APPLICATION
BODINE ELECTRIC COMPANY
note

a technical paper from Bodine Electric Company

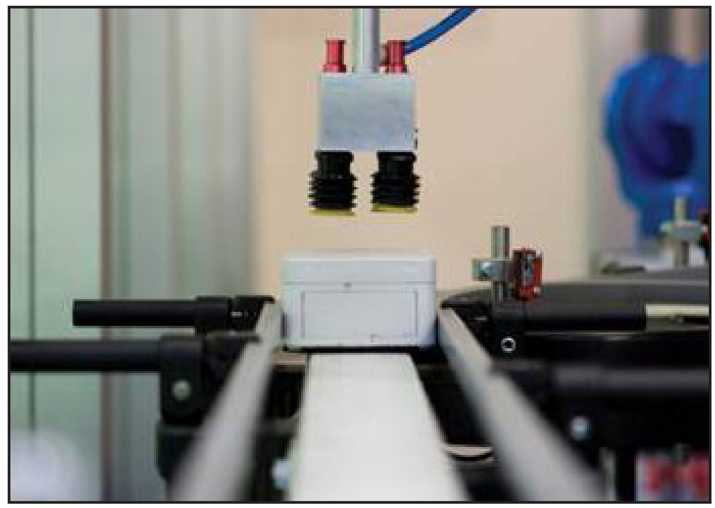
How to Select and Size Gearmotors for Conveyor Applications

This application note provides step-by-step instructions for how to size and select a gearmotor in a belt-driven conveyor application. Before sizing a gearmotor, we must first know the application requirements.

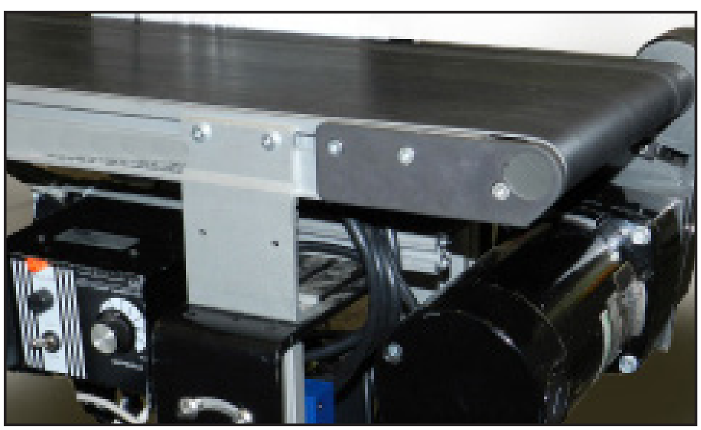
For our example, the conveyor system requirements are as follows:

- Able to handle a 200lb (90kg) load
- Have adjustable speed, up to 12 inches/second
- Be able to accelerate in 1 second
- Powered by 115VAC
- Has 4 inch (102mm) diameter rollers
- Allows for frequent starts/stops
- Zero gearmotor maintenance

Now we must translate these requirements into gearmotor specifications. First, we will determine the required speed and torque, then we review the gearmotor options that best fit with our conveyor specifications, and last, we select a stock gearmotor and drive.



Industrial automation system with belt conveyor.



Belt conveyor with a Bodine 42A-FX gearmotor and WPM speed control

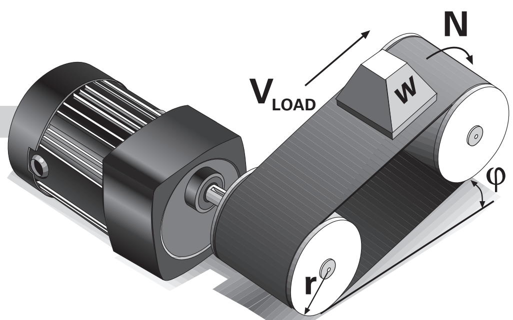
Step 1: Determine speed and torque

In order to size a gearmotor, we need to identify:

