CHAPTER-1
TURBINES

Impulse and reaction blading of gas turbines – Velocity triangles and power output – Elementary theory – Vortex theory – Choice of blade profile, pitch and chord – Estimation of stage performance – Limiting factors in gas turbine design- Overall turbine performance – Methods of blade cooling – Matching of turbine and compressor – Numerical problems.

Introduction

Turbines are work extracting component in an aircraft gas turbine engine, which extracts the work from a gas at higher inlet pressure to lower back pressure by allowing gas to flow through a turbine. The turbine operates on the momentum principle. Part of the energy of the gas during expansion is converted into kinetic energy in the flow nozzles. The gas leaves these stationary nozzles at a relatively higher velocity. Then it is made to impinge on the turbine rotor blades. Momentum imparted to the blades turns the turbine wheel. The output of the turbine is used to turn the compressor (which may also have an associated fan or propeller).

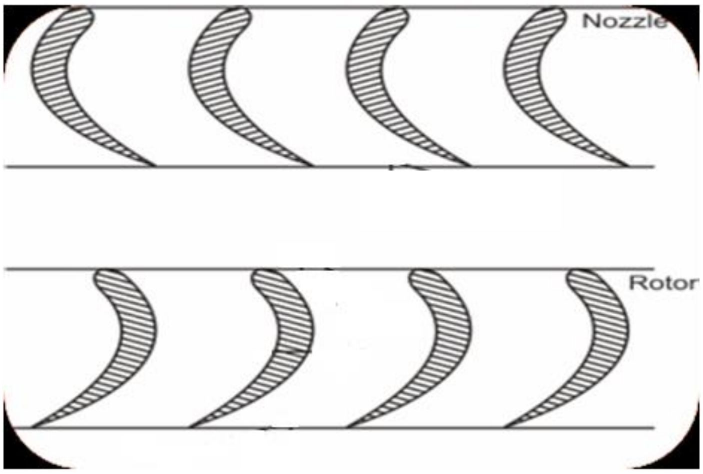
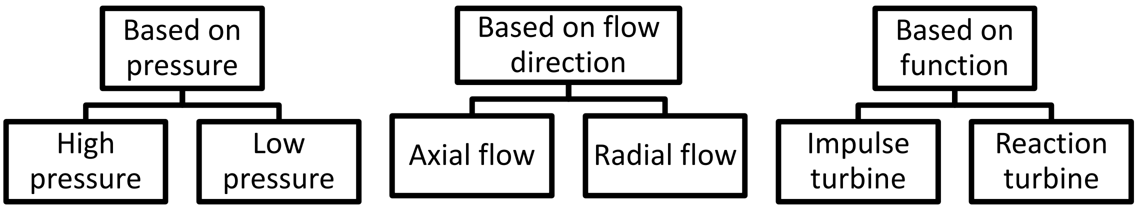


Fig 1.1 Turbine stage

Fig 1.1 shows the turbine stage. The two primary parts of turbine stage are the stator nozzle and the turbine rotor blades. The stage consists of a ring of fixed nozzle blades followed by the rotor blade ring. Most of the turbines possess more than one stage with respective wheels mounted on a common shaft.

Classification of Turbine



Based on pressure

HP turbine is located next to the combustion chamber, which extracts more energy from the gas to run the high pressure compressor. HP turbine rotates at higher RPM.
LP turbine is located next to the HP turbine, which extracts more energy from the gas to run the low pressure compressor and fan. LP turbine rotates at lower RPM.

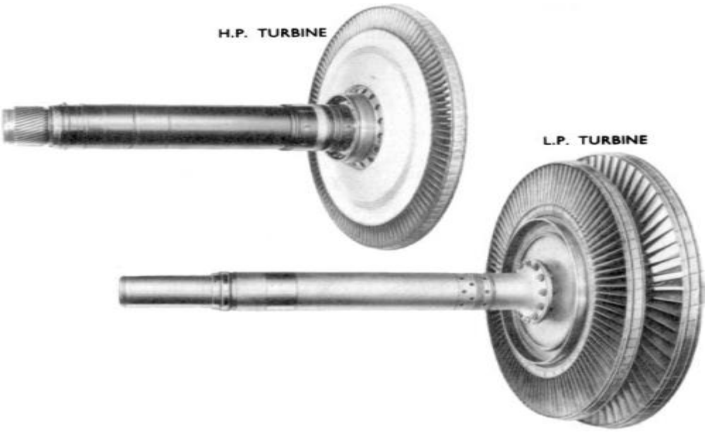


Fig 1.2 HP and LP Turbine blades

Based on flow direction

Based on flow direction there are two basic types of turbine—radial flow and axial flow. The majority of gas turbines employ the axial flow turbine. The radial turbine can handle low mass flows more efficiently than the axial flow machine and has been widely used in the cryogenic industry as a turbo-expander, and as turbochargers for reciprocating engines. Although for the lowest powers the axial flow turbine is normally the more efficient, when mounted back-to-back with a centrifugal compressor. the radial turbine offers the benefit of a very short and rigid rotor. This configuration is eminently suitable for gas turbines where compactness is more important than low fuel consumption.

The axial flow type has been used exclusively in aircraft gas turbine engines to date. Axial flow turbines are also normally employed in industrial and shipboard applications. The single-stage turbine is directly connected to the main and cooling compressors. The axial flow turbine consists of one or more stages located immediately to the rear of the engine combustion chamber. The turbine extracts kinetic energy from the expanding gases as the gases come from the burner, converting this kinetic energy into shaft power to drive the compressor and the engine accessories.

