What

DC BRUSHED ROTARY MOTOR

A DC brushed rotary motor is an electrical motor that powered by direct current electric power and converts electrical energy into mechanical energy. It contains a brushed internal mechanical commutation to reverse motor windings' current in synchronism with rotation.

To transfer current, brushed DC motor needs a mechanical system. A wound armature is attached to the center as a rotor, and permanent magnets are bonded to be a ring surrounding the rotor as a stator. The brushes (two small columns), pressed by spring pressure, are fixed on two specific positions and connected to the commutator, allowing the current to flow into the wound armature.

When the coil is powered, the magnetic fields are generated around the armature and the force then starts to rotate the motor shaft. The rotor coils and commutator rotate, while the stator magnets and brushes fixed. To avoid stopping when armature is horizontally aligned and the torque is zero, the commutator switches direction of current through the coil as the rotor turns, reversing the magnetic fields, and keeping the force in the same direction.

DC BRUSHLESS ROTARY MOTOR

A DC brushless rotary motor is an electrical motor that runs on direct current electricity without brushes and commutator, produces rotary motion or torque and converts electrical energy into mechanical energy.

After the development of semiconductor electronics in the 1970s, the brushes and commutator in the brushed motor could be eliminated, an electronic control system replaces the mechanical commutator contacts. Brushless DC motors (BLDC motors), also known as electronically commutated motors (ECM or EC motors) and synchronous DC motors, powered by DC electricity via an inverter or switching power supply. In a typical brushless DC motor, the permanent magnets are fixed on the rotor and the wound armature (electromagnet coils) become windings of the stator. The speed of the rotor is affected by the speed of the rotating magnetic field of the stator and the number of poles.

The Hall effect sensor is used to perceive the position of permanent magnet pole, for timely switching the direction of current to ensure that the magnetic force is generated in the right direction. But on the market today, there are still many BLDC rotary motors take advantage of back electromotive force instead of using Hall effect sensors.

LINEAR MOTOR

A linear motor is a direct driven electric motor that produces a linear force in a straight line and converts electrical energy into mechanical energy as linear motion without extra transfer mechanism. We can think of it as cutting a rotating motor from radial direction and laying it out flat.

For different moving parts (moving coil and moving magnet track), there are two kinds of systems. Typically, the magnet track is the stationary part and the forcer containing coils is the moving part, for greater acceleration from the lower mass. But moving magnet motors are able to achieve higher precision. Shape of the linear motors could be manufactured as: a plate of surface-mounted track with a moving forcer (Flat linear motors), two parallel magnet tracks facing each other with the forcer in the middle of them (U-channel linear motors), or a forcer moves on a cylindrical bar that houses the magnets (Tubular linear motors). Specific configuration depends on the operating condition and particular application. Few types are followed.

Iron core linear motors consist of three-phase electromagnetic coils that are wound around the iron core (teeth) of laminations on forcer, and the iron core could increase the force output. However, there will also be cogging force and attractive force between forcer and track, affecting thrust force and bearing life.

Ironless linear motors are sometimes referred to as U-channel linear motor, and the windings are mounted in epoxy rather than iron lamination stack. Typically, the coil winding is three-phase, with brushless commutation. Zero cogging and attractive force extend the bearing life, but force output becomes smaller.

Slotless linear motors combine the design elements of iron core motors and ironless motors. The three-phase coils with back iron held together with epoxy over a single track. They have lower cost and better heat dissipation than U-channel ironless design, and lower attractive force and less cogging than iron core design.

The slotless-ironless flat motors consist of coils mounted to an aluminum base. While the slotless-iron flat motors consist of coils mounted to iron laminations, which are used to direct the magnetic field and increase the force, and then mounted to the aluminum base. Attractive force and cogging force are present in construction containing iron laminations, but this design produces more force than ironless design.

Tubular linear motors are another type of linear motors. The coil winding is typically three-phase, with brushless commutation using Hall effect devices, and those motors can be constructed with iron or ironless stators. The tubular linear motor has the coils surrounding cylinder-shaped magnets shaft. When current in the forcer is adjusted across the three-phase, magnetic fields are generated.

Voice coil motor, also known as non-commutated DC linear motor, is a single-phase tubular linear motor with moving coils or moving magnets. It consists of permanent magnetics and coils, and when the current flowing through the coil interacts with the permanent magnetic fields, the moving force is generated.

