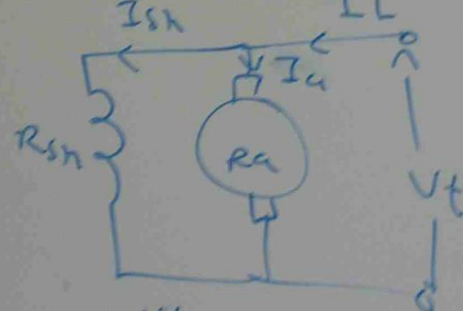
MAXIMUM EFFICIENCY

LOSSES

- IRON + FRICTIONAL LOSS — CONSTANT LOSS
- COPPER LOSS
  - FIELD COPPER LOSS — CONSTANT LOSS
  - ARMATURE COPPER LOSS — VARIABLE LOSS



$$I_{sh} = \frac{V_t}{R_{sh}}$$

SO LONG AS V_t IS CONSTANT

I_{sh} IS CONSTANT & $I_{sh}^2 R_{sh}$

IS CONSTANT.

I_a

CON

VA

MO

I_a DEPENDS ON LOAD CONDITION

CONSTANT LOSSES = IRON + FRICTIONAL LOSSES + SHUNT FIELD COPPER LOSS

VARIABLE LOSSES = ARMATURE COPPER LOSS + SERIES FIELD COPPER LOSS

MAXIMUM EFFICIENCY OCCURS WHEN CONSTANT LOSS IS EQUAL TO VARIABLE LOSS.

ANT

R_{sh}

NSTANT.

SHUNT MACHINE

VARIABLE LOSS = $I_a^2 R_a$

CONSTANT LOSS = VARIABLE LOSS = $I_a^2 R_a$

TOTAL LOSSES = VARIABLE LOSS + CONSTANT LOSS

$= I_a^2 R_a + I_a^2 R_a = 2 I_a^2 R_a$

$$\text{MAXIMUM EFFICIENCY} = \frac{\text{OUT PUT POWER}}{\text{IN PUT POWER}} \times 100$$

$$= \frac{\text{OUT PUT POWER}}{\text{OUTPUT POWER} + \text{TOTAL LOSSES}} \times 100$$

$$\eta_{max} = \frac{V_t I_L}{V_t I_L + 2 I_a^2 R_a} \times 100$$

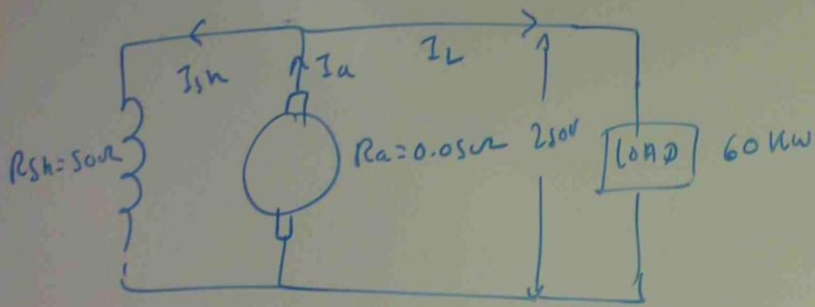
Ex A 60 KW, 250 V SHUNT GENERATOR HAS AN ARMATURE CIRCUIT RESISTANCE OF 0.05Ω, FIELD RESISTANCE OF 50Ω AND A MAXIMUM EFFICIENCY 91%. CALCULATE

