WHITE PAPER

The value of increasing the efficiency of tubular heat exchangers by using turbulators

Introduction

Heat transfer enhancement in all types of heat exchanger systems is of great significance for the cooling and heating industry. In addition to saving energy, it also leads to a reduction in size and weight of equipment. In the last decade energy efficiency has become an increasingly important theme among policy makers as it can enable economic growth, reduce emissions and improve energy security[1].

As a result, manufacturers of heat transfer equipment are confronted with stricter efficiency and emission norms and a market pull for energy efficient products. In response to the stricter directives and the increasing demands from end-users, producers are forced to innovate their products and search for various techniques of enhancing heat transfer.

For many years turbulators have been an important means to improve convective heat transfer in tubular heat exchangers and thereby increase the overall efficiency of the system. This whitepaper will explore the advantages of applying turbulators in tubular heat exchanger systems for manufactures of a diverse range of energy conversion systems.

Contents

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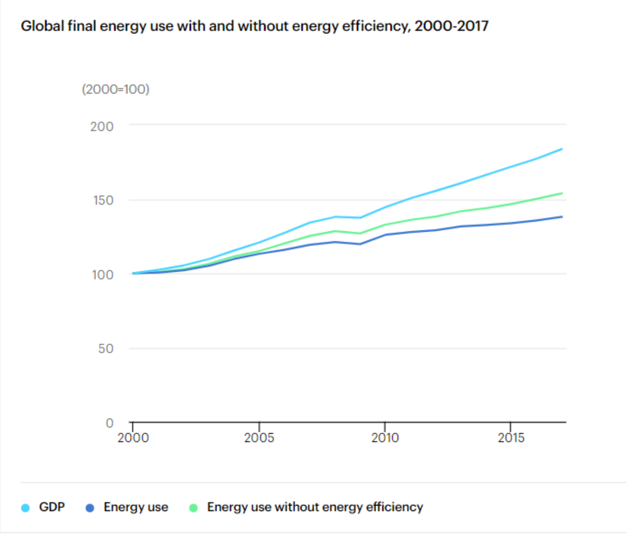
Market drivers for increasing the efficiency of tubular heat exchangers

Three main drivers can be distinguished, illustrating the need for increased energy efficiency, being: Energy security, energy equity and energy sustainability.

1. Energy security: In order to sustain economic development and meet current and future demand, energy efficiency can be of great importance by uncoupling energy consumption from economic development [2] Globally, efficiency gains since 2000 prevented 12% more energy use than would have otherwise been the case in 2017 [3].

[1,2] https://www.iea.org/reports/energy-efficiency-2018
[3] https://www.iea.org/world



Source: IEA, "Global final energy use with and without energy efficiency, 2000-2017", IEA, Paris https://www.iea.org/data-and-statistics/charts/global-final-energy-use-with-and-without-energy-efficiency-2000-2017

2. Energy equity: By increasing efficiency major savings can be made in fuel costs. The importance of energy efficiency to reduce operational cost and make use of certain energy subsidies has become more and more important for end-users, in particular energy-intensive industries due to more stringent energy directives. The use of more efficient heat exchangers often results in cost savings in energy and other operations, as well as lower maintenance costs.

3. Energy sustainability: EU directives such as Eco-design for energy efficiency and emissions have become more stringent. For example for space and combination heaters, energy efficiency is the most important parameter next to emission levels to meet a certain emission class. Additionally energy-efficient heat exchangers contribute to achieving emission targets for CO^2 and NO^x emissions.

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What are the implications of these market drivers for manufacturers?:

Stricter norms and increasing market demand for efficiency requires the manufacturing of compact and efficient heat exchangers. To be future proof, end-users anticipate on future directives and subsidies for energy efficiency. Therefore various techniques and innovations for enhancing the efficiency of heat exchangers are necessary to keep up with competition.

The challenge of increasing the efficiency of tubular heat exchangers

Tubular heat exchangers are traditionally one of the most often used heat exchangers and still are the main category of heat exchangers. They are used in a diverse range of applications to transfer heat between two fluids (liquid or gas), which are separated by a solid tube wall to prevent mixing.

