Fluid Mechanics

ggnindia.dronacharya.info

https://ggnindia.dronacharya.info/Downloads/Sub-info/RelatedBook/5thSem/FLUID-MACHINES-REFERENCE-BOOK-2.pdf

^⇒book page 734

deewanbittal.wordpress.com

https://deewanbittal.wordpress.com/wp-content/uploads/2017/11/fluid-mechanics-machines-ies-gate-ias-20-years-question-and-answers.pdf

^⇒ from page 257

Francis turbine:

1) Construction details:

a) scroll/spiral/volute casing and its function.

b) guide vanes/wicket gates/stator and its function.

c) runner blades/rotor and its function.

d) draft tube and its function.

2) Velocity triangles at the inlet and exit.

3) Derivation of the power transferred from fluid to the runner/rotor.

4) Derivation of the blade efficiency.

5) Derivation of the degree of reaction.

🔷 Francis Turbine – Flow and Component Summary

Basic Design and Operation

Francis turbines are mixed-flow reaction turbines where water enters radially and exits axially. This design combines characteristics of both radial and axial flow

machines. Key components include:

1. **Spiral Casing**: The water enters through a spiral-shaped casing (volute) that surrounds the runner. This design ensures uniform distribution of water around the entire circumference.
2. **Guide Vanes**: Adjustable guide vanes (wicket gates) control the water flow rate and direct water into the runner at the optimal angle. These are crucial for efficiency control under varying loads (varying RPM).
3. **Runner**: The heart of the turbine consists of curved passages formed between complex 3D blades. The unique shape transforms both the pressure energy and kinetic energy of water into mechanical rotation.
4. **Draft Tube**: After passing through the runner, water discharges through a gradually expanding draft tube that recovers pressure energy by reducing the velocity of the exiting water.

Working Principle

In operation, the Francis turbine works through these sequential steps:

1. Water enters the spiral casing at high pressure and moderate velocity
2. The guide vanes direct the flow to strike the runner blades at the optimal angle
3. As water flows through the curved passages of the runner, it undergoes:
    - A reduction in pressure (reaction component)
    - A change in flow direction (impulse component)
4. This dual energy conversion causes the runner to rotate
5. The draft tube creates a suction effect that further improves efficiency

- **Shaft Orientation**

  → Most machines have **vertical shafts**

  → **Smaller turbines** may have **horizontal shafts**

- **Flow Entry**

  → Water enters from the **penstock**

→ Enters a **scroll casing / volute**

→ **Volute surrounds the runner**

- **Scroll Casing Design**

  → **Cross-sectional area decreases** along the spiral

  → Ensures **constant velocity** of fluid

  → Because water keeps entering the runner → flow in casing reduces

- **Guide Vanes / Wicket Gates**

  → Convert **pressure energy → kinetic energy**

  → **Direct water** onto runner at correct **angle**

  → Are **pivoted**, controlled by a **governing mechanism**

  → Help **regulate flow** with load changes

  → Impart **tangential velocity** → gives **angular momentum** to water

- **Runner Flow**

  → **Mixed flow**: Radial + Tangential

  → **Inward flow**: From **periphery → center**

  → **Specific speed ↑ → Runner height ↑**

  → At exit, water is turned into the **axial direction**

- **Draft Tube**

  → Connects **runner exit → tailrace**

  → **Reduces velocity** of discharged water

  → Minimizes **kinetic energy loss**

  → Allows turbine to be placed **above tailwater level**

  → Helps preserve **available head**

Design and components of Francis turbine

Component	Function
Spiral casing	Distributes water evenly
Runner blades	Converts water energy to mechanical power
Guide vanes	Direct and control water flow
Draft tube	Ensures smooth water exit

> In reaction turbines, only part of the total head is converted to velocity head before reaching the runner

> The working fluid completely fills the runner passages (unlike impulse turbines)

> Both pressure/static head and kinetic energy change gradually as fluid passes through the runner

> The runner passage cross-sectional area changes to accommodate static pressure variations

> Reaction turbines are well-suited for low head applications

> Francis turbines are radial flow hydraulic turbines of the reaction type