COURSE CODE	COURSE TITLE	L	T	P	C
1151AE110	COMPRESSIBLE FLOW AERODYNAMICS	2	2	0	3

Course Category:

Programme core

a. Preamble :

This course provides the student with an introduction to the basic concepts of compressible flows, where the density variations are important and must be taken into account. This requires the knowledge on the science of thermodynamics and the basic laws of fluid mechanics. Emphasis will be placed on understanding the physical mechanisms involved in both compressible external and internal flows.

b. Prerequisite Courses:

- Incompressible flow Aerodynamics

c. Related Courses:

- Experimental Aerodynamics
- Hypersonic Aerodynamics
- High Temperature Gas Dynamics
- Missile Aerodynamics
- Ramjet and Scramjet propulsion

d. Course Educational Objectives:

- To introduce the students how the thermodynamic concepts, apply to compressible flow aerodynamics and to analyze 1-D and quasi 1-D flows in typical aerospace applications
- To familiarize the students with the features of inviscid compressible flows, including shock and expansion waves and the governing differential equation of motion of steady compressible flows
- To familiarize the students to estimate the lift and drag for basic aerodynamic shapes in compressible inviscid flows

e. Course Outcomes:

Upon the successful completion of the course, students will be able to:

CO Nos.	Course Outcomes	Knowledge Level (Based on revised Bloom's Taxonomy)
CO1	Discuss the fundamental concepts involved in compressible flow	K2
CO2	Solve typical variable area flow, standing& moving normal –shock, Fanno & Rayleigh flow problems by use of the appropriate equations and tables.	K3
CO3	Solve typical problems involving oblique shock waves and expansion waves (2-D waves) by use of the appropriate equations and tables.	K3
CO4	Apply the compressible equation of motion to calculate lift and drag coefficient of airfoil at subsonic and supersonic regimes and also apply Method of characteristics to design a 2-D supersonic nozzle for aerospace applications (Rockets, Wind tunnels, etc.)	K3

CO5	Examine the aerodynamic characteristics over airfoil, wing and aircraft configurations in compressible flow regime	K3

f. Correlation of COs with POs:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	**H**			**H**			**M**	**H**	**L**			
CO2	**H**			**H**			**M**	**H**	**L**			
CO3	**H**			**H**			**M**	**H**	**L**			
CO4	**H**			**H**			**M**	**H**	**L**			
CO5	**H**			**H**			**M**	**H**	**L**			

H- High; M-Medium; L-Low

g. Course Contents:

UNIT-I COMPRESSIBLE FLOW CONCEPTS L-6 T-6

Compressibility -Continuity, Momentum, Energy and state equations, Velocity of sound, realms of fluid motion, physical differences between incompressible, subsonic and supersonic flow, Karman's rules of supersonic flow, Mach number and Mach angle, Classifications of compressible flow, Characteristic Mach number

UNIT-IIONE DIMENSIONAL FLOW L-6T-6

Isentropic flow, Area-velocity relation, Area -Mach number relation, Flow through convergent-divergent passage, Performance under various back pressures. Normal shock relations, Prandtl's relation, Hugoniot equation, Rayleigh Supersonic Pitot tubeequation, Fanno flow and Rayleigh flow

UNIT-III TWO - DIMENSIONAL WAVES L-6T-6

Oblique shock relations, $\theta - \beta - M$ relation, Shock Polar, Reflection of oblique shocks, left running and right running waves, Interaction of oblique shock waves, slip line, shock-boundary layer interaction, transonic lambda shock, compression corner effect, incident shock interaction Shock Diamonds, Expansion waves, Prandtl-Meyer expansion, Maximum turning angle, Simple and non-simple regions- Shock-Expansion theory

UNIT-IV DIFFERENTIAL EQUATIONS OF MOTION FOR STEADYCOMPRESSIBLE FLOWS L-6T-6

Velocity potential equation-Small perturbation potential theory, Linearized Pressure Coefficient, Prandtl-Glauert Compressibility correction, Improved compressibility correction, Linearized two dimensional supersonic flow theory, Method of Characteristics,2-D supersonic nozzle design

UNIT-V HIGH SPEED FLOW OVER AIRFOILS, WINGS AND AIRPLANE CONFIGURATIONS L-6T-6

Critical Mach number, Drag divergence Mach number, Shock Stall, Supercritical Airfoil Sections, Transonic area rule, swept wing, Airfoils for supersonic flows, Lift, drag, pitching moment and Centre of pressure for supersonic profiles, wave drag, supersonic wings, Design considerations for supersonic aircraft- aerodynamic heating

TotalPeriods:30+30=60

h. Learning Resources

i. Text Books:

1. Anderson, J. D., Modern Compressible Flow with Historical Perspective, 3rd ed., McGraw-Hill, 2004
2. Rathakrishnan, E., "Gas Dynamics", Prentice Hall of India, 2003.

ii. References:

1. Hodge.B.K., "Compressible fluid dynamics", 1st edition, Pearson education India, 2016
2. Patrick H. Oosthuizen, William E. Carscallen, "Introduction to Compressible fluid flow", 2nd edition, CRC press, 2013
3. Michel A Saad, "Compressible Fluid Flow", 2nd edition, Prentice Hall, 1992.
4. Shapiro, A.H., "Dynamics and Thermodynamics of Compressible Fluid Flow", Ronold Press, 1982.
5. Liepmann, H., and A. Roshko, "Elements of Gas Dynamics", Dover Publications, 2002
6. Zucrow, M.J. and Hoffman, J.D., "Gas dynamics", Vol 1, John Wiley 1982
7. McCormick. W., "Aerodynamics, Aeronautics and Flight Mechanics", John Wiley, New York, 1979.
8. Thompson, P. A. Compressible Fluid Dynamics. Maple Press Company, 1984
9. Zucker, R. D. and Biblarz, O., Fundamentals of Gas Dynamics, 2nd ed., John Wiley (2002).
10. John, J. E. A. and Keith, T., Gas Dynamics, 3rd ed., Prentice Hall (2006).
11. George Emanuel., "Gas dynamics: Theory and Applications", AIAA Education Series, 1986.
12. Yahya, S. M., Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion, 3rd ed., New Age International Publishers (2003).