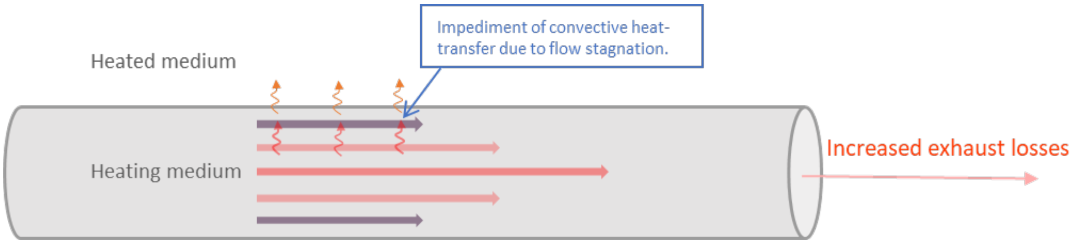
Heat exchanger efficiency

Increasing the efficiency of tubular heat exchangers is complex as it needs to take into account not only the heat transfer rate but also matters like pressure drop, maintenance, long term endurance and cost and size of equipment. In addition it is important to minimize energy losses to the external environment as much as possible.

Foremost tubular heat exchangers are designed with a maximum wall area to increase efficiency while minimizing resistance of the fluid flow through the exchanger. This however, goes hand-in-hand with compromises like the size and cost of the equipment. Furthermore, the flow-conditions of the heating and heated medium are of great importance for efficient convective heat transfer to take place.

Laminar flow conditions in tubular heat exchanger systems

A common problem in tubular heat exchangers is that under certain conditions a laminar flow of the heating or heated medium can occur. As a result, flow stagnation near the tube wall creates a thermal boundary layer which restricts the convective heat transfer around the tube wall. This is an important constraint for efficient heat transfer to take place.

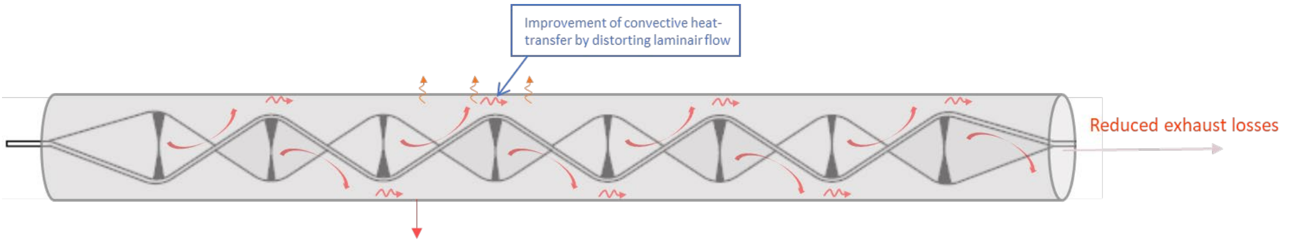


* Example heat exchanger tube without turbulators.

Increasing efficiency of tubular heat exchangers with the use of turbulators

The efficiency of tubular heat exchangers can be improved either by optimizing its geometry and dimensions or by using heat transfer enhancement techniques. One of the main means of heat transfer enhancement is by passive techniques. These techniques increase heat transfer by modifying the surface or geometry of the heat exchanger and therefore do not need an external power source [1]

A key passive heat transfer technique is distorting laminar flow by creating turbulence with the use of deformed metal inserts. These so called turbulators come in a diverse range of geometries depending on, amongst others, the flow and temperature conditions. By increasing the turbulence intensity, turbulators reduce the development of the thermal boundary layer caused by the laminar flow conditions. Hereby the heat transfer coefficient of the heat exchanger increases substantially and so the overall system efficiency due to reduced exhaust losses.



* Example of heat exchanger tube with turbulators.

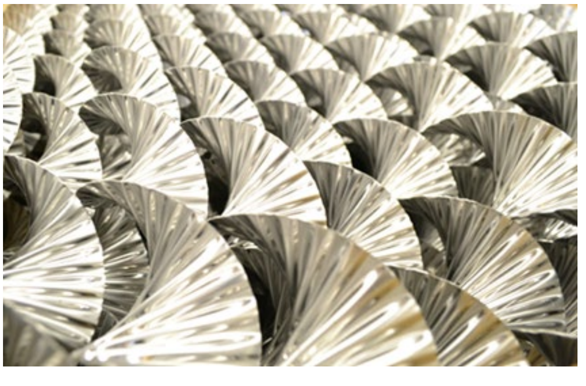
[1] Hasanpour, A., M. Farhadi, and K. Sedighi. "A review study on twisted tape inserts on turbulent flow heat exchangers: The overall enhancement ratio criteria." International communications in heat and mass transfer 55 (2014): 53-62.

Key considerations

For engineers of heat exchanger systems an analytic approach may not offer a solution to estimate the effect turbulators will have on the convective heat transfer coefficient and pressure drop in practice. For accurate calculations, empirical correlations are needed for particular turbulator geometries in relation to the heat exchanger conditions.

