Intermittent Duty Operation

If a motor operates intermittently, it is not necessary that the peak load torque fall within the motor's continuous torque capabilities. However, it is important that the RMS (root mean square) load torque be inside the continuous duty zone. The key here is that a sufficient "off" time follow each "on" time of the motor. The RMS torque is given by:

EQUATION 1

$$T_{RMS} = \sqrt{\frac{T_1^2 t_1 + T_2^2 t_2 + \ldots T_n^2 t_n}{t_1 + t_2 + \ldots t_n}}$$

T_n = Torque at time n

t_n = Duration of time n

The above equation assumes t_1 is small compared to the thermal time constant (TCT) for torque values significantly larger than the continuous torque (T_C). This is not always a good assumption. Where torque values significantly exceed T_C, use the following equation:

EQUATION 2

$$\frac{T_{OUT}}{T_C} = \sqrt{\frac{1 - e^{-t_{on}/(\text{Duty Cycle x TCT})}}{1 - e^{-t_{on}/TCT}}}$$

Where: Duty Cycle = $t_{on}/(t_{on} + t_{off})$

T_{OUT} = output torque

T_C = continuous torque at operation speed

t_{on} = time on

TCT = thermal time constant

As a rule of thumb, this equation is used if the "on" time at twice T_c is greater than 5% of TCT.

Equation 2 expresses operation torque as a function of "on" time. It also breaks the operation cycle down to individual periods of "on" time and "off" time. Substituting for duty cycle and solving for t_{off} yields:

EQUATION 3

$$t_{off} = -TCT \ln\left[1 - \frac{\left(1 - e^{-t_{on}/TCT}\right) T_{OUT}^2}{T_C^2}\right] - t_{on}$$

Thus, for a specific output torque and a given “on” time, the required “off” time is known. This off-time is required so the motor cools sufficiently and does not exceed its thermal limits. The calculated “off” time should proceed the initial “on” time to ensure that ultimate temperature is not surpassed on the first cycle.

It may also be useful to calculate a time to ultimate temperature based on a one time excursion from ambient temperature. Consider the following pair of equations:

EQUATION 4

$$T_{R\ \text{Actual Above Ambient}} = T_{R\ \text{Rated Above Ambient}} \left(\frac{T_{OUTPUT}}{T_C} \right)^2$$

EQUATION 5

$$T_{R\ \text{Rated}} = T_{R\ \text{Ultimate}} \left(1 - e^{-t/TCT}\right)$$

Substituting 4 into 5:

$$T_{R\ \text{Actual}} \left(\frac{T_C}{T_{OUTPUT}} \right)^2 = T_{R\ \text{Ultimate}} \left(1 - e^{-t/TCT}\right)$$

To find the time to ultimate temperature, set $T_{R\ Actual} = T_{R\ Ultimate}$ and solve for t. This yields the following equation:

EQUATION 6

$$t_{max} = -TCT \ln\left[1 - \left(\frac{T_C}{T_{OUTPUT}} \right)^2 \right]$$

Where: t = maximum on time

TCT = thermal time constant of motor

T_C = continuous torque of the motor at the particular operation speed

T_{OUT} = operation torque

This gives the maximum “on” time for a given operation torque beginning at ambient temperature. Examination of this equation reveals that as T_{OUT} approaches T_C, t approaches infinity. This is expected since we can theoretically operate the motor indefinitely at continuous torque without exceeding its thermal limits. Equation 3 defines the motor’s operation time limits.