How-Selection

Power and Torque

The relationship between power and torque is:

$$M = 9550 \cdot \frac{P}{n}$$

where

M: Torque (N·m)
P: Power (kW)
n: Speed of Rotation (rpm)

Also, power can be calculated by：

$$P = F \cdot v$$

where

F: Force (N)
v: Velocity (m/s)

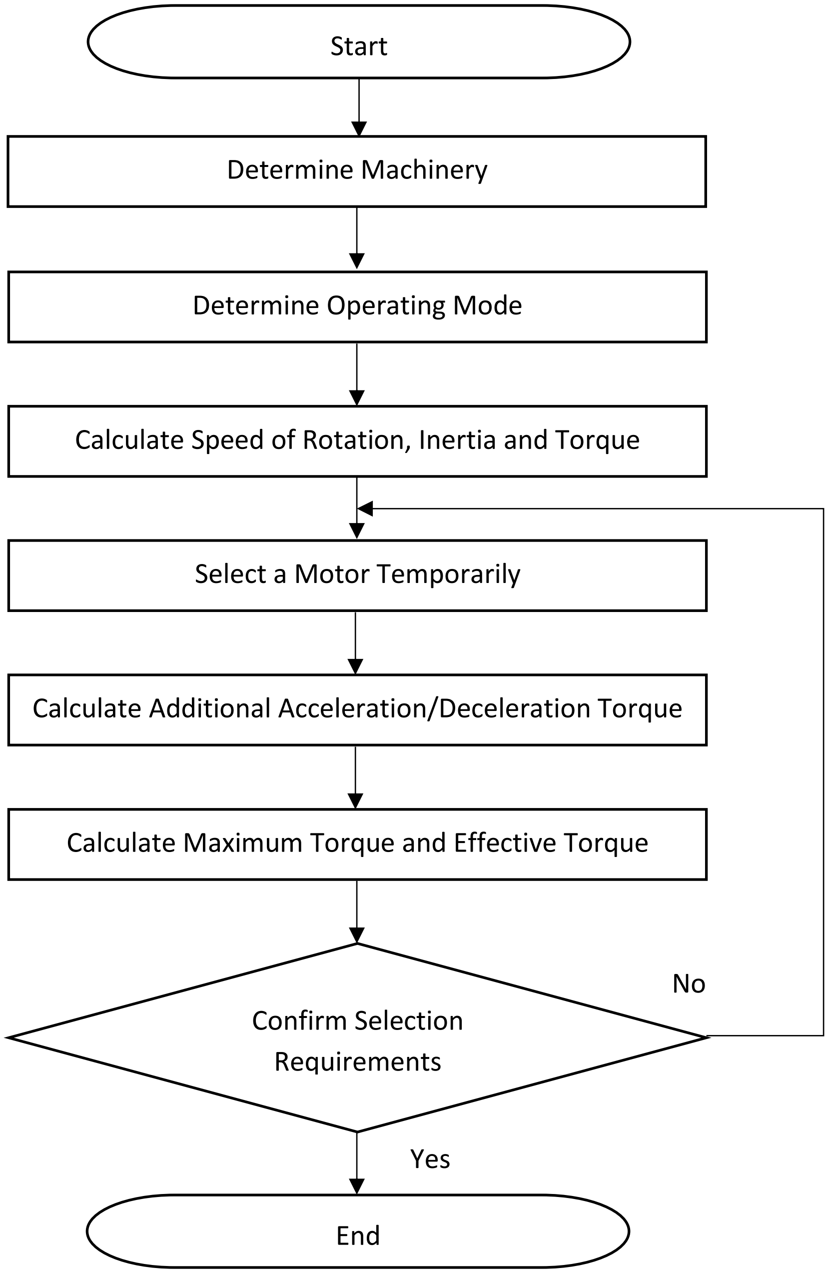
In many cases, when force is friction force,

$$F = \mu m g$$

where

μ: Friction Coefficient
m: Mass (m/s)
g: Gravity Acceleration (m/s^2)

Rotary Motor



1. Determine system (machinery/ application).
2. Determine operating mode (speed, acceleration/deceleration time, positioning time).
3. Calculate speed of rotation (n), inertia (J) and torque (T).
4. Select a motor temporarily.
    - The inertia of the selected servo motor is more than a certain ratio of a load Inertia.

