Chapter 17
Implementation of Thermal and Energy Improvements in Domestic Refrigeration: Case Studies

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ABSTRACT
This chapter concisely discusses two case studies experiences on domestic refrigeration. One of the cases involves the theoretical and experimental analysis of the thermal profile in the compartments of a refrigerator, all this under the modeling and simulation through CFD, thus obtaining interesting results in terms of energy consumption. The second case is focus on the thermal and energy evaluation of new material proposed as thermal insulator, which was developed in a conventional way in the laboratory and presents convenient thermal features. Therefore, the guidelines for this chapter are aimed at finding mechanism that streamline the domestic refrigeration systems, without modifying its cooling performance.

INTRODUCTION
Presently, companies involved in the production of household appliances face heavy regulations related to energy consumption, emissions of greenhouse gases and environmental impact, among others. Energy consumption is the result of the increased level of equipment and comfort that is presented in the residential sector. Refrigerators are among the most manufactured devices because their use is essential in homes. Currently, the most employed method in cold generation is based on vapor compression, which represents a high percentage of energy consumption. Refrigerators based on vapor compression are major energy consumers, and its incidence is increasing in less developed countries. The annual production of refrigerators in 2009 was approximately 80 million units worldwide, which is increasing...
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rapidly (Seong & Soo, 2011). For over a century the same technology has been used to preserve food at a lower temperature than the surrounding environment is. For instance, around 45% of world production of food would be lost if the generation of artificial cold were not available. It is therefore apparent that the refrigeration industry requires the implementation of new mechanisms or environment friendly technologies that contribute to achieve improved energy efficiency, but keeping the demanded thermal load. Consequently, it is possible to identify a wide range of opportunities in the search of improvements in the performance of a domestic refrigerator.

Therefore the proposed chapter focuses on briefly presenting several mechanisms for researching in the area of domestic refrigeration, under thermal and energy analysis. In a particular way, here two case studies will be discussed, the first which is focused on evaluation and improvement of the thermal stratification in a refrigerator of 0.6 m³ (20.3 ft³) through experimental test and numerical modeling in CFD. In the second case, it is shown the thermal and energy evaluation of a novel polymer-ceramic composite as implemented insulation on the surface of a refrigerator of 0.046 m³ (1.6 ft³).

BACKGROUND

In Mexico, refrigeration is responsible for approximately 30% of energy consumption in homes. According to the Trust for Electric Energy Savings (FIDE in Spanish), the refrigerator is the second appliance with the largest energy consumption. The potential for energy savings by replacing old inefficient refrigerators with highly efficient modern refrigerators, indicates savings of 4.7 TWh/year, which represents 33% of total annual consumption in the domestic refrigeration sector (Arroyo-Cabañas et al., 2009).

To put refrigerator usage into context, the average number of units manufactured annually in Mexico over the last four years for volumetric capacities up to 0.3 m³, was 1,500,000 units per year, and approximately twice the number of units for capacities greater than 0.3 m³ (INEGI, 2012). Without disregarding the undoubted increase in production, these numbers indicate that any improvement in the performance of refrigerators is very likely to achieve a great impact on energy savings. In addition, the electric power consumed by a domestic refrigerator is considered to be very costly, a reduction in the electricity consumption of a refrigerator could generate not only a competitive advantage for the manufacturer, but also in terms of the savings in overall energy use and a reduction of the total environmental impact of the product.

Several alternatives to improve the thermal-energy behavior identified in refrigerators have been reported in the scientific literature. These include for example, the use of nanoparticles in refrigerants and lubricating oils (Shengshan et al., 2008, Kwangho et al., 2009, Shengshan et al., 2011), which were found to induce interesting energy savings. The use of alternative refrigerants such as HFO1234yf, also projected improvements in energy performance up to 5% with simple modifications of the cycle (Bansal et al., 2011). Furthermore, thermal stratification in refrigerator compartments plays an important role in the quality of the stored products. Thus, panels have been installed with the phase change materials in the separate compartments to maintain steady temperatures (Gin et al., 2010; Oró et al., 2012). When panels are also placed next to principal components, they achieve a decrease in the number of working cycles of the compressor, and hence, a reduction in energy consumption (Marques et al., 2014; Wen-Long et al., 2011).

Similar studies that analyze the thermal profile of the compartments, the distribution of internal air flow, modifications to accessory design and resulting thermal and energy improvements are presented