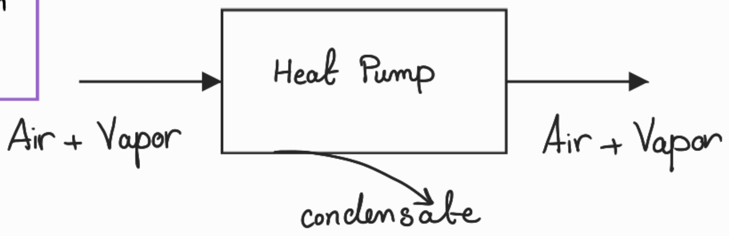
Experiment 1

Experimental Heat Pump and air cooler

vapor compression cycle/ Refrigeration cycle



Calculations

$$P_a = \frac{RT}{P_a}$$

Density

ambient pressure

$$\gamma = \frac{\emptyset P_w}{P_a}$$

specific Humidity

Heat:

$Q_1 = m_1 C_p T_1$ Energy dry air has at inlet

$Q_2 = \gamma m_1 h_v$ Energy of water vapor entering

$Q_3 = m_1 C_p T_2$ Energy dry air has at outlet

$Q_4 = (\gamma m_1 - m_2) h_v$ Energy of water vapor leaving

$Q_5 = m_2 h_w$ Energy of condensate

$Q_6 = m_3 T_3 c_w$ Energy of water entering

$Q_7 = m_3 T_4 c_w$ Energy of water entering

Q_8 = Radiation and stray losses

Note

$$\gamma m_1 = \frac{kg\ vapor}{kg\ dry\ air} \times kg\ dry\ air$$

To calculate Q_8

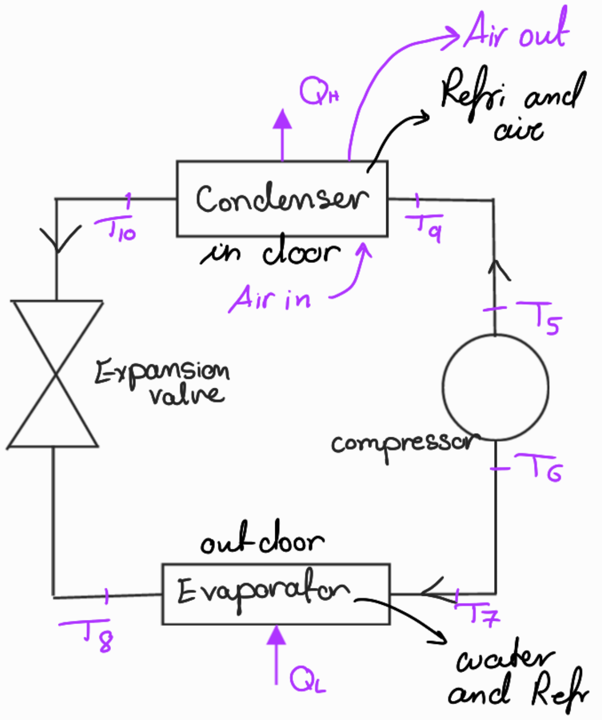
$$(Q_6 - Q_7) + (E_c + E_f) = (Q_3 + Q_4 + Q_5) - (Q_1 + Q_2) + Q_8$$

$$\underbrace{\text{Energy of condensate} + \text{Energy of compressor and fan}}_{\text{Energy Added}} = \underbrace{\text{Energy out} - \text{Energy Entering}}_{\text{Energy needed}} + Q_8$$

To calculate coefficient of performance

Real: $(CP_H)_E = \frac{(Q_3+Q_4+Q_5)}{E_c+E_F} = \frac{\text{Energy Added}}{\text{Energy needed}}$

Ideal: $(CP_H)_{max} = \frac{(T_1+T_2)/2}{(T_1+T_2)/2-(T_3+T_4)/2}$



To calculate internal coefficient of performance

Real: $(CP_H)_I = \frac{(Q_3+Q_4+Q_5)-E_f-(Q_1+Q_2)}{E_c}$

Ideal: $(CP_H)_{max} = \frac{T_{10}}{T_{10}-T_8}$

T_{10} → Ref. out of condenser

$T_{10}-T_8$ → Air to Refrigerant

What are the conditions of the experiment?

1 constant flow rate

2 various flow rate

Note

T_1 constant : Air in

T_2 increase : Air out

T_3 constant : water in

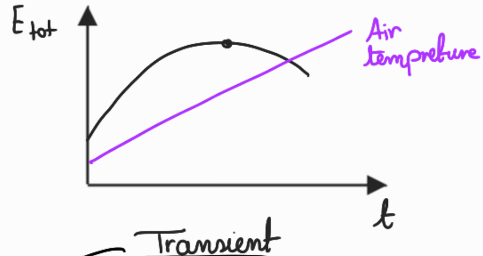
T_4 Decreases : water out

T_{10} increase } Refrigerent

T_7 Decreases }

T_5, T_6, T_8, T_9 :

What are the results of the experiment?



