Electrical Drives

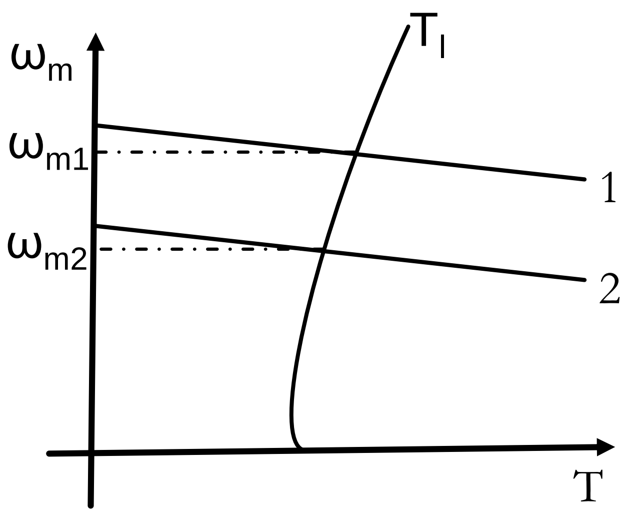
Lecture 5 (12-01-2024)

Control of Electrical Drives

Modes of operation: An electrical drive operates in three modes

- Steady-state
- Acceleration including starting
- Deceleration including braking

The steady state operation for a given speed is obtained by adjusting the steady-state speed-torque characteristics of the motor in such a way that load torque and motor torque are equal at the required speed.



Control of Electrical Drives

Acceleration including starting

Whenever an increase in speed is required drive operates in acceleration mode. For this to happen, motor speed-torque characteristics must be changed so that motor torque exceeds the load torque.

Time taken for given change in speed depends on

- Inertia of the motor-load system
- The amount by which the motor torque exceeds load torque

Deceleration including braking

Whenever a decrease in speed is required deceleration mode occurs.

Drive Classifications

- Constant speed or single speed drives
- Variable speed drives
  - Multi speed drives
  - Stepless speed drives
- Multi motor drive

Variable speed drives

- Constant torque mode
- Constant power mode

Thermal considerations

Unavoidable power losses causes temperature rise in motors

Insulation used in the windings are classified based on the temperature it can withstand.

Motors must be operated within the allowable maximum temperature

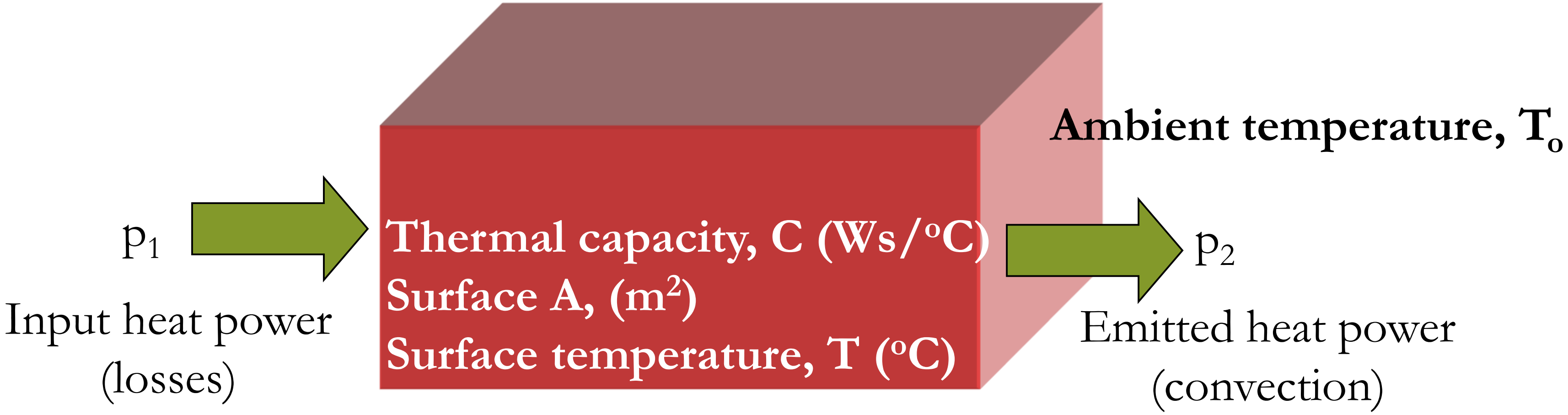
Sources of power losses (hence temperature increase):
- Conductor heat losses (i^2R)
- Core losses – hysteresis and eddy current
- Friction losses – bearings, brush windage

