microgroove™ Update

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

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MICROGROOVE COILS SPAN THE GLOBE: ASIA LEADS THE WAY

The ACR Industry is truly global with respect to supply and demand for every product category. One can find cold-vending machines, refrigerated display cases, heat pumps and air conditioners practically anyplace there are electric outlets available.

This issue provides a broad overview of the status of MicroGroove in China and Japan with particular attention to the manufacture of coils from smaller diameter copper tubes. MicroGroove activities in India will be described in a separate issue.

PIONEERING RESEARCH ON MICROGROOVE IN CHINA

Professor Guoliang Ding pioneered the use of MicroGroove technology at the Institute of Refrigeration and Cryogenics (IRC) at Shanghai Jiao Tong University (SJTU). He and his colleagues conducted computer simulations and laboratory experiments demonstrating the advantages of smaller diameter copper tubes in residential air conditioning applications. Professor Ding's research career was summarized in an "In the Spotlight" column of the *MicroGroove Update* newsletter (Volume 2, Issue 3) and select papers can be found in the MicroGroove Technical Literature webpages.

Supported by ICA and a consortium of ACR OEMs in Asia, Professor Ding demonstrated that refrigerant volume could be significantly reduced by reducing the diameter of the copper tubes while still meeting performance objectives. From this research, various design principles emerged which were of great value to OEMs seeking to optimize material usage in air conditioning and refrigeration applications.

Today, the latest simulation software from China is contained in the HXSim software available from the International Copper Association (ICA). See the "In the Spotlight" column in this issue.

According to the ICA, the use of smaller diameter copper tubes continues to grow in China. Brilliant Consulting estimated that air-conditioning production reached 136-million units in 2017 and that 37-million of these units were made with 5 mm copper tubes. Five millimeter MicroGroove copper tubes were used in about 27 percent of the air-conditioning units made in 2017. The number of units using 5 mm copper tubes increased 42.8 percent compared to 2016, according to the same market research group.

HEAT EXCHANGER TECHNOLOGY ALLIANCE

ICA China founded the Refrigeration and Air-Conditioning Heat Exchanger Technology Alliance (HETA) with the Shanghai Society of Refrigeration. HETA members include Gree, Midea, Haier, Hisense, Chigo and TCL. HETA aims to deepen cooperation with these OEMs, to research heat exchanger technology and strengthen the advantages of copper heat exchanger technology. Through their cooperation on the HETA platform, OEMs are realizing the full potential of smaller-diameter copper tubes and applying this technology to construction of high efficiency heat-exchangers and appliance products.

PRESENTATIONS

UPCOMING EVENTS

25th IIR International Congress of Refrigeration
Aug 24-30
Montreal, Canada

ATMOsphere Europe 2019
Oct 16-17
Airport Hotel Okecie
Warsaw, Poland
https://www.microgroove.net/events

PUBLICATIONS

Yoram Shabtay and Nigel Cotton," Advantages of small diameter tubes in transcritical refrigeration cycles," ATMOsphere America 2019, Atlanta, Georgia.
See Slideshow.

Yoram Shabtay and Nigel Cotton, "Sub-Zero, MTL Cool and LU-VE optimize MicroGroove copper tube ciols for use with natural refrigerants," ATMOsphere Europe 2018, Lago di Garda, Italy.
See Slideshow.

Representatives from Gree, Midea, Haier, Hisense, Chigo and TCL were present at the beginning of the Heat Exchanger Technology Alliance (HETA).

At the Fifth International Conference on Refrigeration Technology (ICRT), which was held in Zhuhai, Guangdong, China in December 2018, Ji Song of HETA delivered a presentation titled "Systematic study on small diameter copper tube heat exchanger technology." The presentation was in Session PS4 on "Heat and Mass Transfer," which was chaired by Guoliang Ding, Professor, Shanghai Jiao Tong University; and Jinping Liu, Professor, South China University of Technology.

ICA China regularly exhibits at the China Refrigeration Expo. It has offices in Shanghai and Beijing. See www.copperalliance.asia for more information. These offices continue to play a vital role in the dissemination of MicroGroove Technology in Asia and throughout the world.

Shankar Sapaliga, Kerry Song and Avinash Khemka represented the Copper Alliance at the HETA exhibit at the 2019 China Refrigeration Exposition.