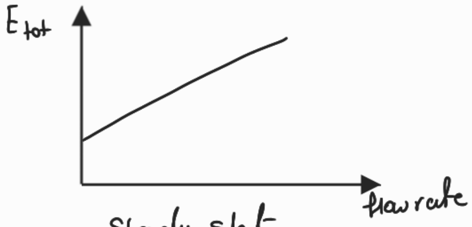
Transient

constant water flow rate
time is changing

Power increases until it reaches maximum point then it decreases

why? because T air in the room as time passes so less power is needed to heat the air

when flow rate of water increases more Power is needed since heat transfer increases



Steady state

Changing flow rate & constant time

Apparatus

- water flow meter in the condenser → Ratameter
- manometer → connected with static tube → air flow rate
- Air properties are : $T_{\text{dry Bulb}}$, $T_{\text{wet Bulb}}$

Expirement 2

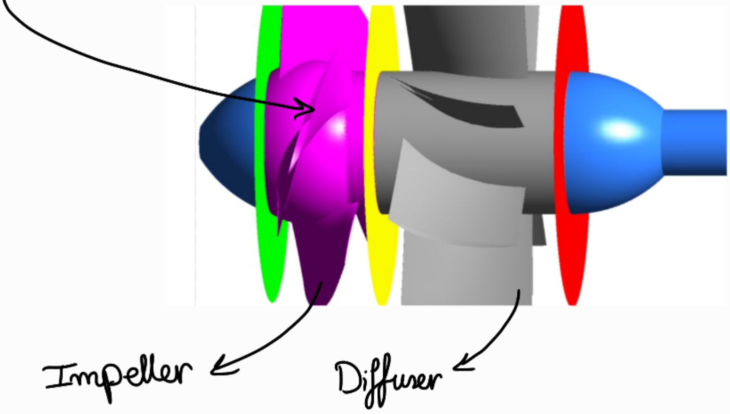
Characteristics of Axial machines

Axial machines
The flow is in the direction of the axis rotation

- Pump : Machine gives power to the fluid
- Turbine : fluid gives power to the Machine

Blade (Rotor) angle (α) : angle between blade and normal to the axis of rotation

Diffuser angle (β)



Calculations

$$\mu_p = \frac{\rho g Q \Delta H}{\underbrace{T \cdot \omega}_{\text{Input power}}}$$

$$\Delta H = 10.194\,(\underbrace{P_7}_{\text{Pump outlet}} - \overset{\text{Pump inlet}}{P_1})$$

$$\omega = \frac{2\pi N}{60}$$

What are the experiments conditions ?

1- Constant rotational speed

2- changing α, β

How did we see the affect of α, β ?

let β constant → change α : Q was changed to take measurements

let α constant → change β : Q was changed to take measurements

what are the effects of changing α, β ?

Experiment 3

Diesel Engine

To obtain characteristics of the engine

1- Engine warmed up at full throttle opening (دعسة كاملة) and at some speed around midpoint of it's range

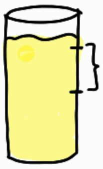
2- Adjust mixture strength and where applicable timing to give maximum Torque

3- Increase load and record speed

To measure air fuel ratio

1- measure fuel consumption using fuel guage

2- measure air flow using orifice



measure time for fuel to pass this volume =50mL

To measure exhaust Temp

Sensor is used

To measure temprature out and into the engine

Thermometer is used

speed and Torque are taken digitally

To measure water flow

Rotameter is used

To measure airflow

Manometer is used

In Part 1:

Throttle was changed: first at 15% then at 40%

Load was applied to the engine by the electrical dynamometer and it is changed to change torque and speed

Note that it is operated as a generator and connected to crankshaft

Note

Throttle is Qualitative in diesel engine So A/F can be controlled

Thrott ↑ → Diesel rich mixt ↑

In Gasoline engine A/F does not change

Calculations

Power: $P = \frac{1}{1000} \frac{2\pi n}{60} \cdot T = \omega \times T$

Fuel consumption: $V = \frac{3600\ (\overset{50mL}{V_G})}{t}$ [L/h]

Air fuel ratio: $$A/F = \frac{\dot{m}_a}{\dot{m}_f} = \frac{C_d \times \frac{\pi}{4} \times D_o \times \sqrt{2 \times g \times H_o \times \overset{\text{water Density}}{\rho_w} \times \underset{\text{air Density}}{\rho_a}}}{V \times \underset{\text{fuel Density}}{\rho_f}}$$

