19-10-2023 Thursday
Name : Deep Narayan
Roll No : 20MM8051
Reg No : 20U10719
Dept. : Metallurgical & Materials Engineering

1)

- Water Turbines
  - Reaction Turbine
    - Propeller Turbines
      - (Low head) (Axial flow)
      - Kaplan (25 - 40m)
      - Tube (2 - 15 m)
      - Bulb (1.3 - 25m)
      - Straflo (2 - 25 m)
    - Francis Turbine (Medium head 40 - 300m) mixed flow (radial + axial)
  - Impulse Turbine
    - Pelton wheel 60 - 700m head
    - Turgo 30 - 210 m
    - Ossberger cross flow 1 - 200 m

Property	Impulse Turbine	Reaction Turbine
→ Fluid flow direction	Tangential to turbine wheel	Radial & axial to turbine wheel
→ Water head	Suitable for high water head	Suitable for low and medium water heads
→ Blade profile	Symmetrical	Asymmetric

Property	Impulse Turbine	Reaction Turbine
Energy conversion	All hydraulic energy is converted into kinetic energy by a nozzle before striking turbine blades	Only some of available energy is converted into kinetic energy before fluid enters runner
Water flow rate	Suitable for comparitevely low water flow rates	Suitable in cases where water flow rates are higher
Turbine casing	Not required	Required
Water discharge	Directly from turbine wheel to the tail race	Into a draft tube first and then into the tail race
Examples	a) Pelton turbines b) Turgo turbines (for medium head) c) Ossberger crossflow turbine (for low head)	a) Propeller turbines b) Francis turbines c) kaplan turbines

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2) Different factors for the selection of hydraulic turbines

The different factors for selection of hydraulic turbines are:

(a) The available head and discharge of water at the site
(b) The specific speed of turbine which depends on the type and design of turbine
(c) The efficiency and performance characteristics of the turbine
(d) The cost and maintenance requirements of the turbine
(e) The environmental and social impacts of turbine

Factors for selection of hydraulic turbines

→ Available head & discharge of water
→ Specific speed of turbine
→ efficiency and performance characteristics
→ cost & maintenance requirements
→ Environmental and social impacts

(P.T.O. ⟶)

Thursday 10-2023

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3) Classification of fuel cells :

According to type of electrolyte:

(a) Phosphoric acid fuel cell (PAFC)
(b) Alkaline fuel cell (AFC)
(c) Polymer electrolyte membrane fuel cell (PEMFC)
(d) Molten carbonate fuel cell (MCFC)
(e) Solid oxide fuel cell (SOFC)

Type of fuel and oxidant used:

(a) Hydrogen - oxygen fuel cell
(b) Hydrogen - air fuel cell
(c) Ammonia - air fuel cell
(d) Synthetic gas - air fuel cell
(e) Hydrocarbon (gas) - air fuel cell
(f) Hydrocarbon (liquid) - air fuel cell

Types of application:

(a) Space application fuel cell
(b) Vehicle propulsion fuel cell
(c) Submarine propulsion fuel cell
(d) Commercial fuel cell
(e) Fuel cell for defense applications

Nature of electrolyte:

(a) Acidic
(b) Alkaline
(c) Neutral

Physical state of fuel:

(a) Gaseous fuel cell
(b) Liquid fuel cell
(c) Solid fuel cell

Operating temperature:

(A) Low temperature (below 150°c)
(b) Medium temperature (150-200°c)
(c) High temperature (250-800°c)
(d) Very high temperature (800-1100°C)

Physical state of electrolyte:

(a) Solid matter
(b) Aqueous Electrolyte fuel cell
(c) Non-aqueous electrolyte fuel cell

4) Efficiency of fuel cell:

→ From first law of thermodynamics, energy equation in steady flow condition:

$$\Delta Q = \Delta W + \Delta(KE) + \Delta(PE) + \Delta H$$

where ΔQ : heat Transfer
ΔW : work done
$\Delta(KE)$: change in kinetic energy
$\Delta(PE)$: change in potential energy
ΔH : change in enthalpy

→ If $\Delta(KE) = \Delta(PE) = 0$, steady state flow equation is:

$$\Delta Q = \Delta W + \Delta H$$

→ For maximum work out, process must be reversible.

