List of Tables

Table 5.1  Test Cases and results
Table 5.2. Solver setting
Table 5.3. Test case for Blended scheme
Table 6.1. Kinematic details of tow-point
Table 6.2. Some OPEMP Directives
Table 6.3. MINPACK functions
Table 6.4 Platforms tested
Table 6.5 Cluster Details
Table 8.1 Weight and Mass Moment of Inertia of the Towed Body
List of Figures

Figure 1.1.a  Single point towing system
Figure 1.1.b  Two-part towing system
Figure 3.1  Lumped mass-spring cable model.
Figure 3.2   Components of Drag forces on the cable
Figure 3.3  Boundary condition at the junction of the three cables
Figure 3.4.  Degrees of freedom of a generic towed body
Figure 3.5  Different types of tow-point configuration
Figure 4.1   Cable Segment
Figure 4.2  Deformed beam
Figure 4.3  Improved cable model
Figure 4.4  Schematic beam model
Figure 4.5  Equivalent nodal forces
Figure 5.1  Generic Control Volume
Figure 5.2  Variation of Φ around the face f
Figure 5.3  Estimation of cell face value by node based approach
Figure 5.3a Numerical solution procedure
Figure 5.4.  Plotted Stream lines using PARAVIEW (test case-1)
Figure 5.5.  Plotted Stream lines using PARAVIEW (test case 2)
Figure 5.6a. Type 1 Mesh Regular - 256 cells
Figure 5.6b, Type 2 Mesh Random 256 cells
Figure 5.6c Type 3 Mesh Perturbed, 256 cells
Figure 5.6d. Assumed distribution of scalar Φ
Figure 5.7  Gradient: CDS
Figure 5.8  Gradient: Node based
Figure 5.9.  Gradient: blended scheme
Figure 5.10 Gradient: CDS
Figure 5.11 Gradient: Node based
Figure 5.12 Gradient: blended scheme
Figure 5.13 Comparism of L2 norm of various schemes.
Figure 5.14  Variation of L2 Norm with blending factor
Figure 5.15  a,b,c,d,e and f :Test case1, Effect of blending factor on stability and accuracy
Figure 5.16  Performance of BNCUS2 at different blend factors
Figure 5.17  Performance of BNCUS1 at different blend factors
Figure 5.18  Performance comparism of BNCUS2 and BNCUS1.
Figure 5.19a  Node based higher order scheme, Limiter Koren
Figure 5.19b  CDS as higher order scheme, Limiter Koren
Figure 5.20a  Node based higher order scheme, Limiter SUPERBEE
Figure 5.20b  CDS as Higher order scheme, Limiter SUPERBEE
Figure 5.21a  Node based higher order scheme, Limiter UMIST
Figure 5.21b  CDS as Higher order scheme, Limiter UMIST
Figure 5.22a  Node based higher order scheme, Limiter VANLEER
Figure 5.22b  CDS as Higher order scheme, Limiter VANLEER
Figure 5.23  Relative performances of various limiters
Figure 5.24  Comparism of CDS and Node based formulation with various limiters
Figure 5.25  Figure 5.25 Drag v/s angle of attack of the towed body
Figure 5.26  Pitching moment v/s angle of attack of the towed body
Figure 5.27  Lift v/s angle of attack of the towed body
Figure 6.1  Simulated configuration of the two-part towing system
Figure 6.2  Sinusoidal tow point disturbance given (input motion)
Figure 6.3  Towed body and depressor heave
Figure 6.4  Experimental heave values from literature
Figure 6.5  Simulated Plan View of the path of ship and towed body
Figure 6.6  Simulated depth variations
Figure 6.7  Depth variation of the towing system when the ship is suddenly stopped
Figure 6.8a  Heave response for Hoboult Schme $\gamma= 1.0$
Figure 6.8b  Heave response for Hoboult Schme $\gamma = 1.2$
Figure 6.8c  Heave response for Hoboult Schme $\gamma = 1.5$
Figure 6.8d  Heave response for Hoboult Schme $\gamma = 1.6$
Figure 6.9  Heave response for Euler Scheme
Figure 6.10 Heave response $\alpha=0.0$
Figure 6.11 Heave response $\alpha=-0.1$
Figure 6.12 Heave response $\alpha=-0.3$
Figure 6.13 Heave response $\alpha=-0.25$
Figure 6.14  Heave response $\alpha=0.4$
Figure 6.15  Heave response $\alpha=0.5$
Figure 6.16  Heave response $\alpha=-0.33$
Figure 6.17.  Heave response with Newmark method
Figure 6.18  Shared memory system
Figure 6.19  Distributed-memory multiprocessors
Figure 6.20  Cluster systems
Figure 6.21  Computational time for 26 degrees of freedom
Figure 6.22  Computational time for 120 degrees of freedom
Figure 6.23  Computational time for 170 degrees of freedom
Figure 6.24  CPU utilization of the serial code (without OPENMP)
Figure 6.25  CPU utilization of the Parallel code (with OPENMP no of CPU =4)
Figure 6.26  Parallel computing setup
Figure 6.27  Software Front End for logging into the network and application deployment
Figure 6.28  Mesh visualiser for partitioned mesh
Figure 6.29  Computational time v/s no of CPUs for test case -1
Figure 7.1.  Variation of heave ratio with length of depressor cable
Figure 7.2.  Variation of heave ratio with length of secondary cable
Figure 7.3.  Variation of heave ratio with the length of the primary cable
Figure 7.4.  Effect of Depressor mass on the heave response of the towed body and depressor
Figure 7.5  Effect of wave frequency on the heave response of the towed body
Figure 7.6  Effect bending rigidity of the cable on the heave ratio
Figure 8.1  Towed body
Figure 8.2  Towed body structure
Figure 8.3  Pressure sensor
Figure 8.4  Tri-axis Accelerometer
Figure 8.5  Electronic Diagram
Figure 8.6  6-channel Data Acquisition System
Figure 8.7  Depressor
Figure 8.8  Sinusoidal wave motion mechanism
Figure 8.9  Assembled sensor array
Figure 8.10  Finished assembly of the towed body
Figure 8.11  Carriage speed control
Figure 8.12  Mass Moment of Inertia Estimation
Figure 8.13  Towing tank
Figure 8.14  deployment of towed body
Figure 8.15  Measured time based heave data
Figure 8.16  Simulated Heave data

