Turbomachinary IMP questions and answers.

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Turbomachinary

1. Sketch Pelton wheel bucket and explain the effect of its size, shape and number on its function.

The Pelton wheel is a type of water turbine used to convert the kinetic energy of a high-velocity water jet into mechanical energy. It consists of a rotor with a series of buckets or cups arranged around its perimeter. Here's an explanation of how the size, shape, and number of buckets affect the function of a Pelton wheel:

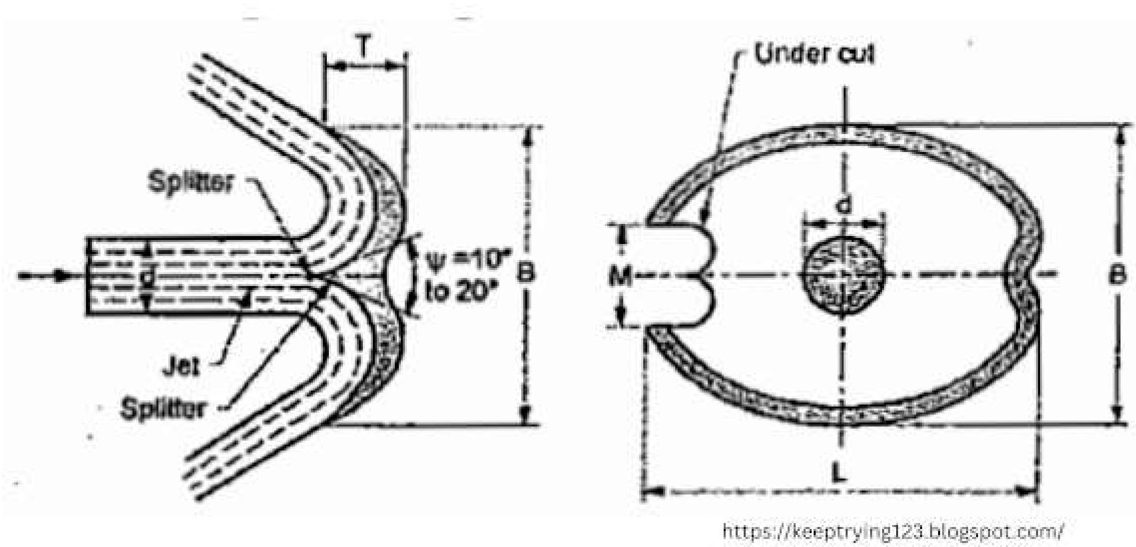


Fig. Bucket

1. Size of Buckets: The size of the buckets on a Pelton wheel has a significant impact on its function. Larger buckets allow for a greater volume of water to be captured, resulting in higher torque and power output. Additionally, larger buckets can accommodate higher flow rates, making the wheel suitable for high-power applications. Conversely, smaller buckets are more suitable for low-power applications with lower flow rates.

2. Shape of Buckets: The shape of the buckets on a Pelton wheel influences the efficiency and performance of the turbine. The most common bucket shape is hemispherical or semispherical, as it helps in efficiently capturing and redirecting the water jet. The curved shape allows the water to be deflected with minimal energy losses. Other bucket shapes, such as rectangular or curved buckets, may be used for specific applications depending on the flow characteristics and design requirements.

3. Number of Buckets: The number of buckets on a Pelton wheel affects the overall efficiency and smoothness of operation. Increasing the number of buckets enhances the balance and stability of the wheel, reducing vibrations and ensuring smoother rotation. Additionally, a higher number of buckets allows for better utilization of the water jet's energy by distributing the load evenly around the circumference of the wheel.

2. Explain the functions of following 1.casing of Pelton wheel 2. Notch of bucket 3. Governing mechanism.

1. Casing of Pelton Wheel:

The casing of a Pelton wheel serves several important functions:

- Enclosure: The casing encloses the entire Pelton wheel assembly, providing a protective housing for the turbine components. It prevents water from splashing out and helps maintain a controlled environment around the wheel.

- Guide Vanes: The casing houses adjustable guide vanes positioned upstream of the Pelton wheel. These guide vanes control the flow of water entering the buckets of the wheel. By adjusting the guide vanes, the operator can optimize the turbine's performance by regulating the water jet's angle and velocity.

- Pressure Regulation: The casing also plays a role in regulating the pressure of the water jet. It allows for the establishment of a controlled environment around the wheel, maintaining a consistent pressure level for efficient turbine operation.

- Flow Direction: The casing directs the water jet into the buckets of the Pelton wheel, ensuring that the water strikes the buckets at the appropriate angle and position. This allows for efficient transfer of kinetic energy from the water to the wheel.

- Water Collection: After the water impinges on the buckets, the casing collects and channels the spent water away from the wheel, directing it back into the tailrace or the water system for reuse or discharge.

2. Notch of Bucket:

The notch of a bucket in a Pelton wheel refers to the opening or gap present at the trailing edge of each bucket. The notch serves a vital function in the turbine operation:

- Water Discharge: The notch allows for the efficient discharge of the spent water from the buckets after it has transferred its kinetic energy to the wheel. The notch ensures that the water does not obstruct the rotation of the wheel and flows out smoothly.