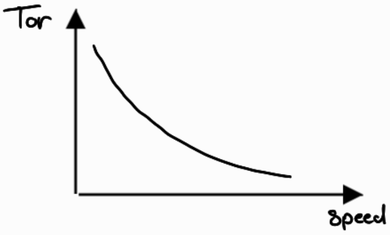
Specific fuel consumption: $s.f.c = \frac{V}{P}$ → Gives a measure of the thermal efficiency of the engine

Swept volume: $V_s = \frac{\pi}{4} \times \overset{\text{cylinder diameter}}{d^2} \times \underset{\text{stroke}}{S} \times \underset{\substack{\text{number of}\\ \text{cylinders}\\ = 4}}{N}$

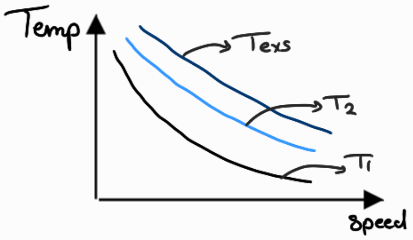
Break mean effective pressure: $b.m.e.p = \frac{P}{N^* \times V_s}$ → Represents pressure that would act upon pistons during each working stroke to achieve the output power

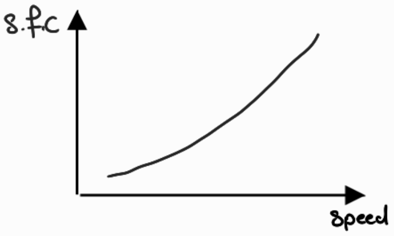
$N^* = \frac{\frac{rev}{s}}{2}$

Results

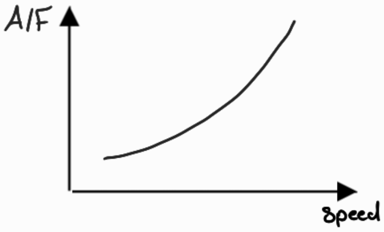


Torque decreases due to 1- increasing friction
2- insufficient heat transfer due to decreased combustion time

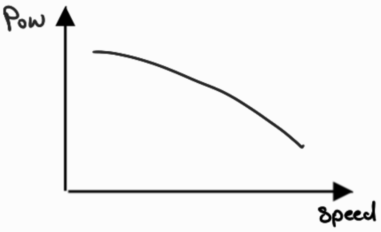




when speed increases, fuel consumption increases since more fuel is needed

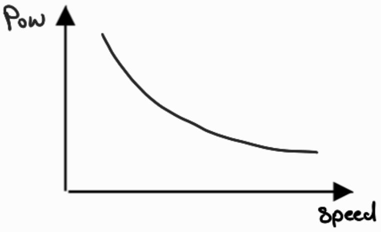


why not decreasing?



why is Power decreasing?

Max power is reached then as speed increases more friction exists and so more losses

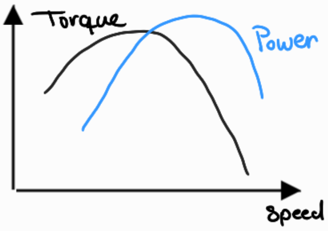


Decreases so torque decreases

Part 2

Conditions: 80% Throttle and full load → Then load decreased to change T, n

objective: to find RPM at which torque is best



Experiment 4

Air conditioning unit

inlet of air

pushes air in

Main components: Rectangular ducts with filters, fan, cooling coil heating coil, humidifier, air regesters, grills and dampers

to increase humidity of air

In the room

Calculations

Process is: sensible cooling

Air density: $\rho_a = \frac{P}{RT}$ → atmospheric pressure

Velocity: $V = \sqrt{2P_v / \rho}$

Average velocity: $V_{avg} = 0.9V$

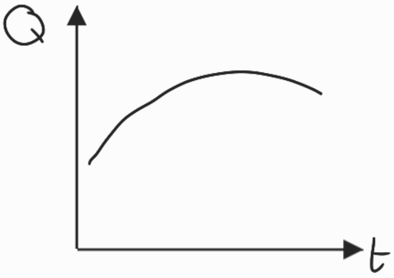
Volume flow rate of air: $\dot{V} = V_{avg} \times A_{duct}$

Mass flow rate of dry air: $\dot{m}_{dry} = \frac{\dot{V}}{v}$: v is from psychrometric (we have dry temp and Relative humidity)

Mass flow rate of condensated water: $\dot{m}_{water} = \dot{m}_{dry} (w_{out} - w_{in})$ → Ans is negative since condensation means water Quantity is decreased

