Chapter 1
Computational Modelling and Simulation to Assist the Improvement of Thermal Performance and Energy Efficiency in Industrial Engineering Systems:
Application to Cold Stores

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ABSTRACT

Computational modelling is nowadays a powerful tool for project and design of engineering systems, anticipating and/or correcting problems that may lead to inefficiencies. This chapter describes three distinct computational tools with different mathematical and numerical models. The computational tools are used with the purpose of improving the thermal and energy performance of cold stores. All tools are applied to the same agrifood company. First, Computational Fluid Dynamics is used to optimize velocity and temperature fields for the interior a cold room. Afterwards, an energy analysis and thermal load simulation is performed to the cold store facility to reduce its thermal loads. Finally, a statistical prediction model based on empirical correlations is used to predict the energy performance of the cold store and compare it to an average behaviour. The numerical results indicate the improvement of the thermal performance and consequently of food safety, as well as considerable energy savings that can be achieved in cold stores by the combined use of different modelling techniques.

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INTRODUCTION

It is recognized by all that energy is a major cost in the operation of many industrial engineering systems. In particular, the refrigeration industry needs to provide cold storage that meets the standards and requirements of food safety. Thus, the energy consumption in this industry reaches significant values. To reduce these high-energy consumption values it is important that the design of the cold stores be developed with special care. Computational modelling is nowadays a powerful tool for project and design of engineering systems, allowing anticipating and/or correcting problems that may lead to inefficiencies. However, to address these problems, several computational approaches can be followed.

The propose of this chapter is to describe the use of three distinct computational tools, with different mathematical and numerical models used for the same purpose which is the improvement of thermal and energy performance of cold stores. Computational Fluid Dynamics (CFD) is used to optimize conditions for the interior of cold stores, in particular the velocity and temperature fields. Additionally, energy analysis and thermal load simulation is performed in order to optimize the envelope of cold store to reduce the mass and thermal loads. Finally, a statistical prediction model based on empirical correlations is used to predict the global behaviour of the cold store as result of management actions and operation of the cold store.

All these computational approaches require the formulation of the physical-mathematical problem. A review on the physical and mathematical representation of phenomena that express fluid flow with heat and/or mass transfer is carried out. To this end, the general governing equations of motion and heat transfer in fluids and solids are described, as well as the simplifications usually considered.

The nonlinearity and complexity of the physical-mathematical models require the use of numerical models for solving the governing equations. The underlying formulations of numerical models are described. The resolution method may involve the discretization through different methods of the differential equations using finite difference or finite volume. Recurrently, the imposition of different boundary conditions is necessary to simulate the physical phenomena. In addition, it is important to highlight the application of techniques to promote the convergence of the solution.

Computational modelling through CFD allows optimizing the inner conditions of cold stores, in particular the velocity and temperature fields. CFD technique consists in predict the behaviour of physical phenomena through computational numerical calculation. The simulation of processes allows predicting the fluid flow with heat and/or mass transfer, species concentration, phase change, chemical reactions, mechanical movements, strains, among others. The mathematical models representing the laws of physics that govern the physical phenomena are described by partial differential equations, many of which without analytical solution.

Other computational tool that uses the finite difference formulation has been tested. This tool was used to perform energy analysis and thermal load calculation in order to optimize the envelope of the cold store to reduce the mass and thermal loads. The simulation accounts for the integrated simultaneous solution of building and engineering systems responses, defining time steps for interaction between thermal zones and the environment. The heat balance based solution technique for building thermal loads is used for simultaneous calculation of radiant and convective effects, while the transient heat conduction through building elements is performed using conduction transfer functions. The tool may include additional models depending on the physical process specifications.

Additionally, a statistical model was tested to predict the overall behaviour of cold stores as result of management and operation actions. The model is used to assess the energy performance of cold stores

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