Compounding of steam turbines:

Compounding of steam turbines is the method in which energy from the steam is extracted in a number of stages rather than a single stage in a turbine. A compounded steam turbine has multiple stages i.e. it has more than one set of nozzles and rotors, in series, keyed to the shaft or fixed to the casing, so that either the steam pressure or the jet velocity is absorbed by the turbine in number of stages.

The steam produced in the boiler has sufficiently high enthalpy when superheated. In all turbines the blade velocity is directly proportional to the velocity of the steam passing over the blade. Now, if the entire energy of the steam is extracted in one stage, i.e. if the steam is expanded from the boiler pressure to the condenser pressure in a single stage, then its velocity will be very high. Hence the velocity of the rotor (to which the blades are keyed) can reach to about 30,000 rpm, which is pretty high for practical uses because of very high vibration. Moreover at such high speeds the centrifugal forces are immense, which can damage the structure. Hence, compounding is needed. The high velocity which is used for impulse turbine just strikes on single ring of rotor that cause wastage of steam ranges 10% to 12%. To overcome the wastage of steam compounding of steam turbine is used.

Types of compounding

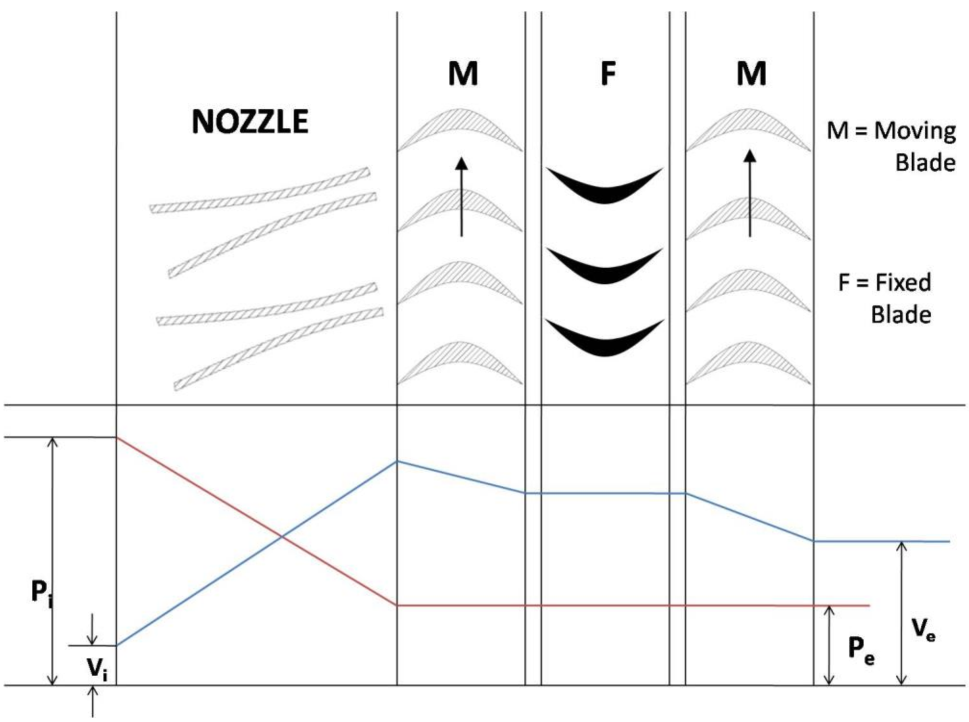
In an Impulse steam turbine compounding can be achieved in the following three ways:

a. Velocity compounding
b. Pressure compounding
c. Pressure-Velocity Compounding

In a Reaction turbine compounding can be achieved only by Pressure compounding.

Velocity compounding of Impulse Turbine

The velocity compounded Impulse turbine was first proposed by C G Curtis to solve the problem of single stage Impulse turbine for use of high pressure and temperature steam. The rings of moving blades are separated by rings of fixed blades. The moving blades are keyed to the turbine shaft and the fixed blades are fixed to the casing. The high pressure steam coming from the boiler is expanded in the nozzle first. The Nozzle converts the pressure energy of the steam into kinetic energy. It is interesting to note that the total enthalpy drop and hence the pressure drop occurs in the nozzle. Hence, the pressure thereafter remains constant.



