GETTING A HANDLE ON INERTIA

Belt drive

To find the total inertia, J of components on common shafts such as this belt driven conveyor roller, add together the individual inertias then divide this sum by the square of the gear ratio, i.

$$J = J_1 + \frac{J_2 + J_3}{i^2}$$

Calculate system inertia before sizing a power transmission component.
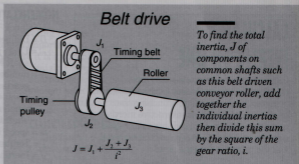
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A torque-limiting clutch may slip momentarily when machinery starts, but once it reaches steady-state speed, it holds tight. The reasons for the slippage may include a large acceleration rate and driven-component inertia. Acceleration is changeable with motor controls, but inertia is a physical property of the system and scales with system size. Larger, heavier components simply have more inertia than lighter ones and require proportionately larger forces to accelerate them.

Installing lighter, smaller parts is not always possible or practical to reduce system inertia. For example, the massive chucks used to hold workpieces for turning operations help quell vibration. These high-inertia parts can also reflect significant inertial forces to other connected parts when the drivetrain changes speed. Therefore, it is important to consider the whole system when selecting individual components.

The first step in determining system inertia is to calculate component inertia. Shafts or flanges, for example, often reduce to simple solid or hollow cylinders or flat plates. Complex shapes require more work but the principle is the same.

Next, address the system configuration. Speed reducers are common components. They include belts and pulleys, gearboxes, and chain drives. Regardless of the type, all reducers modify reflected load inertia according to the inverse square of the re-

Low-speed operation
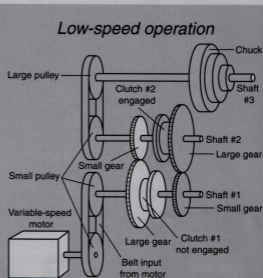
Output speed (rpm), $\omega_3 = \omega_0 \dfrac{D_{P2}}{D_{P1}} \dfrac{N_{S1}}{N_{L2}}$

Torque reflected to motor shaft (lb - in.), $T_1 = T_3 \dfrac{\omega_3}{\omega_1}$

Inertia reflected to motor shaft (lb-in.²),

$$J_1 = \frac{\left[\dfrac{\left(\dfrac{J_{LP3} + J_{S3} + J_C}{\left(\dfrac{D_{P3}}{D_{P2}}\right)^2}\right) + J_{SP2} + J_{SG3} + J_{S2} + J_{LG2} + \left(\dfrac{J_{LG1}}{\left(\dfrac{N_{S1}}{N_{L2}}\right)^2}\right)}{\left(\dfrac{N_{L2}}{N_{S1}}\right)^2}\right]}{} + J_{SG1} + J_{SP1} + J_{S1}$$

The components of a two-speed, machine-tool drive include a variable-speed electric motor, clutches for engaging high and slow-speed gear

CALCULATE INERTIA ON-LINE

Inertia formulas are included in most engineering handbooks but Ogura Industrial, Somerset, N.J., has made crunching the numbers easier with its interactive inertia calculator at www.ogura-clutch.com. Key in component dimensions, shape, and material and the program does the rest.

High-speed operation

Output speed (rpm), $w_{L_1} = w_o \dfrac{D_{P_2}}{D_{P_3}} \dfrac{N_{L_1}}{N_{S_2}}$

Torque reflected to motor shaft (lb - in.), $T_1 = T_L \dfrac{w_{L_1}}{w_1}$

Inertia reflected to motor shaft (lb - in.^{2}),

$$J_1 = \left[\frac{\dfrac{J_{LP3} + J_{L3} + J_C}{\left(\dfrac{D_{P3}}{D_{P2}}\right)^2} + J_{SP2} + J_{M12} + J_{L2} + J_{std2} + \dfrac{J_{LD1}}{\left(\dfrac{N_{L1}}{N_{S2}}\right)^2}}{\left(\dfrac{N_{L1}}{N_{C2}}\right)^2} \right] + J_{LG1} + J_{SP1} + J_{S1} + J_{M01} + \dfrac{J_{LD1}}{\left(\dfrac{N_{L1}}{N_{S1}}\right)^2}$$

sets, and a belt-driven output shaft. Inertia reflected to the motor shaft and the required motor torque change depending on which gear set is driving the load.
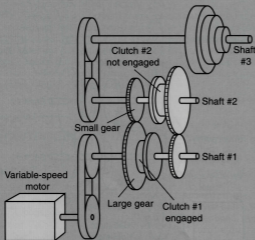
duction ratio, N.

For example, an ideal 2:1 speed reducer placed between a load and a motor output shaft cuts load inertia reflected to the shaft by one-fourth. This same device operating instead as a 1:2 speed increaser boosts reflected load inertia to the motor shaft fourfold. In practice, reducers aren't 100% efficient and this less-than-unity efficiency term, η, also appears in the denominator of the reflected inertia expression but to the first power:

$$J = J_{reducer} + \frac{J_{load}}{N^2 \eta}$$

Still, acceleration and inertia are just part of the picture. Operating speed and cycle time also factor in. For example, if a machine is required to frequently halt from high operating speeds, energy dissipation per cycle is an important metric. And large acceleration rates combined with high inertia would warrant careful attention to clutch and coupler selection. The torque required for acceleration usually determines component capacity because friction forces add to inertia during acceleration. Conversely, friction boosts deceleration.

Lastly, wear and tear can be minimized by scaling components with a service factor appropriate for the intended operation. For low cycle rates and light loads, a 1.0 to 1.5 service factor is generally adequate. Systems with relatively high cycle rates and shock loads may require a service factor of three or higher. ∎

For more information

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