



GUJARAT TECHNOLOGICAL UNIVERSITY

Master of Engineering in CHEMICAL ENGINEERING (30)

Subject Code: 2733007

Semester – III

Subject Name: Computational Fluid Dynamics

Type of course: [Elective – III] (c)

Prerequisite: Numerical Methods

Rationale:

1. To be able to model and simulate all the mass, momentum, and energy transport processes in chemical engineering using the generalized conservation equations.
2. To make students understand the governing equations of fluid dynamics and their derivation from laws of conservation
3. To develop a good understanding in computational skills, including discretisation, accuracy and stability.
4. To acquaint the students with a process of developing a mathematical and geometrical model of flow, applying appropriate boundary conditions and solving system of equations.

Teaching and Examination Scheme:

Teaching Scheme			Credits C	Examination Marks				Total Marks
L	T	P		Theory Marks		Practical Marks		
				ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	2	4	70	30	30	20	150

Content:

Sr. No.	Content	Total Hrs	% Weightage
1	Introduction to Fluid Dynamics Concepts of Fluid Flow, Pressure distribution in fluids, Reynolds transport theorem, Integral form of conservation equations, Differential form of conservation equations, Different Types of Flows, Euler and Navier Stokes equations, Properties of supersonic and subsonic flows, Flow characteristics over various bodies. Philosophy of CFD, Governing equations of fluid dynamics and their physical meaning, Mathematical behavior of governing equations and the impact on CFD simulations, Simple CFD techniques and CFL condition. Numerical Methods in CFD: Finite Difference, Finite Volume, and Finite Element, Upwind and downwind schemes, Simple and Simpler schemes, Higher order methods, Implicit and explicit methods, Study and transient solutions	14	27%



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2	Grid Generation Basic theory of structured grid generation, Surface grid generation, Mono block, multi block, hierarchical multi block, Moving and sliding multiblock, Grid clustering and grid enhancement. Basic theory of unstructured grid generation, advancing front, Delaunay triangulation and various point insertion methods, Unstructured quad and hex generation, grid based methods, various elements in unstructured grids, Surface mesh generation, Surface mesh repair, Volume grid generation, Volume mesh improvement, mesh smoothing algorithms, grid clustering and quality checks for volume mesh. Adaptive, Moving and Hybrid Grids, Need for adaptive and, moving grids, Tet, pyramid, prism, and hex grids, using various elements in combination	14	27%
3	Turbulence and its Modelling Transition from laminar to turbulent flow, Effect of turbulence on time-averaged Navier-Stokes equations, Characteristics of simple turbulent flows, Free turbulent flows, Flat plate boundary layer and pipe flow, Turbulence models, Mixing length model, The k-e model, Reynolds stress equation models, Algebraic stress equation models	10	20%
4	Chemical Fluid Mixing Simulation Stirred tank modeling using the actual impeller geometry, Rotating frame model, The MRF Model Sliding mesh model, Snapshot model, Evaluating Mixing from Flow Field Results, Industrial Examples	8	15%
5	Post-Processing of CFD results Contour plots, vector plots, and scatter plots, Shaded and transparent surfaces, Particle trajectories and path line trajectories, Animations and movies, Exploration and analysis of data.	6	11%

Reference Books:

1. Anderson John D., "Computational Fluid Dynamics: The Basics with Applications", McGraw Hill, 1995
2. Ranade V.V., "Computational Flow Modeling for Chemical Reactor Engineering", Process Engineering Science, Volume 5, 2001
3. Knupp Patrick and Steinberg Stanly, "Fundamentals of Grid Generation", CRC Press, 1994.
4. Wilcox D.C., "Turbulence Modelling for CFD", 1993
5. Wesseling Pieter, "An Introduction to Multigrid Methods", John Wiley & Sons, 1992
6. Thompson J.F., Warsi Z.U.A. and Mastin C.W., "Numerical Grid Generation: Foundations and Applications", North Holland, 1985
7. Patankar S.V., "Numerical Heat Transfer and Fluid Flow", McGraw-Hill, 1981
8. Gatski Thomas B., Hussaini M. Yousuff and Lumley John L., "Simulation and Modelling of Turbulent Flows", Oxford University Press, 1996
9. Laney, C. B., "Computational Gas Dynamics", Cambridge Uni. Press, 1998.



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Course Outcomes:

Sr. No.	CO statement	Marks % weightage
CO-1	Understand the basic principles of mathematics and numerical concepts of fluid dynamics	
CO-2	Develop governing equations for a given fluid flow system	
CO-3	Adapt finite difference techniques for fluid flow models	
CO-4	Apply finite difference method for heat transfer problems	
CO-5	Solve computational fluid flow problems using finite volume techniques	
CO-6	Get familiarized to modern CFD software used for the analysis of complex fluid-flow systems	

List of Experiments:

1. Evaluation of matrix format of conservation equation
2. Grid generation for Ideal CSTR and PFR reactors
3. Grid generation technique for fluidized bed
4. Application of grid refinement on PID of chemical plant
5. Simplification of momentum balance to derive bernoulli's equation
6. Comparison of solution methods for various CFD softwares
7. Evaluation of heat loss using CFD software
8. Evaluation of fluid dynamics in water hammer effect using OpenFOAM
9. Setting up the modelling equation for simultaneous heat, mass and momentum transfer application.

Major Equipment:

1. Concentric pipe with insulation
2. CSTR and PFR

List of Open Source Software/learning website:

1. OpenFOAM (<https://www.openfoam.com/>)
2. ANSYS/Fluent (<https://www.ansys.com/en-in/products/fluids/ansys-fluent>)
3. Star-CD (<https://mdx.plm.automation.siemens.com/star-cd>)
4. Star-CCM+ (<https://mdx.plm.automation.siemens.com/star-ccm-plus>)
5. COMSOL Multiphysics
6. CFDTool (<https://www.cfdtool.com/>)
7. MATLAB
8. C/C++/Python based tutorials