Servo Motor Gearhead Sizing

Gearheads offer the following advantages to a servo application:

- The ability to operate the motor over its optimum speed range
- Minimize motor size by multiplying torque
- Minimize reflected inertia for maximum acceleration
- Provide maximum torsional stiffness

The following relationships apply:

$$\text{Output Speed} = \frac{\text{Input Speed}}{\text{Gear Ratio}}$$

Where: Gear Ratio = Gear input turns/ Gear output turns

Output Torque = Input Torque x Gear Ratio (Gearbox Efficiency)

Where: Gearbox Efficiency = % of Effciency/100

$$J_L\text{ (reflected)} = \frac{J_L}{\text{Gear Ratio}^2} + J_{GEARBOX}$$

Where: J_L = Load Inertia

J_L (reflected) = Reflected Load Inertia

$J_{GEARBOX}$ = Gearbox Inertia

An efficiency term should be applied in the denominator when making acceleration calculations to account for the additional input torque required to overcome gearbox losses.

$$\text{Optimum Gear Ratio (N)} = \sqrt{\frac{J_L + J_{GEARBOX}}{J_M}}$$

Where: J_M = Motor Inertia

There are two basic approaches to sizing gearmotors for servo applications. The simplest approach can be used if the load is basically constant and acceleration or deceleration rates are not a consideration. In this case, Danaher Motion's **GOLD**LINE gearhead selection matrix provides performance data for available motor/gearhead combinations. In this example, it is still necessary to calculate the reflected inertia of the load for amplifier compensation purposes. It is desirable to keep the reflected inertia ≥ 5 x J_M for any motor drive system. This may affect the selection of the motor series. The low inertia B series or the medium inertia M series can be used.

Generally with servo applications, the required peak and continuous motor torque ratings are determined by an analysis of the desired motion profiles and duty cycle by the following procedure.

1. Begin the selection process by choosing the largest ratio available to meet the necessary load speed. Gearhead input speeds are generally limited to 5000 rpm unless otherwise limited by the motor winding selection. Available ratios for **GOLD**LINE motors are shown on the selection matrix. In addition, it is desirable to keep the reflected inertia under 5 x the motor inertia. (The optimum gear ratio will yield a reflected inertia equal to the motor inertia. With gearbox input speeds limited to 5000 rpm, this is not always possible.)
2. Initially, calculate acceleration torques, neglecting motor and gearhead inertia, along with thrust or friction torques. Determine the RMS torque. (See Application Notes V002 and M002 for details on acceleration and intermittent motor/amplifier selection can be made.
3. Calculate the ratio of load to motor inertia (n) first based on the use of a B series (low inertia) model. Include the gearbox inertia with the load inertia.

$$n = \frac{J_L(\text{reflected}) + J_{\text{gearbox}}}{J_M}$$

Should (n) be greater than 5, recalculate (n) based on an M series (medium inertia) model.

Should (n) still be greater than 5, and the maximum possible gear ratio has been chosen, consult an applications engineer for information concerning special amplifier compensation and system performance.

4. Recalculate acceleration and RMS torques (No. 2.of procedure) based on the system selected. Include now the motor and gearhead inertia as part of the total system inertia. Based on the actual acceleration and RMS torque values determined, compare with the motor's torque ratings. A recalculation is often necessary using a motor with a higher torque rating.
5. For planetary gearboxes, confirm gearbox sizing based on the peak and equivalent torque loading on the gearbox. Although gearboxes are typically chosen for a specific motor to meet typical applications, occasionally it is necessary to oversize the gearbox. This is because the equivalent torque rating for a gearbox can significantly exceed the RMS torque rating.

The equivalent torque rating is calculated by the following formula.

$$T_{EQ} = \sqrt[8.7]{\frac{T_1^{8.7}\, n_1\, t_1 \; + \; T_2^{8.7}\, n_2\, t_2 \; + \; T_n^{8.7}\, n_n\, t_n}{(t_1 \; + \; t_2 \; + \; t_n)\, n_m}}$$

Where: T_{EQ} = Equivalent torque

$T_1.T_2$'T_n = Times 1-n

n_1, n_2, n_n = Average speeds for periods 1-n

The average speed is the average of the starting speed and ending speed for a given period

n_m = Mean input speed for the period is defined by the following:

$$n_m = \frac{n_1 t_1 + n_2 t_2 \; + \; n_n t_n}{t_1 \; + \; t_2 \; + \; t_n}$$

A cycling factor is now applied to the equivalent torque (T_{EQ}) per the following:

$$T_{EQM} = \frac{T_{EQ}}{Q}$$

Q	Cycles/HR
1	>0
0.9	>1000
0.7	>2500
0.5	>5000