microgroove™ Update

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

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PRESENTATIONS

UPCOMING EVENTS

2016 AHR Expo

MicroGroove Booth 1293
Orange County Convention Center
Orlando, Florida
Jan 25 2016 – Jan 27 2016

"OAK Next" Events from BOTI, Introducing the Phoenix

Global Digital Event
For more about "OAK Next" events,
www.burroak.com/next

Burr OAK Tool Inc. will deliver four unique seminars on the manufacture of heat exchangers at the AHR Expo, Booth #3831.

Monday, January 25

11:00 a.m.	OAK Product Innovations
1:30 p.m.	New Technology Seminar, Theatre C
3:00 p.m.	MicroGroove Tubes versus MicroChannel
5:00 p.m.	Evolution of Coil and Tube Manufacturing

Tuesday, January 26

11:00 a.m.	MicroGroove Tubes versus MicroChannel
1:00 p.m.	Non-invasive Pressure Expansion
3:00 p.m.	Evolution of Coil and Tube Manufacturing
5:00 p.m.	OAK Product Innovations

Wednesday, January 27

11:00 a.m.	Evolution of Coil and Tube Manufacturing
1:00 p.m.	Non-invasive Pressure Expansion

FEATURE ARTICLE

"Trends in the Design and Manufacture of Round-Tube Plate-Fin Coils from Smaller Diameter Copper Tubes" by Yoram Shabtay and Nigel Cotton, International Appliance Manufacturing, October 2015.
http://click.bnp-digital.com/

NEW PRESSURE-EXPANSION EQUIPMENT IS A GAME-CHANGER FOR HIGH-VOLUME MICROGROOVE MANUFACTURING

Advances continue to be made in tube fabrication, coil manufacture and system design. Taken together, these three disciplines have contributed to an atmosphere of creativity, imagination and innovation in product design.

The industry is moving rapidly toward new refrigerants, new coil designs and new systems. Furthermore, equipment for manufacturing tubes and coils is also advancing rapidly, which directly influences all of the above factors.

LOW GWP REFRIGERANTS, EFFICIENT TUBES

Refrigerant and refrigerant tubes go "hand in glove." For most refrigerants, there is no better fit than copper. Its high thermal conductivity, superior strength and excellent corrosion resistance set it apart from any other material.

But one thing that can be changed is the tube diameter[1]. The trend in recent years has been toward smaller diameter copper tubes, which are advantageous in many respects.

- Firstly, internal heat transfer coefficients (HTCs) are higher for smaller diameter tubes, offering an immediate payback because less tube material and less refrigerant is required to provide the same capacity, whether for the evaporator or the condenser.
- Secondly, the smaller diameter tubes can allow for more efficient and more streamlined airflow outside of the tubes as can be easily shown with simulations.
- Thirdly, a given tube wall thickness can support higher pressures for smaller diameter tubes, which means tube walls can be made thinner, resulting in even less materials usage and even lighter weight.

EXAGGERATED CLAIMS

On occasion, promoters of aluminum tubes point to "microchannel" or "multichannel" brazed aluminum, a technology borrowed from the auto industry, as offering better performance than copper. If one examines closely the details of such comparisons, it usually turns out that the multiple small channels in a flat tube are being compared to large diameter copper tubes, typically 3/8 inch tubes (9.52 mm tubes). The comparisons are misleading since smaller diameter copper tubes are the new benchmark for copper tubes. Exaggerated claims about aluminum microchannel tend to deflate when comparisons are made with MicroGroove smaller diameter copper tubes[1,2].

Further, the aluminium microchannel tubes present their own disadvantages, such as maldistribution of refrigerant, drainage and defrost obstructions, and other challenges.

Meanwhile, MicroGroove coils just keep getting better.

As far as materials go it is hard to imagine a better material for heat transfer than copper.

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RECENT WEBINAR

"A Practical Update on Advanced Copper Alloys and On-Site Joining Methods for HVACR Systems"

Sponsored by the Copper Development Association

Speaker: John Hipchen, Exel Consulting
Moderated by Lori Schiavo, Publisher of the *RSES Journal*

MICROGROOVE WEBINAR SERIES

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https://www.youtube.com/user/MicroGrooveTech

A few materials have better thermal conductivity, notably silver or diamond. Nonetheless, copper offers a unique combination of thermal conductivity and strength, which makes it likely that it will serve as the material of choice for tube material for the foreseeable future.

PERFECTING THE INNER GROOVE

Another trend is to provide surface enhancements to the inside surface of the copper tubes. Again, this increases the inside-the-tube heat transfer characteristics. Much research has been dedicated to understanding the behavior of various refrigerants as they flow through small, inner-grooved tubes at various rates. Here theory and manufacturing capability are closely intertwined. Generally speaking, a grooved inner surface mixes up the refrigerant for more efficient heat transfer between the refrigerant and the tube wall. Surface enhancements can improve the performance of copper tubes both in condenser coils and evaporator coils.