Many experimental studies and scientific research has been done on heat transfer augmentation using turbulators, in particular the helical twisted tape turbulator. The major factors which influence the performance are the pipe a turbulator geometry and the flow characteristics [1]

For each new turbulator geometry new correlations need to be determined for Reynolds, Nusselt and Friction Factors. Many experimental studies on heat transfer enhancement using turbulators have been done[2] , providing availability of a great variety of heat transfer and pressure drop correlations in the public domain. By doing in-house experiments, the company JD Turbulators has acquired the correlations for different turbulator geometries in various heat exchanger pipes with gaseous flow conditions. These correlations enable the calculation of the effect turbulators will have on the thermal performance of various applications. Yet, in most cases it is recommended to test in practice the effect turbulators will have on the efficiency and pressure drop of the application concerned.



Important parameters

In literature convective heat transfer enhancement with use of turbulators is most often expressed in Nusselt and Friction Factor correlations of a specific turbulator geometry in relation to Reynolds numbers and the tube dimensions.

Reynolds numbers are an important guide for determining if the flow conditions are laminar or turbulent. It comprises the fluid properties of density and viscosity, plus the flow velocity and tube inner diameter. Turbulators can both be used in the laminar and turbulence conditions. Higher viscosity and lower flow rates result in lower Reynolds numbers. In general, with higher Reynold numbers turbulators become less effective.

Heat transfer coefficient and Nusselt number: For convective heat transfer the Nusselt number is used to express the heat transfer enhancement. This is the ratio of convective to conductive heat transfer. The higher this number the better the overall convective heat transfer coefficient.

Pressure drop and friction factor: Increasing the heat transfer rate turbulators comes at the cost of increased pressure drop, meaning a higher pumping rate. Oftentimes, the turbulator geometry is determined based on the best effect on heat transfer enhancement and the maximum allowable pressure drop. In literature the pressure drop is characterized by the friction factor giving the loss of pressure along a given length of pipe in relation to the average flow velocity.

Thermal performance factor: To compare the performance of various turbulator geometries under particular fluid flow conditions one can compare the increase in heat transfer coefficient in proportion to the increase in pressure drop. The thermal performance of the turbulator is said to be good if the heat transfer coefficient increases significantly with a minimum increase in pressure drop [3]..

[1,2] Garg, M. O., et al. "Heat transfer augmentation using twisted tape inserts: A review." Renewable and Sustainable Energy Reviews 63 (2016): 193-225.
[3] Hasanpour, A., M. Farhadi, and K. Sedighi. "A review study on twisted tape inserts on turbulent flow heat exchangers: The overall enhancement ratio criteria." International communications in heat and mass transfer 55 (2014): 53-62..

JD Turbulators: Expert in increasing the efficiency of tubular heat exchangers

JD Turbulators obtained the turbulator product range from Van Dijk Heating b.v. and with that, their 40 years of experience in developing and manufacturing turbulators.

The wide range of geometries, dimensions and materials offered by JD Turbulators and flexible production methods enables JD Turbulators to produce the best type of turbulator for a broad scope of applications. The turbulator geometry can be varied to suit different tube sizes, flow regimes and temperatures and different heat transfer and pressure drop characteristics. According to the customers requirements JD Turbulators makes a proposal for the turbulator design and a quote based on the needed quantities. On request we can make performance calculations and provide samples for testing the effect the turbulators will have on the performance of the application at hand.

