Chapter 19
Expansion Power Recovery in Refrigeration Systems

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ABSTRACT

Vapor-compression systems are the most popular method of refrigeration. However, the throttling loss at the expansion valve is one of the “energy parasites” of such systems. This is especially acute in systems with large operating pressure differences like the transcritical CO2 refrigeration systems. In this chapter, a method to solve this issue by using an expander to recover the expansion energy of refrigeration systems is explained. Relevant research works are then discussed to provide a general overview about the state of the art technology. Various types of expander mechanisms, including reciprocating, rolling piston, rotary vane, scroll, screw, turbine, swing piston and revolving vane, are discussed. Works on the various aspects of expanders are also discussed. These include heat transfer, exergy analysis, expansion process, internal leakage, lubrication, integration with refrigeration systems and the economic aspects.

INTRODUCTION

Refrigeration systems are integral parts of modern life. It provides comfort for people, thermal management for industrial processes, preserves food, etc. Among all of the available systems, vapor compression system is currently the most popular. It is compact, reliable and can be used for a wide range of applications. A typical vapor compression system has four main components: compressor, condenser, expansion valve and evaporator as illustrated in Figure 1 (a). In some applications, additional components like internal heat exchangers, accumulators, etc. may be installed. These components are linked with pipes. Refrigerant flows through these components in a closed system in the direction shown by the arrows in Figure 1(a). Pressure and temperature of the refrigerant are increased through compression process in the compressor. This hot and high pressure refrigerant then flows to the condenser and rejects heat. This is the useful heat in heat pumps. In cooling applications, this heat is usually rejected to the ambi-

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Figure 1. Schematic diagrams of vapor compression systems (a) with and (b) without expanders, and (c) pressure-enthalpy diagrams of the systems.

ent as waste heat. The refrigerant then enters the expansion valve to drop its pressure and temperature. The expansion process is typically instantaneous, resulting in a near-isenthalpic expansion process. The resulting cold refrigerant then enters the evaporator and absorbs heat. This is the cooling provided for refrigeration applications. The refrigerant finally goes back into the compressor and the cycle continues.

Performance of such refrigeration systems is usually quantified using a parameter called Coefficient of Performance (COP). Depending whether the system is used for cooling or heating applications, the definitions of COP are expressed in Equations 1 and 2.

\[ COP_c = \frac{Q_{\text{cold}}}{W_{\text{comp}}} \]  
\[ COP_h = \frac{Q_{\text{heat}}}{W_{\text{comp}}} \]

where \( Q_{\text{cold}} \) is the cooling capacity of the system (W), \( Q_{\text{heat}} \) is the heating capacity of the system (W) and \( W_{\text{comp}} \) is the compressor power requirement (W).