DC Motors

Tuesday, February 16, 2016 12:06 PM

NAMEPLATE:

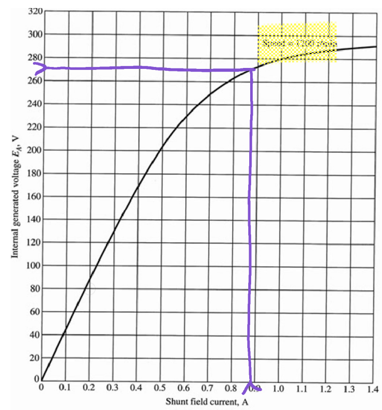
maximum mechanical output power @ full load

P_{rated}=15hp $I_{L,rated}$=55A
V_t=240V N_F=2700 turns per pole
n_{rated}=1200 rpm N_s=27 turns per pole
R_a=0.40 ohm R_f=100 ohm
R_s=0.04 ohm R_{adj}=100 to 400 ohm

external source feeding motor

Rotational losses = 1800W at full load.
Magnetization curve on next slide.

To start, R_{adj} is set at 175 ohm



Ex) GIVEN ABOVE NAMEPLATE AND MAGNETIZATION CHARACTERISTIC, FIND IDLING VELOCITY OF MOTOR

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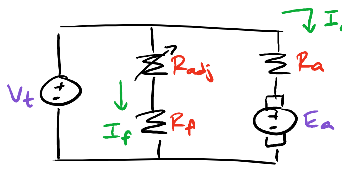
"idling" → no mechanical load
→ output mech. power, $\underline{P_{out} = \emptyset}$



$$I_f = \frac{V_t}{R_{adj}+R_f} = \frac{240V}{175+100\Omega} = 0.87A$$

converted power — output power = $\emptyset$

$$P_{conv} = E_a I_a = P_{rot} + P_{out}$$

rotational losses, friction etc.

↓

$$E_a I_a = P_{rot} = 1800W$$

KVL

↳ $V_t = I_a R_a + E_a$

$240 = I_a(0.4) + E_a$

↓

$\cancel{I_a = 592}$ or $7.596A$

idling so very unlikely @ 592A

↳ $E_a^n = 237V$ ← don't know velocity

@ 1200RPM & $I_f = 0.87A$ → $E_a^{1200} = 270V$

(from mag. characterization curve)

$$\underbrace{\frac{E_a^n}{E_a^{1200}} = \frac{n}{1200}}_{\text{induced voltage \& RPM same ratio}} \longrightarrow n = \frac{237}{270} \cdot 1200 = \boxed{1054\ RPM}$$

↑ idling velocity

Ex) SAME MOTOR AS ABOVE AT FULL LOAD, 15 HP
FIND VELOCITY & SR%

=

$I_f = 0.87A$, $E_a^{1200} = 270V$

$$\boxed{P_{conv} = E_a I_a = P_{rot} + P_{out}} \longrightarrow E_a I_a = 12990W$$

P_{rot}: 1800W; P_{out}: $15hp \times \frac{746W}{hp}$

$\cancel{I_a = 540A}$ or $60A$

$\cancel{E_a = 24V}$ or $216V$

KVL → $V_t = I_a R_a + E_a$ → $240 = 0.4 I_a + E_a$

↑ [illegible] in the

ball-park

$$\frac{E_a^{n}}{E_a^{1200}} = \frac{n}{1200} \rightarrow n = \frac{216}{270}1200 = \boxed{960\text{RPM}}$$

↑ velocity @ full load

SPEED REGULATION PARAMETER

how much load affects the speed

$$\boxed{SR\% = \frac{\omega(\text{idling}) - \omega(\text{full-load})}{\omega(\text{full load})}}$$

$$SR\% = \frac{1054-960}{960}\times 100\% = \boxed{9.79\%}$$

Ex) WHAT IS THE TORQUE AT FULL LOAD?