TECHNOLOGY ADVANCES IN JAPAN

Japan is another technological leader in air-conditioning and refrigeration. In its university and OEM laboratories, experienced heat-exchanger engineers, physical scientists, computer simulation specialists and system designers continue to research the advantages of MicroGroove technology in real world applications. They are investigating ecofriendly refrigerants, copper tube performance and system innovations.

According to Masahiko Wada of the Japan Copper Development Association, "The key benefits of MicroGroove are higher efficiency and less materials usage. We enjoy sharing the latest developments in MicroGroove technology with researchers from around the world."

A seminar for OEMs was recently held by the Japan CDA. Research on small diameter, high performance inner-grooved copper tubes was presented for the next generation refrigerants and equipment. Attendees learned how to improve the heat transfer performance by reducing copper tube diameters. For tubes with smaller diameters, the tube wall can be thinner, the refrigerant can be reduced and the conductivity per unit volume increases. These advances makes copper more competitive versus alternatives.

Professor Inoue of Tokyo University of Marine Science and Technology and Professor Miyara of Saga University described laboratory experiments on copper tubes and the effect of copper tube diameter on heat exchanger performance. The seminar was attended by more than twenty engineers from Daikin, Panasonic, Hitachi, Mitsubishi, and Toshiba and other OEMs as well as representatives from three copper tube makers.

The use of low-GWP refrigerants is growing in Japan. An example is multinational retailer Lawson, one of Japan's biggest convenience store operators. Lawson already had installed CO2 transcritical systems in 3,272 stores across Japan by the end of 2018. The majority of these CO2 systems were supplied by Panasonic. The company is field-testing products from other manufacturers, too, and the total number of installed CO2 transcritical systems is expected to exceed 4000 by 2020 as recently reported by R744.com. Shinichiro Uto, who is in charge of the store development division with Lawson, outlined Lawson's business and environmental objectives in a presentation titled "Lawson's Efforts to phase out Freon" at ATMO Japan 2019.

Japan is a major player in the development of air conditioners, refrigeration and heat pumps and is home to large OEMs such as Daikin, Panasonic and Mitsubishi. Japan has led the way in the development of new technologies such mini-splits and variable refrigerant volume systems.

Japan's Daikin was one of the original members of the consortium that facilitated the adoption of MicroGroove technology by Chinese OEMs. Researchers from Daikin are frequent contributors of technical papers on the latest advances in small tube technology.

Daikin Industries Ltd. acquired Goodman Global in 2012 and the company soon commenced construction the state-of-the-art Daikin Texas Technology Park campus near Houston, Texas. This project was the largest investment made in Daikin's 90-year history. In October 2016, operations at the new facility ramped up and the first Goodman air conditioner and gas furnace units came off the line. Construction of the huge facility concluded in 2017, thereby consolidating Goodman's HVAC manufacturing, engineering, logistics, and customer support under one, very large 4.1 million square foot roof.

Japan is noted for the development of EcoCute, which is a natural refrigerant heat pump water heater. The name EcoCute is derived in part from the Japanese word "kyuto" which literally means "supply hot water" prefixed by the "Eco-," which suggests economic and ecological. EcoCute was one of the first major market successes for CO2 technology. The EcoCute story is described in shecco's "GUIDE to Natural Refrigerants in Japan: State of the Industry 2016," which is available for a free download from shecco here. This "GUIDE" covers much of the history of CO2 in Japan including extensive data on EcoCute and Panasonic.

Yokohama, Japan played host to the quadrennial IIR International Congress of Refrigeration (ICR) in 2015. ICA MicroGroove was a silver sponsor of the Congress where a technical paper titled "A General Steady State Mathematical Model for Multi-Unit Air Conditioner System Based on Graph Theory" was presented. This technique is especially useful when applied to MicroGroove heat-exchanger coils in multi-unit systems. MicroGroove technology has been successfully used in the manufacture of residential air-conditioners for the global market as well as for light-commercial refrigeration systems and large condensers and gas coolers.

MicroGroove exhibited at the quadrennial IIR Intenational Congress of Refigeration in Prague and Yokohama and will exhibit in Montreal in August 2019. The Japan Copper Development was on hand to answer questions in Yokohama.

