A Dynamic Modelling Methodology for the Simulation of Industrial Refrigeration Systems

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Abstract

A dynamic modelling methodology has been developed for the computer simulation of industrial refrigeration systems. A computer program, RefSim, has been developed which embodies the new methodology. RefSim contains a total of 33 separate models — 11 derived from existing models, six which are substantially enhanced and 16 which are new. In general, these models were derived from thermal considerations and ignored the effect of hydrodynamic processes in the refrigeration circuit. Models can be dynamically linked together as specified by the input data in order to simulate a complete plant. The program includes a set of simulation utilities which reduce the amount of work required to develop models. The object-oriented features of inheritance, encapsulation and polymorphism are used extensively.

Substantial model development was carried out to achieve accurate predictions of the heat release profile during chilling and freezing of food product as product cooling makes the greatest contribution to both mean and peak heat loads in many industrial refrigeration plants. The new ordinary differential equation (ODE) model was tested against finite difference (FD) calculations for a range of product shapes and Biot numbers. The ODE model predicted to within ±10% of the FD calculation during almost all of the cooling process under the test conditions. The ODE model required several orders of magnitude less computation than FD while being capable of extension to shapes that could not be handled by FD.

To test the new ODE model against experimental data, a differential air temperature method to measure the cooling food product heat load profile was developed. Both the FD and ODE methods predicted the heat load profile of freezing meat cartons to within the experimental margin for error (±10%). The ODE model also predicted the heat load profile of freezing lamb carcasses to a similar level of accuracy.

Three refrigeration plants (a laboratory water chiller, a 18500 lamb per day meat processing plant, and a 6000 lamb/1000 beef per day meat processing plant)

were surveyed to obtain data for testing the whole simulation environment. RefSim was found to predict the measured data satisfactorily in most cases. The results were superior to those from a commercial refrigeration simulation environment and comparable to an enhanced version of that environment which included the new ODE product heat load model. Differences between the measured values and those predicted by Refsim were probably more attributable to uncertainties in the simulation input data than to model deficiencies. RefSim was found to be a flexible environment which was general enough to simulate both simple and complex refrigeration systems. Unusual components could be simulated by combining existing models rather than implementing custom models.

Nevertheless, the simulation results have indicated a number of areas for further model improvement. The effects of air mixing and the thermal buffering of structural materials were shown to be modelled poorly for some refrigerated rooms. There is some scope for improving the chilling stage of the ODE product heat load model.

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