- Pressure Equalization: As the water exits the bucket through the notch, it helps equalize the pressure within the bucket, preventing excessive pressure differentials that could adversely affect the bucket's stability.

- Prevention of Water Hammer: The presence of the notch helps to mitigate the occurrence of water hammer or sudden pressure surges that can potentially damage the buckets or the wheel due to rapid deceleration of the water.

3. Governing Mechanism:

The governing mechanism in a Pelton wheel system is responsible for controlling the turbine's speed and power output. It ensures that the turbine operates within safe and desired operational limits. The governing mechanism performs the following functions:

- Speed Regulation: The governing mechanism adjusts the flow rate of water entering the Pelton wheel based on the turbine's speed. It modulates the opening or closing of the guide vanes to maintain a consistent speed under varying load conditions.

- Load Control: The governing mechanism monitors the power demand and adjusts the water flow accordingly to match the required load. By controlling the guide vanes or adjusting the flow control valves, it ensures that the turbine operates at an optimal point for maximum efficiency.

- Stability and Protection: The governing mechanism safeguards the turbine from potential damages due to excessive speeds or overloading. It includes safety features such as overspeed protection, emergency shutdown mechanisms, and control systems that maintain stable operation even during sudden load changes.

3. Compare Francis and Kaplan Turbine.

Francis Turbine	Kaplan Turbine
1. Suitable for medium to high head applications (30 to 600 meters)	Suitable for low to medium head applications (2 to 70 meters)
2. Radial flow turbine	Axial flow turbine
3. Best suited for medium flow rates	Best suited for high flow rates
4. Runner blades are fixed	Runner blades are adjustable
5. Lower specific speed range	Higher specific speed range
6. Efficiency is generally higher at part load conditions	Efficiency is generally higher at full load conditions
7. Typically used in dam and reservoir projects	Frequently used in river or canal-based installations
8. Operates in a wide range of head and flow variations	Performs optimally in a narrow range of head and flow variations

9. Requires a large and complex draft tube	Requires a shorter and simpler draft tube
10. More suitable for off-design conditions and varying water flow	More suitable for constant design conditions and consistent water flow

4. Explain the following terms.
i) Spcific speed (ii) Run away speed (iii) Degree of reaction

i) Specific Speed:
Specific speed is a parameter used to characterize the performance and design of a centrifugal pump or turbine. It is a dimensionless number that represents the relative speed at which the machine operates and provides a basis for comparing different pump or turbine designs.

Specific speed (Ns) is calculated using the formula:

$$N_s = \sqrt{\frac{N^2 P}{H^{5/2}}} = \frac{N\sqrt{P}}{H^{5/4}}$$

Where:
- N is the rotational speed of the machine in revolutions per minute (rpm).
- P Power developed or shaft power.
- H is the head, which represents the energy imparted to the fluid by the machine, usually measured in meters (m).

ii) Runaway Speed:
Runaway speed, also known as overspeed, refers to the maximum rotational speed that a machine, such as a turbine or compressor, can reach when there is an uncontrolled increase in speed due to a loss of load or other operating conditions.

In the context of a turbine, runaway speed occurs when the turbine's speed exceeds the design limits, typically due to sudden load rejection or loss of system demand. Runaway speed can be hazardous as it can result in mechanical failures, excessive vibrations, and potential damage to the turbine and connected equipment.

To prevent runaway speed, turbines and other rotating equipment are equipped with safety devices such as overspeed trip systems. These systems monitor the rotational speed and activate protective measures, such as activating emergency brakes or shutting down the machine, when the speed exceeds a predetermined threshold.

iii) Degree of Reaction:

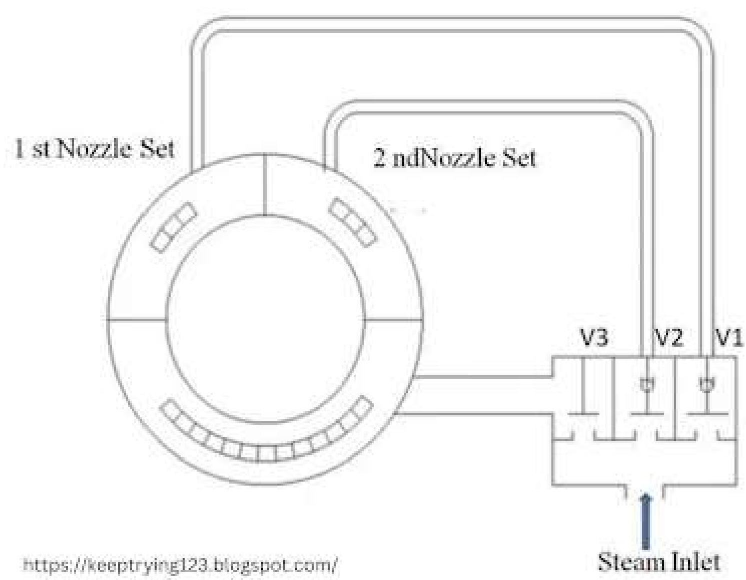
The degree of reaction is a parameter used to describe the internal flow characteristics of a turbine. It represents the proportion of the total energy conversion that occurs in the rotor blades compared to the stator (guide) blades.

