DC Motors

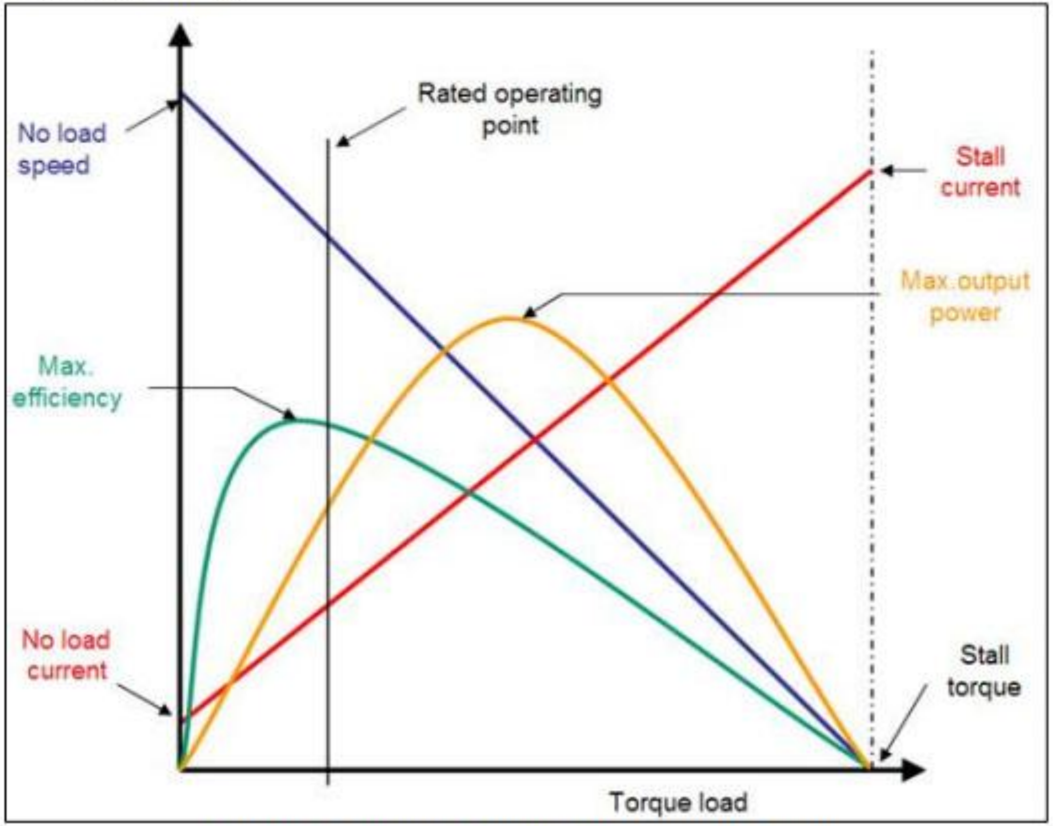


Figure 1. Generic Motor Performance Curves

- With increase in load, speed decreases and current draw increases
- At stall current, motor stops rotating
- Rated operating point is maximum power output that can be sustained without burning out the motor
- If a rated output is not provided by manufacturer, then use 15% of stall torque