in rad/s

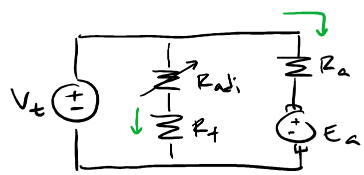
$$\boxed{P_o = \tau_{load}\,\omega_{mech}} \rightarrow \tau_{load} = \frac{P_o}{\omega_{mech}} = \frac{15\text{hp}\cdot 746\frac{W}{\text{hp}}}{960\text{RMP}\ \frac{2\pi}{60}\frac{\text{rad/s}}{\text{RPM}}} = \boxed{111.3\ \text{Nm}}$$

↑ at full load

output mech. power, W

Closer look @ R_{adj}

$R_{adj}\uparrow$ $I_f\downarrow$ $I_a\uparrow$ RPM $\uparrow$



Ex) WHAT HAPPENS IF WE INCRESE R_{adj} TO 250Ω FROM 175Ω?

$$I_f = \frac{V_t}{R_{adj}+R_f} = \frac{240}{250+100} = 0.67A$$

from curve → $E_a = 247V$

$$P_{conv} = E_a I_a = P_{rot} + P_{out}$$

↳ $E_a I_a = 1800W + 15hp(746) = 12990\,W$

KVL → $240 = 0.4\,I_a + E_a$

→ $E_a = \cancel{24.1V}$ or $216V$

→ $n = \frac{216}{247}1200 = \boxed{1049\ \text{RPM}}$

↑ similar velocity as when idling w/ 175Ω R_{adj}

ARMATURE REACTIONS

"this machine has compensation windings"

↳ ie. windings cancel out armature reaction so neglect them if not, consider the following:

$$MMF_f = N_f I_f + N_s I_s - K_{ar} I_a$$

↳ manufacturer usually divides everything by I_f

take this value to curve

$$\boxed{I_f^* = I_f + \frac{N_s}{N_f} I_s - \frac{K_{ar}}{N_f} I_a}$$

manufaturer might say something like:

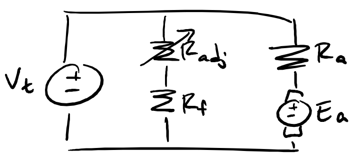
"the armature reaction MMF is given as $K_{ar} I_a = 1200A$ @ $I_a = 55A$"

↳ ie. $K_{ar} = 21.8\ A/A$

for every amp in armature there are 21.8 amps of magnetomotive force subtracted from MMF of field

Ex) $K_{ar} = 21.8\ A/A$, $N_f = 2700$, $N_s = 20$, $R_{adj} = 175\Omega$

everything same as above except ARMATURE REACTION



$$P_{conv} = E_a I_a = P_{rot} + P_{out}$$

1800W, 15hp

not even close

$E_a I_a = 12990W$

$240 = 0.4 I_a + E_a$

$E_a = \cancel{24.1V}$ or $216V$

$I_a = 60.1A$

$$I_f = \frac{240}{175+100} = 0.87A$$

$$I_f^* = I_f + \cancel{\frac{N_s}{N_f} I_s}^{\,\emptyset} - \frac{K_{ar}}{N_f} I_a \longrightarrow I_f^* = I_f - \frac{21.8}{2700} I_a = 0.39A$$

no series coil connected

from curve

$$E_a^{1200} = 167V$$

$$n = \frac{E_a^n}{E_a^{1200}} 1200 = \frac{216}{167} 1200 = \boxed{1552\ RPM}$$

faster than idle

this machine accelerates w/ load and reaches S.S. of 1552 RPM

(negative SR%)

LONG CUMULATIVE COIL

↳ series coil & shunt coil help eachother create stronger mag. field

$$I_f^* = I_f + \frac{N_s}{N_f} I_s + \frac{K_{ar}}{N_f} I_a$$

addition, not subtraction

as before

Ex)

- A 100 hp 250 V cumulative compounded DC motor has an internal resistance, including the series winding, of 0.04 ohm. There are 1000 turns per pole on the shunt field and 3 turns per pole on the series winding. "Idling," the adjustable resistor has been adjusted to make the motor run at 1200 rpm. Neglect core, mech, and stray losses. No armature reaction!