In the case of inner grooves (or "microfins" on the inside walls of tubes) the grooves have widths on the order of hundreds of microns at the top of the groove. It is remarkable that these inner grooves can enhance the HTCs by as much as 300 percent depending on the tube diameter, the flow rate, the refrigerant and the type of enhancement. The variability in HTC enhancement has spurred competition among tube suppliers, who are the experts in fabricating tubes with various kinds of enhancements, for example, herringbone or helical patterns.

Tube manufacturers today can vary the features of these microfins in many ways. They can vary the width at the top of the groove. They can vary the depth of the groove. They can vary the groove wall angle, the helical angle and spacing between the grooves.

Incidentally, the term "microgroove" is reminiscent of the record industry where the term was used to describe the narrow grooves of long playing records introduced in the late 1940s. These "microgrooves" were 50 microns (2 mils) or less at the top compared to earlier coarse grooves which were 150 microns (6 mils) or less at the top[3,4]. This term "microgroove" is therefore apropos for describing the inner surface enhancements of copper tubes, which are of a similar order of magnitude[5].

Nowadays, the number of tube enhancements has proliferated to such an extent that it is necessary to work closely with tube suppliers to optimize the configuration for any given application. The performance of these tubes must then be correlated with laboratory experiments for specific refrigerants, flow rates, pressures, and quality factors. Tube suppliers and/or research labs can provide the necessary correlations to allow for accurate predictions of the efficiency gains that can be realized by using inner-grooved smaller diameter tubes.

A recent white paper prepared by Optimized Thermal Systems (OTS) and Burr OAK Tool Inc. (BOTI) reviews the enhancements available for tubes of different tube diameters from 9.5 mm to 5 mm and smaller [6]. Joint research is ongoing with OTS, BOTI and the Copper Alliance to correlate the surface enhancements with enhanced HTC values and lowered pressure drops. These values already have been precisely measured for commonly used surface enhancements and in many cases have been included in the industry-standard software for designing heat exchanger coils.

RTPF MANUFACTURING GOES HIGH TECH

The round tube plate fin coil has a long and rich history within the ACR industry. The industry has already developed highly sophisticated equipment for handling smaller diameter tubes, including 1) presses and dies for stamping fins with patterns optimized for smaller diameter tubes; 2) hairpin benders capable of high-speed processing of smaller diameter tubes; 3) materials handling tools for lacing the delicate hairpins through the fin plates; 4) tube expanders for establishing thermal contact between the tubes and fins; and finally 5) Various automated or semi-automated methods for the insertion and brazing of the return bends into the flared, open-ends of the copper tubes, completing the tube circuitry.

The above equipment has been described previously in various publications and webinars [7].

THE DEBUT OF PRESSURE EXPANSION

Now the technology is about to take a huge step forward with the introduction of new equipment for pressure expansion from Burr OAK Tool Inc.

This new equipment has been in development for several years and was launched beginning in November in China, Japan, Thailand and India. It will also be on exhibited at the AHR Expo in Orlando in January. (See "In the Spotlight" for a description of the Phoenix.)

"The development of the manufacturing equipment to build RTPF heat exchangers in high volume has changed the face of the ACR industry and laid a firm foundation for the continued use of smaller diameter copper tubes," says Nigel Cotton, MicroGroove Team Leader at the International Copper Association. "We welcome equipment advances such as the OAK's pressure expansion equipment, which will make the production of MicroGroove coils more efficient and open the door to new applications."

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REFERENCES

1. Nigel D. Cotton, Bob Weed and Wenson Zheng, "Building Better Appliances with Smaller Diameter Copper Tubes," *International Appliance Manufacturing,* October 2013.
2. John C. Hipchen, Robert D. Weed, Ming Zhang and Dennis Nasuta, "Simulation-Based Comparison of Optimized AC Coils Using Small Diameter Copper and Aluminum Micro-Channel Tubes," *The International Refrigeration and Air Conditioning Conference*. Paper Number 1305, Purdue University, 2012.
3. Wikipedia, entry on Gramophone record. https://en.wikipedia.org/wiki/Gramophone_record#The_microgroove_.26_vinyl_era
4. R.G. Gupta, "Audio & Video Systems," Tata Mcgraw-Hill Education (2001).
5. Guoliang Ding *et alia*, "Two-phase heat transfer characteristics of R410A-oil mixture flow condensation inside small diameter microfin copper tubes," Conference on Thermal and Environmental Issues in Energy Systems, Sorrento, Italy, May 2010. American Society of Mechanical Engineers (ASME), *Associazione Termotecnica Italiana* (ATI), Unione Italiana di *Termofluidodinamica* (UIT) and International Centre for Heat and Mass Transfer (ICHMT).
6. "A Review of the Influence of Microfin Enhancements on the Condensation Heat Transfer Coefficient for Small Diameter Tubes," unpublished report from OTS and Burr Oak Tool Inc., 2015. Available on microgroove.net.
7. MicroGroove Series of Webinars. For example, "The Manufacture of High-Efficiency Coils with MicroGroove Copper Tubes" by Brian McConnell, President, Burr OAK Tool Inc. See www.microgroove.net/webinars. Also available on the MicroGrooveTech YouTube Channel.