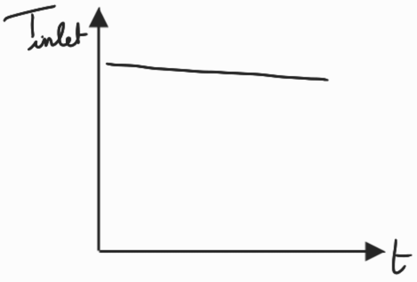
Heat transfer: $Q = \dot{m}_{dry} (h_{out} - h_{in})$ → Ans is negative since heat is removed

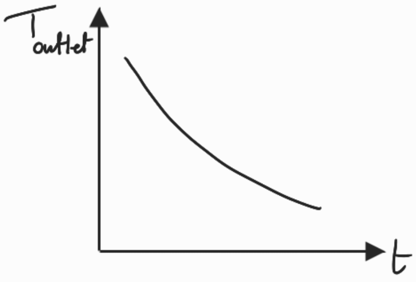
Results

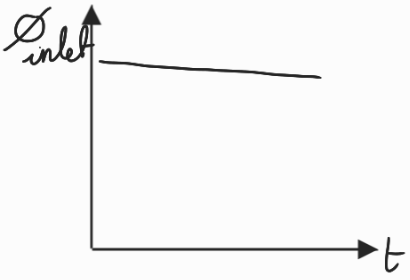


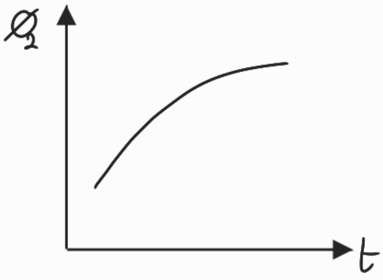
Heat is removed from air until it reaches desirable temprature

Then the heat transfer will be less since the air entering to the unit is cold



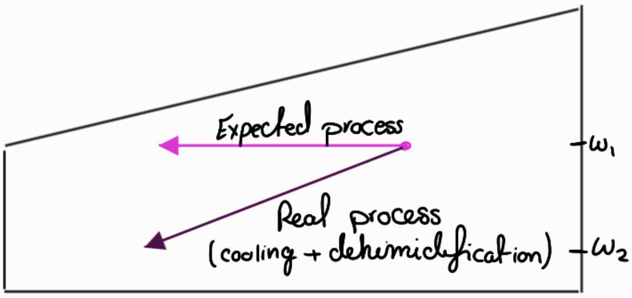






Relative humidity is a measure of how much water air hold so the increment means that is air is able to absorb more moist and that's because air particles came closer due to cooling

Process on the psychrometric chart



$\omega_2 < \omega_1$ → since some vapor has condensed so water can absorb more moisture (dehumidification)

Experiment 5

Pelton turbine test

Turbines classification

1- Impulsive turbines

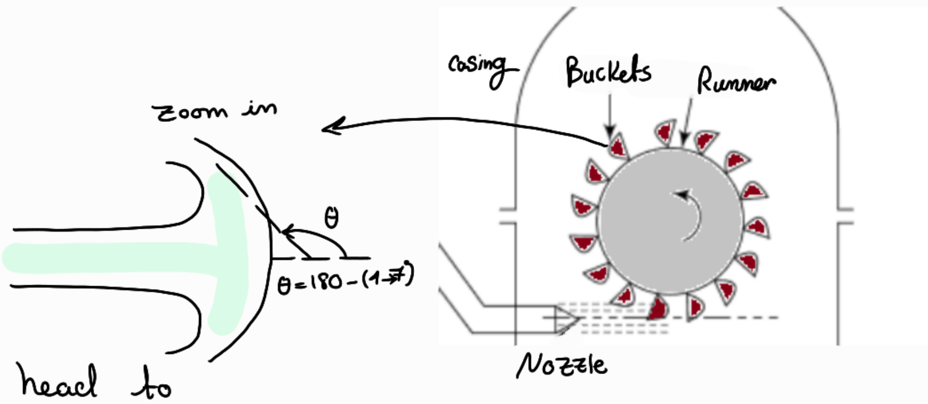
2- Reaction turbines

The conversion of the pressure head of the fluid into Kinetic energy takes place entirely in the stationary nozzle

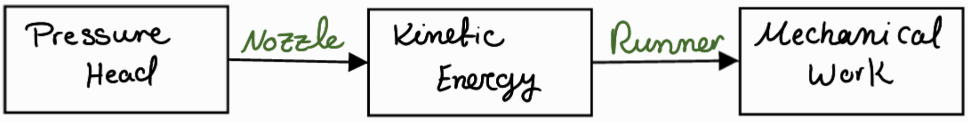
The runner only convert this Kinetic energy into mechanical work

Components

- Inlet nozzle
- Impeller
- Casing



A Turbine converts pressure head to mechanical work



Drift angle (1-7°) is to prevent a complete reflection of the water jet so that it won't hit the back of the next following bucket which will prevent reducing it's speed.