Nomenclature

English Symbols

\begin{itemize}
  \item \textbf{a}, \textit{a} \quad \text{Acceleration}
  \item \textbf{C}_d \quad \text{Drag coefficient}
  \item \textbf{C}_l \quad \text{Lift coefficient}
  \item \textit{e} \quad \text{added mass for the cable segment}
  \item \textbf{F}_D \quad \text{Drag force}
  \item \textit{g} \quad \text{Acceleration due to gravity}
  \item \textit{I} \quad \text{Moment of inertia}
  \item \textbf{K} \quad \text{Stiffness Matrix}
  \item \textbf{C} \quad \text{Damping coefficient matrix}
  \item \textbf{M} \quad \text{Mass Matrix}
  \item \textit{m} \quad \text{Mass}
  \item \textit{n} \quad \text{Direction cosines vector}
  \item \textit{P}, \textit{p} \quad \text{Pressure at the cell centre}
  \item \textit{Pe} \quad \text{Peclet Number}
  \item \textit{Re} \quad \text{Reynolds Number}
  \item \textit{T} \quad \text{Tension in the cable}
  \item \textit{t} \quad \text{Time}
  \item \textbf{U}, \textit{U}(u,v,w) \quad \text{Velocity Vector}
  \item \textit{V} \quad \text{Volume}
  \item \textbf{X}, \textit{X}(x,y,z) \quad \text{Position Vector}
\end{itemize}
Greek Symbols

Γ      Diffusivity
μ      Dynamic viscosity
ν      Kinematic viscosity
ν₁     Kinematic eddy viscosity
ρ      Density
σ      Stress tensor
ψ      TVD limiter
Ω      [p, q, r] is the tow-fish angular velocity

Abbreviations

BD      Blended Differencing
Bi-CG   Bi-Conjugate Gradient
BNCUS   Blended node and cell based upwind scheme
CDS     Central Difference Scheme
CFD     Computational Fluid Dynamics
CPU     Central processing Unit
DNS     Direct Numerical Simulations
DSM     Distributed Shared Memory
FCT     Flux Corrected Transport
FEM     Finite Element Method
FVM     Finite Volume Method
HHT     Hilber, Hughes and Taylor
LES     Large eddy Simulation
LMSM    Lumped Mass Spring Model
MPI     Message Passing Interface
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NVA</td>
<td>Normalised Variable Approach</td>
</tr>
<tr>
<td>PISO</td>
<td>Pressure Implicit with Splitting of Operators</td>
</tr>
<tr>
<td>PVM</td>
<td>Parallel Virtual Machines</td>
</tr>
<tr>
<td>QUICK</td>
<td>Quadratic Upstream Interpolation for Convective Kinematics</td>
</tr>
<tr>
<td>SE</td>
<td>Strain Energy</td>
</tr>
<tr>
<td>SIMPLE</td>
<td>Semi-Implicit Method for Pressure-Linked Equations</td>
</tr>
<tr>
<td>SSH</td>
<td>Secure Socket Shell</td>
</tr>
<tr>
<td>SST</td>
<td>Shear Stress Transport</td>
</tr>
<tr>
<td>TV</td>
<td>Total Variation</td>
</tr>
<tr>
<td>TVD</td>
<td>Total Variation Diminishing</td>
</tr>
<tr>
<td>UDS</td>
<td>Upwind Differencing Scheme</td>
</tr>
<tr>
<td>UMIST</td>
<td>Upstream Monotonic Interpolation for Scalar Transport</td>
</tr>
<tr>
<td>UTV</td>
<td>Underwater Towed Vehicles</td>
</tr>
<tr>
<td>RANS</td>
<td>Reynolds Averaged Navier-Stokes Equation</td>
</tr>
<tr>
<td>CERD</td>
<td>Centre of Engineering Research and Development</td>
</tr>
</tbody>
</table>