4 STEAM TURBINES

Prime movers

A machine which originates mechanical motion using some natural force is a *prime mover*. Prime movers can be classified into engines and turbines.

Differences between engine and turbine

Engine	*Turbine*
1. Engines are pressure machines	Turbines are flow machines
2. Engines are reciprocating type	Turbines are purely rotary
3. Torque on the crank shaft is not even, hence flywheel is required	Torque on the output shaft is even, hence flywheel is not required
4. Reversing operation is possible	Cannot be put into reverse action
5. Bulky and operate at low speeds	Compact and operate at high speeds
6. Examples: Steam engines and internal combustion engines	Examples: Steam turbines, gas turbines, water turbines, wind mills, etc.

A *turbine* is a machine in which a rotary motion is obtained by the gradual change of momentum of the fluid. Steam turbine depends wholly upon the dynamic action of steam. The basic principle of operation of steam turbine is the generation of high velocity steam jet by the expansion of high pressure steam in a nozzle and then conversion of kinetic energy into mechanical work on rotor blades.

The steam turbine is an ideal prime mover and has got a variety of uses. It is used for driving electric generators, ship propellers, pumps, fans, compressors, etc. In general the turbine is well adapted for work, which requires constant speeds even with widely fluctuating loads.

Classification of steam turbines

Steam turbines are mainly classified into two groups :

1. Impulse turbine, and
2. Reaction turbine.

A steam turbine does mechanical work by virtue of the velocity with which th steam strikes (impulse) or leaves (reaction) the moving parts. In impulse turbine t steam expands in nozzles and its pressure does not alter as it moves over the blades. reaction turbine, the steam expands continuously as it passes over the blades and th there is a gradual fall in the pressure during expansion.

Impulse turbine

The impulse turbine, (fig. 4.1*a*) consists basically of a rotor mounted on a shaft that is free to rotate in a set of bearings. The outer rim of the rotor carries a set of curved blades (fig. 4.1*b*) and the whole assembly is enclosed in casing. Nozzles direct steam against the blades and turn the rotor. The energy to rotate an impulse turbine is derived from the kinetic energy of the steam flowing through the nozzles. The term *impulse* means that the force that turns the turbine comes from the impact of the steam on the blades.

De-Laval turbine: De-Lavel turbine is a single stage impulse turbine as shown in fig. 4.2. The top portion shows one set of nozzles, which is followed by a ring of moving blades, and the lower part indicates the changes in pressure and velocity during the flow of steam through the turbine. Steam nozzles, referred to as stationary blades are located at the turbine inlet. As the steam flows through the nozzle, its pressure falls from steam chest pressure to condenser pressure or atmospheric pressure if the turbine does not have a condenser. Due to this relatively higher ratio of expansion of steam in the nozzle, the steam leaves the nozzle with a very high velocity. The high velocity steam is directed over the blades of the wheel. The wheel is thereby, rotated and thus kinetic energy of the steam is converted into mechanical work. The velocity of the steam decreases and its pressure remain constant while passing through the moving blades.

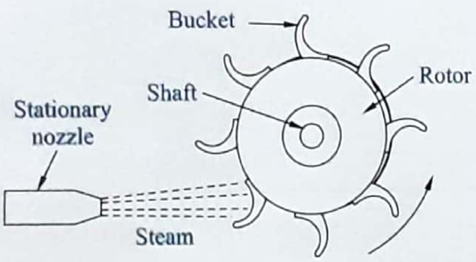

Fig. 4.1(a) Principle of Impulse turbine

Fig. 4.1(b) Impulse turbine blades

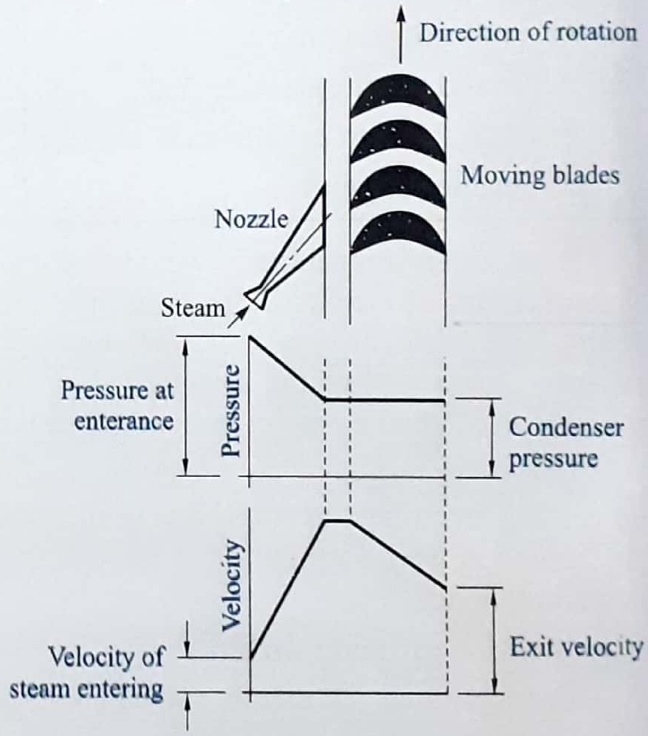

Fig. 4.2 Impulse turbine

Impulse turbines are used to drive forced draft blowers, pumps and ship propulsion. The use of this type of turbine is not so common on account of the following disadvantages.

