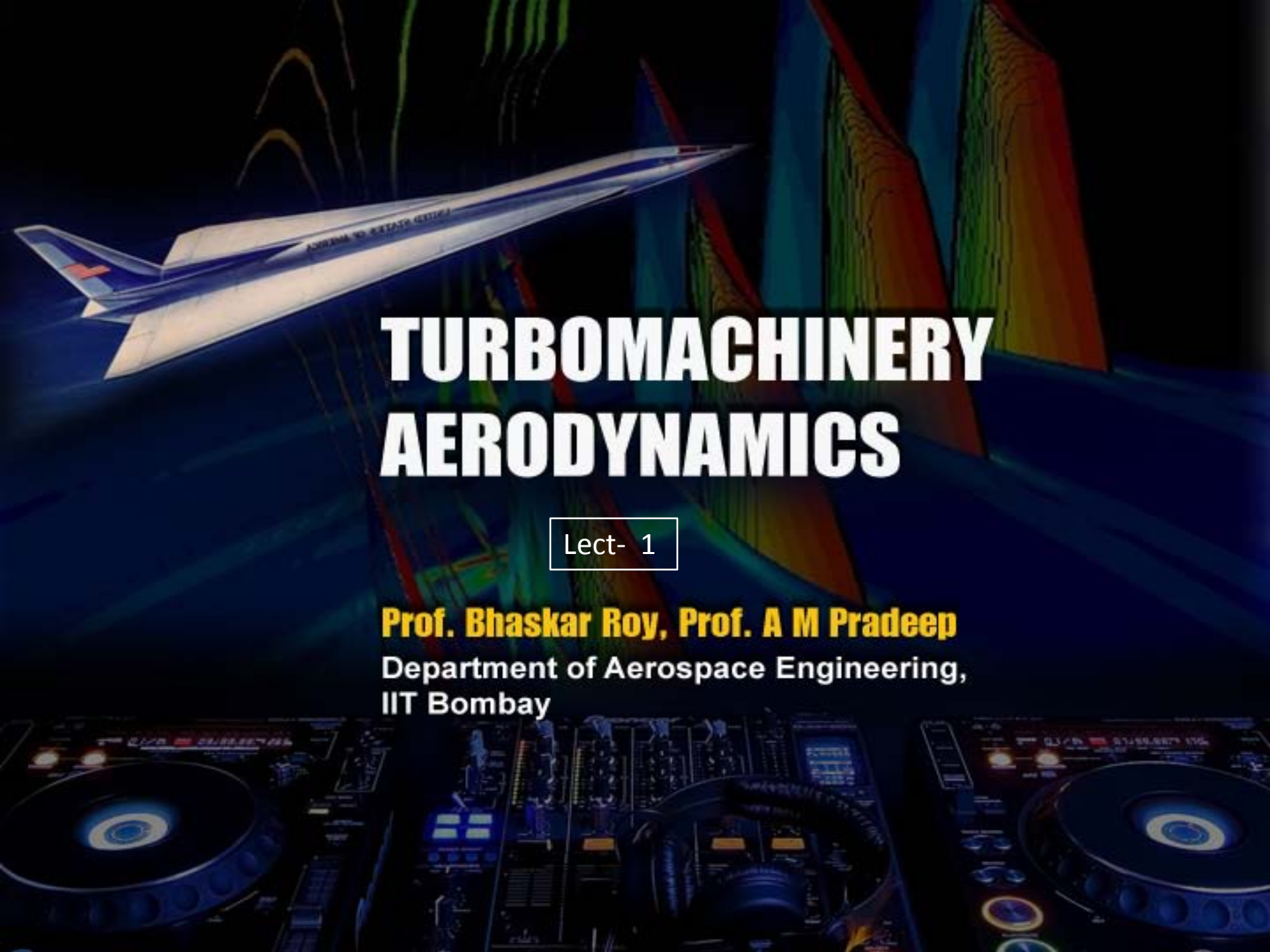

TURBOMACHINERY AERODYNAMICS

Lect- 1

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Turbomachinery Aerodynamics

A Video course by

Bhaskar Roy **A M Pradeep**

Aerospace Engineering Department
I.I.T., Bombay

Course Outline

- **Introduction to Turbomachineries**:
- **Axial flow compressors and Fans:** Introduction; Aero-Thermodynamics of flow thru' axial flow compressor stage; Losses in axial flow compressor stage; Losses and Blade performance estimation; Secondary flows (3-D); Tip leakage flow and scrubbing; 3-D flow analysis; Radial Equilibrium Equation; Axial compressor characteristics; Design of compressor blades-2-D blade designs; Airfoil Data; Axial Flow Track Design; Multi-staging of compressor characteristics; Transonic Compressors; Shock Structure Models in Transonic Blades; Transonic Compressor Characteristics; 3-D Blade shapes of Rotors and Stators; Instability in Axial Compressors; Loss of Pressure Rise; Loss of Stability Margin; Noise problems in Axial Compressors and Fans