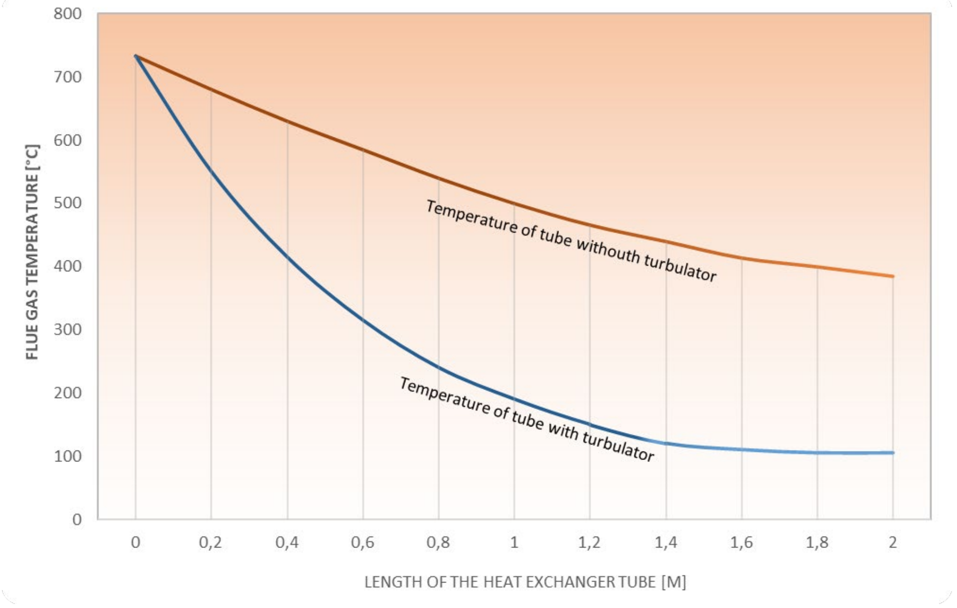
What to expect

The graph below demonstrates the effect of the application of our turbulators on heat transfer improvement of tubular heat exchangers. Our measuring results of flue gas flowing trough a 2-meter-long heat exchanger pipe show that with turbulators the heat transfer coefficient becomes nearly three times greater than in a smooth pipe. In practice this means that with the use of turbulators the length of the heat exchanger tubes can be reduced up to 50% compared to a smooth pipe without turbulators.

Examples of applications

Increasing efficiency is of benefit for manufacturers of various heat exchanger applications. JD turbulators has experience with the manufacturing of turbulators for many different types of tubular heat exchanger applications. Solid and gas fueled boilers and convective air heaters are the most general applications. Yet, the applications we have experience with are numerous. Following are some examples of how our turbulator technology has optimized the thermal performance of various applications:

Example 1: Gas boilers: Left right twisted turbulators are used in fire-tube boilers for decades. Often strict pressure drop limitations exist due to the maximum ventilator capacity. This turbulator design is known to have an optimal ratio between pressure drop and heat transfer with a gaseous heat medium. Based on our own pressure drop and heat transfer correlations JD-Turbulators can make a calculation of the optimal turbulator geometry and material with the given dimensions and conditions of the boiler. For more than 40 years Van Dijk Heating was the main manufacturer in Europe of turbulators for manufacturers of firetube boilers. whether it concerns mass-produced floor standing hot water boilers, one-off (special) boilers, steam boilers, spare parts and replacement, or boosting the efficiency of existing boilers. Our turbulators have increased the efficiency and system size and cost of tens of thousands of boilers worldwide.



Example 2 Air heaters:
The value of applying turbulators in air heaters and radiant tube heaters is known for decades. With more stringent efficiency norms such as the new Eco-design, its use is becoming more and more popular. With turbulators the desired efficiency can be obtained with a considerable smaller heater design.

Example 3 Biomass boilers:
Next to increasing the heat exchanger efficiency, turbulators are used to clean scale deposits of the fluepipes from biomass boilers. As fouling in the heat exchanger is the primary cause of a decreased boiler thermal efficiency within time. Cleaning of the heat exchanger tubes of biomass boilers is essential to restore maximal system performance. Our spiral turbulators are an economic solution for both cleaning and efficiency for many biomass boiler manufacturers in Europe.

Example 4 Heat recovery:
A more recent application of turbulators is in heat recovery shower drains. Our spiral turbulator applied in heat recovery shower drains increased its efficiency such that the shower drain meets the latest Dutch EPC-norm, the energy performance standard for the build environment in the Netherlands.

Example 5 Radiators:
In low temperature radiators for space heating a laminar flow is a common problem due to low flow regimes of the heating medium. With the help of our turbulators, the needed heating power can be obtained with a smaller radiator design. Besides turbulators can be an interesting option for coolers and condensers when the flow regimes and viscosities of the cooling fluids are such that it is causing a laminar flow.

These are one of many examples of turbulator applications. Please contact us to learn what our turbulators can mean for your application.

Conclusion

in modern manufacturing of tubular heat exchanger systems the application of turbulators to increase efficiency continues to be an important one. Stricter efficiency and emission norms and a market pull for energy efficient products has led to a reappreciation of this technology. Although turbulators are relatively inexpensive tools, appropriate design and utilization of turbulators is important for optimal system performance.

This whitepaper revealed the benefits of this proven device and analyzed the value of its use in various kinds of tubular heat exchanger systems. This paper merely touches the surface of turbulator technology. Fortunately, a wealth of information is available in the scientific literature. When searching for a reliable partner with extensive experience to help with a solution for your specific heat transfer problems think about contacting JD Turbulators: The number one supplier of turbulators in Europe.

To find out more about JD Turbulators visit www.jdturbulators.com or call +31(0)647326104

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