In a turbine, energy is extracted from the fluid as it passes through both the rotor and stator blades. The degree of reaction is expressed as a percentage and is calculated as:

5. Explain nozzle governing with sketch.

Nozzle governing refers to the control mechanism used to regulate the flow of a fluid through a nozzle, typically in the context of steam turbines or internal combustion engines. It ensures that the flow rate and pressure of the fluid remain within desired limits.

To explain nozzle governing, let's consider a simplified diagram of a nozzle system:



In this diagram:

In nozzle governing, one common approach involves the use of a movable nozzle ring or a set of nozzle guide vanes (NGVs). These components are located at the inlet of the nozzle and can be adjusted to change the effective area through which the fluid flows.

When the nozzle is fully open, the fluid flows through the nozzle with minimal obstruction, resulting in high flow rate and low pressure at the outlet. On the other hand, when the nozzle is partially closed, the flow area is reduced, causing an increase in pressure at the outlet and a decrease in flow rate.

The position of the nozzle ring or NGVs is controlled by a governing mechanism, which can be based on various factors such as speed, load, or other operating conditions. This mechanism ensures that the nozzle adjusts its opening based on the requirements of the system.

For example, in a steam turbine, the governing mechanism might receive signals related to the power demand of the generator. If the power demand increases, the mechanism will actuate the nozzle ring or NGVs to open, allowing more steam to flow through the nozzle and drive the turbine at a higher speed. Similarly, if the power demand decreases, the mechanism will close the nozzle to reduce the flow rate and maintain the desired speed.

By regulating the nozzle opening, nozzle governing enables the system to maintain stable operation and respond to changing load conditions efficiently.

6. What is compounding of steam turbine? Explain any one of the following. 1. Velocity compounding 2. Pressure compounding

Compounding in steam turbines refers to the division of the pressure drop and expansion of steam into multiple stages, allowing for better energy conversion and increased efficiency. There are two common types of compounding used in steam turbines: velocity compounding and pressure compounding.

1. Velocity Compounding:

Velocity compounding, also known as velocity staging or Curtis compounding, is a method used to increase the overall efficiency of a steam turbine by dividing the expansion of steam into multiple velocity stages. This technique involves using a series of velocity-compounded impulse stages, where each stage extracts energy from the steam by means of a set of moving blades, called buckets or nozzles.

In a velocity-compounded steam turbine, the steam is initially passed through a high-pressure nozzle, where it expands and gains velocity. This high-velocity steam is directed onto a set of moving blades that are designed to extract energy from the steam. After passing through the first stage, the steam is redirected to another set of nozzles and blades, where the process is repeated. This continues for multiple stages, with the steam gradually losing velocity and pressure as it passes through each stage.

The advantage of velocity compounding is that it allows for a gradual reduction of steam velocity and pressure, which helps to minimize energy losses due to excessive turbulence or shock waves. By dividing the expansion process into multiple stages, the overall efficiency of the turbine can be improved, leading to a more efficient conversion of steam energy into mechanical work.

2. Pressure Compounding:
Pressure compounding, also known as pressure staging, is another method used in steam turbines to improve efficiency. In pressure compounding, the steam is expanded in multiple stages, with each stage operating at a successively lower pressure.

In a pressure-compounded steam turbine, the initial high-pressure steam is directed to the first set of moving blades, which extracts energy from the steam. The steam leaving the first stage is then passed through a set of stationary blades, known as diaphragms, which redirect the steam to the next stage at a lower pressure. This process is repeated for several stages, with each stage operating at a progressively lower pressure.

The advantage of pressure compounding is that it allows for a more efficient expansion of steam by reducing the temperature drop across each stage. This helps to minimize energy losses due to condensation or excessive temperature differences. Additionally, pressure compounding enables the turbine to handle a larger pressure drop while maintaining high efficiency.

7. Explain in brief different losses in steam turbine.

In a steam turbine, there are several different types of losses that can occur, affecting its overall efficiency.

1. Steam Leakage: Steam leakage refers to the loss of steam through clearances between rotating and stationary components of the turbine. It can occur at various points, such as blade tips, shaft seals, and glands. Steam leakage reduces the mass flow rate through the turbine and decreases its efficiency.

2. Friction Losses: Friction losses occur due to the interaction between the steam and the internal surfaces of the turbine. As the steam flows through the blades and other components, frictional forces cause energy losses in the form of heat. These losses reduce the available energy for power generation.

3. Blade Profile Losses: Blade profile losses, also known as aerodynamic losses, are caused by the shape and design of the turbine blades. These losses occur due to factors such as blade thickness, blade angle, and flow separation. Inefficient blade profiles can lead to energy losses as the steam passes through the blades.

4. Mechanical Losses: Mechanical losses result from the internal mechanical friction and resistance within the turbine. These losses occur in components such as bearings, couplings, and gears. Mechanical losses manifest as heat and vibrations, reducing the turbine's overall efficiency.

5. Condensation Losses: Condensation losses occur when the steam undergoes rapid condensation as it expands through the turbine. The sudden phase change from steam to water leads to a loss of energy. Proper design and control of steam conditions can help minimize condensation losses.

6. Radiation and Windage Losses: Radiation losses refer to the heat transferred from the turbine to its surroundings through radiation. Windage losses occur due to the resistance faced by rotating components moving through the surrounding air. These losses contribute to a decrease in the turbine's efficiency.

