Commercial and Residential Heat Pump Condenser Optimization for a Major US HVAC OEM

Conducted by Optimized Thermal Systems, Inc.

Sponsored by the International Copper Association, LTD

Optimized Thermal Systems, Inc. (OTS) recently conducted a design and optimization study for an HVAC&R OEM to identify small-diameter copper tube heat exchangers (HX) to replace microchannel heat exchangers (MCHX) in two heat pump systems – a 2-ton residential and a 10-ton commercial. Currently, the MCHXs are purchased from a third-party supplier, whereas the OEM wants to bring the HX manufacturing back in-house. Since they have the tooling and expertise in tube-fin HX manufacturing, they opted to investigate the small diameter tube concept.

OTS used CoilDesigner®, a HX design and simulation software tool, to evaluate the performance of various designs and perform several optimization studies using a multi-objective genetic algorithm (MOGA). The objectives of the optimization were to maximize capacity and to minimize airside pressure drop. In order to design drop-in replacements of the existing heat exchanger, geometric constraints were imposed, including the coil height, width, and depth; fin density; refrigerant pressure drop; and refrigerant charge.

An initial study was performed using specific geometric configurations for wavy and louvered fin patterns available from current 5mm tube-fin HX manufacturers. The analysis resulted in hand designs that were in conformity with design specifications set forth by the OEM, which are depicted in Figure 1. Commercial replacement condensers using wavy and louvered fin patterns showed a 15% to 38% and 29% to 42% increase in air pressure drop, respectively, while maintaining less than a 4% decrease in heating capacity when compared to the baseline MCHX commercial condenser. Residential replacement condensers using wavy and louvered fin patterns showed a 23% and 16% increase in air pressure drop, respectively, while maintaining a negligible (0.2%) decrease in heating capacity as compared to the baseline residential condenser.

Material mass and material volume reduction was achieved for the commercial heat exchanger. Louvered fin designs exhibited total material mass reduction by approximately 26%, while the wavy fin designs had material mass reduction of as much as 35%. The same trend was not achieved by the residential designs since the baseline MCHX is all-aluminum, with approximately half the depth as the commercial coil with lower fin density while having about half the face area; thus, it has much less material than its commercial counterpart. The tube-fin designs are a two-row coil with fixed horizontal spacing; i.e. for the similar face areas, both residential and commercial are very similar coils in size, resulting in similar quantities of tube material, which is not the case for the baseline HX's.

OTS evaluated system level performance using VapCyc®, a vapor compression cycle design and simulation software. The condensers were used in the system model to evaluate overall COP changes that would occur from replacing the MCHX with the sized HX's using a supplier's wavy and louvered fin and tube patterns described above. Louvered fins saw a decrease of 1% COP while wavy fin designs saw a decrease of 4% COP.

An optimization study for 5mm tube fin condensers was conducted to explore new fin patterns that are potentially not available in the market. The design space consisted of variable ranges consistent with current manufacturing capabilities. This optimization found 5mm tube fin designs that were competitive with the baseline microchannel condenser. The additional degrees of freedom in the optimization studies 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% in material mass while maintaining the same air side pressure drop and capacity as the baseline. 5mm Commercial designs shown in Figure 1 demonstrate capacity increases of up to 3% and air side pressure drop decreases of up to 19% while maintaining other performance metrics within the OEM's specified constraints. 5mm Residential designs shown in Figure 2 demonstrate negligible capacity increases (0.2%) and air side pressure drop decreases of up to 20% while maintaining the OEM's constraints.

An additional optimization study for 3-5mm tube fin condensers was conducted to evaluate the potential performance gains for having even smaller tube diameter designs. This resulted in the identification of designs that, though marginally, still dominated the baseline. Figure 1 shows commercial designs with the possibility for 0.5-1.5% increase in capacity with baseline pressure drop, or 10% to 16% decrease in air side pressure drop with baseline capacity. Similar results were found for the residential 3-5mm optimization, shown in Figure 2.