Axial flow turbine:

- It consists of two main elements, a set of stationary vanes followed by a turbine rotor.
- Axial-flow turbines may be of the single-rotor or multiple-rotor type
- Blade shape Dependent on Stress and Cooling but not as much on aerodynamics
- Axial Turbine Stage consists of row of stationary blades called Nozzle row of rotating blades called Rotor

Radial flow Turbine

- The radial flow turbine is similar in design and construction to the centrifugal-flow compressor.

Advantages

- -ruggedness and simplicity

- -relatively inexpensive and easy to manufacture when compared to the axial-flow turbine.

Based on function

The turbines can be classified as (1) impulse and (2) reaction. In the impulse turbine, the gases will be expanded in the nozzle and passed over to the moving blades. The moving blades convert this kinetic energy into mechanical energy and also direct the gas flow to the next stage (multi-stage turbine) or to exit (single-stage turbine). In the case of reaction turbine, pressure drop of expansion takes place in the stator as well as in the rotor-blades. The blade passage area varies continuously to allow for the continued expansion of the gas stream over the rotor-blades.

Impulse turbine

The impulse stage is characterised by the expansion of the gas which occurs only in the stator nozzles. The rotor blades act as directional vanes to deflect the direction of flow. Further, they convert the kinetic energy of the gas into work by changing the momentum of the gas more or less at constant-pressure.

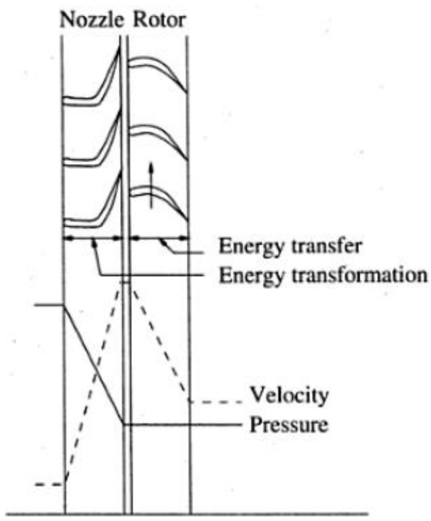


Fig 1.3 Impulse turbine

Impulse turbines are those in which there is no change of static or pressure head of the fluid in the rotor. The rotor blade cause only energy transfer and there is no energy transformation. The energy transformation from pressure head to kinetic energy or vice versa takes place in fixed blades only. Fig 1.3 shows an impulse turbine stage. From the fig, in the rotor blade passage of an impulse turbine there is no acceleration of the fluid i.e no energy transformation. Hence, the changes are greater for separation due to boundary layer growth on the blade surface. Due to this, the rotor blade passage of the impulse turbine suffers greater losses giving lower stage efficiencies.

Reaction Turbine

The reaction stage is one in which expansion of the gas takes place both in the stator and in the rotor. The function of the stator is the same as that in the impulse stage, but the function in the rotor is that it converts the kinetic energy of the gas into work and contributes a reaction force on the rotor blades. The reaction force is due to the increase in the velocity of the gas relative to the blade. This results from the expansion of the gas during its passage through the rotor.

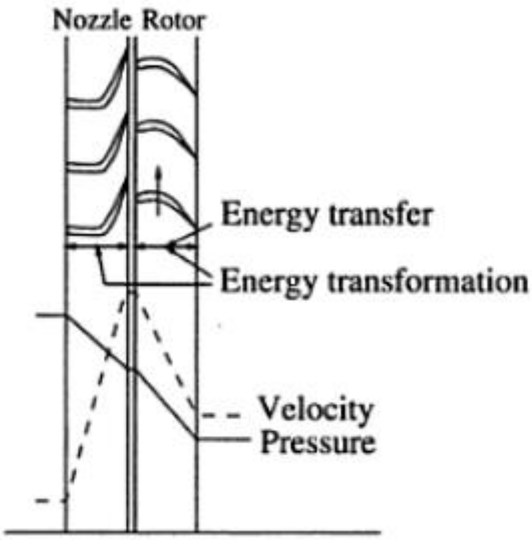


Fig 1.4 Reaction turbine

The reaction turbines are those, in which changes in pressure head occurs both in the rotor and stator blade passage. Here, the energy transformation occurs both in fixed as well as moving blades. The rotor experiences both energy transfer as well as energy transformation. Therefore, the reaction turbines are considered to be more efficient. This is mainly due to continuous acceleration of flow with lower losses. Fig 1.4 shows a single stage reaction turbine along with pressure and velocity changes when the fluid passes through a turbine stage.

Difference between impulse and reaction turbine

Impulse turbine	Reaction turbine
The gas flow through the nozzles and impinges on the impulse turbine blades	The gas is guided by guide blades/vanes to flow over the moving rotor blades
In impulse turbine the entire energy is first converted into kinetic energy	There is no energy conversion in reaction turbine
In impulse turbine the gas impinges on the blades/bucket with kinetic energy	In reaction turbine the gas glides over the rotor blades with pressure energy
In impulse turbine the work is done by the change in the kinetic energy of the jet	In reaction turbine the work is done partly by the change in velocity but almost entirely by the change in the pressure
In impulse turbine the pressure remains constant	In reaction turbine the pressure is reduced after gliding over the vanes
It works on Newton’s second law	It works on Newton’s third law
Energy transformation takes place in the stator	Energy transformation takes place both in the stator and rotor