Application of SFEE.

Nozzle & Diffuser.

A device which increases velocity of any fluid.

⇒ By reducing pressure

Pressure Energy is converted to K.E

Increases pressure

Decreases velocity

Mach Number :-

$$= \frac{\text{velocity of fluid}}{\text{Sonic Velocity}}$$

In an ideal gas

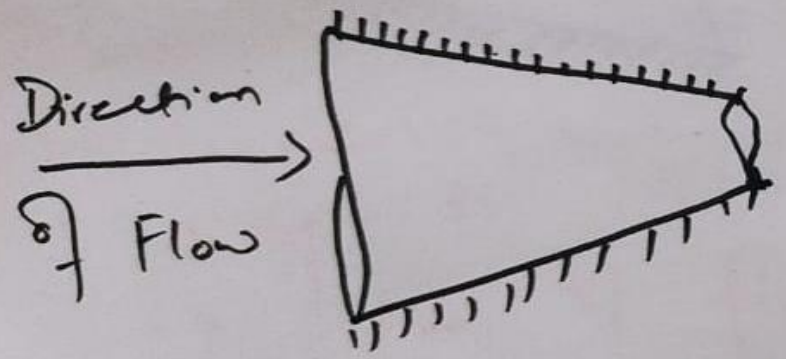
$$\text{sonic velocity} = \sqrt{\gamma R T}$$

$M > 1$ (Supersonic Flow) Velocity of Fluid > Sonic velocity

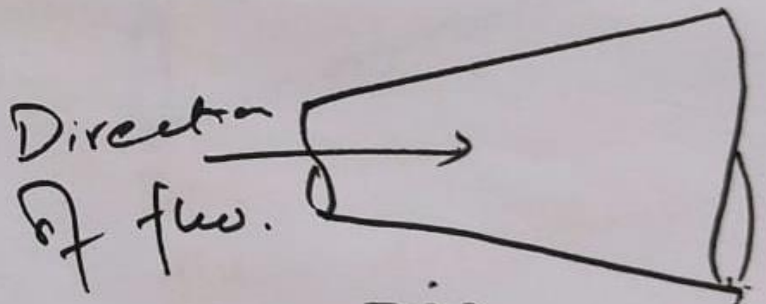
$M < 1$ (Subsonic Flow) Velocity of fluid < Sonic Velocity

$M = 1$ (Sonic Flow) Velocity of fluid = Sonic Velocity

Subsonic Flow $\boxed{M < 1}$



Nozzle



Diffuser

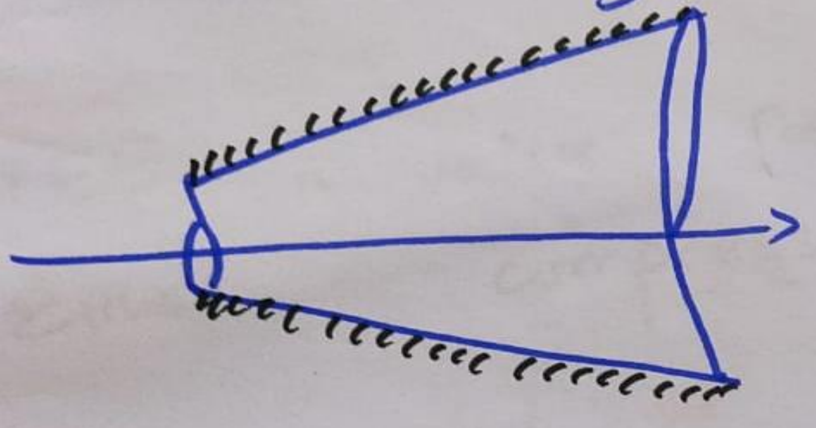
Cross section area decreases along the direction of flow.

Cross section area increases along direction of flow.

(2

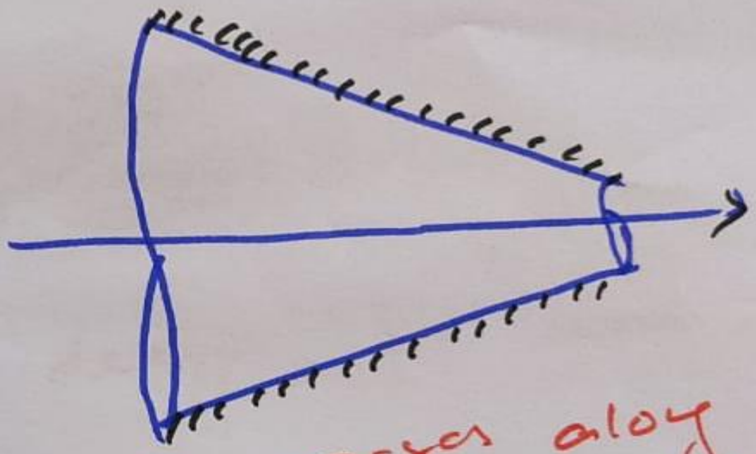
Supersonic Flow $M > 1$

Direction of Flow



Increases along the direction of flow

Nozzle



Decreases along the direction of flow.

