SANTIAGO NUMÉRICO II
Quinto Encuentro de Análisis Numérico de Ecuaciones Diferenciales Parciales
Facultad de Matemáticas, Pontificia Universidad Católica de Chile, Diciembre 9–11, 2010

Fluid dynamics and unsteady heat transfer in non–newtonian liquid solidification with natural convection inside cavities*

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Abstract

Polymer molding, liquid food freezing, alloy and metals solidification are processes often found in industrial applications. The mathematical model used to describe natural convection in the liquid and mushy zone along heat conduction include continuity, linear momentum and energy non–linear coupled partial differential equations. The moving boundary solidification problem is solved in terms of a temperature dependent liquid phase change fraction. Numerical solutions are obtained by using the Finite Volume Method with the SIMPLE classical segregated algorithm and a novel PSIMPLER one. Cases investigated include conjugated 2D mixed convection / solidification pseudo–plastic non–Newtonian solidification in square cavities and inside the annular space between concentric horizontal cylinders. Dynamic time steps, non uniform staggered grids are used along a new iterative implicit segregated algorithm to solve using successive under–relaxation the governing discrete equations. Unsteady results describing the fluid mechanics and heat transfer include: velocity and temperature distributions, instantaneous location of the liquid–solid moving boundary for different physical applications in food freezing and alloy solidifications. Improvements in calculations speed with the new pressure–velocity coupling algorithm are evaluated in terms of the governing dimensionless parameters.

References

[1] Moraga, N., Riquelme, J., Jauriat, L., *Unsteady conjugate water/air mixed convection in a square cavity*. International Journal of Heat and Mass Transfer, vol. 52, pp. 5512–5524 (2009).

[2] Moraga, N., Andrade, M., Vasco, D., *Unsteady conjugate mixed convection phase change of a power law non–Newtonian fluid in a square cavity*. International Journal of Heat and Mass Transfer, vol. 53, pp. 3308–3318 (2010).

*Research supported by CONICYT/Chile through funds provided to Fondecyt 1070186 project.

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[3] Moraga, N., Ramrez, S.; Godoy, M.; Ticchione, P., *Study of Convective Non–Newtonian Alloy Solidification in Molds by the PSIMPLER/Finite–Volume Method*. Numerical Heat Transfer, Part A, vol. 57, 12, pp. 936-953, (2010).

[4] Inaba H., Zhang, Y., Horibe, A., Haruki, N., *Numerical simulation of natural convection of latent heat phase–change–material microcapsulate slurry packed in a horizontal rectangular enclosure heated from below and cooled from above*. Heat Mass Transfer, vol. 43, pp. 459-470, (2007).

[5] Assis, E., Katsman, L., Ziskind, G., Letan, R., *Numerical and experimental study of melting in a spherical shell*. International Journal of Heat Mass Transfer, vol. 50, pp. 1790-1804, (2007).

[6] Mat, M.D., Ilegbusi, O.J., *Application of a hybrid model of mushy zone to macrosegregation in alloy solidification*. International Journal of Heat Mass Transfer, vol. 45, pp. 279–289, (2002).

[7] Lin, P., Jaluria, Y., *Heat transfer and solidification of polymer melt flow in a channel*. Polymer Engineering Science, vol. 37, pp. 1247-1258, (2007).

[8] , G., Assimacopoulus, D., *Numerical modeling of convection-diffusion phase phase change problems*. Computational Mechanics, vol. 21, pp. 409-415, (1998).

[9] Giangi, M., Kowalewski, T.A., Stella, F., Leonardi, E., *Natural convection during ice formation: numerical simulation vs. experimental results*. Computer Assisted Mechanic Engineering Science, vol. 7 (3), pp. 321-342, (2000).

[10] Alawadhi, E.M., *Phase change process with free convection in a circular enclosure: numerical simulations*. Computational Fluids, vol. 33, pp. 1335-1348, (2004).

[11] Patankar, S.V., *Numerical Heat Transfer and Fluid Flow*. Hemisphere (Washington), 1980.