Thermal considerations

Electrical machines can be overloaded as long their temperature does not exceed the temperature limit

Accurate prediction of temperature distribution in machines is complex – heterogeneous materials, complex geometrical shapes

Simplified assuming machine as **homogeneous** body



Thermal considerations

Power balance:

$$C\frac{dT}{dt} = p_1 - p_2$$

Heat transfer by convection:

$$p_2 = \alpha A(T - T_o)$$, where α is the coefficient of heat transfer

Which gives:

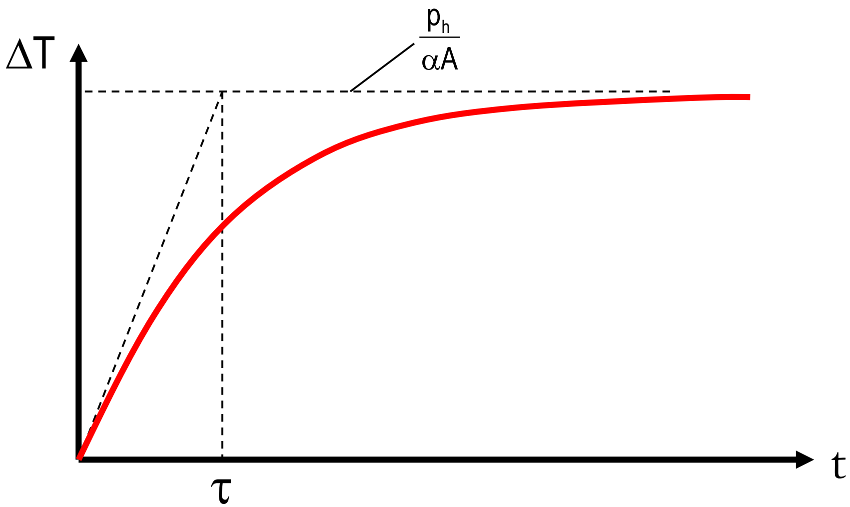
$$\frac{d\Delta T}{dt} + \frac{A\alpha}{C}\Delta T = \frac{p_1}{C}$$

With $\Delta T(0) = 0$ and $p_1 = p_h =$ constant

,

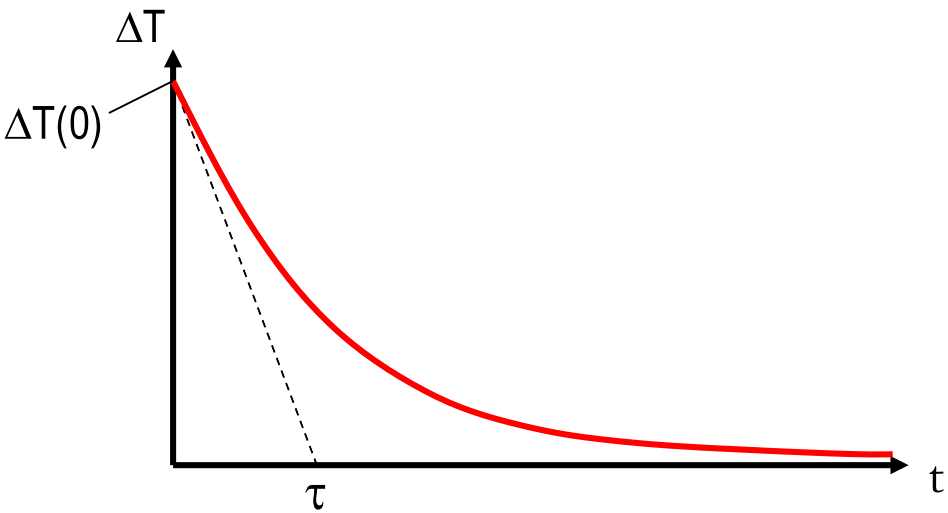
$$\Delta T = \frac{p_h}{\alpha A}\left(1 - e^{-t/\tau}\right)$$, where $\tau = \frac{C}{\alpha A}$