Diffuser

3

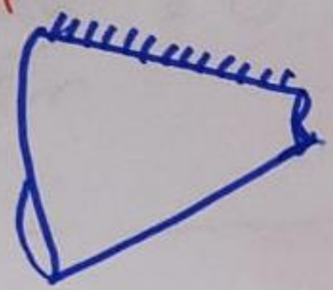
= For compressible Fluid Flow

=> When the velocity is high, it's volume is reduced.

(Importance)

=> SFEE is valid for any ~~to~~type of fluid.
Either compressible or incompressible.

What would be the design for ~~[illegible]~~ sonic flow $M=1$?

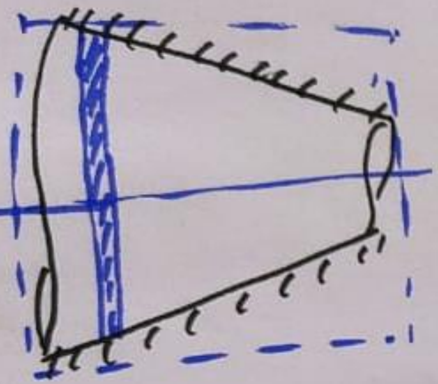


For a fluid to have $M = 1$ is not feasible for longer period of time.

(4

Nozzle

Work transfer = 0



Inlet

P_1, v_1, u_1

Outlet.

P_2, v_2, u_2

Well Insulated

Perfect Insulation

z_1

z_2

$$\frac{dQ}{dm} = 0$$

1) $\frac{dQ}{dm} = 0$

2) $\frac{dW}{dm} = 0$

3) $z_1 = z_2$ $\Delta PE = 0$

4) $\Delta KE \neq 0$

Inlet Sp. Enthalpy - $h_1 = u_1 + P_1 v_1$

Outlet Sp Enthalpy = $h_2 = u_2 + P_2 v_2$

SFEE

$$h_1 + \frac{v_1^2}{2} + g\cancel{z_1} + \cancel{\frac{dQ}{dm}}=0$$

$$= h_2 + \frac{v_2^2}{2} + g\cancel{z_2} + \cancel{\frac{dW}{dm}}=0$$

$$h_1 + \frac{v_1^2}{2} = h_2 + \frac{v_2^2}{2}$$

$$h_1 - h_2 = \frac{v_2^2}{2} - \frac{v_1^2}{2}$$

(b

if $v_2 >> v_1$

$$V_1^2 = \text{neglected}$$

$$\boxed{\frac{V_2^2}{2} = h_1 - h_2} \qquad V_2^2 = 2(h_1 - h_2)$$

$$V_2 = \sqrt{2(h_1 - h_2)}$$

Unity J/kg

SFEE:

$$\text{J/kg} \rightarrow \boxed{h_1 + \frac{v_1^2}{2} + g z_1 + \frac{dQ}{dm} = h_2 + \frac{v_2^2}{2} + g z_2 + \frac{dW}{dm}}$$

(7)

$$K.E = \frac{1}{2} m v^2 \rightarrow Nm \text{ or Joule}$$

$$E = U + K.E + P.E$$

" Dividing by mass "

$$e = u + \frac{v^2}{2} + gz$$

$\longleftrightarrow$ " E/kg "

$\downarrow m^2/s^2$ (Dimension of v)

$$\frac{m^2}{s} \approx J/kg \qquad J = Nm$$

$$N = kg\,m\,s^{-2}$$

$$\text{"} \frac{kg\,m\,s^{-2}\,m}{kg} = m^2/s^2 \text{"}$$

(B

So $\quad v_2 = \sqrt{2(h_1 - h_2)} \Rightarrow$ J/kg

kJ/kg

SFEE:

$$\underbrace{h_1}_{kJ/kg} + \underbrace{\frac{v_1^2}{2000}}_{kJ/kg} + \underbrace{\frac{gz_1}{1000}}_{kJ/kg} + \underbrace{\frac{dQ}{dm}}_{kJ/kg} = \underbrace{h_2 + \frac{v_2^2}{2000} + \frac{gz_2}{1000} + \frac{dW}{dm}}_{kJ/kg}$$

$$V_2 = \sqrt{2000(h_1 - h_2)}$$

$$\boxed{V_2 = 44.72\sqrt{\Delta h}}$$

(a)

