
Enumeration and Selection of Structurally Similar Coil Designs used in Air Conditioners

Sudhakar Munusamy
Technical Lead
Process Technology
Gyan Data Private Limited
Chennai-600113 India
sudhakar.munusamy@gyandata.com

About the Client

Mitsubishi Electric Research Laboratories (MERL) is the corporate R&D organization of Mitsubishi Electric and is located in Cambridge, MA, United States. It is engaged in various application oriented research in the areas of control, optimization and signal processing.

Motivation

Cooling systems like air conditioners, chillers, refrigerators have coils consisting of several tubes connected in serpentine manner through which refrigerant flows and extracts heat away from the air surrounding the coil. The amount of cooling required for the enclosure varies due to changes in the indoor and ambient conditions. Capacity modulation is required to address this varying cooling requirement and this may be achieved by reconfiguration of the refrigerant flow paths in the heat exchanger.

Problem

MERL was interested to explore the minimum number of configurations which cover wider range of heat transfer capacity for a base coil bill of material (BOM). The problem was refined further to systematically enumerate all possible configurations including splitting of flows, plugging certain tubes, provisioning multiple inlet and outlet ports for an identified base coil BOM considering manufacturing feasibility requirements. After enumeration the client was also interested in identifying geometrically closer configurations for that base coil which had wider range of heat exchange capacity modulations.

Solution

Gyan Data approached the problem of systematic enumeration by incorporating a super structure framework for representing all the coil designs. Super structures consisted of a matrix containing geometrically encoded entries where each encoding represented the tube connectivity signifying detached and shorted connection designs.

Various mathematical constructs were framed for the entry of these values in the matrix and each valid entry represented a feasible and thermodynamically functional coil configuration. Using this superstructure all possible configurations were enumerated for the base coil. Each configuration was further provided as input to 'CoilDesigner' application to evaluate the corresponding heat exchange capacity. To find the heat exchange capacity, a code written in MATLAB automated the process of enumeration and was integrated with 'CoilDesigner' application through C# interface. The MATLAB code was validated with coils having smaller number of tubes where possible configurations were verifiable by refrigeration domain experts. The code was

then used for enumerating the configuration of production-grade coil having significantly higher number of tubes.

Gyan Data constructed metrics whose value indicated geometric similarity between tuples of base coil configurations. Using this custom metric resulted in the extraction of geometrically similar configurations for given base configurations. MATLAB code was extended to post process and extract those similar configurations from millions of competing alternatives and subsequently 'CoilDesigner' application was used to evaluate the heat exchange capacity as the required solution for the client's needs.