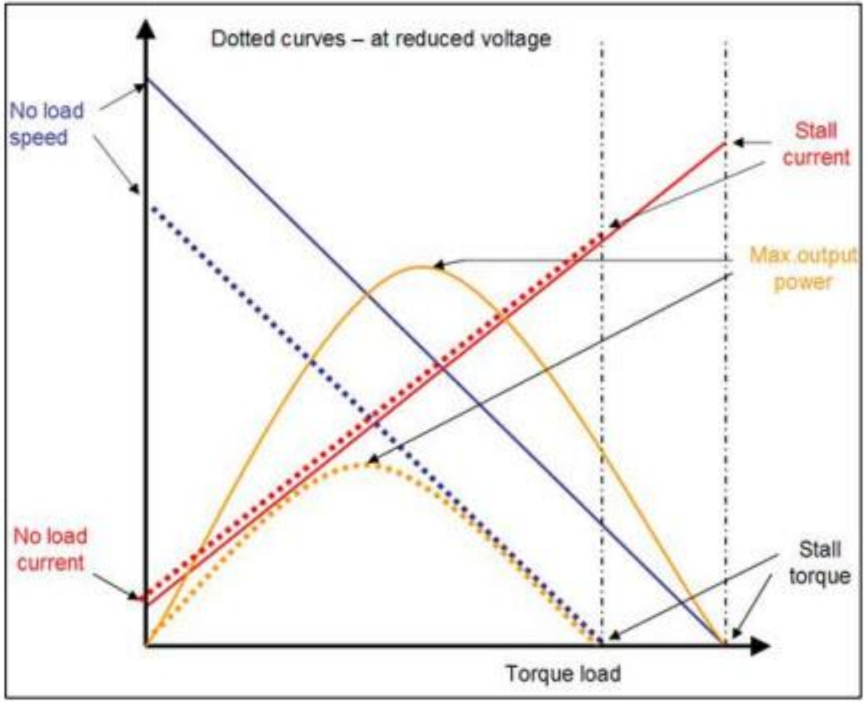
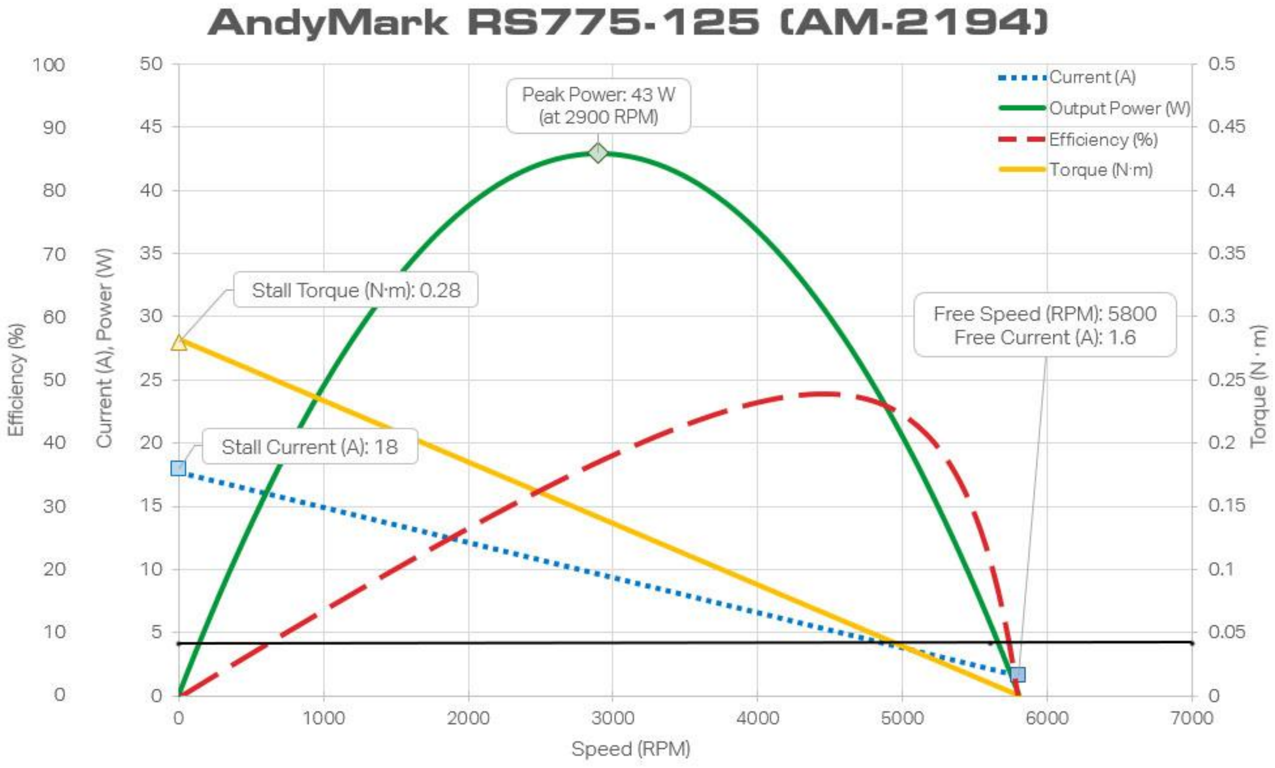


Figure 3. Motor Performance at Reduced Voltage

When voltage is decreased:

- Rotation speed decreases
- Stall current decreases
- Stall torque decreases
- Maximum power output decreases



- no load speed 5700 rpm
- Stall torque 0.28 N.m
- Stall current 18 amps
- 15% stall torque is 0.042 N.m (safe operating rating)
- 4.2 amps current draw at safe operating rating

Torque Requirement for the Robot

- Rolling resistance
- Ground slope
- Air drag

Rolling Resistance

$F = C_{rr} \cdot W$

where

F is the force in lbs.

W is the weight of the robot in lbs.

C_{rr} is the coefficient of rolling resistance.

Rolling Resistance

An estimate of rolling resistance can be made by pulling the robot horizontally across the surface of interest at constant speed. A spring or digital scale should give the approximate force.

Air Drag

The force required to move an object through a resisting medium, is given by:

$$F_D = C_D \cdot A \cdot \rho \cdot v^2/2$$

where,

F_D is the drag force
C_D is the drag coefficient
A is the object’s effective cross sectional area
ρ is the density of the medium
v is the speed

Air Drag

Using 0.00237 slug/ft^3 as the density of air:

$$F_D = C_D \cdot A \cdot v^2 / 840$$

where

F_D is the force in lb
C_D is the drag coefficient (use a value of 105 for a cube-shaped object)
A is the frontal cross sectional area in ft^2
v is the speed in ft/sec

How much force will motor produce?

Torque = 0.042 Nm = 0.03 ft-lb

A wheel of 1 foot radius connected to motor would push the robot with 0.03 lb of force, but we would use a smaller wheel

Force = torque / wheel radius

For a wheel of 2.5 inch radius (which is 0.208 foot) :

Force = 0.03 ft-lb / 0.208 = 0.14 lb

Not much force, but we have not geared down the motor yet (5700 no load RPM)

Add a gearbox to the motor

We are using a wheel of 5 inch diameter, which has a circumference of 15.7 inches. If our wheel is rotating at 400 RPM, how far will it travel in one hour?

15.7 inches x 400 RPM x 60 min/hr = 376800 inches or 5.9 miles (5.9 MPH)

Our motor under no load rotates at 5700 RPM. What gear ratio must our gearbox be to reduce the rotation to 400 RPM?

5700 / 400 = 14.25   ….. The gearbox ratio must be 14.25:1

Gearboxes

- Reduce rate of motor spin and increase torque
- If reduce rate of spin by half, then double torque
- Our gearbox is 14.25:1
- Force calculated output of motor direct = 0.14 lbs
- Add gearbox: 0.14 lb x 14.25 = 2.0 lbs x 2 wheels = 4 pounds forward force
- Above assumes 100% gearbox efficiency, which is never the case. A high efficiency gearbox might have 95% efficiency.