Four Reduced con

1) $\frac{dQ}{dm} = 0$ $\qquad HT = 0$

2) $\frac{dW}{dm} = 0$ $\qquad WT = 0$

Almost always

3) $\Delta PE = 0$ $\qquad z_1 = z_2$

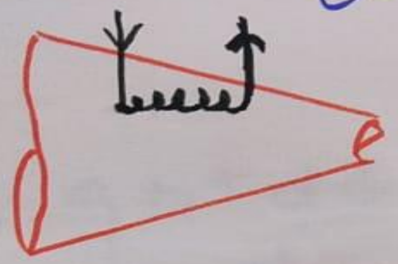
4) $\Delta KE \neq 0$ $\qquad U_2 = \sqrt{\Delta h}$

$U_2 = \sqrt{2(h_1 - h_2)}$

10

Special ~~ca~~ con

This can happen



Electric Work = Power
↓
Heat

$$\frac{dW}{dT}$$

$$= VI$$
$$= I^2 R T \rightarrow dQ$$

But work transfer is always zero.

In case of Diffuser "same approach" will be used

Possibility Different "h_1 & h_2 value". ("

Turbine & Compressor

SFEE

$$h_1 + \frac{v_1^2}{2} + gz_1 + \frac{dQ}{dm} = h_2 + \frac{v_2^2}{2} + gz_2 + \frac{dW}{dm}$$

$\frac{dW}{dm}$ → External Work.

External Work → Shaft Work
External Work → Electrical Work.

Turbine:- Rotodynamic Machine

Provides us shaft Work.

(12)

Turbine :- Consumes thermal Energy
Enthalpy (In case of steam)

and produces Work (Shaft Work)

Turbine : [Thermodynamic System]

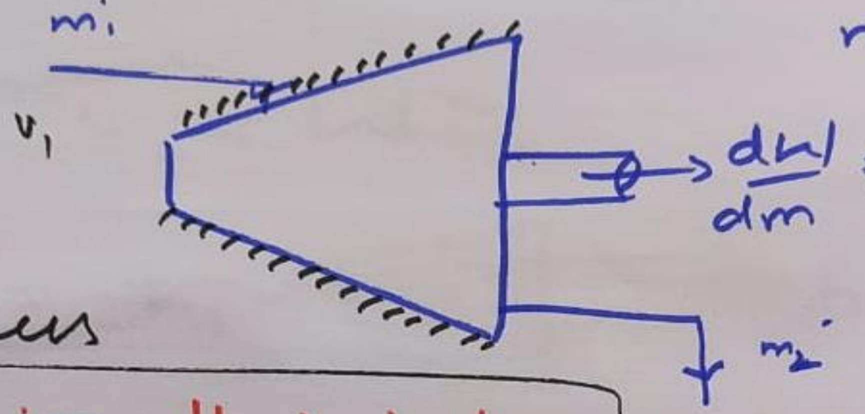
Work from system [+ve]

<u>Compressor</u> :- Reciprocating
&
Centrifugal

(Work done on the system (−ve))

13

SFEE for turbine:



Assumption

No Friction loss / Friction Less

$m_1 = m_2 = m$

$\frac{dW}{dm} \neq 0 \quad \frac{dm}{dt}$

1) assumption :- Heat lost $= 0$

4) $Z_1 = Z_2 \quad \Delta PE$

2) Isentropic (Friction less)

$dS = 0$ (Reversible) + Adiabatic

3) $V_1 = V_2 \qquad \Delta K.E = 0$

Inlet outlet

(14

$\cancel{h_1 +}$ $h_1 = h_2 + dW/dm$ SFEE

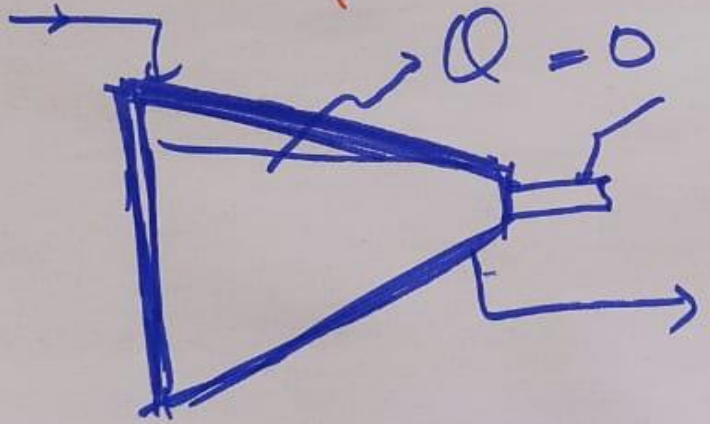
$\Rightarrow$ $h_1 = h_2 + \dot{W}$ $\frac{dW}{dm} \approx \dot{W}$ J/kg

J/kg $\boxed{W = h_1 - h_2}$ $h_1 > h_2$

or

kJ/kg. Work trasfer for turbim.