- **Speed (N)** – The speed required to drive the application per its specifications
- T_{ACCEL} – The reflected acceleration torque
- $T_{FRICTION}$ – The reflected friction torque
- $T_{BREAKAWAY}$ – The reflected breakaway torque
- $T_{GRAVITY}$ – The reflected gravity torque
- T_{CONT} **and** HP_{CONT} – The continuous torque and horsepower needed for the application

NOTE: T_{ACCEL} may be ignored unless acceleration time is critical. T_{ACCEL} and $T_{GRAVITY}$ can be calculated using the equations in this paper. $T_{FRICTION}$ and $T_{BREAKAWAY}$ will have to be measured using one of the methods described in this paper. $T_{BREAKAWAY}$ is only a factor during starting. $T_{FRICTION}$ and $T_{GRAVITY}$ will be used to determine continuous torque (T_{CONT}). $T_{GRAVITY}$ is only considered when the belt is not mounted horizontally.

Step 1: Determine speed and torque, continued



A Speed

Equation 1: $N = (9.55 \cdot V_{LOAD}) / r$

Where 9.55 has the units sec-rev/min.

From the given system requirements, we know V_{LOAD} = 12 in/sec and r = 2 in, therefore **N = 57.3RPM**.

B T_{ACCEL}

T_{ACCEL} may be ignored unless acceleration time is critical. It will be used in determining if the selected gearmotor has adequate starting capability.

Equation 2:

$$T_{ACCEL}\,(\text{oz-in.}) = \left[\frac{W_{LOAD}r^2}{386} + \frac{nW_{ROLLER}r^2}{772} + \frac{W_{BELT}r^2}{386} + J_{MOTOR}R^2E\right]\frac{V_{LOAD}}{r\,t_a}$$

We know that W_{LOAD} = 200 lbs. x 16 oz/lb. = 3,200 oz., V_{LOAD} = 12 in/sec., t_a= 1 sec., r = 2 in. and we will assume that

$J_{MOTOR} = W_{ROLLER} = W_{BELT} = 0$ for our initial calculation. Therefore, **T_{ACCEL} = 199 oz-in**.

C $T_{FRICTION}$

The friction torque ($T_{FRICTION}$) can be estimated through measurements as described in the “Test Motor Method” on page 4.

For our example, we will assume the measured **$T_{FRICTION}$ = 100 oz-in**.

D $T_{BREAKAWAY}$

The reflected breakaway torque can be estimated through measurements as described in the “Spring and Pulley Method”, the “Torque Wrench Method”, or the “Test Motor Method” on page 4.

For our example, we will assume the measured **$T_{BREAKAWAY}$ = 120 oz-in**.

E $T_{GRAVITY}$

Gravity torque only needs to be considered when the belt is not mounted horizontally. It is a positive number when the load is moved upward, and a negative number when the load is moved downward.

Equation 3: $T_{GRAVITY}\,(\text{oz-in.}) = rW_{LOAD}\sin\varphi$

In our example, the conveyor is not inclined, therefore $\varphi = 0°$, which means that **$T_{GRAVITY}$ = 0**.

F T_{CONT} and HP_{CONT}

Now we can calculated the continuous torque required for the application. This will be the torque value we will use to determine the continuous horsepower required, and these are the values, along with the calculated speed, that we will use to select a gearmotor.