THE SUN NEVER SETS ON MICROGROOVE

Truly MicroGroove is a global phenomenon. The coils are made around the world, in China, Korea, Vietnam, Japan and India; in several EU countries; and in the United States, Canada and Mexico. It is a breakthrough, "game-changing technology" in every send of that phrase; and it is paving the way to more eco-friendly solutions for human comfort and the cold chain.

The next articles in this series will survey trends in India and Europe, where MicroGroove continues to grow as the technology of choice for air-conditioning, refrigeration and heat pumps.

WEBINARS

Advantages of Small Diameter Copper Tube-Fin Heat Exchangers Webinar #1 in the OTS-ICA Educational Outreach Program (EOP)
View Recorded Webinar #1

Construction of Small Diameter Copper Tube-Fin Heat Exchangers Webinar #2 in the OTS-ICA EOP
View Recorded Webinar #2

Effective Design of Small Diameter Copper Tube-Fin Heat Exchangers Webinar #3 in the OTS-ICA EOP
View Recorded Webinar #3

See the MicroGroove "Webinars" webpage
http://www.microgroove.net/webinars

Also see MicroGrooveTech YouTube channel for archive of past webinars
https://www.youtube.com/user/MicroGrooveTech

HXSIM IS A POWERFUL TOOL FOR SIMULATING MICROGROOVE COILS

USER-FRIENDLY PLATFORM ACCURATELY PREDICTS PERFORMANCE FROM VERSATILE DATABASE OF DESIGN PARAMETERS

Imagine a coil simulation program that allows one to build a coil from the most basic elements and then predict the performance in intricate detail. Furthermore, imagine a practically limitless choice of design criteria. Then imagine that this software tool could be run on a desktop computer via a user-friendly graphical user interface (GUI) and that it comes with an easy-to-follow user's manual. And, finally, just imagine that it is available at a nominal charge. That in a nutshell is the HXSim "Small Diameter Copper Tube Air Conditioning Heat Exchanger Simulation Tool."

According to the manual, the main function of HXSim is to give accurate calculation results for predicting the capability of small-diameter copper-tube air conditioning heat exchangers in steady state conditions.

Once the user inputs the coil design parameters, the software calculates such quantities as heat exchange capacity, refrigerant-side pressure drop, and airside pressure drop; and it displays the results in easy-to-understand graphic or tabular formats.

The graphical user interface (GUI) makes it easy to enter data and observe simulation results. Both 3D and 2D user interfaces are available.

HXSim can simulate fin-and-tube heat exchangers for a variety of refrigerants and types of heat exchangers. The user can vary the tube size, fin design and tube circuitry as well as many other parameters. The tool gives the heat exchanger engineer deep insights into the interrelationships between various coil design parameters.

This powerful software tool was developed at Shanghai Jiao Tong University (SJTU) for many years under the auspices of the International Copper Association. The project was overseen and coordinated by the renowned Professor Guoliang Ding of the Institute of Refrigeration & Cryogenics in Department of Power & Energy Engineering at SJTU.

Professor Ding was the subject of an "In the Spotlight" column in the June 2012 issue of the MicroGroove Update Newsletter. That same issue outlines basic heat exchanger design principles, which are now captured in the HXSim software. HXSim represents the next big step in simplifying the design of advanced MicroGroove heat exchangers. Since then, Professor Ding has continued to spearhead the development of heat exchangers using smaller diameter copper tubes in a variety of air conditioning and refrigeration products as well as heat pumps.

INPUTTING THE DESIGN PARAMETERS

The latest version of HXSim (version 3.0) is well documented with a user manual submitted by Professor Guoliang Ding. The manual is available for downloading from the technical literature webpage of the microgroove.net.

When using the program to design a MicroGroove heat exchanger, the most basic input has to do with the type of refrigerant, the type of heat exchanger and the heat exchanger dimensions. The three main "Types" of heat exchanger blocks are the I-Type, L-Type and C-Type. (The most basic block shapes roughly corresponding to the shapes of the letters (I, L or C).