Calculations

Turbine efficiency

$$\eta_t = \frac{\overbrace{T\omega}^{\text{Mechanical power}}}{\underbrace{\rho g Q H}_{\text{Hydraulic power}}}$$

Conditions

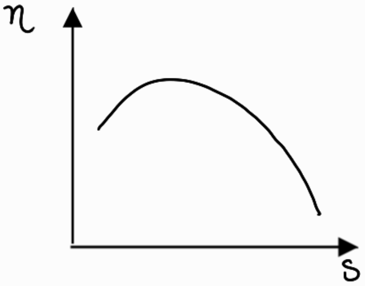
1- constant turbine head

2- changing load on turbine (by brake assembly)
(Throttle)

Note

- head supplied by pump is constant
- Decreasing throttle increases flow restrictions

Results



Efficiency decreases due to friction

Experiment 6

Two stage reciprocating air compressor

A reciprocating two stage compressor, an intercooler and a compressed air storage tank

Note
Reciprocating: Positive Displacement meaning that it is compressed by decreasing the volume of the gas by a Piston

Four components of the system

1- Electric motor
2- 2-stage compressor
3- Temperature sensors
4- Flow sensors

Four components of control panel

1- Emergency push button
2- Wattmeter
3- Voltmeter
4- Ammeter

Procedure

- Compressor speed (RPM) → Electric motor speed regulation potentiometer
- Pressure regulation → pressure regulator
- Air tank → when pressure in the tank reaches the maximum the pressure switch interrupts the motor Supply
- Cooling → heat exchanging between water and compressed air

Calculations

There is heat loss → process not adiabatic

The process is polytropic meaning that volume, Temp and pressure are changing

The air is treated as an ideal gas

To find n: $\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}$

Note

Cooling reduces compressor work because lower air temperature means smaller volume and so higher pressure with less work and smaller cylinder (Cost reduction)

To calculate compression ratio: $Cr = \frac{P_2}{P_1}$

To calculate intake volume: $V_{intake} = V_{End} - V_{start} = V_4 - V_1$

To calculate exhaust volume: $V_{exhaust} = V_{start} - V_{End} = V_2 - V_3$

} of a stage

Air mass flow rate: $\dot{m}_a = Q \times \rho$

specefic heat of polytropic compression: $C_x = nC_v - \frac{C_P}{n-1}$

Specefic work (Work done by compressor on air during compression): $\omega_{spec} = (C_x - C_p)(T_2 - T_1)$

Mechanical power: $P = \omega_{spec} \times \dot{m}_a$

Heat exchange: $Q = C_x\,(T_2 - T_1)$ negative since heat is added to air

Enthalpy absorption: $\Delta H = C_p\,(T_2 - T_1)$ and from first law $\Delta H = Q - \omega_{spec}$

Volumetric efficiency: Theoretical $\eta_v = 1 + C - C\left(\frac{P_2}{P_1}\right)^{\frac{1}{n}}$ C: clearance ratio = $\frac{V_3}{V_1 - V_3}$

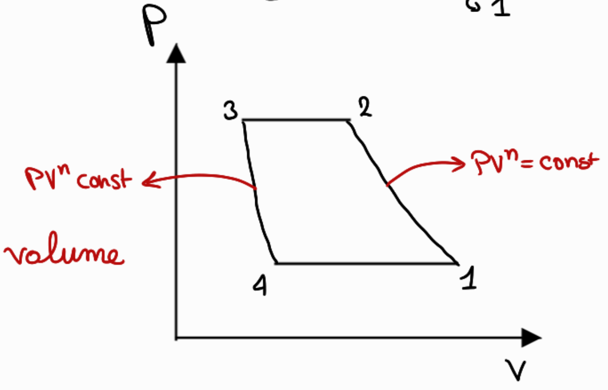
Experimental $\eta_v = \frac{\text{Air volume drawn in}}{\text{Displaced volume}} = \frac{Q}{stroke \times a \times \omega \times 2 \times N_{\hookrightarrow 1}}$

1→2: polytropic compression

2→3: Air exhaust at constant pressure

3→4: polytropic of remained air in clearanc volume

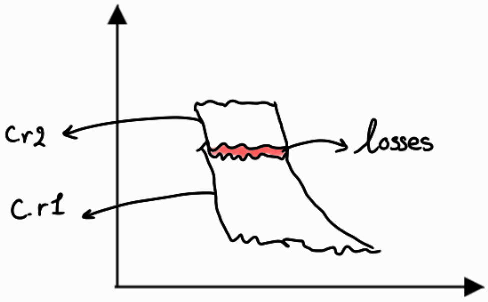
4→1: Air intake at constant pressure



Results

η_v (Theo) $< 100\%$ → clearance volume which is the volume of air trapped in the top of the cylinder makes the air compressed less than air drawn in the compressor

