microgroove™ Update

Attain High Energy Efficiency with Less Materials Using Smaller-Diameter, Inner-Grooved Copper Tubes

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UPCOMING EVENTS

AHR Expo
Jan 22–24, 2018
McCormick Place, Chicago IL, USA
https://microgroove.net/2018-ahr-expo

ACREX India
Feb 22–24, 2018
BIEC, Bengluru, India
https://microgroove.net/acrex-2018

WEBINARS

See the MicroGroove "Webinars" webpage
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Also see MicroGrooveTech YouTube channel for archive of past webinars
https://www.youtube.com/user/MicroGrooveTech

PUBLICATIONS

Nigel Cotton and Yoram Shabtay, "MicroGroove Contributes to the Success of Propane in Refrigeration Appliances," *International Appliance Manufacturing*, October 2017.
http://digital.bnpmedia.com/publication/?i=441273#{"issue_id":441273,"page":44}

Yoram Shabtay and Nigel Cotton, "Select Case Studies of Copper Heat Exchanger Coils for Natural Refrigerants," ATMOsphere America 2017, San Diego, California
http://www.atmo.org/media.presentation.php?id=1051

MICROGROOVE FACES OFF AGAINST ALUMINUM IN OEM PRODUCT DEVELOPMENT

COPPER PROVES ITS SUPERIORITY AS A HEAT EXCHANGER TUBE MATERIAL

MicroGroove consistently has been proven to be better than MicroChannel in many respects. Aluminum has been proposed as a possible substitute for copper in heat exchangers for air-conditioning applications for many decades. Its first foray, in the 1970s, proved unfortunate for the industry[1]. Round-tube, plate-fin (RTPF) coils made from aluminum tubes and aluminum fins rapidly corroded and deteriorated and equipment failures were widespread. All-aluminum RTPF coils did not last long in real world environments and OEMs quickly reverted back to copper.

BRAZED ALUMINUM RADIATORS

It would be several decades before aluminum advocates would try again. Aluminum resurfaced in the form of extruded "multichannel" or "MicroChannel" tubes. (These terms are synonymous.) The automotive industry earlier had developed lightweight aluminum radiators made from extruded aluminum to reduce the overall weight and increase the fuel efficiency of passenger vehicles.

While suitable for high-volume production in manufacturing plants, typical of the automotive industry, the process is quite temperamental and is not easily adapted to the smaller volumes and custom designs typical of the ACR industry. Also liquid-to-air automotive radiators function much differently than evaporators or condensers.

The entry of extruded-and-brazed aluminum into the mix offered new hope to the supporters of aluminum as a tube material. OEMs began experimenting with brazed aluminum multichannel coils, which were marketed as an alternative to copper. The advantages of the smaller channels, i.e., high thermal heat transfer coefficients and reduced refrigerant volume, were heavily advertised.

STRANGE COMPARISONS

Strangely, comparisons were consistently made between aluminum multichannel and conventional large copper tubes. Yet the march toward smaller diameter copper tubes was already underway.

The disadvantages of multichannel were studiously underplayed by its supporters. These disadvantages include maldistribution of refrigerants, large header volumes, difficulty with defrosting and poor drainage. Cleaning of serpentine-style fins squeezed between the ribbon-like multichannel tubes is difficult and fouling and clogging is problematic. Fouling leads also to more corrosion.

THE TRUE STORY

In recent years, MicroGroove has dominated the global residential window air-conditioner marketplace. The optimization of heat exchangers made with MicroGroove tubes has been underway for more than a decade now, especially in China.

Numerous papers have been published on this subject. For example, a simulation performed in 2012 compared the performance of MicroGroove with MicroChannel[2].

Today, tens of millions of window-type residential air-conditioners are made every year with MicroGroove smaller diameter tubes and central AC (ducted) air-conditioning systems are also commonly made with MicroGroove RTPF coils.

FRIEDRICH CASE STUDY

The competitiveness of MicroGroove copper in window-type air-conditioners was demonstrated in a simulation performed for Friedrich as reported in a recent "In the Spotlight" column. Friedrich sought to increase the efficiency of one of its products through a drop in replacement of a more efficient heat exchanger coil.

The MicroGroove coils typically had four rows of tubes with 25 tubes per row for a total of 100 tubes. Compared to the baseline design, one configuration reduced the total internal volume of the tubes from 0.041 cubic feet to 0.032 cubic feet (1.16 liters to 0.91 liters, a reduction of 22 percent) while pushing the COP up by 4 percent; and, at the same time, the total mass of the coil was reduced from 3.97 pounds to 3.21 pounds (1.80 kg to 1.46 kg, a reduction of 19 percent). The total mass of the coil (including aluminum plus copper) was reduced from 11.01 pounds to 6.98 pounds (5.00 kg to 3.16 kg, a reduction of 36 percent).