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Course Outline

- **Axial flow turbines** : Turbine stage; Turbine Blade 2-D analysis ; Work Done and Degree of Reaction; Losses and Efficiency; Flow Passage and flow track in multi-stage turbines; Subsonic, Transonic and Supersonic turbines; Multi-staging of Turbine; Exit flow conditions; Turbine blade cooling; Turbine Blade design – Turbine Profiles ; Airfoil Data and Profile construction;3-D blade design

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Course Outline

- **Centrifugal Compressors :**Introduction; Elements of centrifugal compressor/ fan; Inlet Duct ; Impeller flow; Effect of Slip factor; Concept of Rothalpy; Ideal and real work done; Incidence and lag angles; Diffuser ; Centrifugal Compressor Characteristics ; Surging and Rotating stall; Design variants of modern centrifugal compressors
- **Radial Turbine:** Introduction; Thermodynamics and Aerodynamics of radial turbines; Radial Turbine Characteristics; Losses and efficiency; Design of radial turbine
- **Use of CFD for Turbomachinery analysis and design**

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Course Pre-requisites

A full course in **Aerodynamics**

It is necessary that students of this course are fully conversant with various fundamental aerodynamic theories, many which shall be used in the course of this lecture. Some knowledge of fundamentals of thermodynamics will be useful too.

Text / References

- Nicholas Cumpsty, *Compressor Aerodynamics*, 2004, Kreiger Publications, USA
- Johnson I.A., Bullock R.O. *NASA-SP-36*, *Axial Flow Compressors*, 2002 (re-release), NTIS
- NASA-SP-290, *Axial Flow turbines*, 2002 (re-release), NTIS, USA.
- J H Horlock, *Axial flow compressors*, Butterworths, 1958, UK
- J H Horlock, *Axial Flow Turbines*, Butterworths, 1965, UK
- B Lakshminarayana; *Fluid Mechanics and Heat Transfer in turbomachineries*, 1995, USA

Suggested / Additional Readings

1) Oates Gordon C; *Aerothermodynamics of Aircraft Engine Components*; AIAA series, 1985

2) IGTI/ASME; *The design of Gas Turbine Engines Thermodynamics and Aerodynamics (chapter 8 and 10)*, 2005, American Society of Mechanical Engineers (with video lectures)

Lecture schedule

No.	Topic	Speaker
1	Introduction to Turbomachineries : Syllabus, References and schedules	BR / AMP
2	Axial flow compressors and Fans : Introduction to compressor aerothermodynamics	AMP
3	A two dimensional analytical model (Cascade)	AMP
4	2-D Losses in axial flow compressor stage – primary losses	AMP
5	Tutorial-1– solved examples and tutorial problems	AMP
6	3-D flows in Blade passages, Secondary flows, Tip leakage flow, Scrubbing	BR
7	Three dimensional flow analysis – Radial Equilibrium concept	BR
8	Classical blade design laws– Free vortex and other Laws	BR
9	Tutorial-2 - solved examples and tutorial problems and Quiz 1	BR

10	Full Radial Equilibrium Equation and Streamline curvature theory	BR
11	Axial compressor characteristics - Single stage, Multi-stage and Multi-spool characteristics	AMP
12	Instability in Axial Compressors : Types of distortions	AMP
13	Inlet Distortion and Rotating Stall	AMP
14	Compressor Instability and control mechanisms	BR
15	Design of compressor blades- Airfoil Design – subsonic, transonic ,supersonic profiles	BR
16	· Transonic Compressors and Shock Structure models, Transonic Compr. Characteristics	BR
17	· Axial Flow Track Design ; Inter-spool duct ; 3-D Blade shapes of Rotors and Stators	BR
18	Noise problem in Axial Compressors and Fans	BR

