CHAM

A Review of Some Recent PHOENICS Publications

Michael R. Malin, Technical Support Manager, CHAM Limited, Wimbledon, London, UK

Introduction

PHOENICS was the first general-purpose CFD code to appear on the market in 1981, and therefore it has acquired a long history of usage across a very diverse range of applications. Since the inaugural PHOENICS publication of Professor Brian Spalding [1], the intervening four and a half decades has seen an expansive number of publications making use of this code. In this article, the attention is focussed on describing briefly a small sample of PHOENICS-based articles published in recent times. In the ensuing paragraphs, the following applications are described: the simulation of heat-transfer technology in tubing; the windborne deposition of marine salts on buildings near a river estuary; and the performance of a phase-change-material battery in the climate tower of a building.

Enhanced Turbulent Transfer in Tubes

The use of **helical coiled-wire** and **twisted-tape inserts in circular tubes** is common in industry as a reliable method for enhancing heat transfer by inducing a swirling motion upon the axial-directed core flow. These inserts find applications in heat exchangers, oil-cooling equipment, preheaters, fire boilers and the divertors of fusion reactors.

In a joint collaboration, and for flow conditions typical of a divertor, ***HATA Research Institute*** and ***Kobe University*** in **Japan** [2] used PHOENICS to predict the heat-transfer performance and pressure drop for the flow of water in tubes with inserts. The geometry of the insert was created in SolidWorks, and then imported into PHOENICS. The PARSOL cut-cell solver was used to capture the insert geometry on the background cylindrical-polar mesh; and the turbulence was modelled by means of the high Reynolds-number (Re) form of the Chen-Kim variant of the k-ε model.

The converged solutions were obtained by time marching to steady-state conditions. Experimental and numerical results were reported, both with and without inserts, in the Re range of 20,000 to 100,000, for a tube of 6mm diameter (d) tube and length 104d, with a heated section of 10d, starting some 55d downstream of the inlet.

The PHOENICS predictions of the pressure drop were within 5% of the measurements, whereas the predicted rises in water temperature showed deviations ranging from 0 to 20%. The results were also presented in terms of the Fanning friction factor and Nusselt number vs Reynolds number.

Marine-Aerosol Deposition in an Estuary

Figure The airborne transport of marine chloride-salt aerosols in coastal areas can result in surface deposition on buildings and other structures. This type of exposure promotes weathering and decay processes, which can damage not only the surfaces of buildings, but also their structural integrity.

PHOENICS was used by the **South China University of Technology** [3] to investigate the deposition of chloride salts on building surfaces in the Zhujiang River Estuary. Specifically, the wind fields of NanHeng Village and Zhujiang International Apartment were simulated to explore the effects of building-related factors on chloride-salt deposition.

The main findings were: narrower spacings between buildings promoted greater deposition; surface deposition correlated linearly with offshore distances in the range 500–1500m; and finally, under unobstructed conditions, surface deposition correlated positively with building elevations in the 10–100m range.

Phase-Change Materials (PCMs) in Buildings

PCMs are substances with a high latent heat. This is stored during phase transition, when thermal energy is absorbed and released at essentially constant temperature during the melting and solidification phases. This feature can be used to lower the energy consumed by conventional heating and cooling systems, by reducing peak loads. Consequently, PCMs have been used extensively in the buildings for many years. In particular, they have been exploited to realise the management of interior temperature against external weather and temperature variations.

In a recent study, ***Delft University of Technology*** in the ***Netherlands*** [4] investigated, both experimentally and theoretically, the performance of a PCM battery installed the climate-control tower of a building. The climate-control system comprised a heat-recovery unit, a battery of PCM plates which buffer any fluctuations in the supply-air temperature, and an auxiliary heat pump. For the theoretical investigation, transient CFD simulations were performed using PHOENICS; and system control and optimization, a simplified lumped-parameter model was implemented in MATLAB . Technical support was provided by **CHAM** on the CFD modelling of the PCM melting and solidification process.

A transient, three-dimensional CFD model was developed to simulate the flow and heat transfer within the PCM battery. The liquid and solid regions of this battery were housed within solid casings, and were subject to conjugate heat transfer with the air flow in the adjacent channels. The PCMs experienced melting and solidification processes, with natural convection in the melt. Phase transition was modelled using an enthalpy-porosity formulation, but by means of an effective specific heat capacity, rather than a latent-heat source term. The InForm facility of PHOENICS was used to implement this phase-change model.

The transient performance of the PCM battery through heating and cooling was evaluated by using a steady air-inflow rate at three different inlet velocities with a constant inlet temperature. Reasonable agreement was reported between the measured and predicted temperature behaviour, with a maximum variance of 10%.

Concluding remarks

This brief review has given some insight into PHOENICS usage for applications related to the nuclear, environmental and buildings industries. In future issues of the Newsletter, similar reviews will be conducted to inform readers of other PHOENICS-based publications originating from Academia and Industry.

References

1. D.B.Spalding, D. B., *A general-purpose computer program for multi-dimensional one- and two-phase flow*. Mathematics and Computers in Simulation, 23, 267–276, (1981).

2. K. Hata, M. Shibahara, *Helically-coiled-wire-induced swirl flow heat transfer and pressure drop in a circular tube under velocities controlled*, Int. J of Heat & Mass Transfer 204, 123849, (2023).

3. L.Xiang , Q.Meng , P.Ren, *Effects of environmental and architectural factors on chloride-salt deposition on coastal building surfaces in the Zhujiang River Estuary*, Building & Environment 242, 110554, (2023).

4. P. van den Engel, M.R.Malin, N.K.Venkatesh and L.A. de Araujo Passos, *Performance of a Phase Change Material Battery in a Transparent Building*, Fluid Dynamics & Materials Processing, Vol.19, No.3, (2023)