8. Explain different types of impellers used for centrifugal pumps.

Centrifugal pumps utilize rotating impellers to transfer fluid by converting rotational energy into hydrodynamic energy. There are several types of impellers commonly used in centrifugal pumps, each designed for specific applications and operating conditions. The main types of impellers used in centrifugal pumps are:

1. Open Impeller:
An open impeller consists of blades attached to a central hub without any surrounding shrouds or covers. This design allows for easy passage of fluid and solid particles, making it suitable

for pumping liquids with high solid content or abrasive materials. Open impellers are commonly used in wastewater treatment, mining, and chemical industries.

2. Semi-Open Impeller:
A semi-open impeller has blades attached to a central hub, but with a partial shroud that covers one side of the impeller. This design improves the impeller's efficiency by directing the fluid flow and reducing recirculation losses. Semi-open impellers are used in applications where the pumped fluid may contain small solids or fibrous materials, such as sewage pumping or handling slurries.

3. Closed Impeller:
A closed impeller consists of blades enclosed between two shrouds or covers, forming a fully contained structure. This design increases the impeller's efficiency by minimizing fluid recirculation and promoting a more uniform flow. Closed impellers are commonly used in applications that require higher pressures or higher efficiency, such as water supply systems, heating and cooling systems, and industrial processes.

4. Shrouded Impeller:
A shrouded impeller is similar to a closed impeller, but with the blades and shrouds extending all the way to the outer diameter of the impeller. This design provides better support to the blades, improving the impeller's stability and reducing vibration. Shrouded impellers are used in high-performance applications, such as high-pressure pumping and large-scale industrial processes.

5. Backward-Curved Impeller:
A backward-curved impeller has blades curved away from the direction of rotation. This design allows for efficient handling of fluids with high specific gravity or low viscosity. Backward-curved impellers are typically used in applications that require low flow rates and high head, such as HVAC systems, clean water supply, and circulation systems.

6. Forward-Curved Impeller:
A forward-curved impeller has blades curved towards the direction of rotation. This design is suitable for handling fluids with low specific gravity or high viscosity. Forward-curved impellers are used in applications that require high flow rates and low head, such as ventilation systems, air conditioning units, and exhaust systems.

9. What do you mean by cavitation? Explain the phenomenon of cavitation in centrifugal pump.

Cavitation is a phenomenon that can occur in centrifugal pumps when the local pressure of the liquid falls below its vapor pressure, causing the formation and subsequent collapse of vapor bubbles or cavities within the fluid. This can result in various issues and damage to the pump and surrounding equipment.

When a centrifugal pump operates, it creates a low-pressure zone at the inlet, which draws fluid into the pump. As the fluid enters the impeller, it experiences an increase in velocity and a decrease in pressure. If the pressure drops too much and reaches or falls below the vapor pressure of the liquid, the liquid starts to vaporize and form small vapor bubbles or cavities.

These vapor bubbles travel along with the fluid flow towards the higher-pressure regions of the pump, such as the discharge side. However, as the fluid reaches areas of higher pressure, the vapor bubbles cannot withstand the increased pressure and collapse or implode violently. This implosion creates shockwaves and high-energy forces that can damage the impeller, pump casing, and other components. The collapse of these vapor bubbles also leads to the formation of tiny, highly localized liquid jets that can erode the material surfaces.

Cavitation in centrifugal pumps can be caused by various factors, including:

1. Insufficient NPSHa (Net Positive Suction Head available): NPSHa is the difference between the suction pressure and the vapor pressure of the fluid. If the NPSHa is too low, it means the available pressure is insufficient to prevent the fluid from vaporizing, leading to cavitation.

2. High liquid velocity: Excessive liquid velocity within the pump can cause a significant drop in pressure, increasing the likelihood of cavitation.

3. High impeller speed: Higher rotational speeds can lead to lower pressure regions within the pump, which can trigger cavitation.

4. High fluid temperature: Higher temperatures can reduce the vapor pressure of the liquid, making it more prone to cavitation.

The consequences of cavitation in centrifugal pumps include reduced pump performance, decreased efficiency, increased vibration and noise levels, erosion or pitting of impeller and casing surfaces, and potential failure of pump components.

To prevent cavitation, several measures can be taken, including:

1. Ensuring adequate NPSHa: Properly sizing the pump and ensuring the available suction pressure is sufficient to avoid vaporization of the fluid.

2. Modifying impeller design: Using impellers with appropriate blade profiles, such as inducers or low NPSH impellers, to minimize the risk of cavitation.

3. Reducing fluid velocity: Employing flow control devices, such as throttling valves or impeller trimming, to maintain suitable fluid velocities and prevent excessive pressure drops.

4. Cooling the fluid: If feasible, cooling the fluid can help increase the vapor pressure and reduce the likelihood of cavitation.

10. Explain NPSH in centrifugal pump.

NPSH stands for Net Positive Suction Head, which is a critical parameter in the operation of centrifugal pumps. It is a measure of the amount of pressure energy available at the pump's inlet to prevent cavitation from occurring. NPSH is expressed in terms of head (usually in meters or feet) and is determined by the characteristics of the pump system and the properties of the pumped fluid.