19	Axial flow turbines : Introduction to turbine aerothermodynamics	BR
20	Axial flow turbines : Turbine Blade 2-D (cascade) analysis	AMP
21	Axial flow turbines : Work Done, Degree of Reaction, Losses and Efficiency	AMP
22	Axial flow turbines : Blade and Axial Flow Passages, Exit flow matching with nozzle	AMP
23	Tutorial -3 : Axial Flow Turbines	AMP
24	Multi-staging and Multi-spooling of Turbine	BR
25	3-D flows in Turbine : 3-D flow theories – Free vortex theories etc.	BR
26	Tutorial – 4 : 3-D flows in Axial low Turbines	BR

27	Turbine Blade Cooling – 1 – fundamental of heat transfer and blade cooling	AMP
28	Turbine Blade Cooling Technologies - 2	BR
29	Turbine Blade design – Turbine Profiles : Airfoil Data and Profile construction	BR
30	Turbine Blade design - 3-D blade shapes	BR
31	Centrifugal Compressors	AMP
32	Centrifugal Compressors	AMP
33	Tutorial – 5 : Centrifugal Compressors	AMP

34	Design of Centrifugal Compressors : Design of impellers	BR
35	Design of subsonic and supersonic vaned diffusers, vaneless volutes	BR
36	Radial Turbine : Thermodynamics and Aerodynamics of radial turbines	AMP
37	Radial Turbine Characteristics	BR
38	Tutorial – 6 : Radial Turbines and Quiz-2	BR
39	Design of Radial Turbines	BR

40	CFD for Turbomachinery: Computer aided blade profiles and cascade analysis	BR
41	Grid generation, Periodicity and Boundary Conditions and Flow Analysis	AMP
42	3-D blade generation and analysis using CFD	BR
43	Flow track and inter-spool duct analysis and design using CFD	AMP

