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A lumped-parameter thermal model for scroll compressors including the solution for the temperature distribution along the scroll wraps

Marco C. Diniz [a], Evandro L.L. Pereira [b], Cesar J. Deschamps [a,*]

[a] POLO Research Laboratories for Emerging Technologies in Cooling and Thermophysics, Federal University of Santa Catarina, 88048-300 Florianopolis, SC, Brazil
[b] Embraco, R. Rui Barbosa, 1020, 89219-901 Joinville, SC, Brazil

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ABSTRACT

A lumped-parameter thermal model is presented to predict the temperature in different chambers and components inside scroll compressors with particular attention to gas superheating in the suction process. Thermal resistances between the components are based on global heat transfer conductances, whereas conduction heat transfer through the scroll wraps is solved via a one-dimensional finite volume method. The thermal model was coupled to a thermodynamic model of the compression cycle and then applied to simulate the compressor performance under different conditions of speed and pressure ratio. The model was able to correctly predict the compressor temperature for operating conditions within the range of those adopted for its calibration. The results showed a strong coupling between the compressor thermal profile and the temperatures of the motor and lubricating oil. It has also been found that heat conduction through the scroll wraps reduces slightly the discharge temperature.

Un modèle thermique à paramètres agrégés pour des compresseurs à spirale incluant la solution de la distribution de température le long des enroulements de la spirale

Mots clés : Compresseurs à spirale ; Surchauffe ; Gestion thermique ; Modélisation des compresseurs

1. Introduction

The scroll compressor performs the compression process by using two identical inter-fitting, spiral-shaped scroll elements. These elements are mounted inverted and rotated 180° in relation to each other and, by making contact with each other at sealing points, form multiple compression volumes, hereafter denominated pockets. As the orbiting scroll performs its movement in relation to the stationary scroll, the sealing

* *Corresponding author*. Tel./fax: +55 48 3234 5691.
E-mail address: deschamps@polo.ufsc.br (C.J. Deschamps).

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Nomenclature

Roman

h	Specific enthalpy J kg^{-1}
$\dot{m}$	Mass flow rate kg s^{-1}
$\dot{Q}$	Heat transfer W
T_c	Condensing temperature °C
T_e	Evaporating temperature °C
UA	Global heat transfer conductance W K^{-1}
$\dot{W}_{ele}$	Electrical power consumption W
$\dot{W}_{pv}$	Indicated Power W
$\dot{W}_{shf}$	Shaft Power W

Greek

η_e	Electrical efficiency
η_s	Isentropic efficiency
η_m	Mechanical efficiency
η_v	Volumetric efficiency

Subscripts

dis	Discharge
dis-shl	From discharge chamber to shell
ext	External ambient
in	Compressor inlet
mot	Motor
mot-suc	From motor to suction gas
oil	Oil
oil-shl	From oil to shell
out	Compressor outlet
shf	Shaft
shl	Shell
shl-ext	From shell to external ambient
shl-gas	From shell to compressed gas
shl-suc	From shell to suction gas
suc	Suction

points migrate inward, pushing the pockets to the center of the scrolls, reducing their volumes and compressing the gas.

In addition to gas leakage, the volumetric and isentropic efficiencies of scroll compressors are affected by heat transfer that takes place inside the pockets during the suction and compression processes. The thermal interactions between compressor internal components also influence thermodynamic performance. One of the first studies related to heat transfer applied to hermetic scroll compressors was carried out by Wagner et al. (1992). The authors experimentally analyzed heat fluxes in different components of the compressor. Further experimental investigations were focused on heat transfer inside the pockets (Jang and Jeong, 1999, 2006), and temperature distribution along the scroll wraps (Sunder, 1997; Lin et al., 2005). Other authors (Ooi and Zhu, 2004) have used CFD to predict the temperature of the gas inside the pockets. These studies suggested that a linear temperature profile along the scroll wraps should be prescribed in order to correctly predict heat transfer inside the chambers. Numerical models based on lumped formulations have also been developed to estimate the compressor temperature profile (Lee, 2002; Chen et al., 2002). However, results regarding the compressor temperature in a variety of conditions have not been presented so far. Recently, Pereira (2012) developed a simulation model to characterize the suction, compression and discharge processes of scroll compressors, with correlations especially developed to evaluate leakage and heat transfer in the pockets.

This paper reports the development of a lumped-parameter thermal model to predict the temperatures in different locations inside scroll compressors. Special attention is given to both the suction gas superheating and the temperature profile along the wraps. Measurements of temperature were carried out in different positions and adopted to calibrate the simulation model. The compression cycle was simulated with a lumped thermodynamic model developed by Pereira (2012). The temperature distribution along the scroll wraps was modeled with a one-dimensional formulation and solved via the finite volume method (Diniz et al., 2013). Such models were coupled and adopted to simulate the scroll compressor in different operating conditions.

2. Experimental setup

The model developed to predict the compressor temperature was calibrated with reference to experimental data. In this regard, an R410A scroll compressor was instrumented with

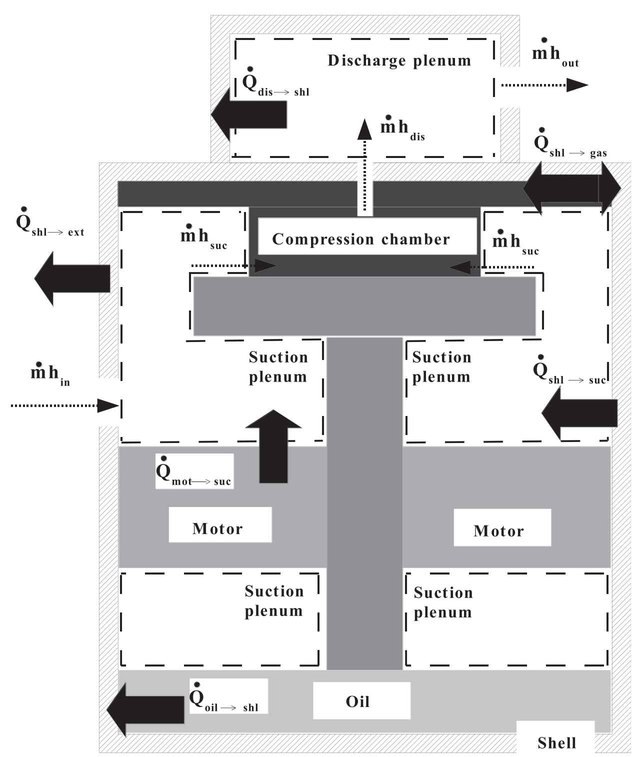

Fig. 1 – Schematic of the compressor geometry and control volumes for energy balance.