→ For reversible process : $\Delta Q = T \times \Delta S$

$\Delta W = \Delta W_{max}$ when $\Delta Q = T \times \Delta S$

$$\Delta W_{max} = -(\Delta H - T \times \Delta S) \quad - (1)$$

→ Gibbs free energy is given by:

$$G = H - TS$$

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→ On differentiating, we get :

$$\Delta G = \Delta H - (T\Delta S - S\Delta T)$$

→ Since Temperature remains unchanged, $\Delta T = 0$

$$\Delta G = \Delta H - T\Delta S \quad - (2)$$

→ From eq. (1) and (2), we get :

$$\Delta W_{max} = -\Delta G$$

→ The efficiency of fuel cell in steady flow condition :

$$\eta = \frac{\text{work output}}{\text{change in enthalpy}} = \frac{\Delta W_{max}}{-\Delta H}$$

$$\eta = \frac{\Delta G}{-\Delta H} \quad — (3)$$

→ Gibbs free energy is related to electromotive forces (E) that drives the electrons through external circuit, which is given by following equation :

$$E = \frac{-\Delta G}{nF}$$

→ where n : no. of $e^{\ominus}$ transferred per molecule of reactant
F : Faraday's constant (96500 coulomb / g mole)

→ Putting value of ΔG in eq. (3)

$$\eta = \frac{nFE}{\Delta H} \quad — (4)$$

→ In case of hydrogen - oxygen fuel cell

$$\Delta G = -237191 \text{ kJ/(kg mole)}$$
$$\Delta H = -285838 \text{ kJ/kg}$$

→ Putting these values in eq. (4), we get

$$\eta = \frac{\Delta G}{\Delta H} = \frac{237191}{285838} = 83\%$$

$$\boxed{\eta = 83\%}$$

5) Operating characteristics of Fuel Cell:

→ A fuel cell consists of 2 electrodes surrounded by an electrolyte.

→ Hydrogen fuel is fed into the 'anode' of the fuel cell while oxygen enters through the cathode

→ Excited by a catalyst, the hydrogen atom splits into proton and electron which take different paths to cathode

→ The proton passes through electrolyte while the electron creates a current which is utilized before they return to the cathode, to be reunited with the hydrogen ions and oxygen to form water.

→ It has already been explained that the amount of energy per mole of hydrogen which can be supplied as electrical energy is the change in Gibbs free energy, i.e.: 237.1 kJ at 25°C

→ The heat energy (or enthalpy) of the reaction is 285.83 kJ under the same conditions. Thus the maximum efficiency of a hydrogen-oxygen fuel cell: 83%.

→ However when a fuel cell operates, it can harness fuel's energy via a chemical reaction into electricity to the extent of 65% only

→ The performance of a fuel cell can be evaluated from a curve of the cell voltage V_c drawn against current density I_s at electrode surface at given temperature.