A Brief Introduction to Compressors and Turbines

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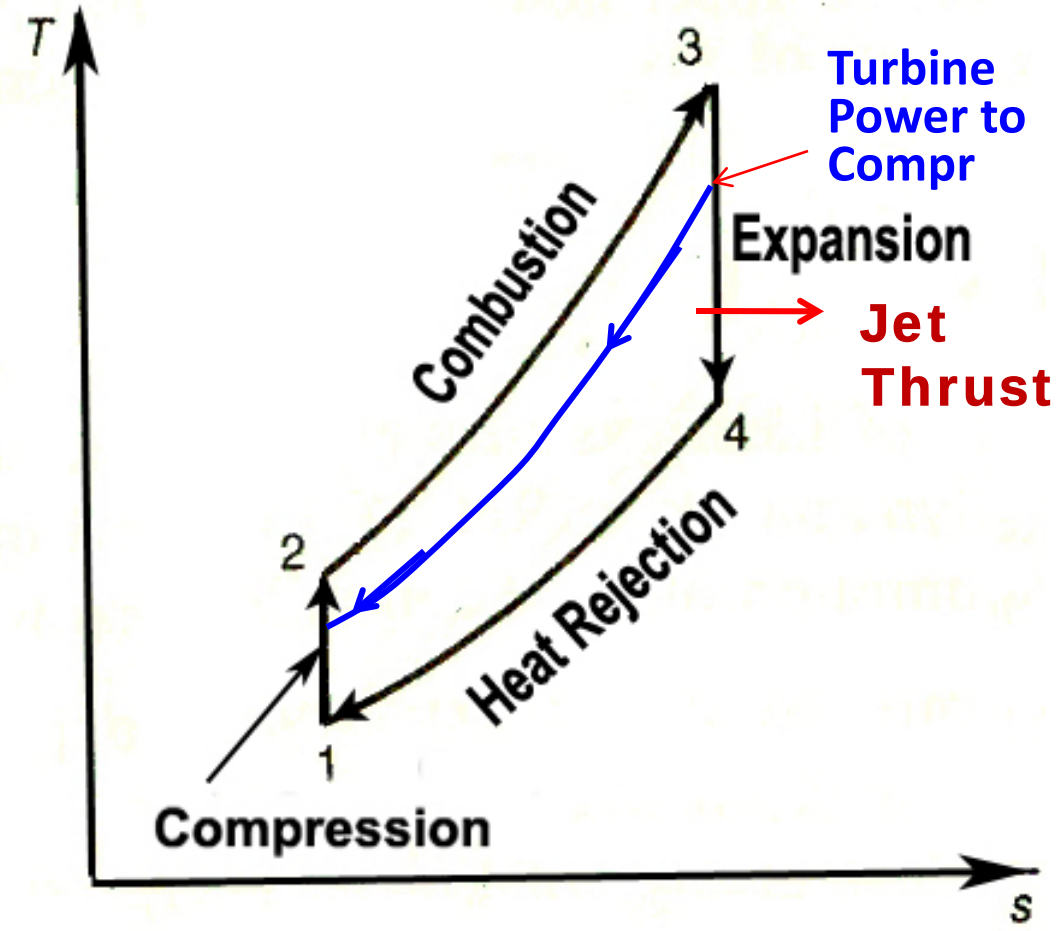
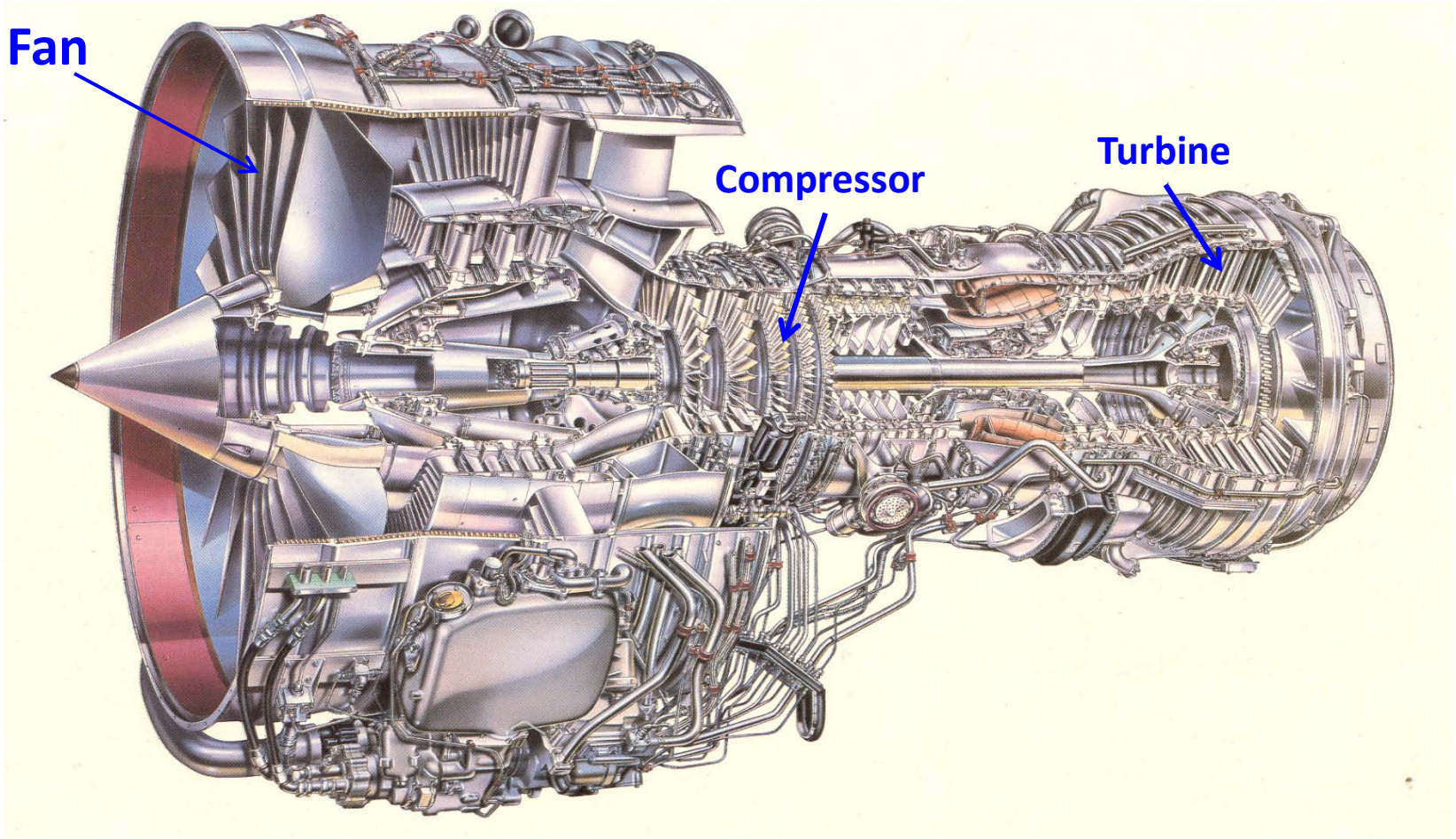


