SERVO MOTOR PERFORMANCE vs TEMPERATURE

George Younkin, P.E.,MSEE

In the process of sizing a brushless dc servo drive on an industrial machine, little consideration is given to the effect of temperature on the dynamic performance of the servomotor. Actually temperature has a significant effect on the motor time constants. The motor resistance increases with temperature as-

$$R(T) = R(T_o)[1 + 0.00393(T - T_o)]$$

where: T= Winding temperature (^oC)

$T_o = \textit{Specified temperature (usually the cold temperature)}\ (^oC)$

$0.00393/^o\ C = \textit{linear}$ temperature coefficient for copper magnet wire.

Likewise, the motor torque constant (K_t) and voltage constant (K_e) vary with temperature for Ferrite magnets as-

$$K_{e,t}(T) = K_{e,t}(T_o)[1 - 0.002\,(T - T_o)]$$

The motor time constants are a function of the above constants [1]. The electrical time constant (t_e) varies with temperature as-

$$t_e = \frac{L}{R(T)} \quad \text{(sec)}$$

The motor mechanical time constant is a function of the motor resistance, total inertia at the motor, the motor voltage constant (t_e) and mechanical time constant (t_m) as-

$$t_m = \frac{R(T)\,J}{K_e(T)\,K_t(T)} \quad \text{(sec)}$$

The motor mechanical time constant varies with temperature as-

$$t_m(T) = t_m(T_o)\left[\frac{1 + 0.00393(T - T_o)}{(1 - 0.002(T - T_o))^2}\right]$$

Supplying the above equations to the servo motor response equation-

$$\frac{w_{(jw)}}{e_{(jw)}} = \frac{1/K_e}{[t_m t_e s^2 + t_m s + 1]}$$

A brushless dc motor-AB 1326AB-B740C at 25^oC and 155^oC will have tabulated constants-

	$25^o\,C$	$155^o\,C$
$K_e \quad \left[\frac{V-S}{rad}\right]$	1.8449	1.36549
$1/K_e$	0.542	0.73240
K_t [lb-in/A]	26.4	19.53
$R \quad [ohms_{(l-l)}]$	0.61	0.92
$J_{total}\ [lb-in-\sec^2]$	0.33152	0.33152
t_m [sec]	0.00359	0.00985
t_e [sec]	0.0186	0.01234

These parameters result in the frequency response comparison of figure 1 and the transient response comparison of figure 2. From these comparisons the cold $25^o\,C$ motor response is more oscillatory than a motor with an internal temperature of $155^o\,C$. As a figure of merit, the mechanical and electrical time constants should be separated by a factor of 4 for stable motor response. The closer these two time constants are, the more oscillatory the motor response will be as can be observed in this example.

These motor response characteristics are just for the motor alone. In actual practice, the servo drive will have an amplifier with some equalization such as proportional plus integral (P,I) compensation. With the proper compensation, the servo can be made stable with the differences in motor response with temperature.

[1] Welch Jr.,Richard, Younkin, George, *How Temperature Affects a Servomotor's Electrical and Mechanical Time Constants*, Proceedings of the IEEE IAS annual meeting, Pittsburgh, October, 2002.