NPSH is divided into two components:

1. NPSHa (Net Positive Suction Head available):
NPSHa represents the absolute pressure head at the pump suction flange, taking into account the pressure at the pump's inlet, atmospheric pressure, and the liquid's velocity head. It indicates the total pressure available to feed the pump, including the pressure head from the liquid's elevation above the pump's reference point (usually the centerline of the impeller) and any additional pressure or suction sources.

NPSHa is influenced by factors such as the height of the liquid source above the pump, the pressure in the supply tank, any additional suction piping losses, and the velocity of the liquid entering the pump. It is important to ensure that NPSHa is sufficient to prevent cavitation, as insufficient NPSHa can lead to vaporization of the liquid and subsequent damage to the pump.

2. NPSHr (Net Positive Suction Head required):
NPSHr represents the minimum pressure head required at the pump's inlet to avoid cavitation. It is determined by the pump manufacturer through testing and is specific to each pump model and size. NPSHr takes into account the pump's design, impeller geometry, operating speed, and other factors that affect cavitation.

NPSHr is essentially the suction side counterpart of NPSHa. It indicates the pressure head needed by the pump to prevent cavitation under specific operating conditions. The pump manufacturer typically provides the NPSHr value in the pump's performance curves or specifications.

To ensure reliable and efficient pump operation, the NPSHa must be greater than the NPSHr. This ensures that the pump has sufficient pressure energy available at the inlet to avoid cavitation. If NPSHa is less than NPSHr, cavitation is likely to occur, resulting in reduced pump performance, increased vibration and noise levels, and potential damage to the pump.

11. What is priming of centrifugal pump ? Why it is necessary?

Priming of a centrifugal pump refers to the process of filling the pump casing and suction piping with liquid to remove any air or gases present in the system before starting the pump. It ensures that the pump is fully filled with the pumped fluid and eliminates any air pockets, which can hinder the pump's performance and potentially lead to cavitation.

Priming is necessary for centrifugal pumps for the following reasons:

1. Removal of Air: Centrifugal pumps are designed to handle liquids, not gases. When a pump is not primed, there may be pockets of air or gases trapped in the pump casing or suction piping. If the pump starts with air present, it can lead to issues such as reduced flow, decreased efficiency, and potential damage due to cavitation. Priming the pump ensures the removal of air and creates a continuous liquid column for proper pump operation.

2. Improved Pump Performance: Centrifugal pumps rely on the presence of liquid for proper functioning. Air or gases in the system can disrupt the flow dynamics, causing inefficiencies and reduced performance. By priming the pump and ensuring it is fully filled with liquid, the pump can operate at its designed efficiency, providing the intended flow rate and pressure.

3. Prevention of Cavitation: Cavitation is a detrimental phenomenon that occurs when the pressure at the pump's inlet drops below the vapor pressure of the liquid, resulting in the formation and collapse of vapor bubbles. Air or gas pockets in the pump can contribute to cavitation. Priming the pump eliminates air and ensures that the pump is completely filled with liquid, reducing the risk of cavitation and associated damage to the pump.

4. Protection of Pump Components: Air or gas in the pump can lead to dry running, which can cause excessive heat generation and damage to the pump's impeller and seals. By priming the pump and ensuring proper lubrication and cooling from the pumped fluid, the risk of damage to pump components is minimized.

The priming process can be accomplished through various methods depending on the specific pump design and application. Common methods include manually filling the pump casing and suction piping with liquid, using a priming pump or ejector system to evacuate air and draw in the liquid, or employing self-priming pump designs that can automatically remove air and prime themselves.

12. Explain various efficiencies of a centrifugal pump.

A centrifugal pump has several efficiency parameters that measure its performance in converting mechanical power into hydraulic power. These efficiency parameters provide insights into the effectiveness of the pump and can help in evaluating its overall performance. Here are the main efficiencies of a centrifugal pump:

1. Overall Efficiency (η):
The overall efficiency of a centrifugal pump, denoted by η (eta), is the ratio of the hydraulic power output to the mechanical power input. It represents the effectiveness of the pump in converting the mechanical energy supplied to it into hydraulic energy transferred to the fluid. The overall efficiency takes into account all losses in the pump, including friction losses, leakage losses, and losses due to internal recirculation.

η = (Hydraulic Power Output / Mechanical Power Input) * 100%

2. Hydraulic Efficiency (ηh):
The hydraulic efficiency of a centrifugal pump, denoted by ηh, is the ratio of the hydraulic power output to the water power input. It indicates how efficiently the pump converts the supplied power into useful hydraulic power without considering the mechanical losses in the pump. Hydraulic efficiency takes into account losses due to hydraulic friction, impeller design, and other factors affecting the conversion of mechanical power into hydraulic power.

ηh = (Hydraulic Power Output / Water Power Input) * 100%

3. Volumetric Efficiency (ηv):
Volumetric efficiency, denoted by ηv, measures the efficiency of a centrifugal pump in terms of its ability to transfer a given volume of fluid per unit time. It is the ratio of the actual flow rate

delivered by the pump to the theoretical flow rate based on the pump's displacement volume. Volumetric efficiency takes into account factors such as leakage losses and slip between the impeller and the pump casing.

