Introduction to Aerospace Propulsion

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Lecture No - 39

In this lecture ...

- Advanced propulsion concepts (Variable cycle engines)
- Supersonic transport propulsion
  - Mid-Tandem fan concept
  - Mixed flow turbofan ejector
- Short Take-off Vertical Landing engines
- Engine with intercooling, reheating and regeneration

Advanced propulsion concepts

- Supersonic transport (SST) can minimize travel time substantially.
- One of the most successful SST aircraft was Concorde.
- However its services were discontinued due to a variety of reasons: safety, economic viability, noise etc.
- No SST aircraft operational currently.

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SST propulsion

- Revisit of SST aircraft technology
- Key challenges:
  - Better fuel economy
  - Increased safety
  - Lower noise
  - Lower emissions
- Conflicting design requirements
  - Supersonic cruise: high specific thrust
  - Subsonic cruise: high propulsive efficiency (low specific thrust), lower noise

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SST propulsion

- A “flow-multiplier” device, which during take-off and subsonic cruise can increase mass flow rate.
- This device can also adjust flow rates during supersonic cruise.
- This requires an engine that can operate with multiple/variable thermodynamic cycles.
- Two such concepts seem promising
  - Mid-tandem fan concept
  - Mixed flow turbofan with ejector

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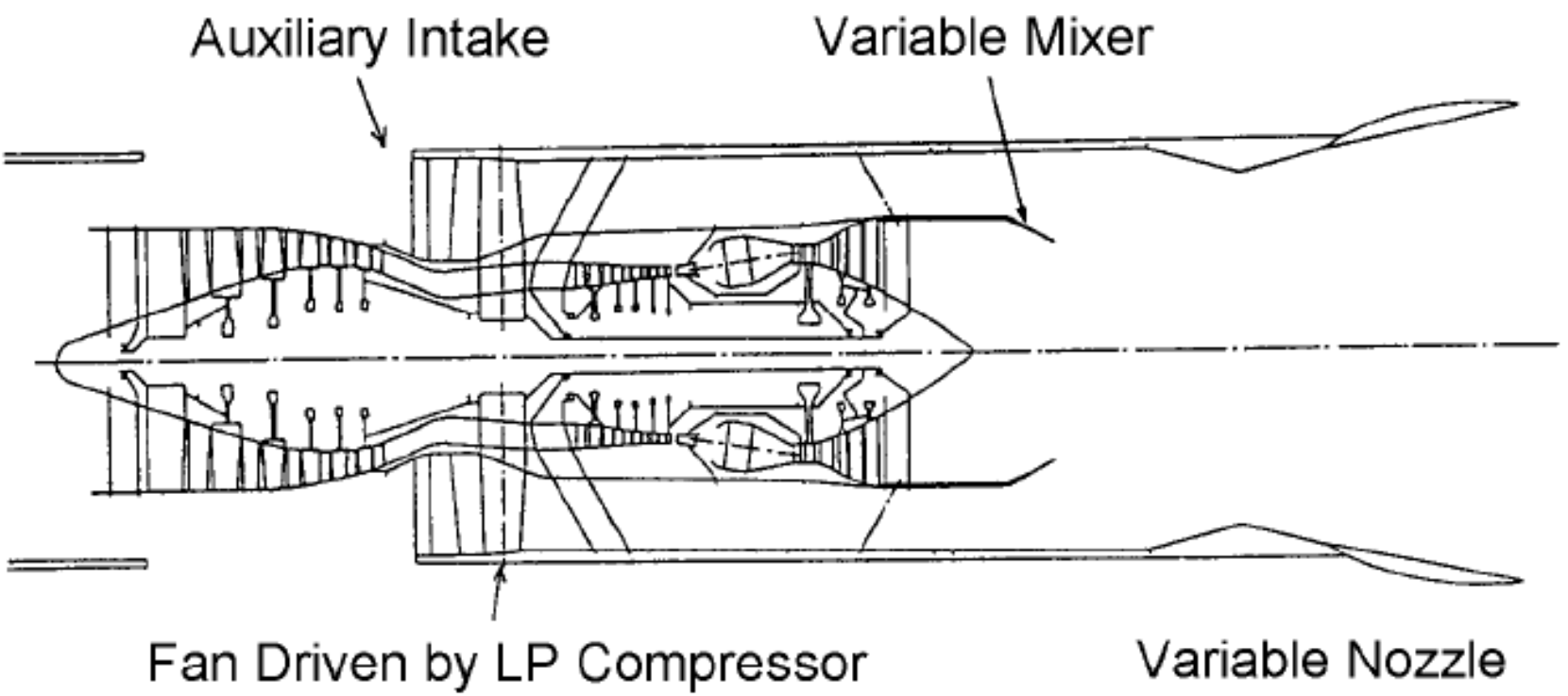
Mid-tandem fan concept