(a) TOTAL LOAD FOR WHICH THE EFFICIENCY IS APPROXIMATELY A MAXIMUM

(b) STRAY POWER LOSS

$$\eta_{max} = \frac{V_t I_L}{V_t I_L + 2 I_a^2 R_a} \times 100$$

$$91 = \frac{V_t I_L}{V_t I_L + 2 I_a^2 R_a} \times 100$$



$V_t = 250V$

$$91 = \frac{250\, I_L}{250 I_L + 2\, I_a^2 \times 0.05} \times 100$$

$$I_a = I_L + I_{sh}$$

$$I_{sh} = \frac{V_t}{R_{sh}} = \frac{250}{50} = 5 \text{ Amp}$$

$$I_a = I_L + 5$$

$$0.91 = \frac{250\, I_L}{250 I_L + 2 \times (I_L + 5)^2 \times 0.05}$$

$$\begin{array}{r} I_L + 5 \\ I_L + 5 \\ \hline I_L^2 + 5I_L \\ 5I_L + 25 \\ \hline I_L^2 + 10I_L + 25 \end{array}$$

$$0.91 = \frac{250\, I_L}{250 I_L + 0.1\left(I_L^2 + 10I_L + 25\right)}$$

$$0.91 = \frac{250\, I_L}{250 I_L + 0.1 I_L^2 + I_L + 2.5}$$

$$0.91\left(250 I_L + 0.1 I_L^2 + I_L + 2.5\right) = 250\, I_L$$

$$227.5\, I_L + 0.091 I_L^2 + 0.91 I_L + 2.275 = 250 I_L$$

$$0.091 I_L^2 - 21.59\, I_L + 2.275 = 0$$

$$A x^2 + B x + C = 0$$

$$x = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$$

$$I_L = \frac{-(-21.59) \pm \sqrt{(-21.59)^2 - 4 \times 0.091 \times 2.275}}{2 \times 0.091}$$

$$= 247.2 \text{ Amp.}$$

STRAY loss $= I_a^2 R_a - V_t \times I_{field}$

$I_a = I_L + I_{sh} = 247.2 + 5 = 252.2$ Amp

$I_{field} = I_{sh} = 5$ Amp

STRAY Loss $= I_a^2 Ra - V_t I_{sh}$

$= (252.2)^2 \times 0.05 - 250 \times 5$

$= 1800$ WATT.

STRAY loss = $I_a^2 R_a - V_t \times I_{field}$

$I_a = I_L + I_{sh} = 247.2 + 5 = 252.2$ Amp

$I_{field} = I_{sh} = 5$ Amp

STRAY loss = $I_a^2 Ra - V_t I_{sh}$

$= (252.2)^2 \times 0.05 - 250 \times 5$

$= 1800$ WATT.

MACHINE TEMPERATURE RISE

MACHINE TEMPERATURE RISE CAN BE MEASURED BY

(a) THERMOMETER

(b) EMBEDDED THERMOCOUPLE (OR) THERMISTOR

(c) COMPUTATION FROM HOT AND COLD RESISTANCE

$$\frac{R_F}{R_{RT}} = \frac{234.5 + T_F}{234.5 + T_{RT}}$$

R_F = FINAL RESISTANCE

R_{RT} = RESISTANCE AT ROOM TEMPERATURE

T_F = FINAL TEMPERATURE

T_{RT} = ROOM TEMPERATURE (25°C)

Ex THE RESISTANCE OF AN ARMATURE WINDING AT 25°C WAS FOUND TO BE 0.26Ω. AFTER A HEAT RUN, IT BECOMES 0.296Ω. CALCULATE TEMPERATURE RISE OF THE WINDING.

$T_{RT} = 25°C$, $R_{RT} = 0.26\Omega$

$R_F = 0.296\Omega$

$T_F = ?$

$$\frac{R_F}{R_{RT}} = \frac{234.5 + T_F}{234.5 + T_{RT}}$$

$$\frac{0.296}{0.26} = \frac{234.5 + T_F}{234.5 + 25}$$

$$\frac{0.296}{0.26}(234.5 + 25) - 234.5 = T_F$$

$$T_F = 61°C$$

TEMPERATURE RISE $= T_F - T_{RT} = 61 - 25 = 36°C$

TO

ANALYSIS OF POWER LOSSES IN DC MACHINE

ROTATIONAL LOSSES

(a) BEARING FRICTION
(b) WIND FRICTION
(c) BRUSH FRICTION —— DEPENDS ON KIND OF BRUSH
(d) HYSTERESIS
(e) IRON EDDY CURRENT LOSSES