Load/Motor inertia ratio	Option 1	Option 2	Option 3
Closed loop stepping motor	50	100	200
Stepping	30	40	50

motor			
DC brushed servomotor	3	5	10
DC brushless servomotor	3	5	10
DC brushless torque motor	10	20	30

Note: For large inertia (> 20kg·m^2), DC brushed motors and DC brushless motors usually use ratio of 3 or 5

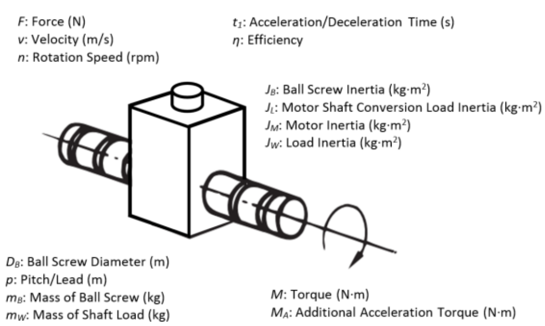
- 80% of the Rated Torque of the selected servo motor is more than the load torque of the servomotor shaft conversion value.

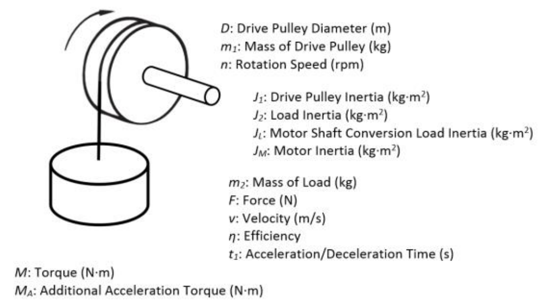
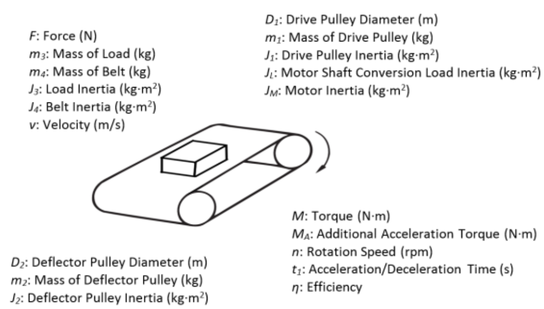
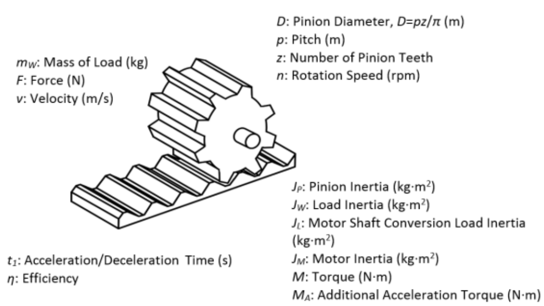
5. Calculate additional acceleration/deceleration torque (M_A).
6. Calculate maximum momentary torque and calculate effective torque
   Acceleration torque (N·m): $M_1 = M + M_A$
   Uniform torque (N·m): $M_2 = M$
   Deceleration torque (N·m): $M_3 = M - M_A$
   Effective torque/Root mean square torque (N·m):

$$M_{RMS} = \sqrt{\frac{1}{(t_1 + t_2 + \cdots + t_n)}\left(t_1 \cdot {M_1}^2 + t_2 \cdot {M_2}^2 + \cdots + t_n \cdot {M_n}^2\right)}$$

7. Confirm motor selection requirements and verify selected motor.
   The maximum torque of the motor is larger than M_1.
   The rated torque of the motor is larger than M and M_{RMS}.
   The rated speed of the motor is larger than n.

Formulas for different machinery

<table>
<tr><td rowspan="3">Screw</td><td rowspan="3">
</td><td>Speed of Rotation</td><td>$n = \frac{60}{p} \cdot v$</td></tr>
<tr><td>Inertia</td><td>$J_B = \frac{1}{8} \cdot m_B \cdot {D_B}^2$
$J_W = m_W \cdot \left(\frac{p}{2\pi}\right)^2$
$J_L = J_B + J_W$</td></tr>
<tr><td>Torque</td><td>$M = F \cdot \frac{p}{2\pi\eta}$
$M_A = \frac{2\pi n}{60 t_1} \cdot \left(\frac{J_L}{\eta} + J_M\right)$</td></tr>
<tr><td rowspan="2">Lift</td><td rowspan="2"></td><td>Speed of Rotation</td><td>$n = \frac{60}{\pi D} \cdot v$</td></tr>
<tr><td>Inertia</td><td>$J_1 = \frac{m_1 D^2}{8}$
$J_2 = \frac{m_2 D^2}{4}$
$J_L = J_1 + J_2$</td></tr>
</table>