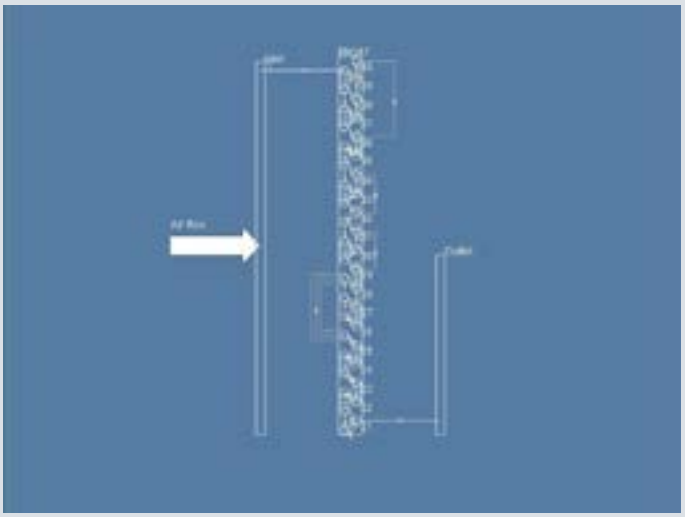

Figure 1: Heat exchanger in 2D view.

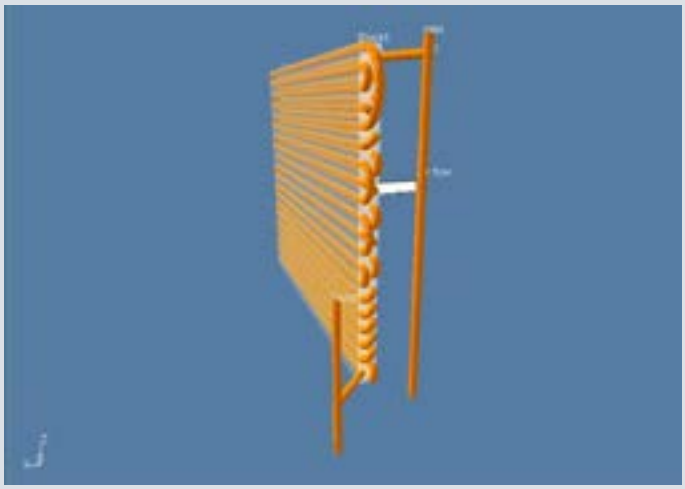

Figure 2: Heat Exchanger in 3D View.

Figures 1 and 2 show the graphical user interface for an I-Type heat exchanger in two and three dimenions, respectively.

The detailed meanings of the dimension input window are shown in Table 1. In these inputs, the "Row number" is of first importance. Only after inputting the row number can the column number of each row and the tubes in each column be defined.

Next the designer can input the row spacing and the column numbers for the tube locations. Then the fin-type can be selected and data can be entered on the joints. The "Connect Tubes" function is a vital step, which can also be accomplished through the easy-to-use 2D or 3D graphical user interface.

The program allows the user to select the inlet airflow, which does not need to be uniform across the heat exchanger. A number of variables are available with respect to the inlet airflow.

A database of tube types as well as fin types is available for use. The outer diameter of the MicroGroove tubes and the tube wall thickness as well as the inside-the-tube enhancements can also be varied. See Figure 3.

In summary, users can input parameters such as dimensions of heat exchanger, tube and fin geometry, refrigerant circuitry and operating conditions through the interactive GUI. The details of block, tubes, fins, refrigerant and air-flow are entered via data input dialog windows. Clicking the "Ok button" checks the values and closes the window. A warning dialog shows if the input data entered into some edit box is not apropos.

OUTPUTTING THE PERFORMANCE RESULTS

Once all the inputs have been provided the user is ready to run a simulation. Figure 4 shows how simulation results can be presented as a three-dimensional colored graph. Actually, a much finer analysis is available with steady-state values of temperature and pressure available at practically any point in the path of the refrigerant.

The simulation package will output calculated quantities such as heat exchange and outlet conditions of both refrigerant and air. The calculated results can be displayed in tables and

Parameter	Unit	Remark
Block type	—	I, L or C
Rows	Number	The number of rows of tubes in the heat exchanger
Depth	mm	Depth of fin-and-tube heat exchanger
Height	mm	Height of heat exchanger
Length	mm	Length of heat exchanger
Ambient Temperature	°C	Ambient Temperature
Fin type	—	Input by clicking button "Fins"
Fin pitch	mm	For variable fin pitch, click button "Specify"
Fin name	—	The name of the fin of the block
Continuous fins	—	Continuous planes or separated as bands
Control volume number	—	The maximum number is 10