C.r 2 < C.r 1



Experiment 8

Hydrogen fuel cell

Fuel cell: a device in which chemical energy is converted to electrical energy

Working Principle

There are two electrodes with an electrolyte in the middle. (Acidic medium) PEM

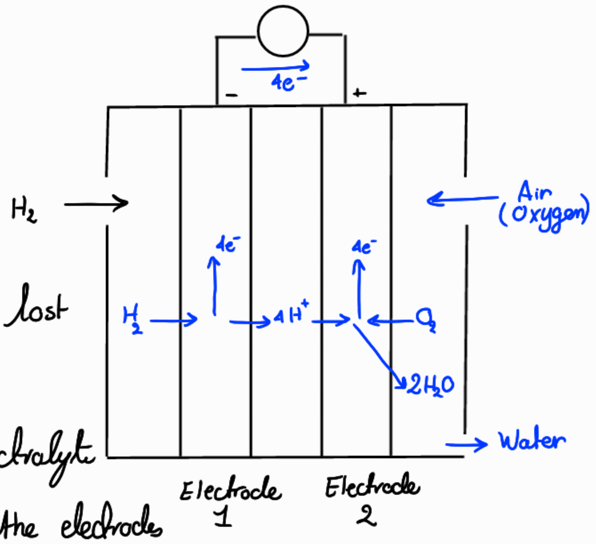
Two reactions occur to provide energy:

1- Reaction of H_2 entering to the cell $2H_2 \longrightarrow 4e^- + 4H^+$

2- Reaction hydrogen ions with electrons and oxygen entering with air to the cell

$$4H^+ + 4e^- + O_2 \longrightarrow 2H_2O$$

This results in electrical current and water



losses in the cell

1- Activation losses: some of the voltage generated is lost in the transfer of electrons from the electrodes

2- Internal current: Electron conduction through the electrolyte

3- ohmic losses: voltage drop as current flow through the electrode and interconnections

4- Concentration losses: results from the change of concentration on reactants at the surface of electrodes

Components of the System

1- Fan: controls air enterance to cell

2- Purge valve: assures the accumulated inert gases are blown out

3- Solenoid valve

4- Flow meter of hydrogen

- There are 10 fuel cells in the stack connected in series
- The current is discharged to the current collectors located at the ends

Informations read from cell module are:

1. hydrogen volumetric flow to the fuel cell module
2. Output current of the fuell cell module
3. Output voltage of the fuell cell module
4. Fan power
5. stack temperature

Calculations (See procedure from manual)

Part 1: Constant Tempreture and fan auto

Stack power: $P_{stack} = V_{stack} \times I_{stack}$

Stack Efficiency: $\eta_{stack} = \frac{P_{out}}{P_{in}} = \frac{P_{stack}}{LHV\ \dot{V}_{H_2}} = \eta_V \times \eta_I$

Voltage efficiency: $\eta_V = \frac{V_{stack}}{\underset{\text{number of cells}}{a}\ V_{rev\ LHV}}$

$\dot{V}_{rev\ LHV}$: reversible thermodynamic voltage related to lower heat value

Current efficiency: $\eta_I = \frac{I_{stack}}{I_{Th}} = \frac{I_{stack}}{\dot{V}_{H_2} F \underset{=2}{z} / a V_m}$

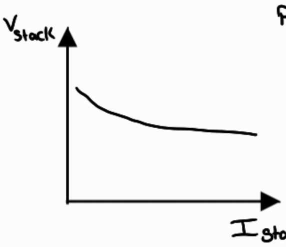
V_m: molecular volume = 22

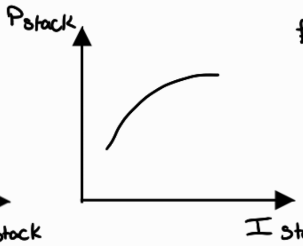
F: Faraday constant

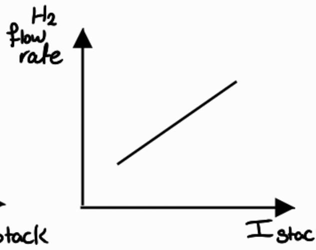
Part 2: 6% fan and tempreture is changing

