Available online at www.sciencedirect.com
ScienceDirect
International Journal of Refrigeration 30 (2007) 482–488
REVUE INTERNATIONALE DU FROID
INTERNATIONAL JOURNAL OF
refrigeration
www.elsevier.com/locate/ijrefrig

Optimization of finned-tube condensers using an intelligent system☆

Piotr A. Domanski*,[1], David Yashar

HVAC&R Equipment Performance Group, National Institute of Standards and Technology, 100 Bureau Drive, Mailstop 8631, Gaithersburg, MD 20899, USA

Received 17 December 2005; received in revised form 11 August 2006; accepted 16 August 2006
Available online 22 November 2006

Abstract

The refrigerant circuitry influences a heat exchanger's attainable capacity. Typically, a design engineer specifies a circuitry and validates it using a simulation model or laboratory test. The circuitry optimization process can be improved by using intelligent search techniques. This paper presents experiments with a novel intelligent optimization module, ISHED (Intelligent System for Heat Exchanger Design), applied to maximize capacity through circuitry design of finned-tube condensers. The module operates in a semi-Darwinian mode and seeks refrigerant circuitry designs that maximize the condenser capacity for specified operating conditions and condenser slab design constraints. Examples of optimization runs for six different refrigerants are included. ISHED demonstrated the ability to generate circuitry architectures with capacities equal to or superior to those prepared manually, particularly for cases involving non-uniform air distribution.

Keywords: Refrigeration system; Air conditioning; Modelling; Optimization; Design; Air condenser; Finned-tube

Optimisation des condenseurs à tubes ailetés à l'aide d'un système intelligent

Mots clés : Système frigorifique ; Conditionnement d'air ; Modélisation ; Optimisation ; Conception ; Condenseur à air ; Tube aileté

1. Introduction

Finned-tube condensers and evaporators are the predominant types of refrigerant-to-air heat exchangers. Their performance is affected by a multitude of design parameters, some of which are limited by the application or available manufacturing capabilities. Once a heat exchanger's outside dimensions, tube diameter, tube and fin spacing, and heat transfer surfaces are selected, the design engineer needs to specify the sequence in which tubes are connected to define the flow path of the refrigerant through the coil, i.e., the refrigerant circuitry. The goal of the design engineer is to specify a circuitry that maximizes coil capacity. The number of refrigerant circuitry options is overwhelming; for example, a three-depth row heat exchanger with 12 tubes per row

☆ This paper was originally presented at the IIR International Conference, Thermophysical Properties and Transfer Processes of Refrigerants, Vicenza, Italy, August 31–September 2, 2005.

* Corresponding author. Tel.: +1 301 975 5877.
E-mail address: piotr.domanski@nist.gov (P.A. Domanski).
[1] Member of IIR Commission B1.

0140-7007/$35.00 © 2006 Elsevier Ltd and IIR. All rights reserved.
doi:10.1016/j.ijrefrig.2006.08.013

Nomenclature

COP	Coefficient of performance	*Subscripts*	
P	Pressure	Sat	Saturation
Q	Capacity	Sup	Superheat
S	Skew factor – defined in text		
T	Temperature		

has approximately 2×10^{45} possible circuitry architectures. Currently, circuitry design is primarily driven by engineer's experience aided by supplemental heat exchanger simulations, which are performed manually. Designing an optimized refrigerant circuitry is particularly difficult if the airflow is not uniformly distributed over the coil surface. In such a case, the design engineer may be tempted to assume a uniform air velocity profile, which will result in capacity degradation [1].

Among papers considering refrigerant circuitry optimization, an analytical evaluation of the optimum number of parallel sections in an evaporator showed that the maximum capacity is obtained when the drop of refrigerant saturation temperature is 33% of the average temperature difference between the refrigerant and the tube wall [2]. A simulation study of six circuitry arrangements concluded that the heat transfer surface area may be reduced by 5% through proper design of the refrigerant circuitry, compared to common configurations [3]. Another study considering performance of R22 alternatives in condensers demonstrated that different refrigerants require different circuitry architectures to maximize the capacity [4]. The simulation results showed that high-pressure refrigerants are more effective when used with higher mass fluxes than R22 because of their small drop of saturation temperature for a given pressure drop. This conclusion supports the concept of a penalty factor [5], which takes into account a refrigerant's saturation temperature drop during forced convection condensation.

A common aspect of the above studies is that they considered finned-tube heat exchangers with different pre-arranged refrigerant circuitries. A different approach is now possible, through advances made in machine learning, in which customized circuitry designs can be generated for individual heat exchanger applications with uniform and non-uniform inlet air distributions. These capabilities have been demonstrated by a novel optimization system called ISHED (Intelligent System for Heat Exchanger Design) [6]. The follow up work presented the application of ISHED for optimizing refrigerant circuitries in evaporators working with isobutane (R600a), R134a, propane (R290), R22, R410A and R32 [7]. This paper extends the application of ISHED to condensers working with the same six refrigerants, and it constitutes one of the stages of the effort to incorporate ISHED into the heat exchanger simulation package EVAP–COND [8] as a refrigerant circuitry optimization option.

2. Circuitry optimization with ISHED

Fig. 1 presents a general diagram of the ISHED system. It consists of a heat exchanger simulator, which provides capacities of heat exchangers with different circuitry architectures, and a set of modules which participate in the preparation of new architectures. ISHED uses the conventional evolutionary approach in that it operates on one generation (population) of circuitry architectures at a time. Each member of the population is evaluated by the heat exchanger simulator, which provides the heat exchanger capacity as a single numerical fitness value. The designs and their fitness values are returned to the Control Module as an input for deriving the next generation of circuitry designs. Hence, the optimization process is carried out in a loop, and is repeated for the number of generations specified by the user. The user also specifies the number of members in each population at the outset of the optimization run.

The ISHED scheme involves two modules for ''breeding'' new refrigerant circuitry generations, the Knowledge-Based Evolutionary Computational Module and the Symbolic Learning Module. The Control Module decides which module is utilized to produce the next generation (population). At the outset of an optimization run, the Knowledge-Based Module, which produces designs by applying probabilistically selected circuitry modifying operations to well

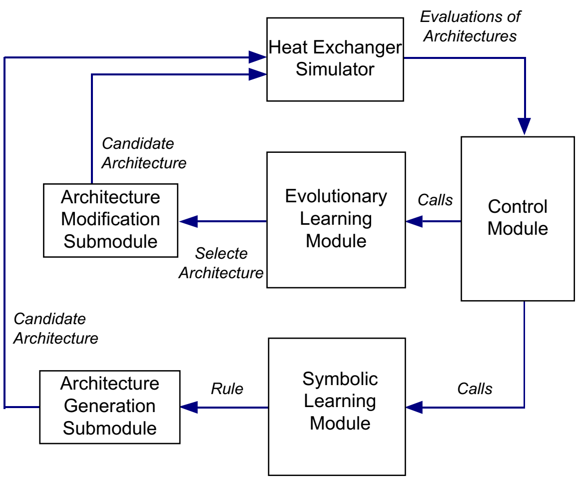

Fig. 1. Functional architecture of ISHED.