

Developing a Conjugate Heat Transfer Solver

Mansour A. Al Qubeissi

Abstract—The current paper presents a numerical approach in solving the conjugate heat transfer problems. A numerical heat conduction code is coupled internally with a computational fluid dynamics solver for developing a coupling conjugate heat transfer solving package. Methodology of treating non-matching meshes at interface has also been introduced. The package can deal with a wide range of compressible flow conjugate heat transfer problems. The solver is also able to deal with various geometrical and thermal complexities. The validation results for the developed conjugate heat transfer code have shown close agreement with the available analytical solutions.

Keywords—Computational Fluid Dynamics, Conjugate Heat Transfer, Heat Exchanger, Heat Transfer

I. INTRODUCTION

THE increase in temperature in many industrial conjugate heat transfer systems is associated with a significant increase in power outputs and efficiencies. As a result, effective cooling is an essential feature in the design requirements. Predicting the temperature distribution profile for such domains is very important. When heat transfer occurs between two (or more) different materials, (fluid/solid mostly), boundary conditions are continuously interacting between these different domains. This operation is described as a conjugate heat transfer system. The main challenge in solving such problems is interface data interaction. Types of governing equations applied and data interacted depend on: type of domain (fluid/solid) and purpose of operating this system. This operation is processed in coupling fluid flow and heat conduction solvers. A cell vertex (vertex-centered) Finite Volume Method (FVM) is used for solving the heat conduction equation [1]. The fluid flow equations are solved numerically with a commercial computational fluid dynamics code (SURF) [2].

Treatment of non-matching interface meshes is made using linear interpolation. This method has been used by [3] and described as a simpler, well working data interaction technique. The linear interpolation technique in matching nodes has been previously applied on structured grids using the second order central difference method [4]. In unstructured meshes, transferring accurate data can be more complicated because the finite difference technique will not be valid. In addition, the sizes and shapes of the boundary elements may differ from one side to another.

M. A. al Qubeissi, a Researcher in Computational Fluid Dynamics (CFD) development at TFMRC, University of Sussex, Brighton, BN1 9QT UK (Phone: 01273 87 6706; e-mail: ma292@sussex.ac.uk).

II. HEAT CONDUCTION EQUATION

HC code is developed to solve the heat conduction equation. The governing equation is solved for a control volume, shown in Fig. 1, with no internal heat generation as:

$$\rho C \frac{\partial T}{\partial t} + \nabla \cdot \vec{q} = 0 \quad (1)$$

In (1), T is the temperature value given in (K) and ρC represent density and heat capacity with units (kg m^{-3}) & ($\text{W kg}^{-1}\text{K}^{-1}$) respectively. \vec{q} is the heat flux in three components, given by Fourier's law as:

$$\vec{q} = -k \nabla T \quad (2)$$

The numerical solutions of (1) & (2) are further described in [1].

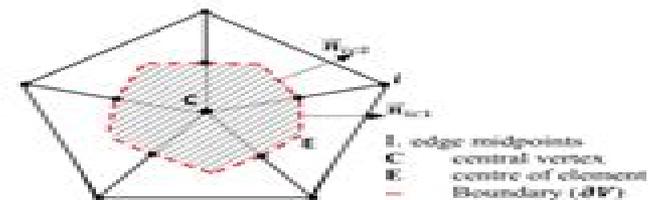


Fig. 1 2D view of the vertex centered control volume [1]

III. FLUID FLOW EQUATIONS

The fluid flow equations of Navier stokes, momentum and energy conservation are solved numerically using Spalart and Allmaras turbulent model [5]. SURF is validated, as a computational fluid dynamics tool, to deal with steady and unsteady, compressible, three dimensional flow problems [2]. The heat transfer between the solid-interface surface and the fluid layer adjacent to that interface can be assumed of pure conduction by considering the fluid in that region as motionless [6]. The thermal boundary layer thickness δ_T can be obtained in a relation with the velocity boundary layer thickness and Prandtl number [6] as:

$$\delta_T = \text{Pr} \delta_v \quad (3)$$

Where, δ_v is the velocity boundary layer thickness and Pr is Prandtl number, which is assumed for approximation as

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