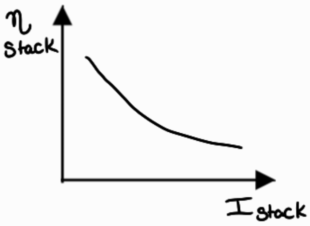
$P_{stack} = V_{stack} \times I_{stack}$

Results



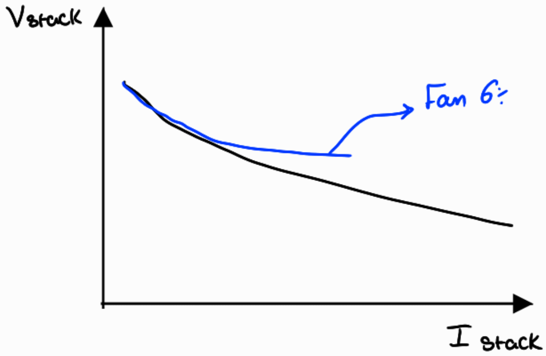






- V_{stack} decreases due to losses in the cell
- H_2 increases since it is considered to be the fuel of the cell, so more current needs more H_2

Comparison between part 1 and part 2



Since oxygen is limited, reactions stops at lower current

Experiment 8

Solar energy Minilab

How it works

The solar cell has 2 silicon layers : N-type which has extra electrons and P-type has holes → PN Junction

When the light hits the surface of the solar cell , the light photons remove the electrons from the N-type silicon layer , these are attracted to holes in the P- layer

This movement of electrons is considered to be a current , this is taken to an external circuit and used to produce power

Characterestics of the cell

Short circuit current I_0 : value of current intensity for null value of load resistance

No load voltage V_0 : potential difference at end of the open circuit cell

Efficiency : $\eta \leq 15$ → ratio between highest electrical power delivered by the cell and the power of the radiation incident to it's surface

Top working temperature T_L : It is the highest temperature which the cell can work at it reaches 120°C

Calculations

Part 1 : θ is changing

$I_\theta = I_0 \cos\theta$ (Theoretical I_θ)

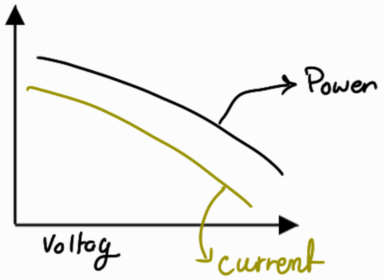
$$P = \underbrace{I}_{\text{measured}} \times V$$

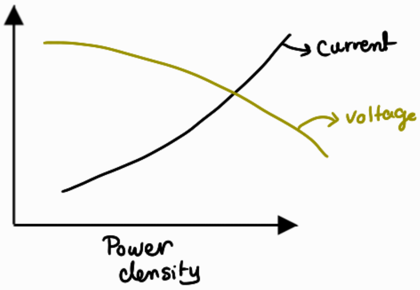
$$\text{Ratio} = \frac{I_\theta \curvearrowright \text{measured}}{I_0 \swarrow}$$

at θ = 0

Part 2 only power is calculated

Results





- As θ decreases, higher voltage and current are produced since θ↓ → Radiation flux ↑
- As load increase, Power and current increases
- As H decrease, Power and current increase since radiation losses decrease
- As light intensity increases, Power and current increase
- Smaller cell is more efficient since less energy is wasted

Experiment 9

Four stroke Petrol Engine

Components

- The system is a small air cooled single cylinder petrol engine with:

1- overhead valves

2- Carburator with manual choke

3- Electric spark ignition

4- Splash lubrication by crankshaft

5- Recoil starter: starter handle and cord, wrapped around a pulley on the flywheel

The Governor: A centrifugal device inside the engine that stops it from running too fast by forcing the carburator to reduce the fuel/air mixture that enters the cylinder

Lubrication is done by engine oil stored in a small pump at the base of the engine body

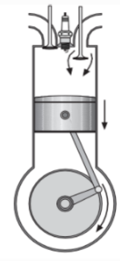
There are fins around the engine flywheel that provides air cooling

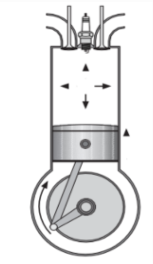
Spark creation: The flywheel has a permanent magnet fixed to its edge when the flywheel turns, the magnet passes the primary winding of electric ignition coil and forces a current to flow in the coil.

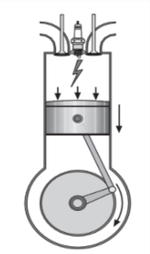
The engine capacity is 200 cm^3 → volume of the cylinders in the engine.

