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Attain High Energy Efficiency with Less Materials Using Smaller-Diameter, Inner-Grooved Copper Tubes
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MICROGROOVE TUBES FACILITATE ADOPTION OF LOW GWP REFRIGERANTS

The industry is opting to replace high-GWP refrigerants with low- and ultralow-GWP refrigerants, necessitating a reduction in refrigerant volume due to considerations about cost and flammability. Global Warming Potential, or GWP, is an index of the greenhouse gas effect for a given molecule or mixture of gases.

Tools for designing heat exchangers made of smaller diameter copper tubes are advancing rapidly in response to the demand to reduce refrigerant charge and facilitate the adoption of low-GWP refrigerants. One important design tool is simulation software that uses correlations for refrigerant-side heat transfer, building on the research results from many laboratories around the globe.

Recently, research results on low-GWP refrigerants in smaller diameter copper tubes have become available. In particular, laboratory experiments on MicroGroove tubes were conducted at three universities: the University of Padova, Padova, Italy[1, 2]; Tokyo University of Marine Science and Technology[3]; and Kyushu University, Fukuoka, Japan[4].

Such research provides predictive correlations that can be used in simulations of the performance of coil designs that use smaller diameter copper tubes with a variety of inside-the-tube enhancements (i.e., microfins) and low- and ultra-low GWP refrigerants.

RESEARCH FROM UNIVERSITY OF PADOVA

According to the Padova group, in reference to previous research in this field, "the literature about smaller diameter microfin tubes (i.e., inner diameter lower than 6 mm or so) is poor if compared with larger tubes." They aptly dubbed these "mini microfin-tubes" in contrast to traditional (larger diameter) microfin tubes. These researchers measured flow boiling heat transfer and pressure drops inside copper tubes with internal enhancements[1]. In this first paper, the copper tubes had an outer diameter (OD) of 5 mm and the refrigerant was R134a. The saturation temperature was 10 °C. The vapor quality was varied from 0.1 to 0.95; the mass velocity from 100 to 800 kg/m^{2}s, and the heat flux from 15 to 90 kW/m^2. As expected, the dominant mechanisms are convective boiling at low heat fluxes, and two-phase forced convection at high heat fluxes. The authors concluded that the results highlight the promising heat transfer capabilities of mini microfin tubes during flow boiling. Looking forward, they state that "additional heat transfer measurements with different tube diameters, different helical geometries, and different type of refrigerants are surely needed."

In a second paper, the Padova group also measured flow boiling heat transfer and pressure drop for an ultralow-GWP HFO1234ze(E) refrigerant inside smooth tubes having an OD of 4 mm[2]. The heat transfer coefficients for the HFO were similar to those for HFC134a at the same operating conditions but the pressure drops were 10 to 25 percent higher for the HFO. According to these authors, the heat transfer measurements confirm that HFO1234ze(E) is a very promising low-GWP candidate for HFC134a replacement.

RESEARCH FROM JAPAN

The Tokyo research measured pressure drops and evaporative heat transfer coefficients for R32 refrigerant passing through 4-mm OD copper tubes with a broad range of internal enhancements, including "microfin" heights of 0.1 mm and 0.2 mm.[3] Measurements were made at saturation temperature of 15 °C with mass velocity ranging from 50 to 400 kg/m^{2}s and heat flux from 5 to 20 kW/m^2.

Meanwhile, the Kyushu group measured heat transfer coefficients for mixtures of R32 with HFOs[4]. This research is especially important because it provides performance data for different compositions of the refrigerant mixtures. "Temperature glide" is known to compromise performance in R32/HFO mixtures compared to single components (i.e., R32 or HFO alone). The Kyushu results provide predictive correlations including the effects of microfins for these refrigerant blends, which are likely to play an important role in future air conditioning and refrigeration systems. The microfins in the 4-mm diameter copper tubes had heights of 0.26 mm.

SUMMARY AND CONCLUSION

The design of appliances using smaller diameter copper tubes has never been easier than now. Precise laboratory experiments and advances in CFD simulations allow for optimization of coil designs without building a single coil. Prediction correlations are better than ever and include tube correlations for smaller diameter copper tubes with a variety of tube enhancements and for many refrigerants. Manufacturing also is becoming easier with improved manufacturing methods offering improved throughput and reliability.

These advances are just in time as the industry begins to replace high-GWP refrigerants with low-GWP and ultralow GWP refrigerants, necessitating a reduction in refrigerant volume due to considerations about cost and flammability. The smaller diameter copper tubes allow for refrigerant volumes to be reduced without compromising energy efficiency and other advantages such as cleanability, drainage and ease of manufacturing.

REFERENCES

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IN THE SPOTLIGHT

UNFCCC, COP21 AND THE MONTREAL PROTOCOL

The United Nations Framework Convention on Climate Change (UNFCCC) is an international treaty signed in 1992. The aim of "the Convention" is to contain anthropogenic greenhouse gas emissions (caused by human activity) in order to avoid a major disruption of the planet's climate system.

In alignment with these aims, the Conference of the Parties (COP) is the supreme decision-making body of the UNFCCC. The 196 Parties (195 countries and the European Union) have met every year since 1995. COP21 in Paris was especially significant because it resulted in the Paris Agreement, which is scheduled to go into effect in the year 2020. A small group of countries including India, Pakistan and some Gulf states, pushed for and secured an even later start in 2028, saying their economies need more time to grow. Environmental groups had hoped that the deal could reduce global warming by half a degree Celsius before the end of this century.

COP21 was held in Paris in December 2015. COP22 was held in Marrakech from November 7 to 18, 2016. Of the 197 Parties to the Convention, the number who have ratified the Paris Agreement can be viewed online here.

http://unfccc.int/2860.php

Meanwhile, delegates met in Rwanda (in its capital city Kigali) in October 2016 for talks on hydrofluorocarbons, or HFCs. A deal was reached by more than 150 countries to limit the use of harmful GHGs[1]. More than 100 developing countries, including China, will start taking action by 2024 and developed countries including the United States agreed to a gradual process beginning in 2019. The Kigali deal is perhaps more significant that the Paris Agreement since it is legally binding as an amendment to the Montreal Protocol

REFRIGERANT OPTIONS

R32 is an HFC similar to methane except that two of the four hydrogen atoms have been replaced by fluorine atoms. It has a Global Warming Potential (GWP) of 675, which is still quite high but relatively low compared to other HFCs still in use. Hydrofluoroolefins (HFOs) are also compounds of hydrogen, fluorine and carbon but are distinguished from HFCs by being derivatives of alkenes (olefins) rather than alkanes. Researchers are already seeking to understand how R32 and HFOs and blends of these refrigerants behave when they are passed through smaller diameter copper tubes.

Here is where the refrigerant cost versus low GWP comes to a climax. The HFOs have ultralow GWP and factually are less flammable than R32; however, they are currently more costly because production of these compounds has not been scaled up. Meanwhile, R32 is cheaper and more widely available but it is more flammable and has a much higher GWP.

Applications that use R290 as a refrigerant typically also use smaller diameter copper tubes to reduce the requirements for refrigerant charge. HFOs are not as flammable as R290 but still they are flammable and minimizing refrigerant charge is desirable[2].

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