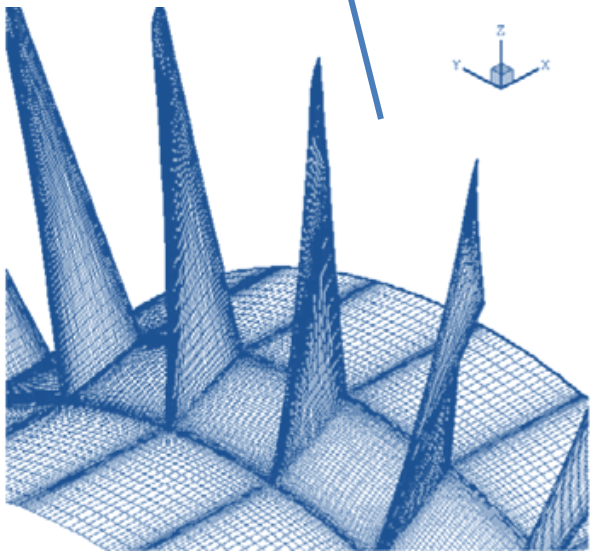
- Heat Engines require compression before combustion for efficient combustion

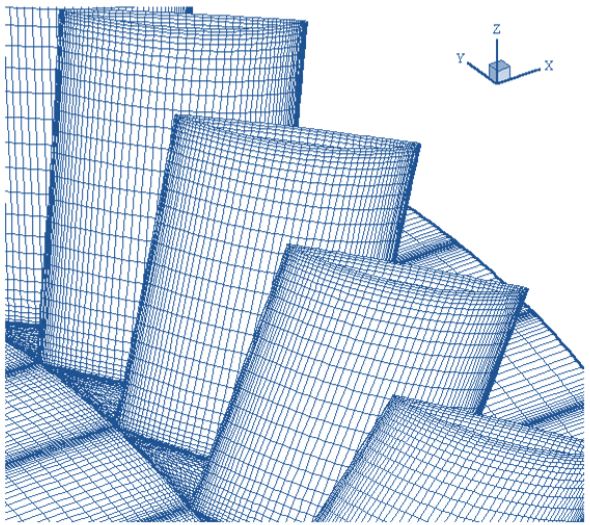
- Compressed burnt gas facilitates turbine work production

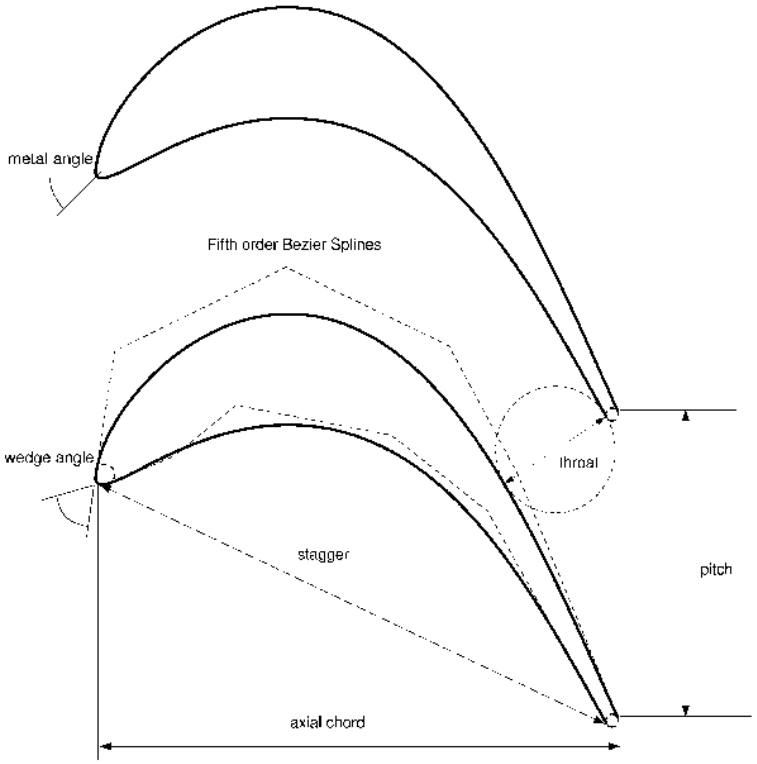
- For jet engines Jet thrust creation requires compressed gas expansion through jet nozzle


