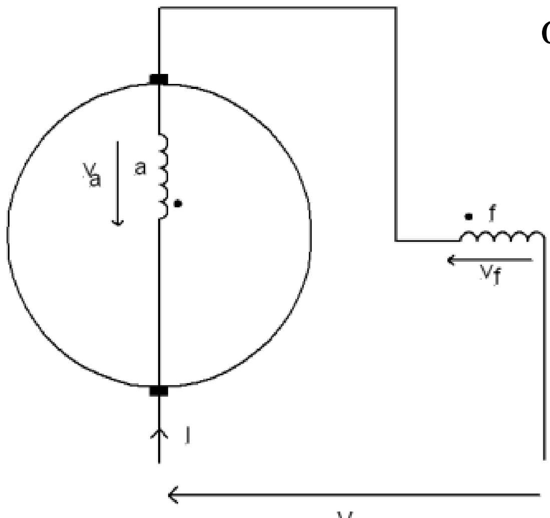
Modelling of Machines

Section 7

Universal series motor

Kron primitive



ω_r in elec rad/s

Rotor coil (on q-axis) often called armature coil
- Hence subscript ‘a’

•Same current passes through the stator and rotor coil
•Reversing the current does not affect direction of rotation and so can be used on both DC and AC supplies – hence the term universal
•Speed on AC supply not restricted by mains frequency (e.g. 2-pole induction machine with is <3000rpm)
•Widely used in mass-market, cost-sensitive applications such domestic appliances, main power tools and kitchen gadgets as low-cost, high-speed machine

BUT – has several performance drawbacks so only used up to <1kW (often cited as being fractional horsepower machines)

Analysis

$$\begin{vmatrix} v_a \\ v_f \end{vmatrix} = \begin{vmatrix} R_a + L_a p & \omega_r M \\ 0 & R_f + L_f p \end{vmatrix} \begin{vmatrix} i_a \\ i_f \end{vmatrix}$$

Constraining equations:

$V = V_a + V_f$

$I = I_a = I_f$

DC operation

On DC the equations reduce to

$$\begin{vmatrix} v_a \\ v_f \end{vmatrix} = \begin{vmatrix} R_a & \omega_r M \\ 0 & R_f \end{vmatrix} \begin{vmatrix} i_a \\ i_f \end{vmatrix}$$

Applying the constraining equations yields:

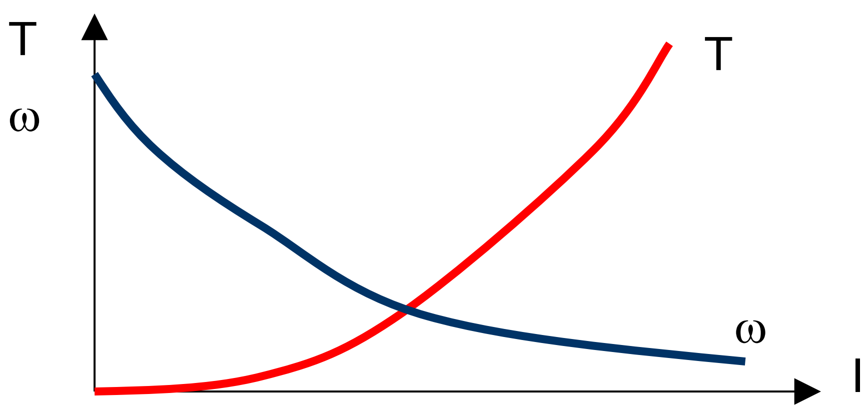
$V = I\,(R_a + R_f + \omega_r M)$

$$T = \frac{Output\ \ power}{\omega_{r_{mech}}} = \frac{Output\ \ power}{\omega_{r_{elec}}} \times pole\ \ pairs$$

Electrical power input = VI = $I^2R + \omega_r M I^2$ Mech. out

Losses

$$T = \frac{pole\ \ pairs(\omega_r M)I^2}{\omega_r} = pole\ \ pairs \times MI^2$$



Typical form of torque-speed curve on fixed voltage supply

In practice, square law torque behaviour limited by saturation