HYSTERESIS LOSS

- DEPENDS ON QUALITY OF IRON
- FREQUENCY OF AC CURRENT

$$f = \frac{PN}{120} \text{ Hz}$$

- FLUX DENSITY IN ARMATURE CORE
- MASS OF IRON

$$\boxed{P_h = K_h \, f \, B^{1.6} \, m \quad \text{WATT}}$$

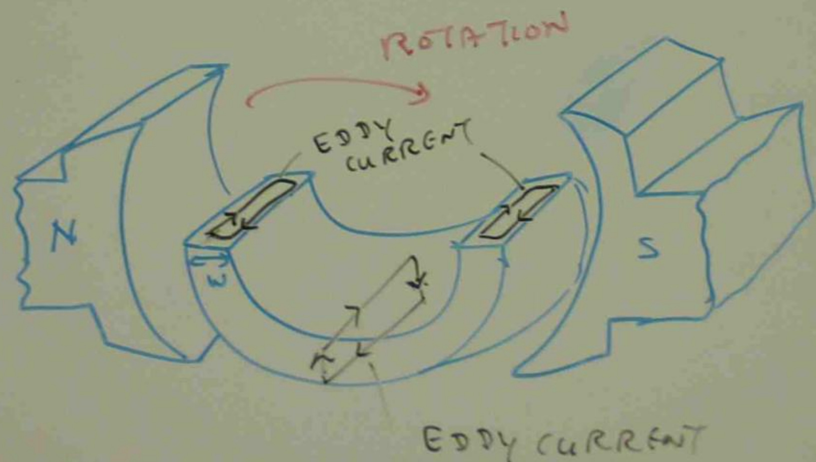
K_h = CONSTANT DEPENDING ON MATERIAL & UNIT USED

f = FREQUENCY (Hz)

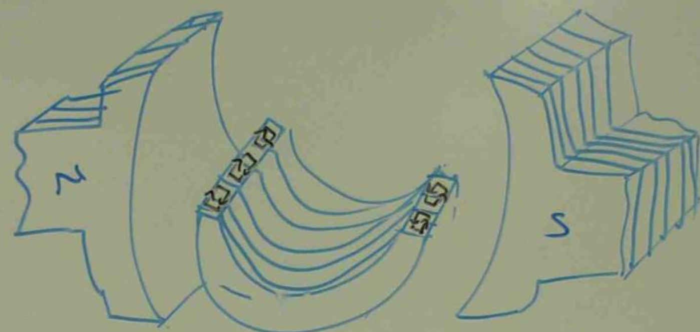
B = MAXIMUM FLUX DENSITY (T)

m = MASS OF CORE (Kg)

EDDY CURRENT PATHS IN SOLID CORE



EDDY CURRENT PATHS IN LAMINATION



THE EDDY CURRENT LOSS DEPENDS ON

- FREQUENCY OF THE ALTERNATING CURRENT (OR) FLUX IN ARMATURE CORE
- THE THICKNESS OF THE ARMATURE CORE LAMINATION
- THE FLUX DENSITY IN THE CORE
- THE VOLUME OF THE IRON.

