Applied Thermal Engineering 41 (2012) 61–70

Contents lists available at SciVerse ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

Experimental investigation of transient fluid flow and superheating in the suction chamber of a refrigeration reciprocating compressor

A. Morriesen, C.J. Deschamps*

POLO Research Laboratories for Emerging Technologies in Cooling and Thermophysics, Department of Mechanical Engineering, Federal University of Santa Catarina, Campus Universitário, Florianópolis, SC, 88040-900, Brazil

ARTICLE INFO

Article history:
Received 1 May 2011
Accepted 6 December 2011
Available online 13 December 2011

Keywords:
Refrigeration compressor
Superheating
Temperature transient
Cold-wire sensor

ABSTRACT

The gas superheating that takes place along the suction path of refrigeration compressors considerably decreases their volumetric and isentropic efficiencies. This paper reports an experimental investigation of transient fluid flow and superheating in the suction chamber of a 3600 rpm refrigeration compressor under two operating conditions. Hot-wire and cold-wire probes are applied to measure velocity and temperature transients, whereas measurements of pressure pulsation are acquired with a piezoelectric sensor. The results reveal a very complex phenomenon with steep variations in all flow parameters during the operation cycle. Significant superheating is observed during the period in which the suction valve is closed, suggesting high rates of heat transfer between the gas and the chamber walls. It was observed that the opening of the valve leads to a steep temperature drop in the suction chamber due to both the associated gas expansion process and the supply of fresh gas from the suction muffler.

1. Introduction

Recent figures show that approximately 8% of the residential electrical energy consumption in the United States is associated with refrigerators and freezers [1]. This is one of the main reasons behind the increasing demand for high-efficiency cooling systems. Among the components of a vapor-compression refrigeration system, the compressor has a key role in its energy consumption. Fig. 1 presents a schematic view of a reciprocating compressor and its indicator diagram for a typical cycle. When the piston moves downwards, it reaches a position where low-pressure vapor is drawn in through the suction valve, which is opened automatically by the pressure difference between the cylinder and the suction chamber. The vapor keeps flowing in during the suction stroke as the piston moves toward the bottom dead center (BDC), filling the cylinder volume with vapor at the suction pressure, p_s. The suction process is represented by curve B–C in the indicator diagram of Fig. 1b. After reaching the BDC, the piston starts to move in the opposite direction, the suction valve is closed, the vapor is trapped, and its pressure rises as the cylinder volume decreases. Eventually, the pressure reaches a value higher than that in the discharge chamber, p_d, and the discharge valve is forced to open. After the opening of the discharge valve, the piston keeps moving toward the top dead center (TDC), represented by point A. It should be noted that suction and discharge processes do not take place at constant pressure due to the valve dynamics and the flow restriction imposed by the valve passage areas. Therefore, as shown in the indicator diagram, the compression process continues after pressure p_d is reached and the same occurs for the expansion stroke after pressure p_s.

The overall efficiency of a compressor can be understood as being the result of three factors: i) electrical efficiency, associated with the driving motor and its startup auxiliary device; ii) mechanical efficiency, related to the bearing system; iii) thermodynamic efficiency, due to the irreversibility of the suction, compression and discharge processes. A simple analysis of the current efficiency levels of state-of-art household reciprocating compressors [2] indicates an electrical efficiency of around 88%. The use of synchronous motors could further increase this efficiency, but in some cases such alternatives are not adopted because of cost issues. Concerning the mechanical system, the efficiency levels are also quite high and can reach levels of up to 92%. In fact, linear compressors and variable speed compressors running at lower speeds can offer even higher mechanical efficiencies. The thermodynamic efficiency is much lower and usually between 80 and 83%. Therefore, it is clear that future improvements in the compressor efficiency will very likely be associated with a reduction in thermodynamic losses.

* Corresponding author. Tel.: +55 48 3234 5691; fax: +55 48 3234 5166.
E-mail address: deschamps@polo.ufsc.br (C.J. Deschamps).

1359-4311/$ – see front matter
doi:10.1016/j.applthermaleng.2011.12.011