Table 1: Meanings of Parameters in Dimension Input Window

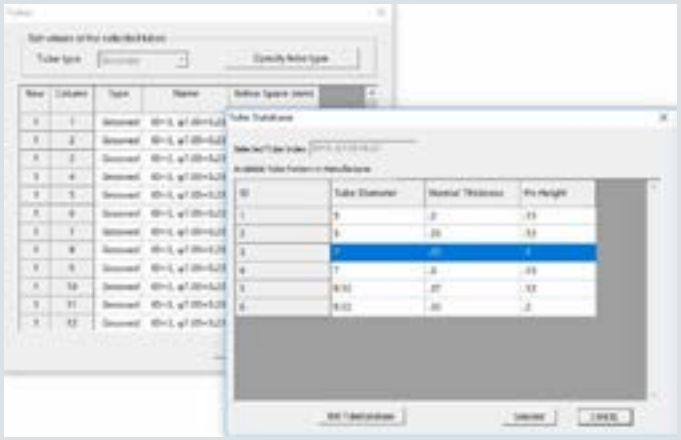

Figure 3: The tube diameter, tube wall thickness and inside-the-tube enhancements can be varied.

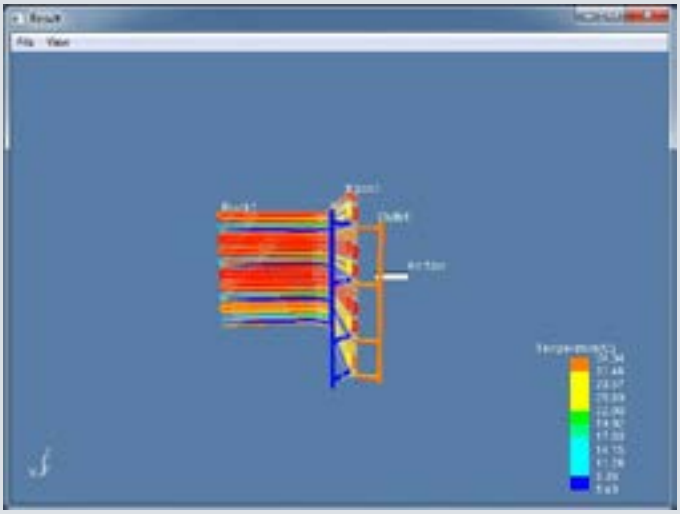

Figure 4: Simulation results in color gradation.

charts as well as 3D colored visualization of the properties at every location in the coil. It is also possible to print 2D and 3D heat exchanger graphs. Results can be saved and files can be serialized allowing for the application of various optimization algorithms.

The following menu items are available only after the simulation of heat exchanger is accomplished.

"Chart" provides an access to see both inlet and outlet state parameters of air/refrigerant in every control volume of every tube through a selected refrigerant path in charts.

"Table" provides an access to see both inlet and outlet state parameters of air/refrigerant in every control volume of every tube through a selected refrigerant path in a whole table.

"Graph" provides an access to open the results window which shows the simulation results. Figure 4 shows an example of 3D simulation results for temperature gradations in an L-Type heat exchager

Additionally, the menu item "Cost" provides an access to open the cost window which shows the heat exchanger cost. This menu item is available independently of the simulation results.

AVAILABLE FROM MICROGROOVE

The International Copper Association wants you to become an expert in the design of heat exchangers made from smaller-diameter copper tubes. The HXSim software package makes it easier than ever to grasp the relationship between various design parameters. It helps to strike and perfect balance between cost limitations and performance objectives.

Running HXSim simulations on proposed designs allows one to accurately predict the performance of the coils before building and testing prototypes and investing in the tooling to manufacture coils in volume.

Of course, many coil manufacturers and heat transfer engineers have developed their own specialized software programs for simulating the performance of heat exchangers. ICA has supported the development of tube correlations through contracts with many universities and research laboratories.

Additionally, ICA has co-funded optimization studies through Optimized Thermal Systems, along with numerous OEMs. See for example, information about the OTS-ICA educational outreach program and webinar series.

Nonetheless, for an easy-to-use and inexpensive, yet powerful and accurate, tool for the design and simulation MicroGroove coils, the HXSim platform can't be beat. For more information on HXSim, contact the MicroGroove Team Leader or one of the MicroGroove team members.