ηv = (Actual Flow Rate / Theoretical Flow Rate) * 100%

4. Mechanical Efficiency (ηm):

The mechanical efficiency of a centrifugal pump, denoted by ηm, is the ratio of the water power input to the mechanical power input. It represents the efficiency of the pump in converting mechanical power into the power transmitted to the fluid, without considering losses in the hydraulic or volumetric aspects.

ηm = (Water Power Input / Mechanical Power Input) * 100%

5. Overall Motor Efficiency (ηmotor):

The overall motor efficiency, denoted by ηmotor, is the efficiency of the electric motor or prime mover that drives the centrifugal pump. It represents the ratio of the hydraulic power output to the electrical power input to the motor. This efficiency parameter takes into account losses in the motor, such as electrical losses and friction losses.

ηmotor = (Hydraulic Power Output / Electrical Power Input to Motor) * 100%

13. Explain Construction and working of centrifugal compressor with neat diagram.

Construction of Centrifugal Compressor:

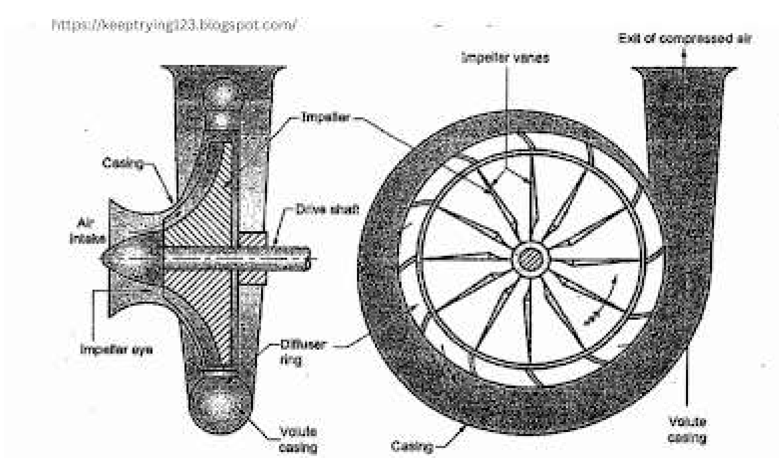


Fig. Centrifugal compressor

A centrifugal compressor consists of the following main components:

1. Impeller: The impeller is a rotating component with curved blades that accelerates the incoming gas. It is connected to a shaft and driven by a motor. The impeller's shape and design play a crucial role in the compressor's performance.

2. Diffuser: The diffuser is a stationary component that follows the impeller. It converts the high-velocity, low-pressure gas discharged from the impeller into high-pressure, low-velocity gas. The diffuser achieves this by gradually increasing the cross-sectional area of the gas flow.

3. Casing: The casing or housing encloses the impeller and diffuser. It is designed to provide support, maintain alignment, and create a pressure boundary to contain the compressed gas.

4. Inlet and Outlet: The compressor has an inlet where the gas enters and an outlet where the compressed gas is discharged. These are typically connected to piping systems for gas intake and distribution.

Working of Centrifugal Compressor:

1. Gas Intake: The gas enters the compressor through the inlet and flows into the impeller. The impeller's rotation imparts centrifugal force to the gas, causing it to move radially outward.

2. Gas Acceleration: As the gas moves radially outward, it gains velocity due to the impeller's rotating blades. This increase in velocity leads to a decrease in pressure according to Bernoulli's principle.

3. Diffusion: After leaving the impeller, the high-velocity, low-pressure gas enters the diffuser. The diffuser's gradually expanding passage converts the kinetic energy of the gas into pressure energy. This process reduces the gas velocity and increases its pressure.

4. Gas Discharge: The compressed gas leaves the diffuser and flows into the casing. From there, it is directed towards the outlet and discharged into the downstream piping system.

5. Cooling and Lubrication: During the compression process, the gas temperature rises. Centrifugal compressors often incorporate cooling systems to maintain temperature within acceptable limits. Additionally, the compressor may have lubrication systems to ensure smooth operation and reduce friction between rotating components.

The continuous rotation of the impeller maintains a steady flow of gas through the compressor, resulting in a continuous compression process.

14. Explain Construction and working of axial flow compressor with neat diagram.

Construction of an Axial Flow Compressor:

An axial flow compressor is a type of compressor commonly used in gas turbine engines and other applications where high volumes of air or gas need to be compressed. It consists of the following main components:

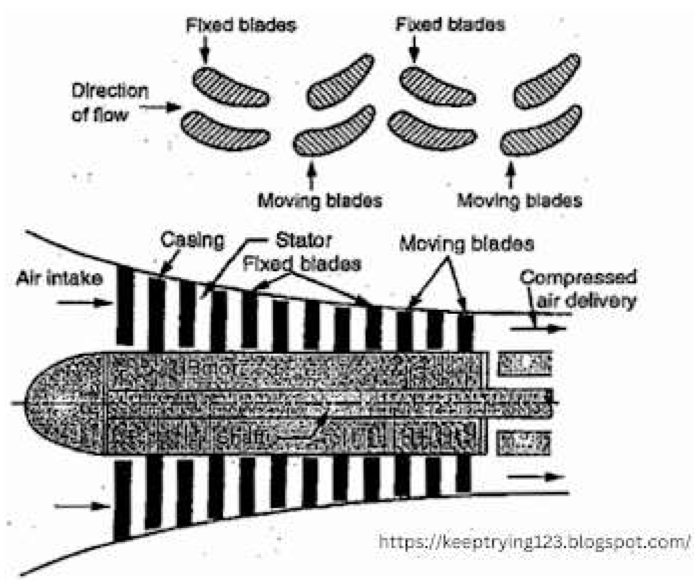


Fig. axial flow compressor

1. Rotor: The rotor is the central rotating component of the axial flow compressor. It consists of a series of airfoil-shaped blades mounted on a shaft. The rotor blades are designed to accelerate the incoming air or gas and transfer energy to it.