		Torque	$M = F \cdot \frac{D}{2\eta}$ $M_A = \frac{2\pi n}{60 t_1} \cdot \left(\frac{J_L}{\eta} + J_M\right)$
Belt		Speed of Rotation	$n = \frac{60}{\pi D_1} \cdot v$
		Inertia	$J_1 = \frac{m_1 {D_1}^2}{8}$ $J_2 = \frac{m_2 {D_2}^2}{8} \cdot \frac{{D_1}^2}{{d_2}^2}$ $J_3 = \frac{m_3 {D_1}^2}{4}$ $J_4 = \frac{m_4 {D_1}^2}{4}$ $J_L = J_1 + J_2 + J_3 + J_4$
		Torque	$M = F \cdot \frac{D_1}{2\eta}$ $M_A = \frac{2\pi n}{60 t_1} \cdot \left(\frac{J_L}{\eta} + J_M\right)$
Rack and Pinion		Speed of Rotation	$n = \frac{60}{pz} \cdot v$
		Inertia	$J_W = m_W \cdot \left(\frac{pz}{2\pi}\right)^2$ $J_L = J_P + J_W$
		Torque	$M = F \cdot \frac{pz}{2\pi\eta}$ $M_A = \frac{2\pi n}{60 t_1} \cdot \left(\frac{J_L}{\eta} + J_M\right)$
Four-Wheel Vehicle		Speed of Rotation	$n = \frac{60}{\pi D} \cdot v$
		Inertia	$J_F = \frac{1}{8} \cdot m_1 \cdot D^2 \cdot 4$ $J_W = m_2 \cdot \left(\frac{D}{2}\right)^2$ $J_L = J_F + J_W$

