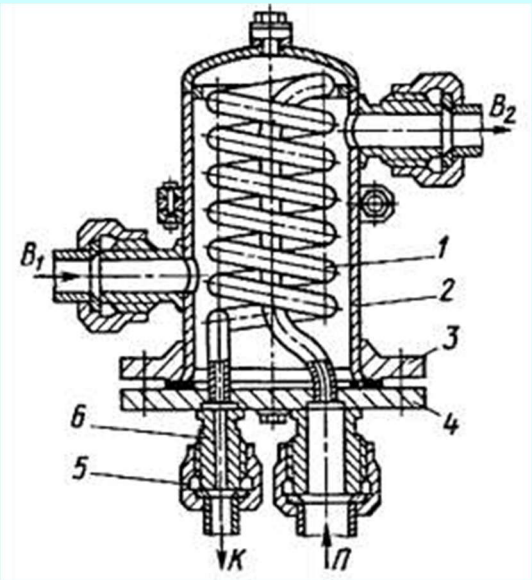
Shell and Tube Heat Exchanger is common in large-scale industries, these exchangers provide high heat transfer efficiency and are suitable for high-pressure applications.

Plate Heat Exchanger is composed of multiple thin plates, this type enhances heat transfer due to increased surface area.

Finned Tube Heat Exchanger is used where extended surfaces are needed to facilitate heat dissipation.

Air-Cooled Heat Exchanger is utilized in locations where water supply is limited, making use of ambient air for cooling.

Notably, when the discs are removed and their amplitude increases, a monotonic rise in the α coefficient is observed on their lower surface across all particles. The coefficient α depends on the shape, size, and density of the suspended particles. An increase in the diameter and thickness of the layer is associated with the intensification of flow within the dispersed medium. As a result, particles maintain a constant cross-section and greater thickness, enhancing heat exchange. The high intensity of heat transfer in freely floating bodies is primarily due to the unsteady nature of gas flow and the particles formed within the vibratory layer.



A spiral coil enclosed in a cylinder shell makes up a coil heat exchanger. Steam or gas emerges from the coil's tubes (Fig. 1). The heat transfer coefficient between steam and liquid on the coil's outside wall is likewise low because of the vast volume of the liquid-filled container and the extremely low velocity of the liquid inside. A bowl-shaped container is inserted within the device to decrease its size and boost the liquid's velocity. *Fig. 1. Coil Heater: 1 – Coil; 2, 3 – Flange housing; 4 – Cover; 5 – Nut; 6 – Housing; 7*

ISSN 3030-3907

– Nozzle; V1 – Water inlet; V2 – Water outlet; P1 – Nominal input; P2 – Condensate outlet.

Coils made up of multiple parallel sections are fitted if there is a lot of coolant. When the portions are connected in such a parallel fashion, the medium's speed and path of travel diminish, which also lowers the device's hydraulic resistance. Since the heated liquid in these devices primarily travels slowly, heat is delivered from the coil wall by free convection. Although they are simple to fix, their relatively modest heat exchange surface and heat transfer coefficient are a drawback. The tube is placed within a cylindrical foam container and is curled like a coil. There is a liquid within container 2 with a cylindrical shell that requires heating.

CONCLUSION. Heat transfer efficiency is a critical factor in chemical engineering, directly influencing energy consumption and operational costs. By optimizing parameters such as flow rate, heat transfer coefficient, and surface area, industries can significantly enhance performance. Regular maintenance, advanced materials, and innovative heat exchanger designs contribute to sustainable and cost-effective energy use. Ongoing research and technological advancements continue to drive improvements in heat exchanger efficiency, ensuring better resource utilization in industrial applications.

LIST OF REFERENCES:

1. Пальченок А.И., Тамарин А.И. // Инженерно-физический журнал. – 1983. – Т. 45. – № 3. – С. 427–433.

2. Тамарин А.И., Пальченок Г.И., Горюнов К.Е. Тепло- и массообмен модельных частиц в псевдоожиженном слое инертного материала // Тепломассообмен – VII. – 1984. – Т. V. – Ч. 1. – С. 27–31.

3. Prins W., Draijer W., Swaaij W.P.M. Heat transfer to immersed spheres or freely moving in a gas fluidized bed // Heat and Mass Transfer in Fixed and Fluidized Beds: XVII CHMT International Conference.

4. Лайковская Е.Ю. Некоторые особенности теплообмена в вибрирующем слое дисперсного материала // Тепло- и массоперенос и неравновесная термодинамика дисперсных систем. Труды УПИ. – Свердловск: Изд-во УПИ, 1974. – Сб. 227. – С. 190–193.

5. Багоутдинова А.Г., Золотоносов Я.Д. Змеевиковые теплообменники. Моделирование, расчет: монография. – Казань: Изд-во Казанского гос. архитектурно-строительного университета, 2016. – 245 с.

6. Нурмухамедов Х.С., Нигмаджонов С.К., Шералиева О.А. и др. Асосий технологик жараён ва курилмалар. Дарслик.- Тошкент: “Science and Innovation” нашриёти. 2025.-256 б.

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