Compressor :-



1) $\Delta KE = 0$

2) $\Delta PE = 0$

3) $dQ = 0$

15

$$h_1 = h_2 + W$$

$$h_1 = h_2 + (-W)$$

$$\boxed{W = h_2 - h_1}$$ KJ/kg or J/kg

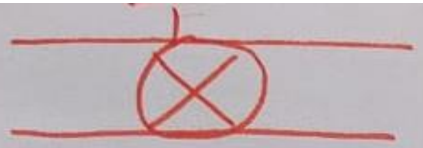
SFEE for compressor

Throttling Process:- Irreversible Process

Rapid reduction of pressure.

(16

① Examples of throttling process

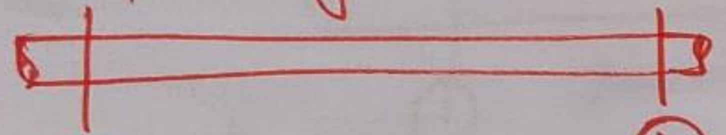


valves / tubes

→ Partially open valve.

→ Adjustable valve

→ Capillary tube ②



① $P_1 >> P_2$ ②

By virtue of friction pressure is reduced

→ Capillary tube is example of throttling process.

③ Porous plugs

$P_1 >> P_2$

$P_2 << P_1$

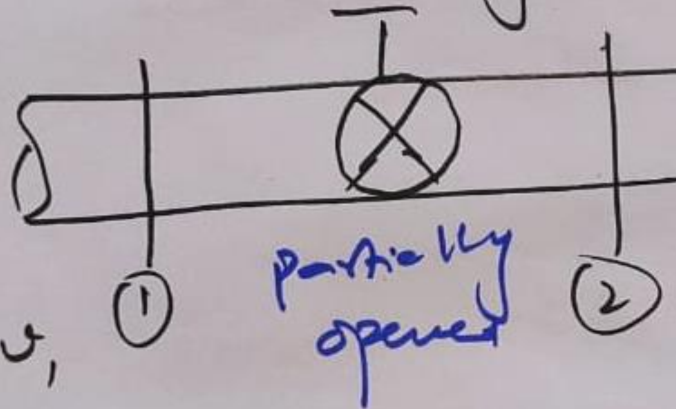
(17

Throttling process

$\Rightarrow$ Isenthalpic Process $\boxed{h_1 = h_2}$

"But it doesn't mean all Isenthalpic process are throttling process"

Real gases :-



$h_1 = u_1 + P_1 v_1$ $\qquad$ $h_2 = u_2 + P_2 v_2$

(18

if $\quad P_1 v_1 >> P_2 v_2 \qquad u_1 - u_2 = P_2 v_2 - P_1 v_1$ $\quad$ Temp will increase along flow

$\boxed{u_1 - u_2 = -ve} \qquad \boxed{u_2 > u_1} \quad \boxed{T_2 > T_1}$

if $P_2 v_2 >> P_1 v_1$

$T_1 > T_2$

{ xtless
Temp will ~~increase~~ decrease along the direction of flow)

So it doesn't mean that temperature will always reduce in case of throttling because of reduction in pressure,

It can also increase in direction of flow, meanwhile pressure decreases

(19)

For Ideal gas

$h = f(T)$ → Throttling case for ideal gases temperature remain constant.

$h_1 = h_2$

$\boxed{T_1 = T_2}$

In case of real gases we are getting both heating $T_2 > T_1$ & cooling $(T_1 > T_2)$ {Joule's Thompson coefficient of expansion)

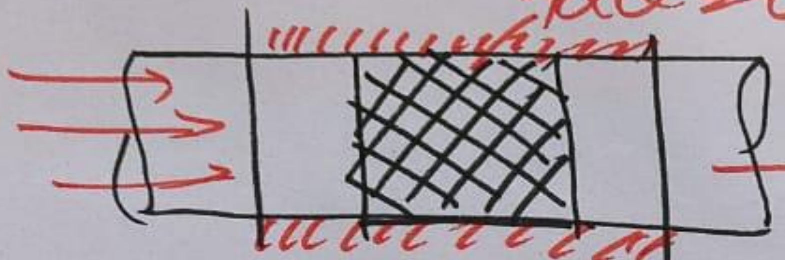
(20

Throttling Process (SFEE)

Joule Thomson process

Not enough time

plug Not enough area to transfer heat



$dQ = 0$ $\quad dQ/dm = 0$

$W = 0$

$\frac{dW}{dm} = 0$

(1) Porous plug (2)

$z_1 = z_2$ → $\Delta P.E = 0$

$v_1 = v_2$ → $\Delta KE = 0$

SFEE

$$\boxed{h_1 = h_2}$$