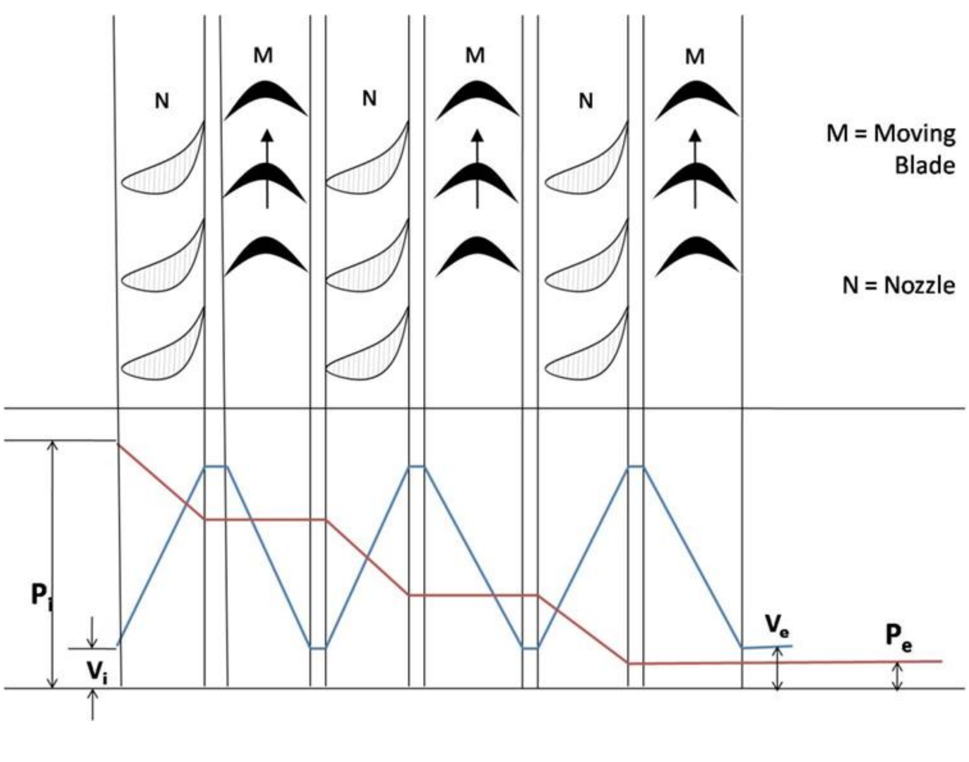
This high velocity steam is directed on to the first set (ring) of moving blades. As the steam flows over the blades, due the shape of the blades, it imparts some of its momentum to the blades and loses some velocity. Only a part of the high kinetic energy is absorbed by these blades. The remainder is exhausted on to the next ring of fixed blade. The function of the fixed blades is to redirect the steam leaving from the first ring of moving blades to the second ring of moving blades. There is no change in the velocity of the steam as it passes through the fixed blades. The steam then enters the next ring of moving blades; this process is repeated until practically all the energy of the steam has been absorbed.

A schematic diagram of the Curtis stage impulse turbine, with two rings of moving blades one ring of fixed blades is shown in figure. The figure also shows the changes in the pressure and the absolute steam velocity as it passes through the stages.

Pressure compounding of Impulse Turbine

The pressure compounded of Impulse turbine is also called as Rateau turbine, after its inventor. This is used to solve the problem of high blade velocity in the single-stage impulse turbine. It consists of alternate rings of nozzles and turbine blades. The nozzles are fitted to the casing and the blades are keyed to the turbine shaft. In this type of compounding the steam is expanded in a number of stages, instead of just one (nozzle) in the velocity compounding. It is done by the fixed blades which act as nozzles. The steam expands equally in all rows of fixed blade. The steam coming from the boiler is fed to the first set of fixed blades i.e. the nozzle ring. The steam is partially expanded in the nozzle ring. Hence, there is a partial decrease in pressure of the incoming steam. This leads to an increase in the velocity of the steam. Therefore the pressure decreases and velocity increases partially in the nozzle.

This is then passed over the set of moving blades. As the steam flows over the moving blades nearly all its velocity is absorbed. However, the pressure remains constant during this process. After this it is passed into the nozzle ring and is again partially expanded. Then it is fed into the next set of moving blades, and this process is repeated until the condenser pressure is reached. This process has been illustrated in figure. It is a three stage pressure compounded impulse turbine. Each stage consists of one ring of fixed blades, which act as nozzles, and one ring of moving blades. As shown in the figure pressure drop takes place in the nozzles and is distributed in many stages. An important point to note here is that the inlet steam velocities to each stage of moving blades are essentially equal. It is because the velocity corresponds to the lowering of the pressure. Since, in a pressure compounded steam turbine only a part of the steam is expanded in each nozzle, the steam velocity is lower than of the previous case.