$$\boxed{P_E = K_e f^2 t^2 B^2 V}$$

WATT

P_E = EDDY CURRENT LOSS WATT

K_e = CONSTANT DEPENDING ON THE RESISTIVITY OF THE IRON AND DIMENSIONS EMPLOYED FOR THE FACTOR

f = FREQUENCY HZ

t = THICKNESS OF LAMINATION m

B = MAXIMUM FLUX DENSITY IN CORE T

V = VOLUME OF IRON IN CORE

NT

$$\boxed{P_h = K_h\, f\, B^{1.6}\, m \quad \text{WATT}}$$

K_h = CONSTANT DEPENDING ON MATERIAL & UNIT USED

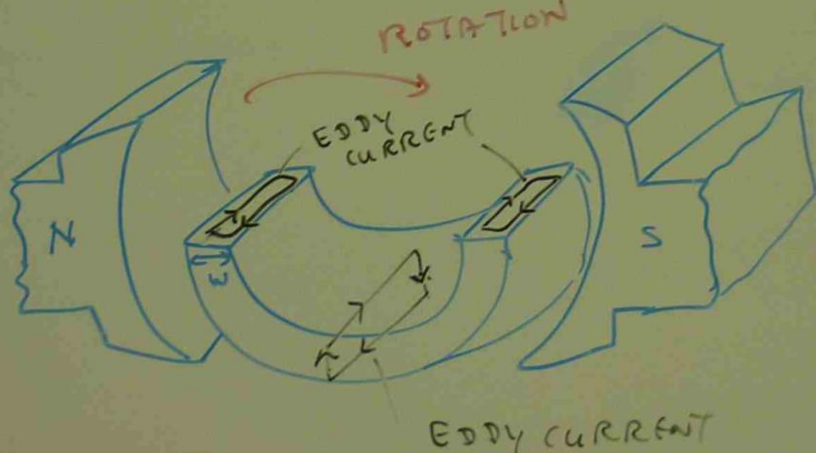
f = FREQUENCY (HZ)

B = MAXIMUM FLUX DENSITY (T)

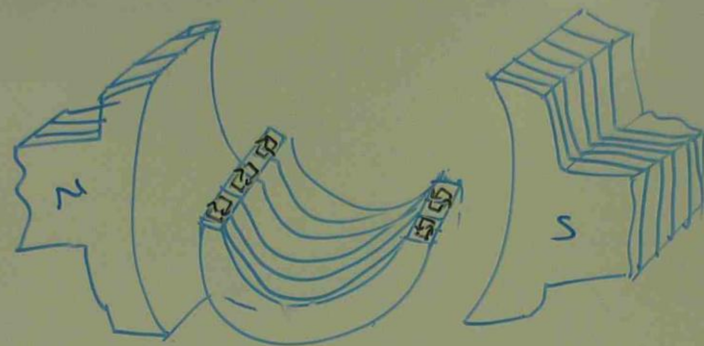
m = MASS OF CORE (Kg)

RUSH

EDDY CURRENT PATHS IN SOLID CORE



EDDY CURRENT PATHS IN LAMINATION



THE EDDY CURRENT LOSS DEPENDS ON

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P_E = EDDY CURRENT LOSS WATT

K_e = CONSTANT DEPENDING ON THE RESISTIVITY OF THE IRON AND DIMENSIONS EMPLOYED FOR THE FACTOR

f = FREQUENCY HZ

t = THICKNESS OF LAMINATION m

B = MAXIMUM FLUX DENSITY IN CORE T

V = VOLUME OF IRON IN CORE (m^3)

ENT

EX CALCULATE EDDY CURRENT AND HYSTERESIS LOSSES FOR THE GIVEN DC MACHINE

$K_e = 3$, $K_h = 2$ FREQUENCY = 60 HZ

THICKNESS OF LAMINATION = 0.5 mm

CORE FLUX DENSITY = 10 TESLA

VOLUME OF CORE = 7 m^3

MASS OF CORE = 50 kg

$$P_h = K_h f B^{1.6} m$$

$$= 2 \times 60 \times (10)^{1.6} \times 50$$

$$= 120 \times 39.8 \times 50$$

$$= 238864 \text{ WATT}$$

$$= 238.86 \text{ kW}$$

$$P_e = K_e f^2 t^2 B^2 V$$

$$= 3 \times (60)^2 \times (0.5 \times 10^{-3})^2 \times 10^2 \times 7$$

$$= 3 \times 3600 \times 0.25 \times 10^{-6} \times 100 \times 7$$

$$= 189000 \times 10^{-6}$$

$$= 1.89 \text{ WATT}$$

PERCENTAGE VOLTAGE REGULATION

WHEN THE LOAD IS APPLIED ON A SELF- EXCITED SHUNT GENERATOR THE TERMINAL VOLTAGE WILL DROP DUE TO THREE EFFECTS. THESE ARE