Thermal considerations



$$\Delta T = \frac{p_h}{\alpha A}\left(1 - e^{-t/\tau}\right)$$

Heating transient



$$\Delta T = \Delta T(0) \cdot e^{-t/\tau}$$

Cooling transient

Thermal considerations

The duration of overloading depends on the modes of operation:

Continuous duty

Load torque is constant over extended period

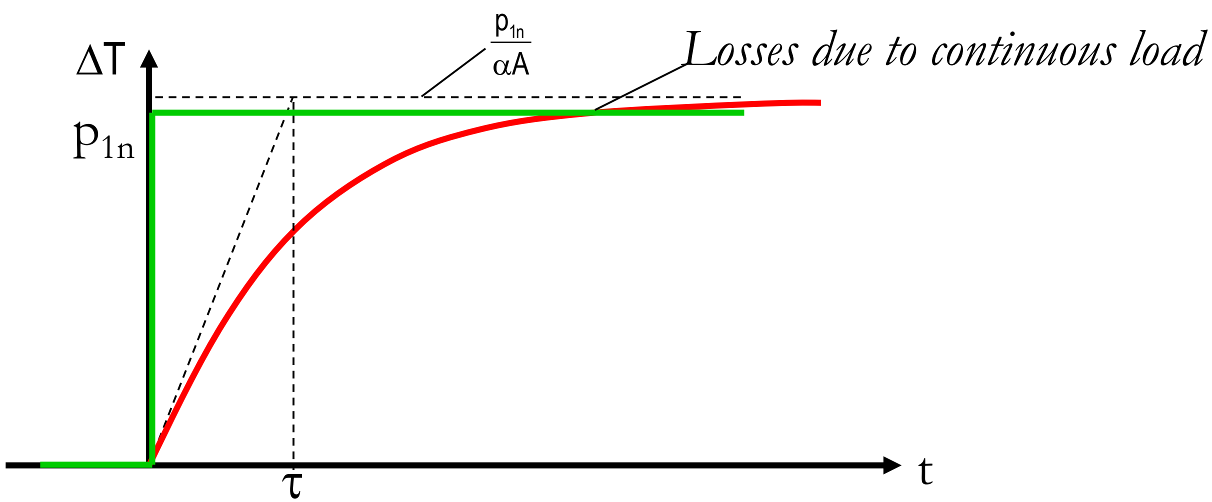
Continuous duty

Short time intermittent duty

Periodic intermittent duty