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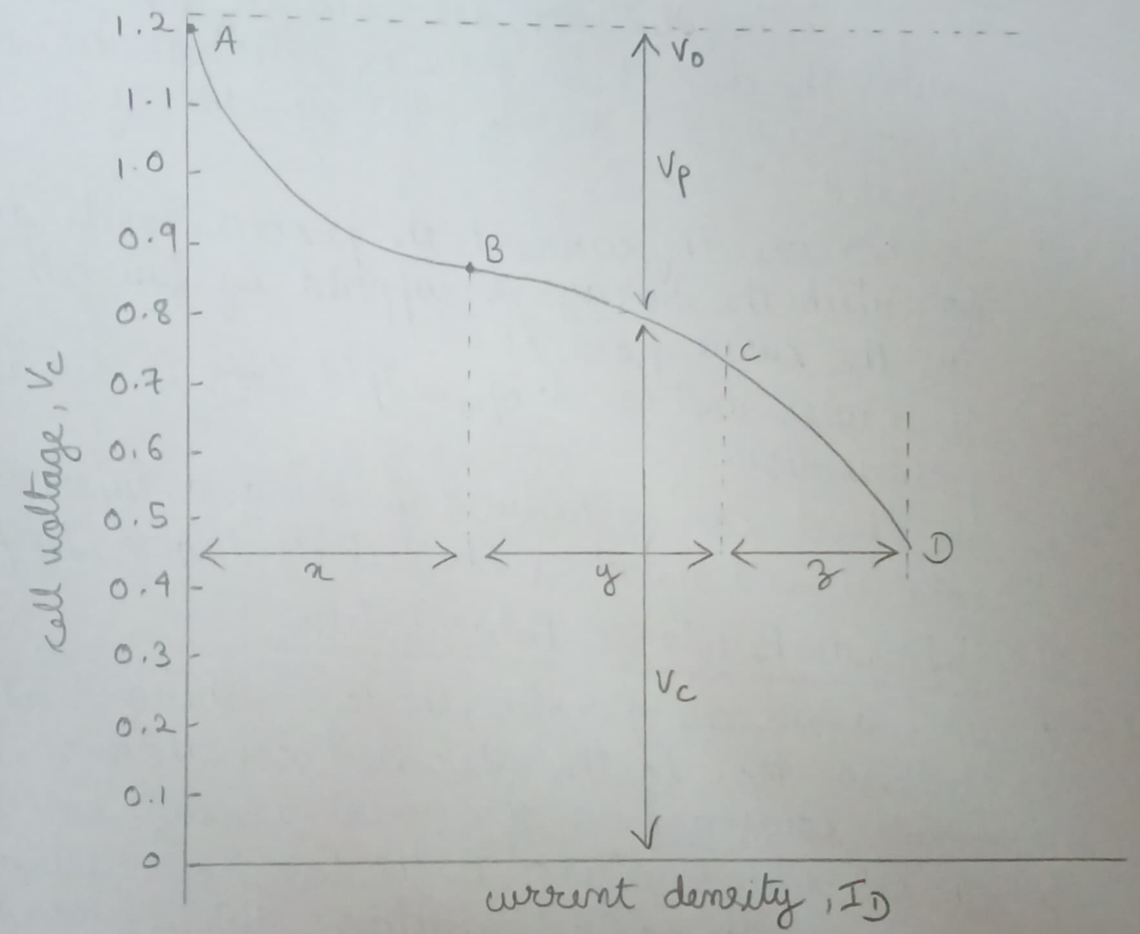

→ The difference in open - circuit voltage (V_0) and closed circuit voltage (V_c) is due to the polarization effect within the cell. The drop in voltage V_p is expressed as:

$$\boxed{V_0 = V_c + V_p}$$

→ The 'polarization loss' at electrodes denotes the difference in open circuit voltage and closed circuit voltage. electrode losses can be divided into 3 categories:
(a) chemical polarization
(b) internal resistance polarization
(c) electrolyte concentration polarization

chemical polarization:

→ In fuel cells, electrons are released and their movement causes the current to flow in external circuit.

→ At low current density, less number of electrons are liberated

→ To increase the current the process needs acceleration for which the energy is supplied by fuel cell represented by the curve part AB.

→ It causes voltage drop, output loss is due to chemical polarization

→ The effect can be reduced by using a superior electrode catalyst and operating the cell at higher temperature.

Internal Resistance Polarization

→ when a fuel cell operates, the ions liberated at one electrode move to the other electrode through the electrolyte causing flow of current in external circuit.

→ The internal resistance is the total of electrode resistance, the contact resistance between electrode and electrolyte and the electrolyte resistance. It is represented by curve part BC.

→ The internal resistance polarization can be reduced by decreasing the electrode size, coating the electrodes with a good electric conductor, increasing the electrolytic concentration and reducing the distance between 2 electrodes

Electrolyte concentration polarization

→ when a fuel cell operates, there is reduction in voltage due to concentration loss of the electrolyte which causes slow ionic movement. Represented by CD.

→ Remedy: Increase electrolyte conc. by continous stirring and operate cell at higher temperature