PHANTOM

2017
CASE STUDY

The Heat Is On: Examining Two-Phase Flow and Heat Transfer

Air-water flow through a pin-fin array designed to break up large bubbles and generate more interface area.

Examining Two-Phase Flow and Heat Transfer with High-Speed Cameras

Here's something to ponder: Heat, energy and temperature pervade our everyday lives in ways we don't realize. Think about it; the outside temperature often dictates our daily behavior, including what we wear and how many times we decide to leave the house. This is because the human body is highly sensitive to hot and cold, which is why many of us have heating and cooling systems in our homes and workplaces that control the temperature to keep us comfortable. A good example of this is air conditioning, which is one of the most popular industrial advancements found in nearly every American home and workplace.

Industrial technologies like air conditioning and refrigeration rely on heat transfer to function. A heat exchanger is a device that transfers heat between one or more fluids, essentially working to increase heating and cooling efficiency and flow. For example, in a building air-conditioning system, the interior space is kept cool by transferring heat to a boiling refrigerant stream in an evaporator heat exchanger. This heat is ultimately rejected to the outside air through a condenser heat exchanger. Heat exchangers are one of the most important and common pieces of process found in industrial sites around the globe.

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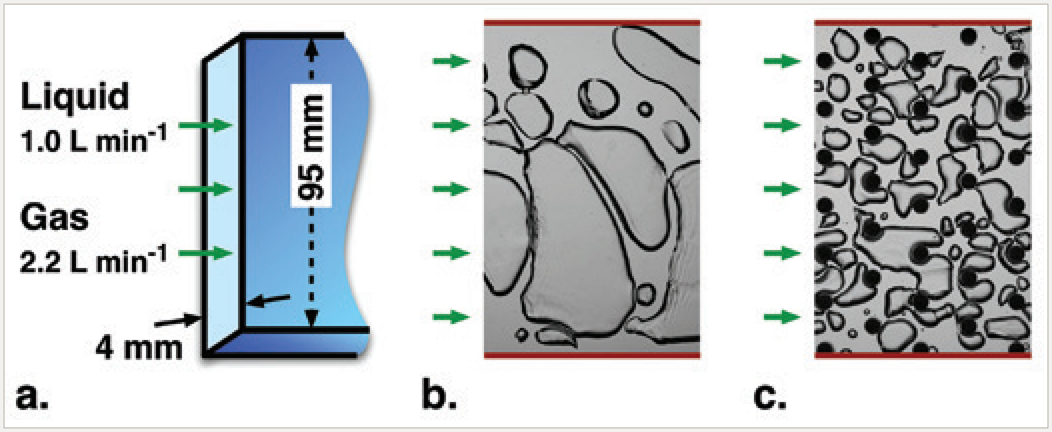
They are widely used in all different applications including space heating, refrigeration, power stations, and chemical plants to name a few. According to a recently published report by Global Industry Analysts, the market for heat exchangers is bullish and is expected to top $24.5 billion in the U.S. by the year 2022. The report cites that an aging installed base of heat exchangers worldwide will drive demand for future growth.



a. Using high-speed shadowgraphy, two-phase liquid-gas flows are observed in a mini-gap (4 x 95 mm).

b. Relatively poor mixing and low interfacial area density is apparent in a plain channel, limiting heat and mass transfer rates between the phases.

c. The addition of a staggered array of circular pin fins breaks up large vapor plugs. This can lead to improved heat exchanger performance and efficiency of thermal energy systems.

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Advancing Heat Transfer and Energy Technologies

A group of students at Pennsylvania State University are studying two-phase flow and heat transfer phenomena in an effort to advance these processes and further the technology behind them. Alex Rattner, Assistant Professor in the Department of Mechanical and Nuclear Engineering, leads a research group of graduate and undergraduate students who are working at the university's Multiscale Thermal Fluids and Energy Lab. Their focus: to make energy systems more efficient.

Rattner explained, "We're studying thermal energy systems including power generation, waste-heat recovery powered refrigeration, and membrane distillation water purification. To increase system performance and efficiency, core heat exchanger components must be enhanced and tailored to specific applications. To achieve this, we have to advance our understanding of the underlying liquid-vapor phase change processes of boiling and condensation."

Many heat transfer and phase change processes occur at miniscule scales and at high speeds. Its because of this that Rattner turned to Vision Research for its broad line of digital high-speed cameras, which are widely used in science and technology applications to capture data that cannon be seen with the human eye. "We worked closely with Vision Research to select the right camera for this project, and together we concluded that the Phantom Miro 340 would suit our project perfectly," Rattner said.