- Mid-tandem fan concept
  - This concept involves using variable components such as compressors with variable inlet guide vanes, auxiliary intakes, or variable geometry mixers and turbines.
  - All these can be scheduled to deliver higher or lower specific thrusts depending upon the requirement.
  - Key to success of this concept is innovative design of these complex components with good aerodynamic performance.

Mid-tandem fan concept



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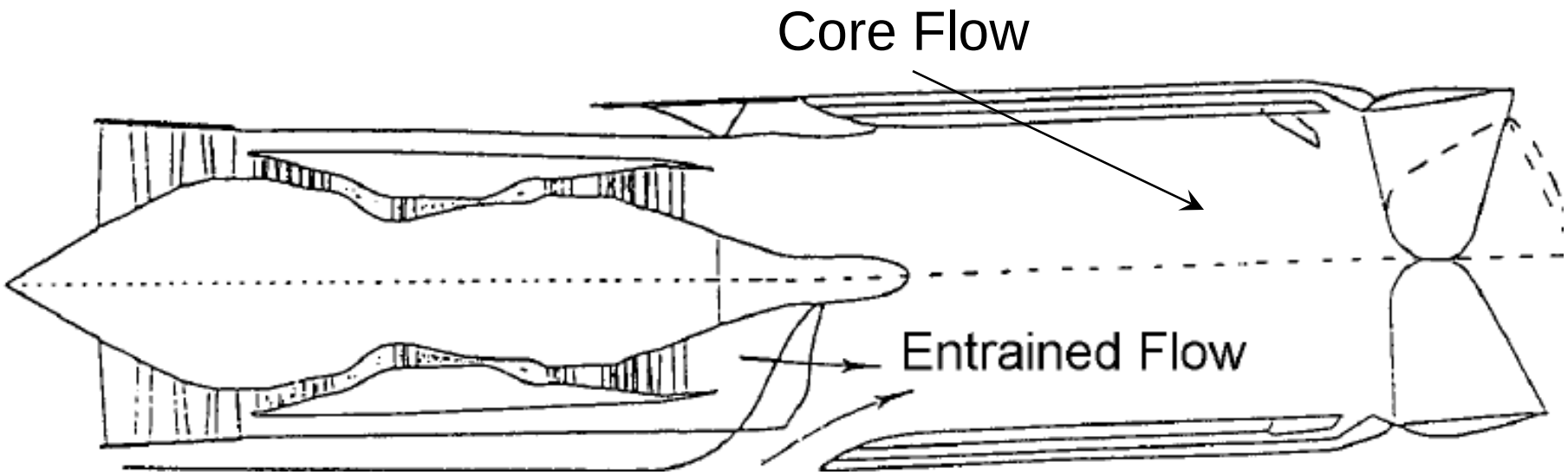
Mixed flow turbofan with ejector

- Mixed flow turbofan with ejector
  - Comprises of a long mixer-ejector nozzle
  - This nozzle entrains outside freestream air that is mixed with the core flow
  - This leads to a cooler, slower exhaust jet reducing noise substantially.
  - The ejector may be used only during subsonic, low altitude operation.
  - During supersonic cruise, the ejector can be switched off resulting is a high exhaust velocity and hence higher specific thrust.

Mixed flow turbofan with ejector



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Short Take-off Vertical Landing

- Short Take-Off Vertical Landing (STOVL)
  - Another application where innovative engine cycles (variable cycles) are required.
  - Low bypass required at high flight speeds and high bypass at low flight speeds close to ground
  - Thrust is vectored downwards to support the weight of the aircraft when flight speed is not enough to get lift from wings
  - A part of the thrust is vectored down for short take off and all of it is vectored down for vertical landing

Short Take-off Vertical Landing

- For take off and landing jet velocity is low and so mass flow requirement is high, requiring a high bypass engine
- Achieved using a tandem fan configuration
- Two fans used in series or parallel configuration; series for low bypass requirements and parallel for high bypass requirements