Steady state temperature reached

Nominal output power chosen equals or exceeds continuous load



Thermal considerations

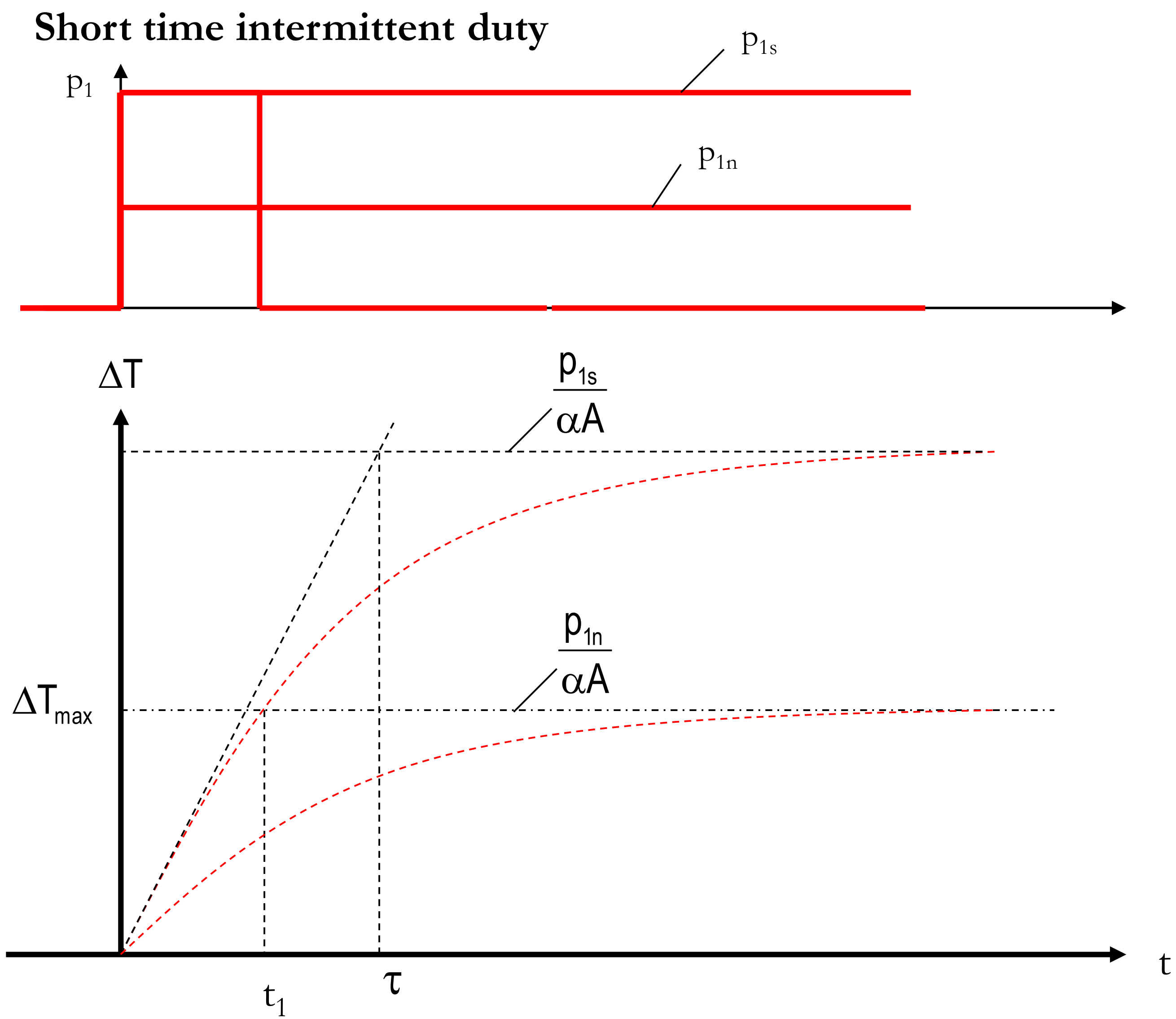
Short time intermittent duty

Operation considerably less than time constant, τ

Motor allowed to cool before next cycle

Motor can be overloaded until maximum temperature reached

Thermal considerations



Thermal considerations

Periodic intermittent duty