1. Since all the kinetic energy is absorbed by one row of the moving blades only, the speed of the wheel is too high varying from 25000 to 30000 rpm. Such a high speed produces large centrifugal forces, increases vibration, causes over heating of the bearings, etc., and this makes it impossible for direct coupling to other machines.
2. Loss of energy due to higher exits velocity of steam.

Compounding of impulse turbines

In impulse turbine, the steam is expanded from the boiler pressure to condenser pressure in one stage, and the speed of the rotor becomes tremendously high. Such a high speed is far beyond the maximum allowable safety limits because of the centrifugal stress on the rotor material. In addition, the large steam velocities result in large friction losses and a reduction in turbine efficiency. The high rotor speeds would also necessitate large and bulky reduction gearing to the electric generator. A method of reducing the speed of the impulse turbine to the practical limits is called *compounding*. Three different methods of compounding are : 1. Velocity compounding, 2. Pressure compounding, and 3. Pressure-velocity compounding.

In all these methods a multiple system of rotor in series, keyed on a common shaft and steam pressure or jet velocity is absorbed in stages as it flows over the rotor blades.

Reaction turbine

The reaction turbine is turned by reactive force rather than by a direct push or impulse. The blades that project radially from the periphery of the rotor are formed and mounted so that the spaces between the blades have the shape of nozzles. Since these blades are mounted on the revolving rotor, they are called moving blades. When the steam comes out through the nozzles, the velocity of steam increases. The resulting reacting force on the nozzle rotates the rotor that is mounted on a shaft. The shaft rotates in the opposite direction to that of the steam jet exit (fig. 4.3).

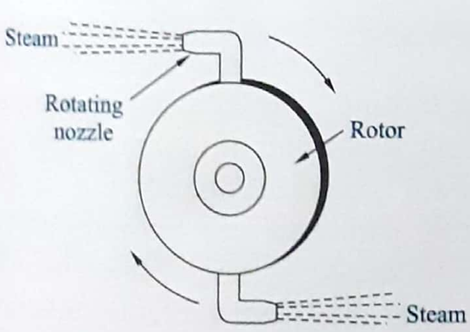

Fig. 4.3 (a) Principle of reaction turbine

Fig. 4.3(b) Reaction turbine blades

In reaction turbine there is a gradual pressure drop, which takes place continuously over the fixed and moving blades. Thus the rotation of the shaft carrying the moving blades is the result of both impulse and reactive forces in the steam. It is also called *impulse-reaction turbine*. The reaction turbine includes rows of stationary guide blades and rows of moving blades. The fixed guide blades act as nozzles, which are attached to the casing. The moving blades are attached over the rim of a wheel, which in turn is keyed to the shaft. The function of the fixed blades is to alter the directions of the steam as well as to allow steam to expand. As the steam passes over the moving blades they absorb its kinetic energy. The principal example of this turbine is the *Parason's* reaction turbine.