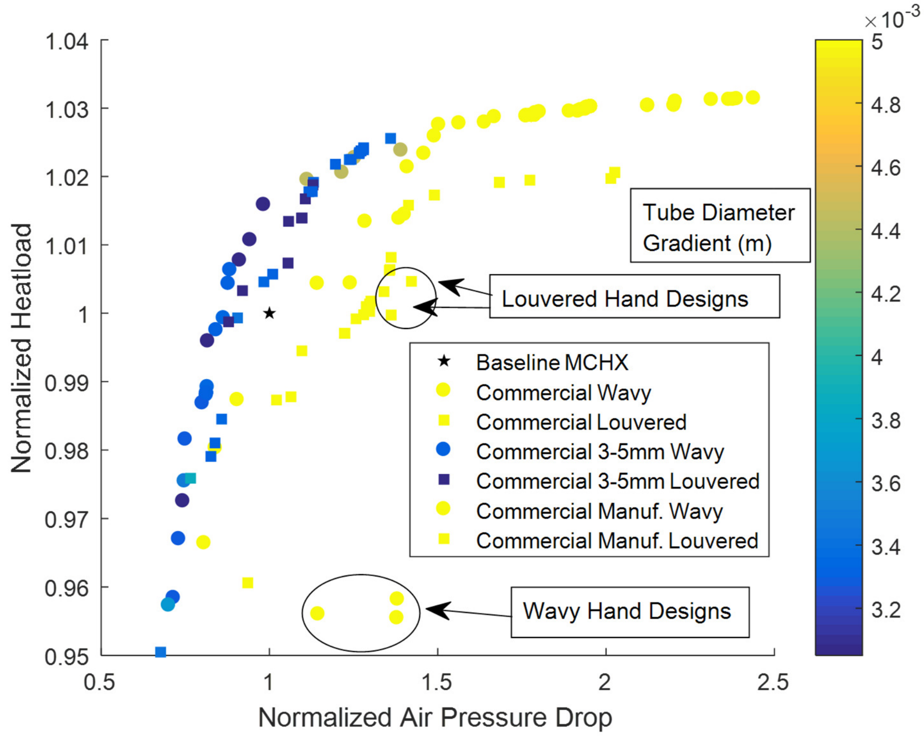

Figure 1. Commercial Pareto Comparison

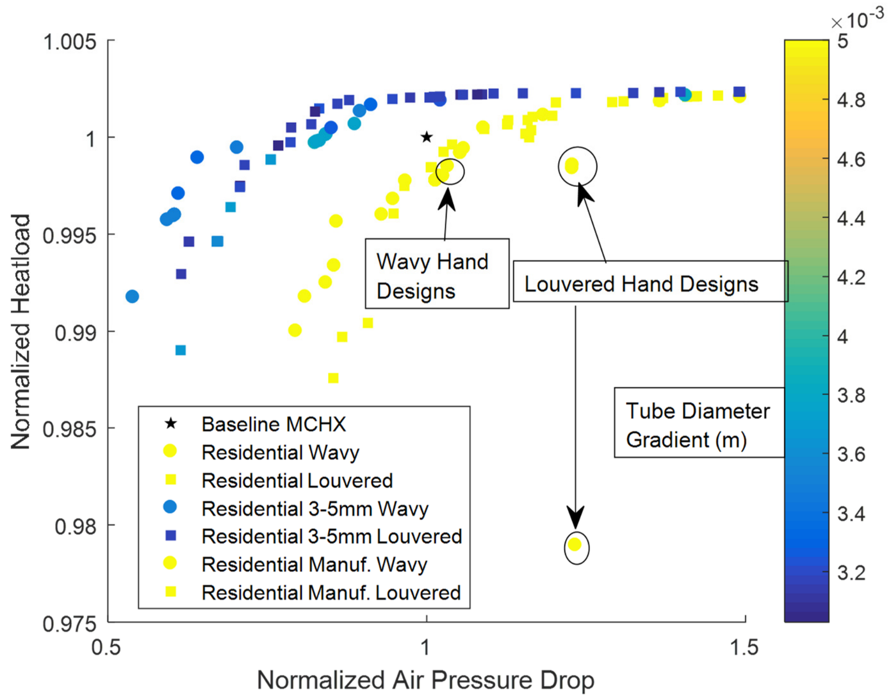

Figure 2. Residential Pareto Comparison

In summary, OTS has identified several currently-manufactured fin designs that could be used to replace a MCHX with limited performance improvements but with potential for weight and volume reduction (commercial system). OTS also identified several 5mm new tube-fin condenser designs with significant potential to match the performance of a MCHX condenser. Furthermore, OTS identified several 3-5 mm tube-fin condenser designs with significant potential to outperform, although marginaly, the MCHX.