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Numerical and Experimental Investigation of Air Distribution System of Larder Type Refrigerator

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Abstract : Almost all of the domestic refrigerators operate on the principle of the vapor compression refrigeration cycle and removal of heat from the refrigerator cabinets is done via one of the two methods: natural convection or forced convection. In this study, airflow and temperature distributions inside a 375L no-frost type larder cabinet, in which cooling is provided by forced convection, are evaluated both experimentally and numerically. Airflow rate, compressor capacity and temperature distribution in the cooling chamber are known to be some of the most important factors that affect the cooling performance and energy consumption of a refrigerator. The objective of this study is to evaluate the original temperature distribution in the larder cabinet, and investigate for better temperature distribution solutions throughout the refrigerator domain via system optimizations that could provide uniform temperature distribution. The flow visualization and airflow velocity measurements inside the original refrigerator are performed via Stereoscopic Particle Image Velocimetry (SPIV). In addition, airflow and temperature distributions are investigated numerically with Ansys Fluent. In order to study the heat transfer inside the aforementioned refrigerator, forced convection theories covering the following cases are applied: closed rectangular cavity representing heat transfer inside the refrigerating compartment. The cavity volume has been represented with finite volume elements and is solved computationally with appropriate momentum and energy equations (Navier-Stokes equations). The 3D model is analyzed as transient, with k-ε turbulence model and SIMPLE pressure-velocity coupling for turbulent flow situation. The results obtained with the 3D numerical simulations are in quite good agreement with the experimental airflow measurements using the SPIV technique. After Computational Fluid Dynamics (CFD) analysis of the baseline case, the effects of three parameters: compressor capacity, fan rotational speed and type of shelf (glass or wire) are studied on the energy consumption; pull down time, temperature distributions in the cabinet. For each case, energy consumption based on experimental results is calculated. After the analysis, the main effective parameters for temperature distribution inside a cabin and energy consumption based on CFD simulation are determined and simulation results are supplied for Design of Experiments (DOE) as input data for optimization. The best configuration with minimum energy consumption that provides minimum temperature difference between the shelves inside the cabinet is determined.

Keywords : air distribution, CFD, DOE, energy consumption, experimental, larder cabinet, refrigeration, uniform temperature
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