Get more out of your heat exchangers with heat transfer enhancement: Part 4 – Introduction to dual-enhanced tubes

In this series of articles we will look at the idea of heat transfer enhancement. The benefits of enhancement are that your heat exchangers will provide the same performance at a lower cost or provide better performance at the same or smaller overall size and footprint.

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In the last article we discussed low-fin tubes which enhance heat transfer by providing a 2.5-3 times area increase on the outer surface of tubes (shell side). In this part we will discuss dual-enhanced tubes. Dual-enhanced tubes provide increased surface area or enhance the heat transfer coefficient both on the outside and inside of tubes. Figure 1 shows three types of dual-enhanced tubes. The inside area enhancement shown here (sometimes referred to as 'ribs' or 'internal helical fins') can also enhance the heat transfer coefficient.

When to use dual enhanced tubes

The considerations mentioned in Part 3 for low-fin tubes all apply to dual enhancement as well. Dual-enhanced tubes have been commercially used in the refrigeration and power industries since the 1990s. Their application in polypropylene, ethylene, and LNG plants began in debottlenecking or revamp scenarios in the early 2000s, and more recently in grassroots designs. The enhanced boiling tube (Figure 1b) consists of an external nucleate boiling enhanced surface with an internal helical fin structure, suitable for horizontal shell side boiling as well as tubeside gas cooling and condensing services. The enhanced condensing tube (Figure 1c) is another dual-enhanced tube which is suitable for horizontal shell side condensation. The inside helical fins are a "low fouling" (LF) structure in services such as cooling water. Applications include the propane chiller and the water-cooled propane condenser in LNG production, various boiling and condensing services in the cold section of ethane crackers, quench water services in naphtha crackers, and several fouling services found in refineries.
New vs Retrofit: The value proposition for dual-enhanced tubes will vary depending on whether the project is for new equipment or a retrofit, or debottlenecking, of existing units. When designing a new heat exchanger and optimizing the thermal design with plain tubes, consider if the shell side or tube side resistance is controlling (see Part 2 for an explanation of "controlling resistance"). If the side with the greater resistance is enhanced, the other side may become the controlling resistance. Dual-enhanced tubes can provide extra benefits in such cases. Retrofitting an existing heat exchanger with the goal of increasing the heat duty with dual-enhanced tubes will increase the shell side surface area and will also increase the tube side heat transfer rate without having to change the shell size or piping layout.

Area and heat transfer enhancement

Internal helical fins provide a surface area increase on the inside, the enhancement factor depending on the fin geometry and number. For a 1" (25.4 mm) outside diameter carbon steel tube, the surface increases by approximately 25-40%, with either 19 or 30 fins/inch. Considering the idea of thermal resistance (see Part 2 in this series), and taking only the area enhancement but ignoring the additional effect of turbulence, the tubeside thermal resistance can be decreased by about 25-40%. Due to the flow pattern created by the internal helical fins, the heat transfer coefficient on the tubeside is also enhanced. There are different types of structures depending on the service, e.g. single-phase liquid or gas or two-phase condensing and boiling. The performance improvement ranges between 1.5 to 4 for the heat transfer and 1.5 to 2.5 for the pressure drop with respect to the plain tube surface. The heat transfer performance improvement ranges between 1.5 to 4, with the best improvements achieved in the transition to turbulent and turbulent flow regimes.
As one would expect, the heat transfer enhancement comes at the cost of pressure drop - 1.5 to 2.5 times compared to a plain inside surface. In the vast majority of the design cases the additional pressure drop can be accommodated (compared to the maximum allowable) either by a more compact heat exchanger (shorter tube length), or by reducing the number of tubeside passes.
Manufacturers of these tubes can properly optimize the heat transfer vs pressure drop effects and provide an optimum solution.

Figure 1. GEWA dual-enhanced heat exchanger tubes. (a) GEWA-KS, with fins on both sides, (b) GEWA-PB, with boiling enhancement outside (c) GEWA-CLF (Low Fouling), with condensing enhancement outside. Images courtesy of Wieland.

Boiling and condensing enhancements (Figures, 1b and 1c) increase the heat transfer coefficient substantially above the level of a conventional low fin tube, allowing the operation of enhanced shell and tube heat exchangers at very low cold-end approach temperatures. The increase in heat transfer coefficient is in the range of 1.5-20 for boiling and 2-5 for condensing. The best results can be achieved at low heat fluxes and small temperature differences. As an example of the total benefit, in the propane chiller in an LNG precooling refrigeration system, the overall surface area, and therefore the tube length, can be decreased by up to 60% and the total heat exchanger weight by 55%, by using a dual-enhanced boiling tube [Ref. 1].

[Ref. 2] can be used to understand the heat transfer and pressure drop enhancements provided by internal fins, including data on various fin configurations in laminar and turbulent flow.

Available materials and tube sizes

Dual enhanced tubes are available in the commonly used tube sizes - tube outside diameters in the range of 5/8-1" (15-25 mm), and materials –- carbon, low temperature carbon steels including 3.5 % Ni, copper and copper alloys, stainless steel and titanium.

The testing of low-fin and dual enhanced tubes during fabrication follows the same principles as plain tubes. Destructive testing is done in accordance with the relevant standards by eddy-current or pressure testing, and even field testing with internal eddy current testing is feasible.

Upcoming in this series

In upcoming articles in this series we will look at applications of boiling and condensing enhancement and show case studies which quantify the benefits for typical applications. ■

References

[1] Wieland Website with references. https://www.wieland.com/en/solutions/energy/ process-industry

[2] Principles of Enhanced Heat Transfer, 2ndEd, Ralph L. Webb & Nae-Hyun Kim, Taylor & Francis 2005.

About the authors

Himanshu Joshi retired from Shell in 2021 after 34 combined years with ExxonMobil and Shell, during which he specialized in heat exchangers and fouling. He was part of a team that was granted a patent related to fouling deposit analysis at ExxonMobil, and led applied fouling R&D projects at both companies. He has made several presentations about the field aspects of fouling and fouling mitigation, and deployed many mitigation technologies in the field. He can be reached by email at alph.hmj@gmail.com.

Lou Curcio has over 30 years of experience in design, troubleshooting and repair of all types of heat exchangers. Leader of technology development projects and advisor for ExxonMobil's global manufacturing teams. Co-inventor of two U.S. patents and co-author of papers on enhanced heat transfer and fouling of heat exchange.

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