a) What is the idling shunt field current?
b) Cumulative compounded, find rpm if I_a=200A
c) Differentially compounded, rpm, I_a=200A

I_f (A)	1	2	3	4	5	6	7	8	9	10
E_a (V)	65	130	180	220	250	265	275	283	287	289

$V_t = 250V$

$N_f = 1000$

$N_s = 3$

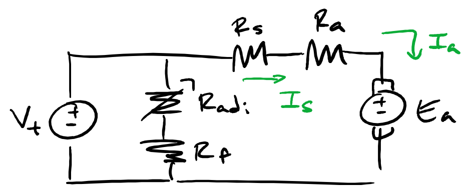
$P_{rot} = \emptyset$ loss

$P_{out} = \emptyset$ idling

$n = 1200$ RPM

$R_a + R_s = 0.04\,\Omega$

Because compounded



$P_{conv} = P_{rot} + P_{out} = E_a I_a$

$\hookrightarrow E_a I_a = \emptyset$

same because compound

a) $E_a = k\phi\omega \leftarrow \omega \neq \emptyset$ & $\phi \neq \emptyset$ $\therefore E_a \neq \emptyset$ $\therefore \underline{I_a = \emptyset}$ & $\underline{I_s = \emptyset}$

$\hookrightarrow \therefore E_a = V_t$ because if $I_a = \emptyset$, no drop across $R_s + R_a$ branch

$\underline{E_a = 250V}$

Determine I_f^* from E_a & table (use interpolation if necessary)

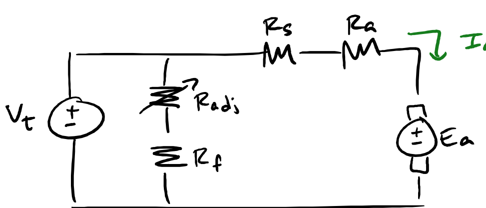
@ 1200RPM $\underline{I_f^* = 5A}$

$$I_f^* = I_f + \cancel{\frac{N_s}{N_f} I_s}^{\,\emptyset} - \cancel{\frac{k_{ar}}{N_f}} I_a^{\,\emptyset}$$

$I_s = I_a = \emptyset$

$\hookrightarrow I_f = I_f^* = \boxed{5A}$

b)



$I_a = 200A$

$I_s = I_a$

KVL $\longrightarrow$ $V_t = I_a(R_s + R_a) + E_a$

$\hookrightarrow E_a = 250 - 200(0.04) = 242V$

$$I_f^* = I_f + \frac{N_s}{N_f} I_s - \cancel{\frac{k_{ar}}{N_f}} I_a^{\,\emptyset}$$

b/c problem says no armature reaction

$\hookrightarrow I_f^* = 5A + \frac{3}{1000} 200 = \underline{5.6A}$

same as before

Determine E_a from table given $I_f^* = 5.6$ & interpolation

Determine E_a from table using $I_f^* = 5.6$ & interpolation

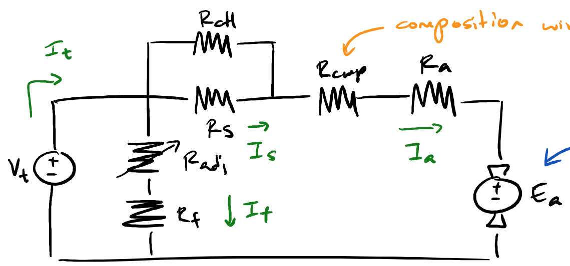
@ 1200RPM $\quad E_a^{1200} = 262V$

$$\frac{E_a^{n}}{E_a^{1200}} = \frac{n}{1200} \longrightarrow n = 1200\,\frac{242}{262} = \boxed{1108 \text{ RPM}}$$

can calculate everything else, P_{out}, τ_{load} etc. from this.

DC MOTOR WITH COMPOUND EXCITATION

composition winding resistance



$P_{conv} = P_{rot} + P_{out} = E_a I_a$

$P_{out} = \tau_{out}\,\omega_{mech}$