The upshot is that the smaller diameter tubes reached the target COP while decreasing the amount of copper by almost 20 percent while reducing the refrigerant by 22 percent.

These types of performance increases obtained simply by switching from conventional copper tubes to MicroGroove copper tubes are commonplace today.

MICROGROOVE IN, MICROCHANNEL OUT

ICA recently supported a design study for an OEM, to examine the effects of replacing MicroChannel with MicroGroove in OEM heat-pump systems, including a 2-ton residential and a 10-ton commercial system.

The objective was to maximize capacity and to minimize airside pressure drop for drop-in replacements. Geometric constraints were placed on coil height, width, and depth; other design criteria included fin density, refrigerant pressure drop and refrigerant charge. CoilDesigner® was to evaluate the performance of various designs.

Initially, currently available wavy and louvered fin patterns for 5-mm tubes were used. For commercial replacement condensers, the air pressure drop increased 15 to 38 percent for wavy fins and 29 to 42 percent for louvered fins, while maintaining less than a four percent decrease in heating capacity compared to the baseline multichannel aluminum commercial condenser. The air pressure drop for the residential replacement condensers increased 23 percent for the wavy fins and 16 percent for louvered fins, while maintaining a negligible (less than 0.2 percent) decrease in heating capacity as compared to the baseline multichannel aluminum residential condenser.

The material mass of the commercial heat exchangers was reduced by approximately 26 percent for the louvered fin designs and as much as 35 percent for the wavy fin designs. The baseline residential MCHX used much less material than the baseline MCHX commercial design because it had about half the depth and half the face area as well as lower fin density. On the other hand, in the case of the RTPF replacement designs, the residential and commercial designs both used two-row coils with fixed horizontal spacing so the materials savings for the residential design was not as pronounced as for the commercial design.

System level performance was evaluated using VapCyc®, a vapor compression cycle design and simulation software. The condensers were used to evaluate overall COP changes that would occur from replacing the MicroChannel coils with MicroGroove coils. The louvered fin design decreased the COP by one percent while wavy fin designs decreased the COP by four percent.

NEW FIN PATTERNS

To improve airside pressure drop, an optimization study for 5 mm tube-fin condensers was conducted to explore new fin patterns. The design space consisted of variable ranges consistent with current manufacturing capabilities. This optimization found 5 mm tube-fin designs that were competitive with the baseline MicroChannel condenser.

The additional degrees of freedom allowed the optimizer to find designs with similar air side pressure drop and capacities to that of the baseline. The best design within this optimization study demonstrated a reduction of approximately 28 percent in material mass while maintaining the same airside pressure drop and capacity as the baseline.

The 5-mm commercial designs had capacity increases of up to three percent and airside pressure drop decreases of up to 19 percent while maintaining other performance metrics within the OEM's specified constraints. The 5 mm residential designs had negligible capacity increases (0.2 percent) and airside pressure drop decreases of up to 20 percent while maintaining the OEM's constraints.

FLAMMABLE REFRIGERANTS

A recent article titled "MicroGroove Contributes to the Success of Propane in Refrigeration Applications" describes how MicroGroove copper has become the technology of choice in applications in which reduced refrigerant volume is needed because of the high flammability of the refrigerant. The full story can be read in the 2017 issue of *International Appliance Manufacturing* magazine, which is readily available online[3].

That said, MicroGroove is suitable not only for use with propane in light commercial refrigeration applications but for use with isobutane in high-end residential applications. Isobutane is another flammable refrigerant that is subject to strict usage limitations by regulatory authorities. See the "In the Spotlight" column for more on the performance of MicroGroove in residential applications.

CONCLUSION

The copper industry continues to march forward with advances in MicroGroove technology. Copper lends itself well to smaller diameters because of its strength, ductility and corrosion resistance. Copper performs better as the tube diameters are reduced. Copper delivers on the promise of increased heat transfer efficiency of the coils and reduced refrigerant volume. Moreover, the equipment for tube handling and tube expansion is readily available.

Although multichannel aluminum supporters predicted rapid market penetration, MicroGroove proved itself highly competitive in key applications. Ironically, one of the most successful applications has been in the low-cost, high-volume residential air conditioners.

More recently some attempts have also been made to revive round aluminum tubes, but these are difficult to process at smaller diameters; and they are again subject to corrosion despite the use of specialized coatings that add cost to the tubes and coils.

OEMs expect to see comparisons of aluminum-tube MicroChannel heat exchangers technology with copper MicroGroove technology. The choice is no longer between MicroChannel and conventional copper. In application after application, MicroGroove copper is asserting its value.