2. Stator: The stator is a stationary component located downstream of the rotor. It also consists of airfoil-shaped blades. The stator blades serve to guide the airflow and redirect it from the rotor to the next stage of compression. They help convert the kinetic energy of the air into pressure energy.

3. Casing: The casing, also known as the compressor housing, surrounds the rotor and stator and provides structural support. It contains the rotating blades and stator blades, ensuring that the airflow is confined within the compressor.

Working of an Axial Flow Compressor:

The working principle of an axial flow compressor involves the continuous acceleration and compression of air or gas as it flows through the rotor and stator blades. Here are the main steps in the working of an axial flow compressor:

1. Inlet and Diffuser: The incoming air enters the compressor through an inlet section. The inlet may include a diffuser, which slows down the incoming air and increases its pressure before it enters the rotor blades.

2. Rotor Blades: The rotating rotor blades, also known as compressor blades, accelerate the air and impart kinetic energy to it. As the rotor blades rotate, they create a pressure gradient that compresses the air in the axial direction. The shape and angle of the rotor blades are designed to efficiently convert the rotational energy into kinetic energy and compression.

3. Stator Blades: The compressed air leaving the rotor blades enters the stator section. The stator blades guide the airflow, redirecting it to flow in a more axial direction and further increasing its pressure. The stator blades convert the remaining kinetic energy of the airflow into pressure energy, preparing it for the next stage of compression.

4. Multiple Stages: Axial flow compressors typically consist of multiple stages, each consisting of a rotor and stator pair. The compressed air from one stage enters the next stage for further compression. This multi-stage design allows for higher pressure ratios and more efficient compression.

5. Outlet: After passing through multiple stages, the air exits the axial flow compressor at a significantly higher pressure than the inlet. It is then directed to the next component in the system, such as a combustion chamber or another compressor stage.

15. Differentiate between centrifugal compressor and axial flow compressor.

Parameters	Centrifugal Compressor	Axial Flow Compressor
Flow Direction	Radial outward from the center	Axial (parallel to the compressor shaft)
Compression	Dynamic compression (kinetic energy	Dynamic compression (kinetic energy conversion)

Mechanism	conversion)	
Blade Orientation	Perpendicular to the shaft	Parallel to the shaft
Pressure Ratio Range	Low to medium	Medium to high
Efficiency	Typically higher than axial flow compressors	Efficiency can vary based on design and application
Size	Compact design	Longer and more elongated
Operating Range	Suitable for a wide range of flow rates	Optimal for high flow rates and large volume flows
Applications	HVAC systems, air compression, small gas turbines	Gas turbine engines, large-scale industrial compressors, aircraft engines
Advantages	Lower initial cost, better surge tolerance	High flow capacity, better efficiency at high speeds
Disadvantages	Limited pressure ratio, lower efficiency at high speeds	Limited surge margin, larger size and footprint

16. Explain in detail surging and choking phenomenon in centrifugal compressor.

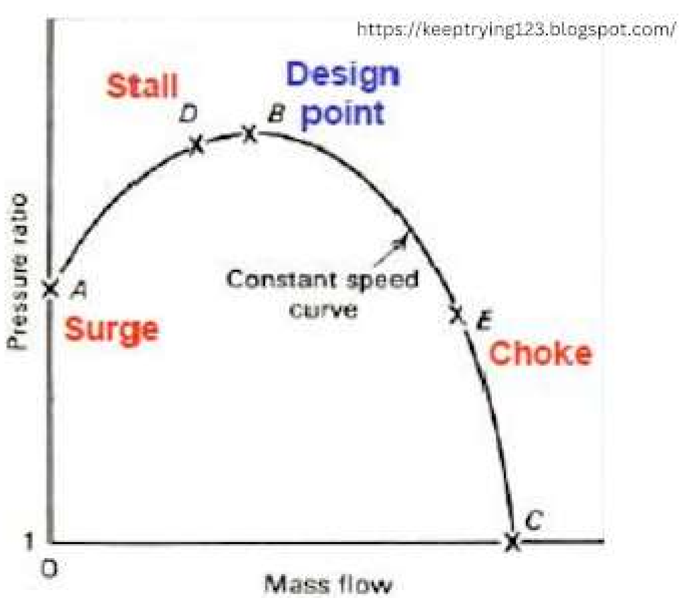


Fig. Surging choking & Stalling

1. Surging:

Surging is a flow instability phenomenon that occurs in centrifugal compressors when the flow rate through the compressor becomes unstable. It is characterized by a pulsating or oscillating flow pattern and is accompanied by a significant decrease in compressor performance and efficiency. Surging is typically associated with a loud noise resembling a "roar" or "rumble" and can lead to severe mechanical damage if not addressed promptly.

