Lezione 6 - Classification and Description of Fluid Machine

Direction of energy transfer

↳ $P, h \downarrow, \ell > 0$, motor machines convert fluid energy to mechanical energy

Pressure

↳ Operating machine → mechanical energy → fluid energy, → $P, h \uparrow, \ell < 0$

Volumetric behaviour of fluid

↳ There are two models based on the compressibility.

↳ Incompressible → we use ideal liquid (thermal machines)

↳ Compressible → we use perfect / ideal gas (change in ρ is relevant

Operating way

↳ Volumetric / positive displacement machines → exchange energy through cyclic change of volume or displacement of the fluid. → low flow velocity / flow rate
No limitation on the specific work we can generate given no technological limitations.

↳ Turbo machine energy exchange occurs through continuous interactions between the fluid and rotating components.

↳ high flow velocity / flow rate, limited specific work.
↳ (since ρ is variable, even though h is low)

↳ if we put too much work we can get stall, meaning

that there is a limit to the specific work that we can generate
→ we can increase many rotors

Aero-engines vs. ICE → turbomachinery vs. pistons.

All these engines are called "air-breathing engines"

<Table of classification and nomenclature>

Turbo compressors are not turbo gas engine!

Volumetric machines:
→ Reciprocating machines
→ Rotative machines
→ we capture the fluid in the rotation and depending on the operating way the volume we use to capture can be lower or greater than the original volume, assuming it's compressible.

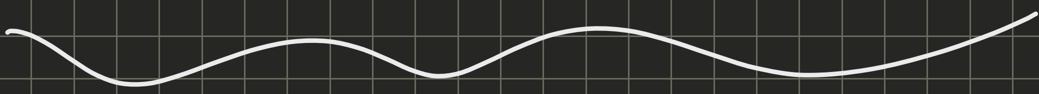
They are suitable for low flowrate and high specific work.

Turbomachines
→ we exchange work by making fluid interact with airfoils.
→ the flow is deflected by the specific shape of the air foil, the flow cannot be deflected too much in one go.
→ To be able to use multiple rotors, we need to use stators

between them to return the flow to the undeflected.

Rotor + Stator = Stage

↳ The deflection is the way in which we generate work.



For compressors.

In turbines, the deflection is very great, creating a large pressure gradient.

Turbo machine architecture

Radial flow machine can be centripetal and centrifugal.

Mixed flow machines → use principles of both.

Axial flow machines

↳ Made for high flow rate, since they have higher cross section so we don't need velocity

↳ They have a limit on the pressure ratio.

Radial flow machines

↳ The work exchanged is proportional to the radial path

↳ They are more efficient since they can deal with higher pressure ratios.

When we have several stages, the flow is complex, so it can be hard to determine if it axial or radial.

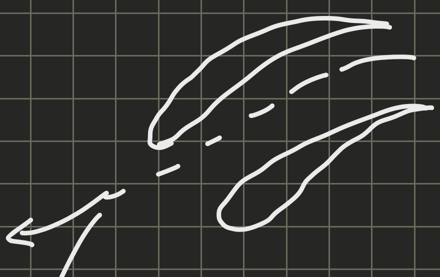
So to be able to classify it, we used to ratio of the peripheral velocities from inlet to outlet
stream lines → Stream surface.

$\boxed{9:38}$ Dealing with mixed flow machine is complex since its a 3D problem. The way we deal with it is taking 3 planes, one is parallel to the base, one is called the meridional plane from this plane we can get the axial and radial component, it allow us to visualize the flow lines and define the stream surface. It also allow to classify between axial and radial components

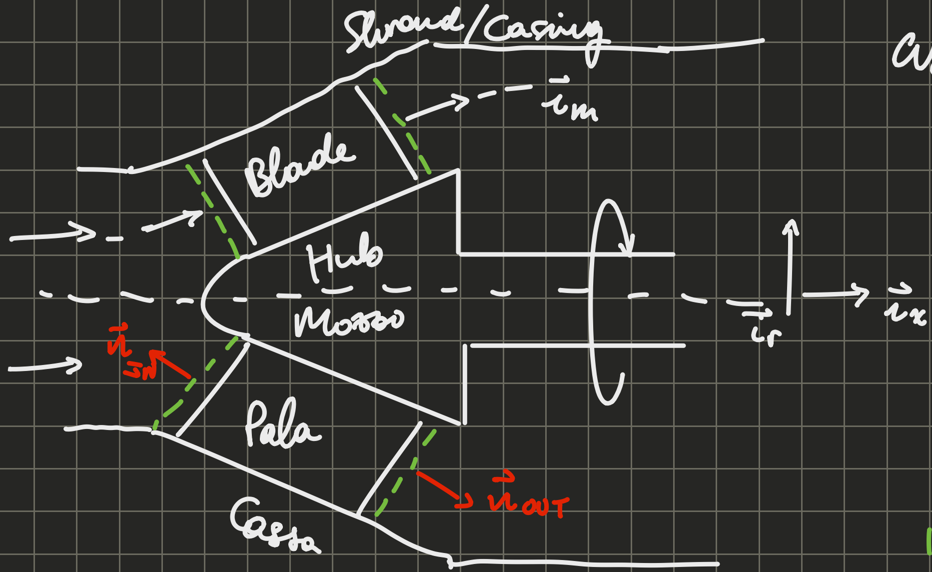
The Blade to blade surface, allow us to visualize the interaction between blades. The horizontal direction is the tangential direction, the vertical is a mix of the axial and radial depending on the shape.

To find the velocity we combine the meridional velocity with the tangential velocity.

Defining the flow in a fixed flow machine



Meridional View



We use a

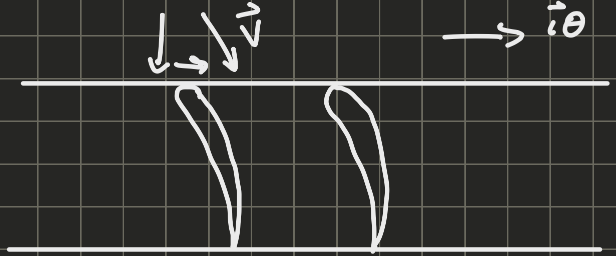
$$\vec{V} = \underbrace{V_x \vec{i}_x + V_r \vec{i}_r}_{} + V_t \vec{i}_\theta$$

$$\vec{V}_m = V_m \vec{i}_m$$

$$\vec{V} = V_m \vec{i}_m + V_t \vec{i}_\theta$$

→ control volume

Blade to Blade



$$\dot{m} = \int_{A_{cross}} \rho \vec{V}\cdot\vec{n}\, dA = \rho V_m A_{cross}$$

cross sectional area

$$\vec{V}\cdot\vec{n} = V_x \vec{n}_x + V_r \vec{n}_r + V_t \cancel{\vec{n}_\theta}^{\,0} = V_m \vec{n}_m = V_m$$

the cross section is perp. to the tangent plane

$$A_{cross} = \pi D_m b$$

b → blade height

D_m → mean diameter.