Equation 4: $T_{CONT}\,(\text{oz-in.}) = T_{FRICTION} + T_{GRAVITY}$ at a speed of $\frac{9.55V_{LOAD}}{r}$

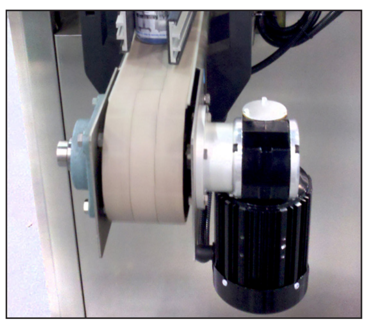
Therefore, **T_{CONT} = 100 oz-in = 6.25 lb-in.**

Equation 5: $HP_{CONT} = \frac{(T_{FRICTION} + T_{GRAVITY})V_{LOAD}}{105{,}592\,r}$ at a speed of $\frac{9.55V_{LOAD}}{r}$

Therefore, **HP_{CONT} = .00568 = 1/176.**

Definition of Variables

- T_{ACCEL} = the reflected acceleration torque (oz-in.).
- W_{LOAD} = weight of the load (oz.)
- W_{ROLLER} = weight of roller (oz.)
- W_{BELT} = weight of belt or roller (oz.)
- J_{MOTOR} = motor inertia (oz-in-sec^2)
- r = radius of roller, screw, gear or pulley (in.)
- E = gearmotor gear efficiency (contact factory)
- φ = angle of screw or belt from horizontal (degrees)
- n = number of rollers
- R = gearmotor gear ratio
- t_a = time to accelerate (sec.)
- N = speed (RPM)
- V_{LOAD} = linwear velocity of load (in./sec.)
- r = radius of roller, screw, gear or pulley (in.)



Conveyor with a Bodine Pacesetter 3-phase, AC inverter duty, hollow shaft gearmotor

We have completed all of the initial calculations required to select a gearmotor. Once we have one selected, we must ensure that its starting torque capability is greater than or equal to the sum of all 4 torques above (T_{ACCEL}, $T_{FRICTION}$, $T_{BREAKAWAY}$, and $T_{GRAVITY}$).

Step 2: Determine the type of motor/gearmotor that is best for the application.

We can determine what type of motor to use by answering some basic questions:

Is the available power supply AC or DC?	AC
If AC, is the power supply 1 phase?	YES
If AC, is the power supply 3 phase?	NO
If DC, is the power supply low voltage (12/24VDC)?	NO
If DC, is the power supply high voltage (90/130VDC)?	NO
Does the application require adjustable output speed?	YES
Does application require point-to-point positioning?	NO
Does application require controlled acceleration and deceleration, even when an overhauling load is present?	NO
Would a brush motor be undesirable because of airborne dust, mechanical noise, electrical noise or brush maintenance needs?	YES

Based on the above answers a **Brushless DC Motor/Gearmotor with AC-Powered Speed Control** or a **3-Phase AC Motor/Gearmotor with AC-Powered Speed Control** would be the best choice for this application.

Step 3: Select a Gearmotor

Right Angle Gearmotor vs. Parallel Gearmotor

- Does the application have sizing/spacing constraints? (sometimes, right angle is better)
- Does the application require a self-locking gearmotor to prevent backdriving? (choose right angle, high ratio)
- Is gearmotor efficiency important for the application? (choose parallel shaft, more efficient)

In this case, none of the reasons for choosing a right angle gearmotor are present, so we will choose a **parallel shaft gearmotor.**

Step 4: Select a Stock Product

The following Bodine products match the specifications determined above, and the types of gearmotors we decided to use for this application.

Solution 1

A brushless DC parallel shaft gearmotor with AC-powered control

- Model 3329, Type 22B2BEBL-D3 gearmotor.
- Speed of 83 RPM.
- Continuous torque rating of 29 lb-in.
- Model 3911 or 3912, filtered SCR brushless DC control.

22B-D brushless DC gearmotor and enclosed speed control

Solution 2

An AC 3-phase inverter duty parallel shaft gearmotor with an AC-powered inverter.

- Model 2216, Type 30R4BEPP-D3 gearmotor.
- Speed range of 19-175 RPM.
- Continuous torque rating of up to 19 lb-in.
- Model 2982 or 2998 AC Inverter.

30R-D3 variable speed AC gearmotor and chassis speed control

Methods for Measuring the Breakaway and Friction Torque of a Machine.