Pressure compounding of Reaction Turbine

As explained earlier a reaction turbine is one where there is pressure and velocity loss in the moving blades. The moving blades have a converging steam nozzle. Hence when the steam passes over the fixed blades, it expands with decrease in steam pressure and increase in kinetic energy. This type of turbine has a number of rings of moving blades attached to the rotor and an equal number of fixed blades attached to the casing. In this type of turbine the pressure drops take place in a number of stages. The steam passes over a series of alternate fixed and moving blades. The fixed blades act as nozzles i.e. they change the direction of the steam and also expand it. Then steam is passed on the moving blades, which further expand the steam and also absorb its velocity. This is explained in figure 3.

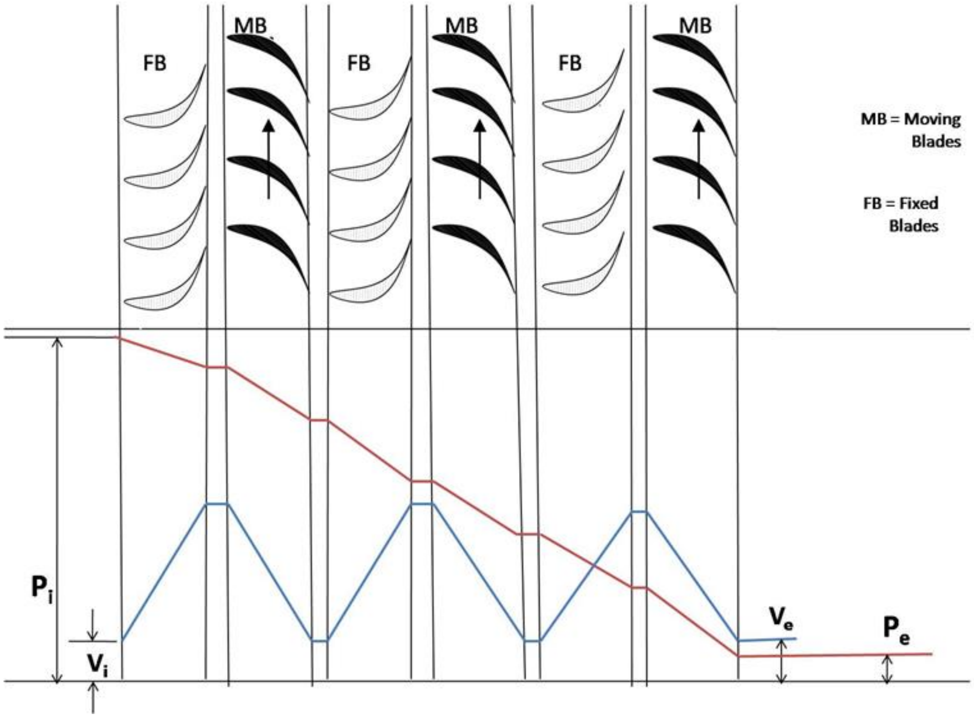
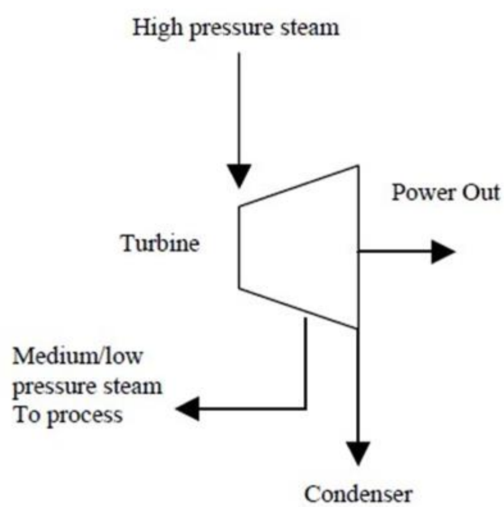


Figure 3

Extraction Steam Turbine

The extraction turbine contains two outlets as shown in figure 1. The first outlet extracts the steam with intermediate pressure for the feeding of the heating process while the second outlet extracts the remaining steam with low-pressure steam for the condensation. The extraction of heat from the first outlet can be stopped to generate more output. Steam control valves at this outlet make this steam very flexible and allow adjusting the output as per demand. The steam from the second outlet goes to the condensation chamber where cooling water brings the temperature of the steam down. The condensed water then goes back to the boiler for the regeneration of the electricity of power, therefore, it is also known as the regenerative steam turbine. The scheme of extraction turbine with cogeneration system is shown in figure.



Back-pressure steam turbine /non-condensing steam turbine

The non-condensing steam turbine uses high-pressure steam for the rotation of blades. This steam then leaves the turbine at the atmospheric pressure or lower pressure. The pressure of outlet steam depends on in the load, therefore, this turbine is also known as the back-pressure steam turbine. This low-pressure steam uses for processing and no steam is used for condensation. The schematic diagram of the back process steam turbine with cogeneration system is shown in figure.