(1) THE DROP IN THE RESISTANCE OF THE ARMATURE WINDING WHICH IS TERMED $I_a R_a$ DROP

(2) THE EFFECT OF THE ARMATURE FIELD ON THE MAIN FIELD WHICH WILL DECREASE THE EFFECTIVE FLUX

(3) THE RESULTANT DROP IN (1) & (2)

$$\text{PERCENTAGE REGULATION} = \frac{E_g - V_{FL}}{V_{FL}} \times 100$$

V_{FL} = FULL LOAD RATED VOLTAGE

E_g = NO LOAD OPEN CIRCUIT (GENERATED) VOLTAGE pb

V_{FL} of a shunt generator is 480 volt. What is percentage regulation if the open circuit voltage is 510 V?

$$\%\ \text{Regulation} = \frac{E_g - V_{FL}}{V_{FL}} \times 100$$

$$= \frac{510 - 480}{480} \times 100$$

$$= 6.85\ \%$$

(a)

pb A 75 kW 500 volt generator has a voltage regulation of 4%. Calculate

(a) The open circuit voltage

(b) Assuming the voltage varies uniformly between no load and full load current.

Calculate the kW output of a terminal voltage of 510.

(c

520

5

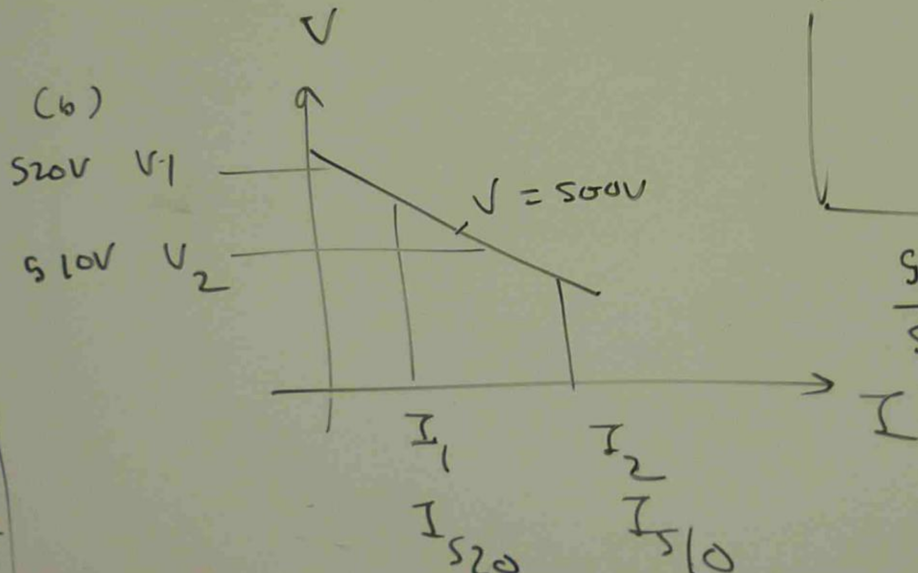
(a) $$\%\,REG = \frac{E_g - V_{FL}}{V_{FL}} \times 100$$

$$4 = \frac{E_g - 500}{500} \times 100$$

$$\frac{4 \times 500}{100} + 500 = E_g$$

$$E_g = 520V$$

(b)