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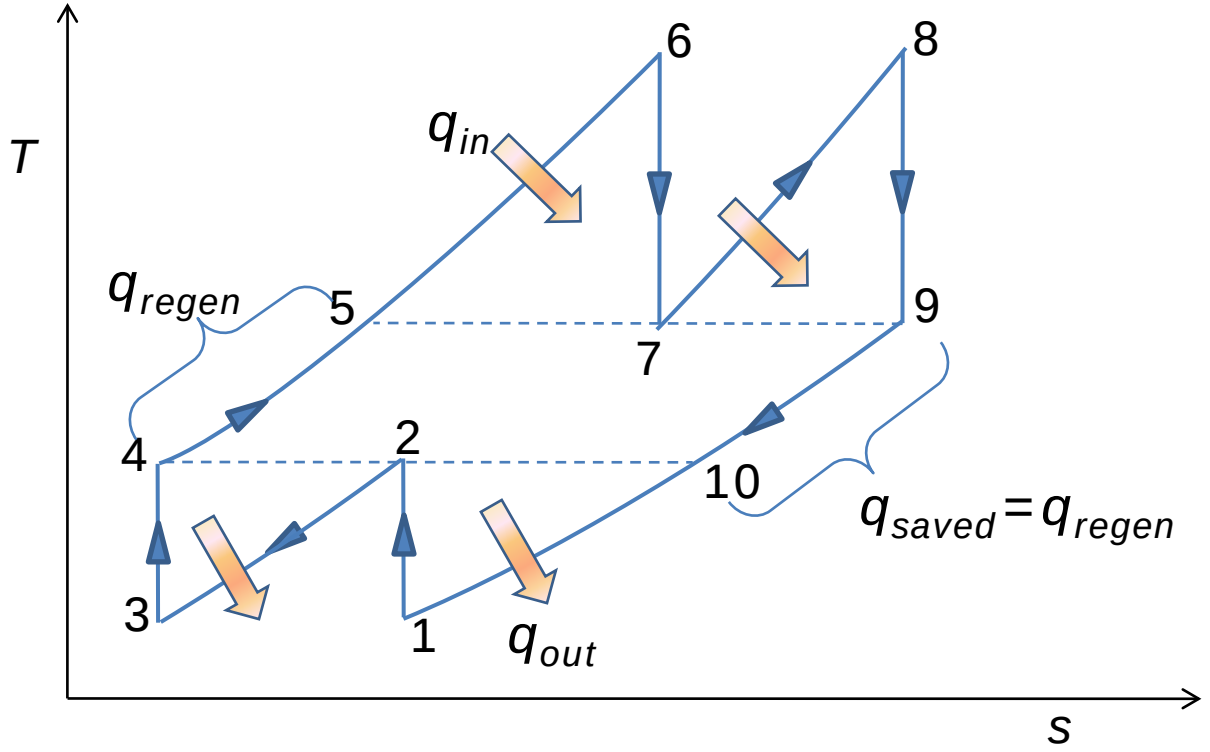
Short Take-off Vertical Landing

- In series configuration the whole flow through the front fan passes through the second fan
- Functions like a common turbo fan engine with two fans
- For parallel configuration, the flow from the first fan is vectored downwards and the second fan takes in air through auxiliary intakes thus giving us a high bypass engine

Other concepts for improved engine performance

- Engine performance can be improved by effecting other changes in the cycle
  - Intercooling
  - Reheating
  - Regeneration
- Reheating has been extensively used in both land based as well as aircraft engines.
- In aircraft engines, reheating is referred to as afterburning.

Brayton cycle with intercooling, reheating and regeneration



T-s diagram of an ideal gas-turbine cycle with intercooling, reheating, and regeneration

Other concepts for improved engine performance

- Intercooling
  - The work required to compress a gas between two specified pressures can be decreased by carrying out the compression process in stages and cooling the gas in between: multi-stage compression with intercooling.
  - Intercooling reduces the work required for compression.
  - This would in turn reduce the turbine work output.
  - Intercooling is not currently used in aircraft engines, but is a topic of research interest.

Other concepts for improved engine performance

- Reheating
  - Afterburning turbojet engines are commonly used in military aircraft.
  - Acceleration and supersonic cruise
  - In land based power plants, reheating is sometimes used between turbine stages.
- Regeneration
  - Energy storage can be carried out by using fuel as a coolant.
  - Preheating the fuel also improves the overall efficiency of the cycle.