Causes of Surging:

Surging can be caused by several factors, including:

a) Excessive Flow Resistance: If there is a sudden increase in flow resistance downstream of the compressor, such as a closed valve or blocked discharge line, it can create a surge condition by limiting the flow rate and causing a buildup of pressure within the compressor.

b) Rapid Changes in Load: Abrupt changes in the system's load or operating conditions, such as a sudden decrease in demand or a rapid closure of a downstream valve, can disrupt the flow balance within the compressor and trigger surging.

c) Insufficient System Resistance: In systems with low resistance to flow, such as short discharge piping or a low-pressure downstream system, surging can occur when the compressor produces more flow than the downstream system can handle.

d) Inlet Flow Disturbances: Unsteady or distorted flow at the compressor inlet, caused by factors such as inlet restrictions, recirculation, or flow separation, can disrupt the compressor's stable operation and lead to surging.

Effects of Surging:

Surging has several detrimental effects on the centrifugal compressor and the overall system, including:

- Reduced Efficiency: Surging causes fluctuations in pressure and flow, leading to reduced compressor efficiency and performance. The compressor operates at lower pressure ratios, resulting in lower compressed air or gas output.

- Vibration and Mechanical Stress: The oscillating flow patterns associated with surging create dynamic forces within the compressor, resulting in excessive vibrations and mechanical stresses. These can lead to damage to the impeller, bearings, seals, and other compressor components.

- Increased Energy Consumption: Surging increases the power consumption of the compressor as it struggles to maintain stable flow. The energy wasted during surging can significantly impact the overall energy efficiency of the system.

- Potential Component Damage: Prolonged or severe surging can cause mechanical damage to the compressor, including fatigue failure of blades, excessive wear, and shaft deflection. This can result in costly repairs and downtime.

Prevention and Control of Surging:
To prevent or control surging in centrifugal compressors, the following measures can be taken:

- Proper System Design: Ensure the compressor system is properly designed, taking into account factors such as discharge line sizing, pressure regulation, and system resistance. Adequate piping lengths and diameters can help provide the necessary system stability.

- Surge Control Devices: Install surge control devices, such as anti-surge valves or recycle lines, that can divert excess flow back to the compressor inlet during surge conditions. These devices help stabilize the flow and protect the compressor from surging.

- Control System Optimization: Implement advanced control strategies that continuously monitor and adjust the compressor operation based on system conditions. These strategies can include surge detection algorithms and adaptive control algorithms to maintain stable operation.

2. Choking:
Choking, also known as compressor stall or flow choking, is a condition that occurs when the airflow through the compressor becomes restricted or blocked, leading to a significant reduction in compressor performance and flow capacity. Choking is characterized by a sudden drop in pressure ratio and can lead to compressor instability and damage.

Causes of Choking:
Choking can occur due to various factors, including:

a) High Pressure Ratios: Operating the centrifugal compressor

at high pressure ratios beyond its design limits can lead to choking. At these high ratios, the flow velocity through the compressor reaches sonic or supersonic speeds, causing flow separation and blockage.

b) Compressor Fouling: Accumulation of dirt, debris, or icing on the compressor blades can disrupt the airflow, leading to flow blockage and choking.

c) Inlet Flow Disturbances: Unsteady or distorted flow conditions at the compressor inlet, such as vortices or recirculation zones, can cause flow separation and choking.

Effects of Choking:
Choking in a centrifugal compressor has several effects, including:

- Reduced Flow Capacity: Choking significantly restricts the flow capacity of the compressor, resulting in a reduced volume flow rate and limited output.

- Loss of Efficiency: Choking causes a drop in pressure ratio, leading to reduced compressor efficiency and performance. The compressor operates at lower efficiency points, requiring more power for the same flow rate.

- Vibrations and Mechanical Stress: Choking can induce flow instabilities and unsteady pressure fluctuations, causing vibrations and mechanical stresses that may lead to component damage.

Prevention and Control of Choking:
To prevent or control choking in centrifugal compressors, the following measures can be taken:

- Operate within Design Limits: Avoid operating the compressor at pressure ratios beyond its design limits. Ensure the compressor is operating within its specified range to prevent choking.

- Regular Maintenance: Perform routine maintenance to keep the compressor blades clean and free from dirt, debris, or ice accumulation. Regular inspections and cleaning can help prevent choking caused by fouling.

- Inlet Air Conditioning: Control and condition the inlet air to minimize flow disturbances and prevent choking due to unsteady or distorted inlet flow conditions.

- Surge Control Measures: The surge control devices, such as anti-surge valves, used to prevent surging can also help prevent choking by maintaining stable flow and preventing flow restrictions.

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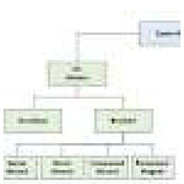

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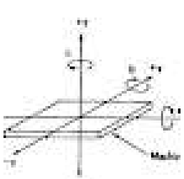

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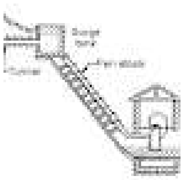

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