Fan
Compressor
Turbine

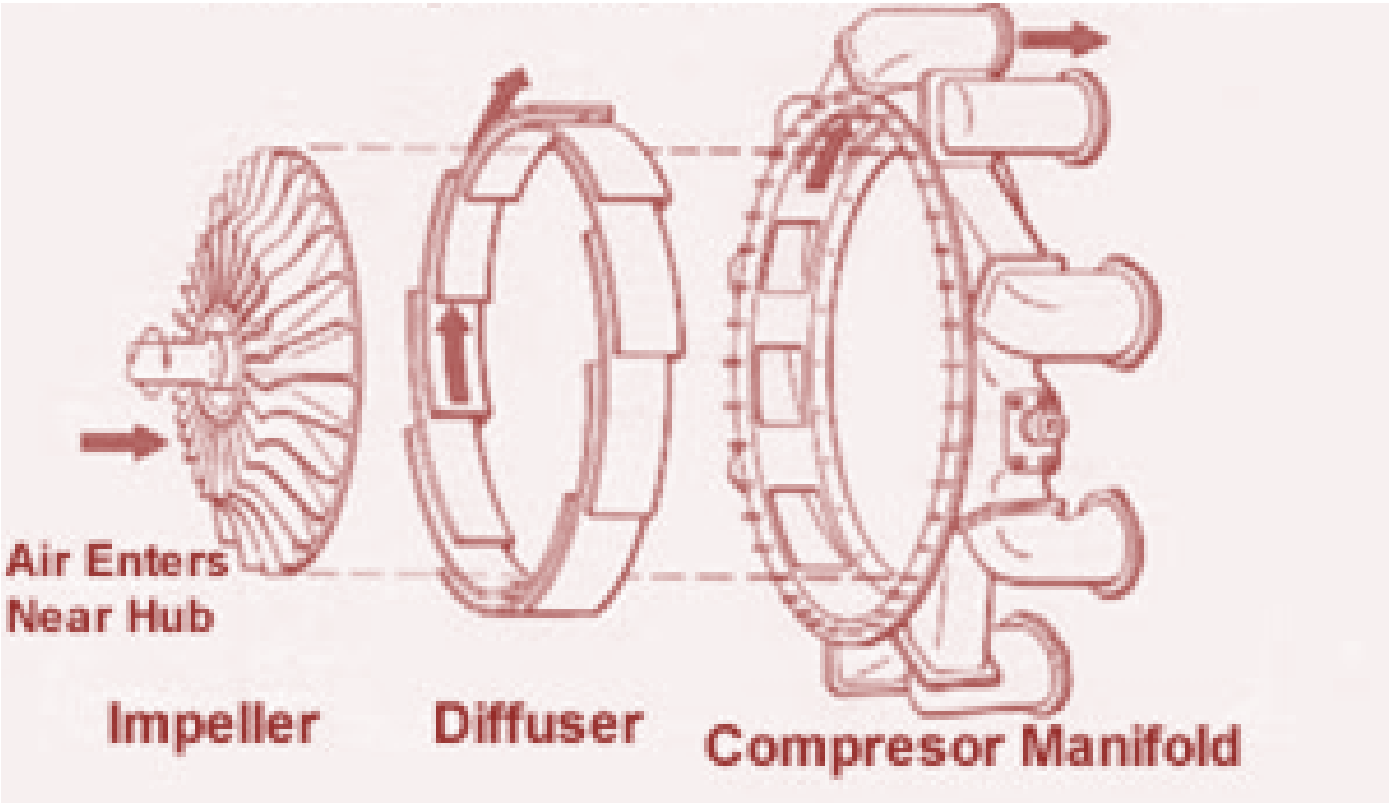

Compressor
Compressor
Stator Casing
Assembly






metal angle
Fifth order Bezier Splines
wedge angle
throat
stagger
pitch
axial chord

Centrifugal Compressor Components



- Creation of Compressors and Turbines require substantial knowledge of aerodynamic behaviour of flow through these machines.

- Modern compressor and turbine design is substantially aided by Computational Fluid Dynamics (CFD)

- Final blade shaping requires sophisticated geometric modelling softwares.