(continued from page 4)

Zero Shrink Process

Tetzloff explains that pressure expansion is inherently a zero shrink process. Lévy-Mises equations describing plastic flow in material are used to show that a tube experiences zero lateral strain while pressure is applied to expand the tube diameter plastically[1]. In effect, the internal pressure that causes hoop stress in the tube resulting in expansion of the tube diameter also places tension on the tube, in the precise amount needed, to prevent the tube from shrinking. "This is really exciting," explains Tetzloff, "when you understand the impact that compressive loading and bullet interaction can have on the tube and fin bond." Tang, Li and Peng of the School of Mechanical Engineering in Shanghai have studied the effect of collar compression[2].

Test results indicate improvements in the tube-to-fin contact of coils that are expanded with the non-invasive pressure approach rather than mechanical bullet expansion.

No Deformation of MicroGrooves

The second significant advantage of using pressure to expand tubes is that the internal tube enhancements are not disturbed as they are when using a mechanical bullet. This comparison is illustrated in images of small diameter internally enhanced MicroGroove tubes. For the bullet method, the stresses exerted in the internal enhancements of the tube are significant. The bullet method could deform the tops of fragile types of inner fins. Expanding tubes with pressure will enable tube manufacturers and researchers to explore new designs of surface enhancements.

It can be seen then that the use of a non-invasive expansion process opens the door to the use of more delicate inner-fin structures. The immediate effect is that existing enhancements will be unaffected by the manufacturing process. This phenomenon is already being tested in joint research by the ICA, OTS and BOTI, to determine what effects, if any, non-invasive expansion has on the performance of surface enhancements and the values of heat transfer coefficients[3].

REFERENCES

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2. Ding Tang, Dayong Li, Yinghong Peng, "Optimization to the tube–fin contact status of the tube expansion process," *Journal of Materials Processing Technology,* 211 (2011) 573–577.
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THE PHOENIX RISES AT BURR OAK TOOL INC.

New equipment from OAK uses pressure to expand smaller-diameter copper tubes into fin plates. (Photography Courtesy of Burr OAK Tool Inc.)

The techniques for making coils from copper tubes and aluminum plate fins are quite familiar to anyone who has been involved in the manufacture of residential or commercial air conditioners and refrigeration equipment. One key step in the process is the mechanical expansion of the copper tubes until they make contact with the collared aluminum fins.

New technology being launched by Burr OAK Tool of Sturgis, Michigan, incorporates the proven technology of tube expansion to join the tube and fin. The new product, which was just released to the market in November 2015, "uses precisely controlled pressure to expand tubes for an interference fit between the tubes and fins," according to Jason Halling, Manager of Business Development & Marketing for OAK.

OAK is extending a special invitation to all subscribers of the *MicroGroove Update* newsletter to attend one of its "OAK Next" events. (Visit www.burroak.com/next for more information on events surrounding the launch of the Phoenix.)

MEETING THE CHALLENGES

The manufacturing process of RTPF coils creates a rigid assembly from parts that are individually rather delicate. Small diameter tubes have much higher strength for resisting internal pressure. However, when not assembled into a coil, the small diameter of these tubes can make them weaker in resisting bending and buckling.

The joining of tubes and fins is what makes the assembly strong. For smaller diameter tubes, depending on the wall thickness, higher forces may be required to expand the tubes but tube expansion is still practical. In addition to creating a rigid assembly, the joint between the tube and fin creates a path for heat conduction. If the tubes are improperly joined to the fins then the boundaries between the tubes and fins can become barriers to heat flow.

The preferred method for joining tubes and fins is through a process of tube expansion to generate an interference fit between the tube and the extruded fin collar. This expansion is typically performed using a spherical "bullet" that is pushed through the tube by a smaller diameter rod. The bullet diameter is larger than the original tube inside diameter, causing the tube to expand.

Friction between the tube and bullet induces column loading on the tube, which could cause the tube to buckle if not contained. Also, as the tube expands in diameter, material along the length of tube is drawn into the increased circumference of the tube; consequently the tube shrinks in length during the expansion process. Early adopters of small diameter tubes faced challenges in the expansion process, which led to development of "limited-shrink" expansion by OEMs. This approach enabled successful expansion by placing the tube in tension to prevent buckling and to control shrinkage. The proper balance of bullet friction force and tube tension also allows zero shrinkage of the tube.

NON-INVASIVE TUBE EXPANSION BREAKTHROUGH

The method of using pressure to expand tubes is commonly used in the hydroforming industry where containment for the final tube shape is determined with dies that encapsulate the material. In the case of expanding MicroGroove tubes into fins, the fin collar provides the necessary containment, resisting expansion and establishing a secure bond between the tube and fin. Halling explains that pressure expansion is not a new process to the HVAC industry. Some manufacturers routinely use pressurized fluids to expand coils. "This solution has inherent benefits that the industry will use to take MicroGroove to the next level," states Halling.

Regarding non-invasive expansion, according to Roger Tetzloff, Innovations Manager for OAK, there are at least two benefits, including zero shrinkage of the small diameter tubes and no deformation of the inner-grooves.

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