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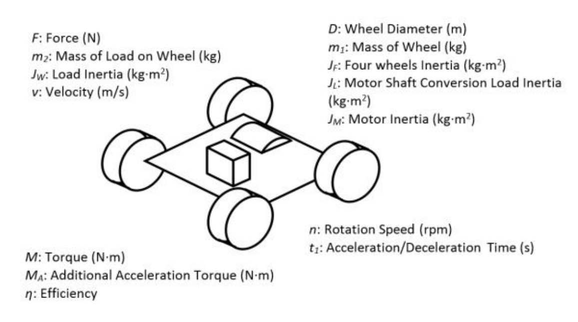
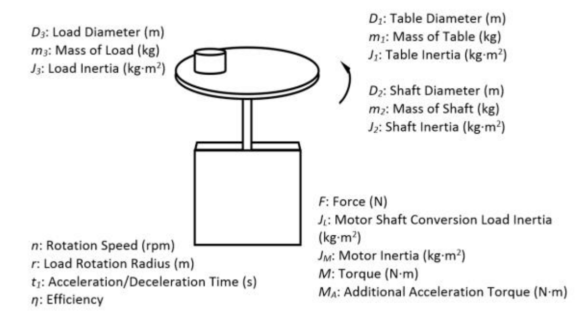
<td>
</td>
<td>Torque</td>
<td>$$M = F \cdot \frac{D}{2\eta}$$ $$M_A = \frac{2\pi n}{60 t_1} \cdot \left(\frac{J_L}{\eta} + J_M\right)$$</td>
</tr>
<tr>
<td rowspan="4">Table</td>
<td rowspan="4">
</td>
<td>Speed of Rotation</td>
<td>$$n$$</td>
</tr>
<tr>
<td>Inertia</td>
<td>$$J_1 = \frac{1}{8} \cdot m_1 \cdot {D_1}^2$$ $$J_2 = \frac{1}{8} \cdot m_2 \cdot {D_2}^2$$ $$J_3 = \frac{1}{8} \cdot m_3 \cdot {D_3}^2 + m_3 \cdot r^2$$ $$J_L = J_1 + J_2 + J_3$$</td>
</tr>
<tr>
<td>Torque</td>
<td>$$M = F \cdot \frac{d}{\eta}$$ $$M_A = \frac{2\pi n}{60 t_1} \cdot \left(\frac{J_L}{\eta} + J_M\right)$$</td>
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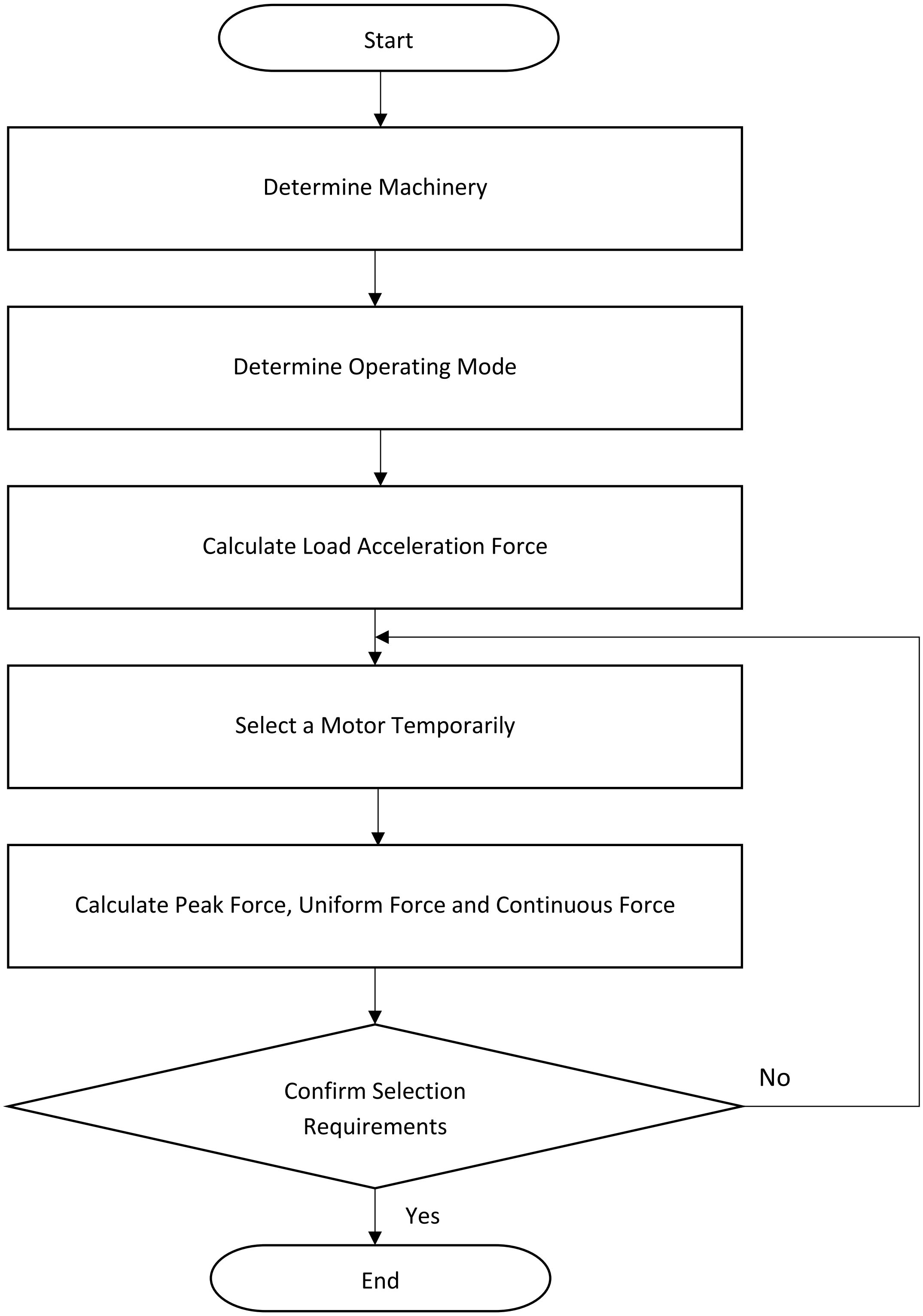
Linear Motor



1. Determine system (machinery/application).
2. Determine operating mode (duty cycle, speed, acceleration/deceleration time, positioning time).

3. Calculate acceleration, and load acceleration force:

$$F_a = ma$$

where
m: Load Mass (kg)
a: Acceleration (m/s^2)
4. Temporarily select a motor meeting the requirements of force
5. Calculate peak force:

$$F_{max} = F_1 = Ma + \mu Mg + F_e$$

where
M: Total Mass (kg)
F_1: Acceleration Force (N)
F_e: External Force (N)
μ: Friction Coefficient
g: Gravity Acceleration (9.8m/s^2)
6. Calculate continuous force
Uniform force (N): $F_2 = \mu mg + F_e$
Deceleration force (N): $F_3 = ma - \mu mg + F_e$
Continuous force (N):

$$F_{RMS} = \sqrt{\frac{1}{(t_1 + t_2 + \cdots + t_n)}\left(t_1 \cdot {F_1}^2 + t_2 \cdot {F_2}^2 + \cdots + t_n \cdot {F_n}^2\right)}$$

7. Confirm motor selection requirements
The maximum force of the motor is larger than F_1.
The continuous force of the motor is larger than F_2 and F_{RMS}.