

ADJOINT TUBE SHAPE OPTIMIZATION OF AN AIR-TO-REFRIGERANT HEAT EXCHANGER SUBJECT TO FLOW MALDISTRIBUTION

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Abstract

Air-to-refrigerant heat exchangers (HX) are key components in heating, ventilation, air conditioning, and refrigeration (HVAC&R) systems. Modern package design allows for compact system design, though often at the cost of capacity degradation resulting from airflow maldistribution. Several authors have modified the flow path on the refrigerant side so as to reduce capacity penalties and in some cases even enhance thermal performance. However, further improvements are limited by a finite number of possible flow paths as well as manufacturing constraints. One interesting and under-explored approach would be to modify the shapes of the heat transfer surfaces themselves to maximum thermal-hydraulic performance, enabled by recent advancements in additive manufacturing. This work explores adjoint tube shape optimization of an air-to-refrigerant HX subject to non-uniform velocity profiles. The baseline flow distributions are validated against PIV data from the literature, and multi-objective optimization using weighted sums is used to explore tradeoffs between improvements in thermal performance and reductions in fan power. Variation in tube shape along the height of the HX leads to a reduction in flow maldistribution along the height of the HX and between adjacent slabs, with optimal HX designs delivering up to 10% reduction in hydraulic resistance with minimal impact on heat transfer capacity. Designs with multiple tube shapes are compared against those with a single non-round tube so as to quantify the benefit of adjoint-based HX designs.