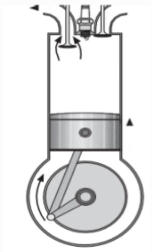
The engine has 4-strokes → intake, compression, combustion and exhaust

releases energy from fuel


Intake


Compression


Power


Exhaust

Calculations

fuel consumption: $\dot m_f = \frac{\overset{\text{Pipette volume}}{V} \times \rho}{t}$

Heat of combustion: $H_f = \dot m_f C_L$

Air mass flow rate $\dot m_a = C_d \left(\frac{\pi d^2}{4}\right) \sqrt{\frac{2 P_A \Delta P}{R T_A}}$

d: Orifice diameter
P_A, T_A: Ambient

Inlet air enthalpy $H_A = C_p T_A \dot m_a$

Power: $P = \omega \times T$

Air fuel ratio : $A/F = \frac{\dot m_a}{\dot m_f}$

Specific fuel consumption: $s.f.c = \frac{\dot m_f \times 3600}{P/1000}$

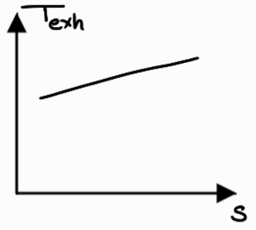
Thermal efficiency: $\eta_T = \frac{P}{H_F} \times 100\%$

Volumetric efficiency $= \frac{\text{Measured volume}}{\text{Calculated volume}} = \frac{\dot m_a \times T_A \times R \;/\; P_A}{\text{Engine capacity} \times N / \left(\frac{\text{Strokes}}{2}\right) \times 60}$

Brake mean efficitive pressure : $B.m.e.p = \frac{60 \times P \times (\text{Strokes}/2)}{0.1 \times \text{Speed} \times \text{Engine Capacity}}$

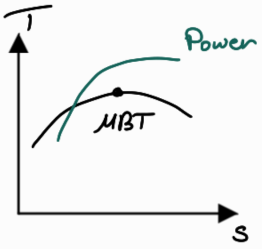
Results

Exhaust temprature



Texh increases with speed since there is less time for heat exchanging

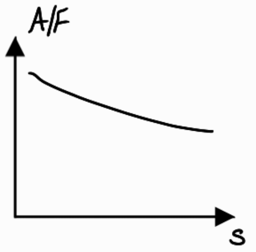
Torque



Torque keeps increasing until it reaches MBT (Maximum Brake Torque) then it starts decreasing because cylinders move so fast so not all exhausts are discharged (less time). Also, heat loss to walls of cylinders since the engine will do more cycles.

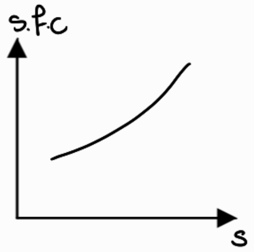
Power decreases due to friction losses and heat losses

Air fuel ratio



- A/F < stoichometric (rich mixture)
- Decreases so A/F is more rich meaning that fuel consumption increases because speed is increasing

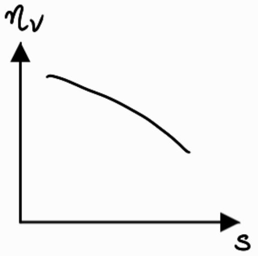
Specific fuel consumption

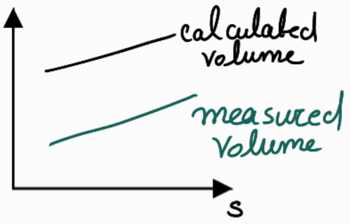


volumetric efficiency

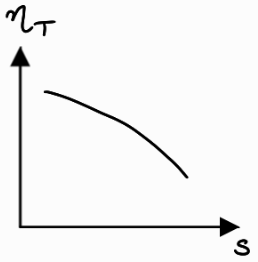
- η_v is the ability of engine to fill cylinders with air
- calculated volume increases so does measured volume but rate of increment of calculated volume is higher than measured

Also swept volume decreases so not all volume is filled



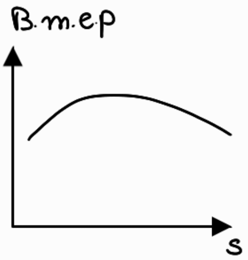


Thermal efficiency



- $\eta_T \simeq 22\%$ Because energy from chemical fuel will be loss to cylinder's walls in form of high exhaust temprature

B.m.e.P



- As speed, cylinders pressure increases but at high RPM heat losses and friction increases so b.m.e.p decreases

Gasoline vs Diesel engines

- Diesel engine relies on air compression which produces hot air and then diesel is injected
- Diesel engine has lower RPM since cylinders are made from heavier materials so it cannot produce P as much as petrol
- Diesel engine produces higher torque at lower RPM since Compression ratio is higher
- Diesel itself has more energy then gasoline so less fuel is needed which makes Thermal efficiency higher