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Role of entropy generation during convective thermal processing in right-angled triangular enclosures with various wall heatings

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ABSTRACT

Thermal energy conservation is at the heart of energy efficiency in process industries. This allows researchers to go for advances in CFD methods to track the requirement of thermal energy for various thermal processing applications. CFD models need to be incorporated into optimization principles to achieve efficient industrial process designs. In this study, entropy generation due to natural convection in right-angled triangular enclosures (cases 1–4) has been studied numerically for energy efficient processing of various fluids ($Pr = 0.025$, 7 and 1000). It is found that maximum value of entropy generation due to heat transfer ($S_{\theta,max}$) occurs near the vertex of the enclosures for cases 1 and 3, near corner between left wall and bottom wall for case 2 and near lower portion of the right wall for case 4. On the other hand, maximum value of entropy generation due to fluid flow ($S_{\psi,max}$) is observed near middle portions of the side walls for all cases and the location of $S_{\psi,max}$ mainly depends on the presence of high velocity gradients. The entropy generation rates and heat transfer rates were also shown for various angles. Triangular cavities with specific angles are recommended for various processing fluids.

Keywords: Thermal processing; Entropy generation; Convective heat transfer; CFD; Triangular enclosures

1. Introduction

To achieve sustainability goals, chemical processes should be improved in such a way that the raw materials would be converted into finished products by minimal consumption of energy through better energy efficient process design. These goals may also be achieved through efficient process design by maximizing the reuse of valuable by-products, eliminating the release of harmful pollutants into the environment and utilizing the existing energy resources in an efficient manner. Innovative process designs in this field can help to minimize the aggressive use of available energy sources in product manufacturing. Process heating accounts for higher fraction of the total energy used in industrial manufacturing applications and in some industries, this percentage is much higher. As energy sources continue to deplete, industrial plants need effective ways either to reduce the energy used for process heating by improved process designs or to develop methods to uncover the opportunities for efficient energy use by recognizing energy losses in process heating systems.

The energy conservation of process industries is also receiving great deal of attention in the recent past research. Indeed, thermal energy conservation is at the heart of energy efficiency in process industries. One important aspect of this vast subject, convective heat transfer has wide applicability in science and engineering (Perez et al., 2001; Dawes et al., 2009; Nazridoust and Ahmadi, 2007; Wang et al., 2008; Das et al., 2003; Smit et al., 2005; van der Gulik et al., 2001; Whitney and Viljoen, 2003; Quarini and Chang, 2002; Muhaimin et al., 2009; Fazeli et al., 2008; Gerogiorgis and Ydstie, 2005; Kar et al., 2009; Su, 2006; Campbell et al., 2006; Yacob and Ishak, 2011). Advances in Computational Fluid Dynamics (CFD) methods are now being used widely in these process industries (Jayakumar et al., 2008; Roy et al., 2006; Ganguli et al., 2011, 2009; Vedantam et al., 2006) to tract the requirement of thermal energy for various processes in order to achieve more efficient use of available energy by various optimization methods.

Transient natural convection in a cylindrical enclosure has been investigated by Ganguli et al. (2011) and the effect of

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