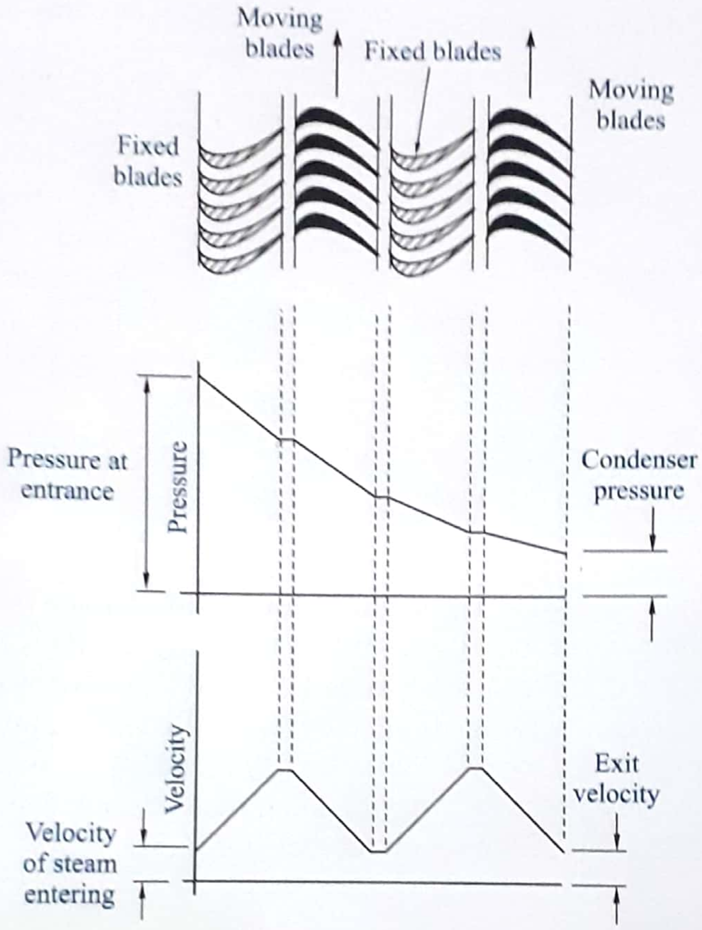

Fig. 4.4 Reaction turbine

Fig. 4.4 shows a two stage Parason's reaction turbine. The change in pressure and velocity are also shown therein. The steam entering at one end of the turbine passes first through a row of fixed guide blades, which direct the steam against the first row of moving blades. The steam does work against the blades as they revolve, its pressure falls a little and its volume increases. It is then redirected by a row of fixed blades in the stator to the next row of moving blades on rotor. Thus the steam expands and does work on the blades and again its pressure falls. In each stage, the expansion of steam was restricted to the extent that allowed the greatest extraction of kinetic energy without causing the turbine blades to over speed.

Difference between impulse and reaction turbines

Impulse turbine	Reaction turbine
1. The torque on the shaft is due to impulse force of the steam.	The torque on the shaft is due to impulse and reaction forces of the steam.
2. The steam completely expands in the nozzle and its pressure remains constant during its flow through the blade passage.	The steam expands partially in the nozzle (fixed blade) and further expansion takes place in the rotor blades.
3. Turbine blades have symmetrical profile.	Turbine blades have aero-foil profile.
4. The pressure on both ends of the moving blade is same.	The pressure on two ends of the moving blades are different.
5. Less efficient.	More efficient.
6. High speed and requires less space.	Comparatively less speed and requires more space.
7. Suitable for small power requirements.	Suitable for medium and higher power requirements.
8. Compounding is necessary to reduce the speed.	Compounding is not necessary.

Advantages of steam turbines over other prime movers (heat engines)

1. Thermal efficiency of a steam turbine is higher.
2. The turbine develops power at uniform rate and hence does not need any flywheel.
3. In the absence of reciprocating parts, the balancing problem is minimised. Hence heavy foundation is not required.
4. Less noise, less maintenance and more life.
5. Steam turbine requires less floor space.
6. No internal lubrication is required as there are no sliding parts in the steam turbine. Hence the exhaust steam is free from oil.
7. Steam turbine can take considerable over-load with only a slight reduction in its efficiency.
8. Suitable for large power plants.
9. Greater range of speed is possible.

Choose the correct answer:

1. A prime mover in which the heat energy of steam is transformed into mechanical energy in the form of rotary motion is called
   (a) Steam engine (b) Steam turbine (c) Steam generator (d) I.C. engine
2. A turbine is a machine which is of
   (a) Rotary type (b) Reciprocating type
   (c) Pressure type (d) Operate at slow speeds
3. In an impulse turbine, steam expands in
   (a) Nozzle (b) Blades (c) Partly in nozzle and partly in blades (d) None of the above
4. At the nozzle inlet of the impulse turbine, the steam is at
   (a) Low pressure and low velocity (b) Low pressure and high velocity
   (c) High pressure and low velocity (d) High pressure and high velocity
5. De-Laval turbine is
   (a) Single rotor impulse turbine (b) Reaction turbine
   (c) Velocity compounded impulse turbine (d) Multi-stage impulse turbine
6. A single stage impulse turbine is not used in practice, because it
   (a) Cannot generate more power
   (b) Cannot utilize the heat energy fully
   (c) Has low efficiency
   (d) Needs large reduction gearing due to high speeds
7. To reduce the speed of impulse turbines, the method used is
   (a) Velocity compounding (b) Pressure compounding
   (c) Pressure-velocity compounding (d) All of the above
8. In reaction turbine, the steam is expanded in
   (a) Fixed blades only (b) Moving blades only
   (c) Both in fixed and moving blades (d) None of the above
9. Example of reaction turbine is
   (a) De-Laral turbines (b) Parason's turbine
   (c) Curtis turbine (d) Moore turbine
10. In reaction turbines, the pressure drops,
    (a) In fixed nozzles (b) In moving blades
    (c) In fixed blades (d) In both fixed and moving blades
13. The turbine in which expands completely in nozzles is called
    (a) Impulse turbine (b) Francis turbine
    (c) Reaction turbine (d) Flow turbine

Review questions

1. Define a steam turbine and state its fields of application.
2. What are the advantages of a steam turbine ?
3. How are steam turbines classified?
4. Describe the working principle of simple impulse turbine with a suitable sketch.
5. What do you mean by compounding of steam turbines? What are the different methods of compounding? (VTU, July 2008)
6. Describe the working principle of a reaction turbine with a suitable sketch.
7. List the differences between an impulse and a reaction turbine. (VTU, June 2012)
8. Sketch and explain the working of a reaction steam turbine with the help of pressure and velocity profiles. (VTU, Jan 2013)
9. What are the advantages of steam turbines over other prime movers? (VTU, July 2004)
10. With neat sketch, explain the working of pressure velocity compounding. (VTU, Jan 2009)
11. Explain the working principle of operation of impulse and reaction turbines. (VTU, Dec 2011)