$$\boxed{\frac{V_1 - V_2}{V_1 - V} = \frac{I_2}{I_1}}$$

$$\frac{520 - 510}{520 - 500} = \frac{I_{510}}{I_{520}}$$

V_1 = NO LOAD VOLTAGE

V = FULL LOAD VOLTAGE

V_2 = ANY VOLTAGE

$$\frac{10}{20} = \frac{I_{s10}}{I_{s20}}$$

FULL LOAD CURRENT => TERMINAL VOLTAGE 500V

NO LOAD VOLTAGE 520 V

$$= \frac{\text{POWER}}{\text{TERMINAL VOLTAGE}}$$

$$= \frac{75 \times 10^3}{500}$$

$$I_{s20} = 150 \text{ Amp.}$$

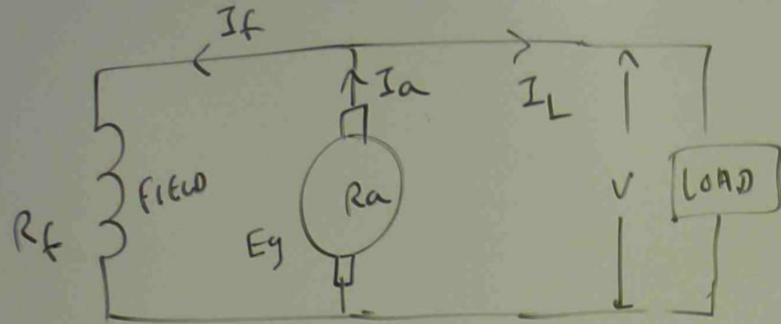
$$\frac{10}{20} = \frac{I_{s10}}{150}$$

$$I_{s10} = 150 \times \frac{10}{20} = 75 \text{ Amp.}$$

$$\text{OUTPUT} = V \times I = 510 \times 75 = 38250\,W$$

$$= 38.25\,kW$$

LOADING A GENERATOR



$$E_g = V + I_a R_a$$

$$I_a = I_L + I_f$$

$$I_f = \frac{V}{R_f}$$

GENERATED VOLTAGE EQUATION

$$E_g = \frac{\phi Z N}{60} \times \frac{P}{a}$$

E_g = GENERATED VOLTAGE (V)

ϕ = FLUX (Wb)

Z = NO. OF ARMATURE CONDUCTORS

N = SPEED (RPM)

P = NO. OF POLES

a = NO. OF ARMATURE PARALLEL PATHS

$a = m \times P$ LAP

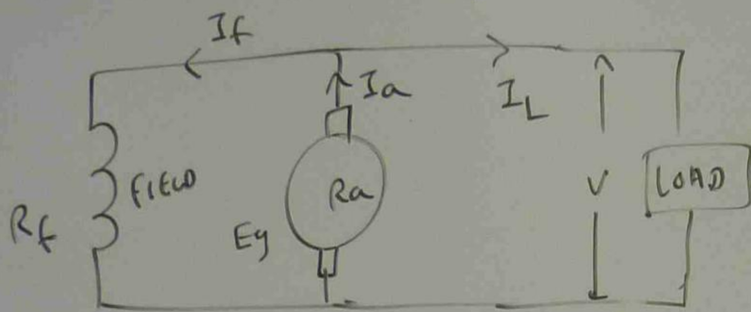
$m = 1$ SIMPLEX

$= 2$ DUPLEX

$= 3$ TRIPPLEX

$a = m \times 2$ WAVE

LOADING A GENERATOR



$$E_g = V + I_a R_a$$

$$I_a = I_L + I_f$$

$$I_f = \frac{V}{R_f}$$

GENGRATED VOLTAGE EQUATION

$$E_g = \frac{\phi Z N}{60} \times \frac{P}{a}$$

E_g = GENGRATED VOLTAGE (V)

ϕ = Flux (wb)

Z = NO. OF ARMATURE CONDUCTORS

N = SPEED (RPM)

P = NO. OF POLES

a = NO. OF ARMATURE PARALLEL PATHS

$a = m \times P$ LAP

$m = 1$ SIMPLEX

$= 2$ DUPLEX

$= 3$ TRIPPLEX

$a = m \times 2$ WAVE