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VOLUMETRIC METHODS FOR EVALUATING IRREVERSIBLE ENERGY LOSSES AND ENTROPY PRODUCTION WITH APPLICATION TO BIOENGINEERING FLOWS

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ABSTRACT Methods for calculating irreversible energy losses and rates of heat transfer from computational fluid dynamics solutions using volume integrations of energy dissipation or entropy production functions have been developed. These methods contrast with the more usual approach of performing first law energy balances over the boundaries of a flow domain. Advantages of the approach are that the estimates involve the whole flow domain and are hence based on more information than would otherwise be used, and that the energy dissipation or entropy production functions allow for detailed assessment of the mechanisms and regions of energy loss or entropy production.

The research was motivated by a need to clarify energy losses by haemodynamics in the greater vessels of the human body, in particular the Fontan connection. For this application irreversible energy losses were calculated using the viscous dissipation function. The process is demonstrated here for a lid driven cavity where the work expended by the moving boundary against the viscous drag of the fluid, estimated by a boundary integration, is shown to be equal to the volume integrated viscous dissipation. For the Fontan connection streamwise integration of the viscous dissipation function is used to explore the ways in which different flow structures contribute to energy losses.

The use of volume integrations to estimate heat transfer rates is demonstrated for two dimensional natural convection in a side heated square cavity. A second law analysis calculates the overall increase in entropy using an integration of the volumetric rate of entropy production. Comparison with the entropy increase across a stationary heat conducting layer leads to a volume integral expression for the Nusselt number. The predictions using this method compare well with benchmark results.