REFERENCES

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3. Nigel Cotton and Yoram Shabtay, "MicroGroove Contributes to the Success of Propane in Refrigeration Applications" *International Appliance Manufacturing* magazine, October 2017. https://microgroove.net/sites/default/files/IAM-2017-MicroGroove-Article.pdf

IN THE SPOTLIGHT

SUB-ZERO WEIGHS THE ADVANTAGES OF MICROGROOVE IN CONDENSER COILS

Since 1945, Sub-Zero has pioneered the science of home refrigeration. As the leading manufacturer of high-end built-in residential refrigerators, freezers and wine coolers, the company has accumulated in-depth knowledge of refrigeration cycles and its engineers are especially knowledgeable of isobutane, or R600a.

Its products are favorites among discerning homeowners whose seek best-in-class appliances that bring substance to luxury. They are highly admired in international markets as well as the United States for delivering world-class food preservation.

Sub-zero is the pioneer of the dual-refrigeration concept, separate and independent sealed systems for refrigerator and freezer. As a result, the same condenser would have two refrigerant circuits, one for each of two independent vapor compression cycles. One circuit is for the refrigerator compartment; and the other is for the freezer compartment. This way, there is no air being shared between the refrigerator and freezer thus leading to ultimate food preservation.

Regulatory agencies have placed a limit on the allowable refrigerant charge for isobutane because of its flammability. That limit is 150 grams in Europe and it has been 57 grams in the USA for residential applications. If the use conditions are 150 grams then there is no need to further reduce refrigerant charge.

Already most products in this category use copper tubes with outer diameters of five-sixteenths inch (7.9 mm) or one quarter inch (6.35 mm) copper tubes.

Sub-Zero considered adopting even smaller diameter MicroGroove tubes. The company initially was motivated to meet the 57-gram "use conditions" on isobutane, a flammable refrigerant. The 57- gram limit would be challenging to meet and challenging design measures would be necessary as F-Gases are phased out by the year 2021. That led Sub-Zero to explore the advantages of MicroGroove tubes with copper tube outer diameters of 5 mm.

Optimized Thermal Systems, Inc. (OTS) offers customized software and services for the design and optimization of thermal systems. Engineers from Sub-Zero approached OTS for assistance in using CoilDesigner®, a proprietary heat exchanger design and simulation software tool. The primary objective was to design a condenser coil that would equal the performance of the existing (baseline) coil while lowering the refrigerant charge. Secondary objectives were to reduce the total footprint of the coil and the total tube-and-fin material mass.

The baseline condenser coil uses copper tubing, flat plate fins and a low fin density. The condenser has two refrigerant circuits, with each circuit serving an independent vapor compression cycle for the refrigerator and freezer compartments. A CoilDesigner® model of the condenser was developed and validated against experimental data.

Prior to evaluating potential small diameter replacements, a study was conducted to evaluate the effect of refrigerant circuitry on the existing coil performance. Three operation modes were evaluated: only the refrigerator circuit running, only the freezer circuit running, and both circuits running.

It was found that for a particular tube circuitry heat load and refrigerant sub-cooling increased for both refrigerator and freezer circuits.

From this initial review, this circuitry design was selected and used as the baseline reference for the optimization study.

The optimization study was conducted to identify condenser designs that could reduce the internal volume and lower the refrigerant charge. Five millimeter tube designs were evaluated and compared to the baseline design and significant reductions were found in internal tube volume. The best 5-mm design reduced the internal tube volume by as much as 41 percent as compared to the baseline, along with a 57 percent reduction in coil footprint. The results for the best 5-mm designs are plotted in the accompanying graph.

The new designs used wavy-herringbone fins with a reduced fin thickness as compared to the baseline. Other variables included the horizontal and vertical spacing of the tubes; number of tubes per bank; fin density; wavy fin pattern depth; and tube length. The design criteria are as follows.

- Heat rejection greater than or equal to the heat rejection of the baseline design;
- Sub-cooling equal to or greater than sub-cooling of the baseline coil; and
- Saturation temperature drop kept within one degree of the baseline.

Multiple factors contributed to an increase in airside pressure drop with the smaller diameter tube coils, including fin type, face area of the coils, and fin density. The baseline system used flat fins, yet all of the optimized designs used wavy fins, which inherently contribute to higher pressure drops. The face area was reduced for all coils to maintain the tube spacing ratio; yet, for a fixed airflow volume, reduced face area increases the air velocity.

Nonetheless, for this application, reduced internal volume was considered to be more important than the airside pressure drop.

In summary, OTS identified several new condenser designs with significant potential to reduce internal volume while maintaining performance, and thereby reducing total system charge. The reduced footprint of the coils allows for a smaller enclosure.

This study is a starting point for the development of high performance condenser coils for this application. With a high-performance condenser, condenser fan speed can be reduced, resulting in a quieter refrigerator unit. Also, this high performance condenser could be designed to be robust to fouling yet retaining some of its heat transfer benefits leading to a hassle-free operation.

Tube Diameter, mm	Internal Volume Reduction, %	Footprint Reduction, %	Tube Material Reduction, %	Fin Material Reduction, %
5	41	57	61	68