EXCERPT FROM THE *BODINE HANDBOOK*, CHAPTER 7, AND *THE BODINE SELECTION GUIDE*

The String and Pulley Method

Affix a pulley to the shaft of the machine to be driven (see Figure A). Secure one end of a cord to the outer surface of the pulley and wrap the cord around it. Tie the other end of the cord to a spring scale. Pull on the scale until the shaft turns. The force, in pounds indicated on the scale, multiplied by the radius of the pulley (in inches) gives the breakaway torque in pound-inches.

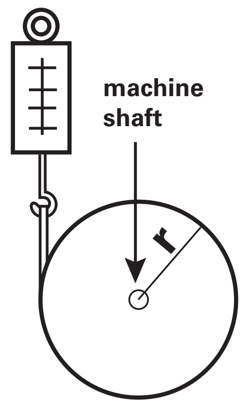


Figure A–Simple "string and pulley" method of torque measurement (Torque = Force reading on spring scale mulitplied by radius of the pulley)

Torque Wrench Method

A simple torque wrench can be applied to the shaft of the machine to be driven. Turn the wrench as you would an ordinary pipe wrench, and when the shaft begins to rotate, read the value for $T_{BREAKAWAY}$ (in ounce-inches or pound-inches) on the torque wrench gauge.

Test Motor Method

Both AC and DC test motors or gearmotors can be used to measure breakaway torque, ($T_{BREAKAWAY}$), and friction torque, ($T_{FRICTION}$). This method requires more time and instrumentation, but can be well worth the expense in the long run. It is the best way to optimally match machine and drive unit, and is popularly used for all high volume OEM (original equipment manufacturer) applications. After using these methods, contact the motor manufacturers' sales engineer for help in interpreting the data.

Test With An AC Drive–Use a torque wrench or "string and pulley" to find the approximate size of the test motor or gearmotor needed. An AC motor or gearmotor whose rated output speed is close to the desired "final" speed of the machine should be obtained. Next, hook up the AC drive, along with a variable autotransformer to the load (See Figure B). With a voltmeter connected to the line, increase the voltage supplied by the autotransformer until it starts and accelerates the load up to speed (to check speed use a tachometer or stroboscope). Record the starting voltage at all possible starting locations of the device. This is proportional to the $T_{BREAKAWAY}$. Next, back off slowly until the motor stalls. Read the voltage. This is proportional to the $T_{FRICTION}$.

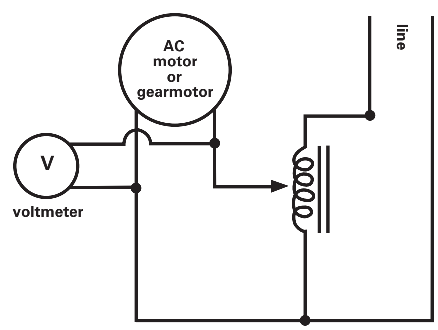


Figure B–AC motor or gearmotor with adjustable autotransformer, and voltmeter connected for load measurement.

"Test" With A DC Drive–The DC method requires that both voltage and amperage readings be taken from the armature circuit (See Figure C). Speed of the DC motor is proportional to the voltage while $T_{FRICTION}$ is proportional to the armature amperage.

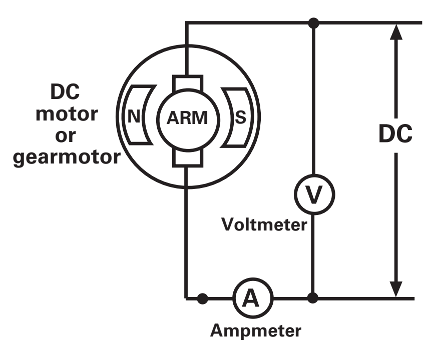


Figure C–PMDC motor or gearmotor with voltmeter and ampmeter connected for load measurement.