The Phantom Miro 340 is a popular mid-size camera in Vision Research's strong and growing line of digital high-speed imaging products. It has a 4 Mpx sensor (2560 x 1600) a throughput of 3.2 Gpx/s, and a frame rate of 800 fps at full resolution. Scientists and engineers can also take advantage of precise timing, camera synchronization, and flexible triggering. The Phantom Miro 340 uses a micro-lens on its custom-designed CMOS sensor with 10 µm pixel pitch to achieve increased light sensitivity.

Examining the Two-Phase Flow with the Phantom Miro 340

Inside the lab, Rattner and his students are using the Phantom Miro 340 to capture what's known as 'two-phase' (gas-liquid) flow and phase change dynamics in heat exchanger geometries for the aforementioned applications. He explained, "In order for us to improve the performance of heat exchangers, we have to characterize flows and mixing in complex enhanced channel geometries. To understand two-phase flow processes, we need to be able to closely examine interactions between the liquid and vapor phase, and we can only do this with an advanced high-speed camera."

Using a technique called shadowgraphy, Rattner and his research group examine a transparent test section containing a two-phase flow. The test section incorporates a grid of small pins to improve mixing in the flow and break up large vapor plugs into smaller bubbles. Situated above the test section is a powerful LED light panel that provides ample high intensity uniform lighting. "Underneath that, we have the Phantom Miro camera pointed up at the test section, so we're observing shadows cast by the two-phase flow. We're observing the interfaces around the liquid vapor structures, which are moving at incredible speeds across the camera's viewfinder. We're capturing them with an exposure of a couple of microseconds. Without this type of imagery, we wouldn't be able to observe what's going on," he continued.

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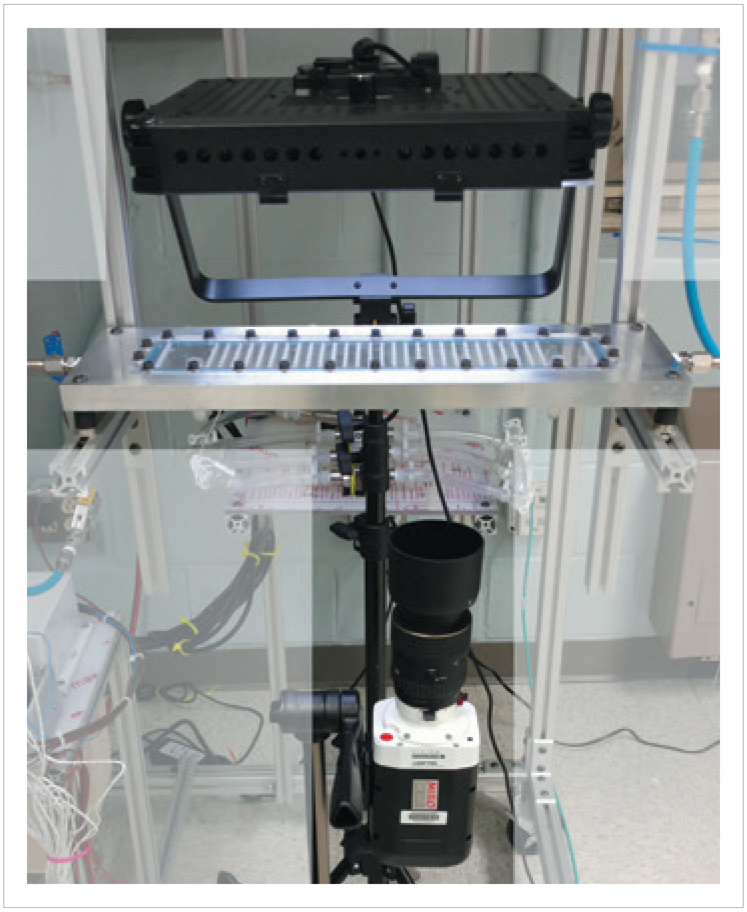
With the Phantom Miro 340's 12-bit pixel depth, Rattner and his research team get superior image quality and never have any issues with lighting. "The Miro 340 has worked flawlessly throughout this project, and it was incredibly easy to learn. Within one day we had the camera up and running and were collecting the high-quality flow visualization data that we anticipated. The images were incredibly sharp, and overall this project was a huge success. Insights from this effort will help us design better heat exchangers and therefore more efficient energy systems across a range of industrial applications," Rattner said.

The Phantom Miro 340 is now a dedicated piece of equipment at Penn State's Multiscale Thermal Fluids and Energy Lab. Rattner said the lab plans to use the camera for future projects, especially ones to continue the advancement of heat transfer research. "We definitely see a lot of use for the camera in the future. We're already earmarking it for a few pending projects that involve studying heat transfer and flow," he said.



Phantom Miro 340 camera setup.

See YouTube Video:

https://youtu.be/VC6-JsI2CrE

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