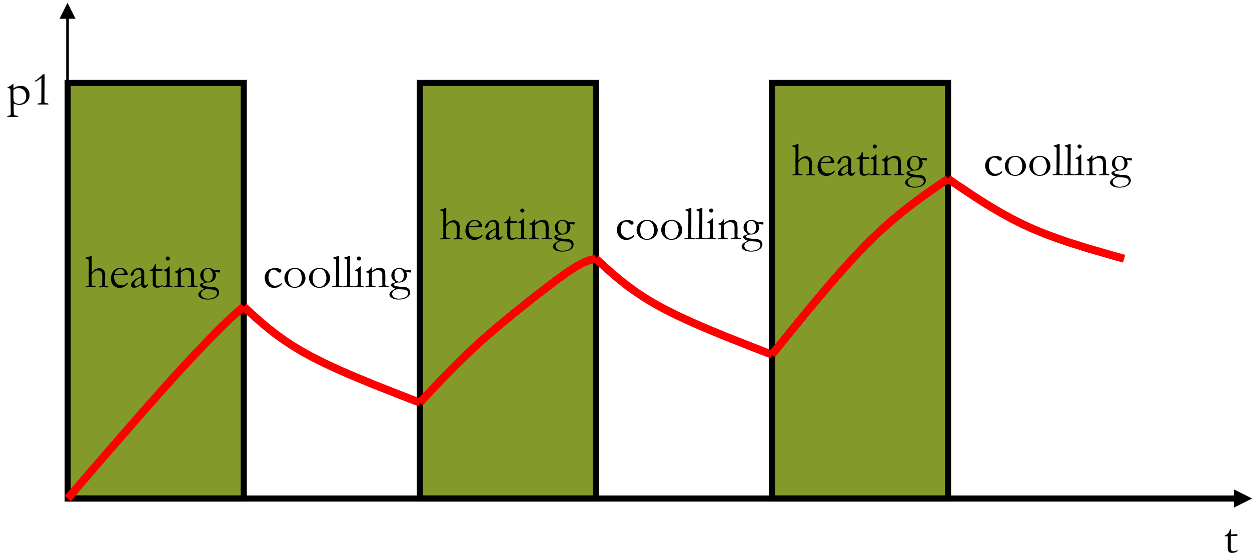
Load cycles are repeated periodically

Motors are not allowed to completely cooled

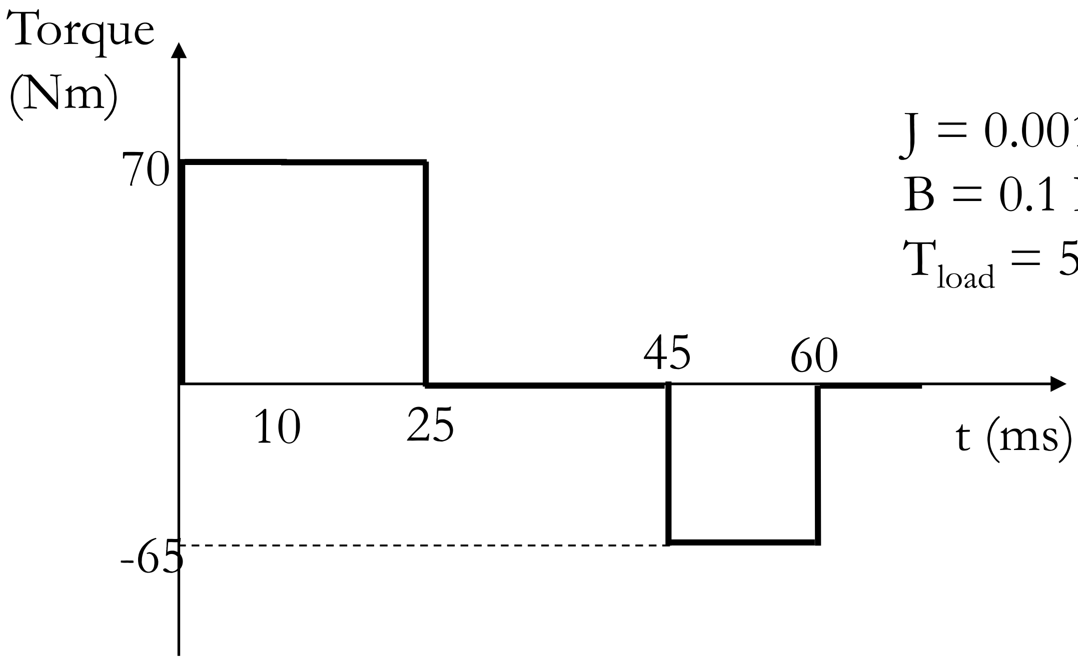
Fluctuations in temperature until steady state temperature is reached

Thermal considerations

Periodic intermittent duty



Problem ?



$J = 0.001$ kg-m^2,
$B = 0.1$ Nm/rads^{-1} and
$T_{load} = 5$ Nm.

For the system with the motor torque profile given above, what would be the speed profile?