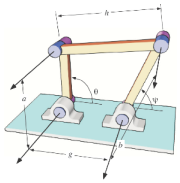
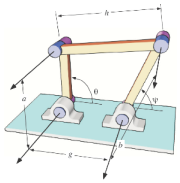


# Motor Torque and Power

**J. Michael McCarthy**



# DC Motors

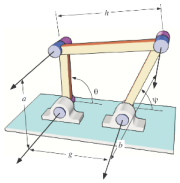
PITTMAN brand brush commutated gearmotors is a product of Ametek Technical and Industrial products, http://www.ametektip.com/


Local Representative: Halbar Associates
Email: halbar@halbar.net
Contact: 3002 Dow Avenue, #412
Tustin, CA 92780
Phone: 714-731-2222
Fax: 714-368-9781
www.halbar-assoc.com


AMETEK® TECHNICAL & INDUSTRIAL PRODUCTS

**Series GM 8000 LO-COG® Brush Commutated DC Motors**

| Reduction Ratio | Maximum Continuous Torque oz-in (N-m) | No-Load Speed rpm (rad/s) | Peak Torque (Stall) oz-in (N-m) | Torque Constant oz-in/A (N-m/A) | Back EMF Constant V/krpm (V/rad/s) | Resistance Ω | Inductance mH | Rated Voltage V | Encoder | Outline Drawing Page Number | Part Number |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6.3:1<br>6.3:1 | 6<br>(.04) | 1227<br>(128.5) | 26[1]<br>(.184) | 3.06<br>(0.022) | 2.27<br>(0.022) | 10.8 | 5.4 | 19.1 | None | PE-10 | GM8712-11 |
| 19.5:1<br>19.5:1 | 15.5<br>(.109) | 396<br>(41.5) | 72[1]<br>(.51) | 3.06<br>(0.022) | 2.27<br>(0.022) | 10.8 | 5.4 | 19.1 | None | PE-10 | GM8712-21 |
| 60.5:1<br>60.5:1 | 46<br>(.325) | 128<br>(13.4) | 201[1,2]<br>(1.42) | 3.06<br>(0.022) | 2.27<br>(0.022) | 10.8 | 5.4 | 19.1 | None | PE-10 | GM8712-31 |
| 187.7:1<br>187.7:1 | 100<br>(.71) | 41<br>(4.3) | 557[1,2]<br>(3.93) | 3.06<br>(0.022) | 2.27<br>(0.022) | 10.8 | 5.4 | 19.1 | None | PE-10 | GM8712-41 |
| 187.7:1<br>187.7:1 | 100<br>(.71) | 41<br>(4.3) | 557[1,2]<br>(3.93) | 3.87<br>(0.027) | 2.86<br>(0.027) | 17.2 | 8.62 | 24 | None | PE-10 | GM8712S030 |
| 6.3:1<br>6.3:1 | 14.5<br>(.102) | 720<br>(75.4) | 42[1]<br>(.297) | 3.09<br>(0.022) | 2.29<br>(0.022) | 4.33 | 2.34 | 12 | None | PE-10 | GM8724S008[3] |
| 6.3:1<br>6.3:1 | 14.5<br>(.102) | 720<br>(75.4) | 42[1]<br>(.297) | 3.09<br>(0.022) | 2.29<br>(0.022) | 4.33 | 2.34 | 12 | 500 CPR | PE-10 | GM8724S009[3] |
| 6.3:1<br>6.3:1 | 14.5<br>(.102) | 720<br>(75.4) | 42[1]<br>(.297) | 6.18<br>(0.044) | 4.57<br>(0.044) | 17 | 9.35 | 24 | None | PE-10 | GM8724S010[3] |
| 6.3:1<br>6.3:1 | 14.5<br>(.102) | 720<br>(75.4) | 42[1]<br>(.297) | 6.18<br>(0.044) | 4.57<br>(0.044) | 17 | 9.35 | 24 | 500 CPR | PE-10 | GM8724S011[3] |
| 9.9:1<br>9.9:1 | 21<br>(.148) | 455<br>(47.7) | 60[1]<br>(.424) | 3.09<br>(0.022) | 2.29<br>(0.022) | 4.33 | 2.34 | 12 | None | PE-10 | GM8724S012[3] |
| 9.9:1<br>9.9:1 | 21<br>(.148) | 455<br>(47.7) | 60[1]<br>(.424) | 6.18<br>(0.044) | 4.57<br>(0.044) | 17 | 9.35 | 24 | None | PE-10 | GM8724S013[3] |



# Brush Commutated DC Motor

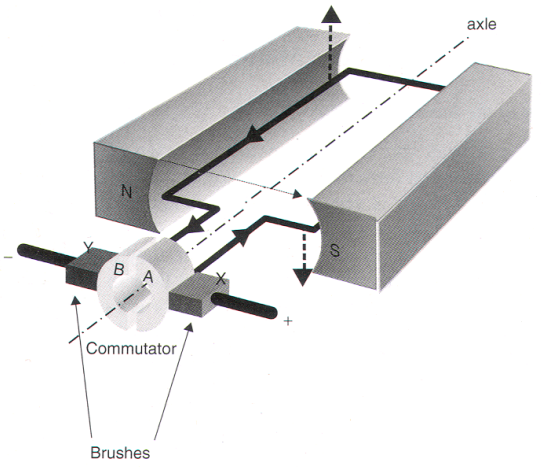



**Figure 6.1** Diagram to explain the operation of the simple permanent magnet DC motor

The classical DC motor consists of permanent magnets, a wire coil and commutator.

The interaction of the current passing through the coil and the magnetic field of the magnets generates a torque on the axis of the armature holding the coil.

The commutator changes the direction of current in the coil as it turns so the torque is consistent.

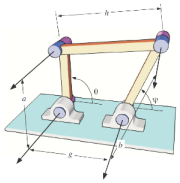
The motor torque $T$ is proportional to the armature current $I$, where $k_t$ is the torque constant.

The current I is defined by the armature resistance R and the *difference* between the supply voltage $V_s$ and the opposing electro-motive force $V_b$ generated by the rotation of the armature windings.

$$T = k_t I, \quad I = \frac{V_s - V_b}{R}, \quad \text{and} \quad V_b = k_e \omega,$$

$$\text{therefore} \quad T = \frac{k_t V_s}{R} - \frac{k_t k_e \omega}{R}.$$

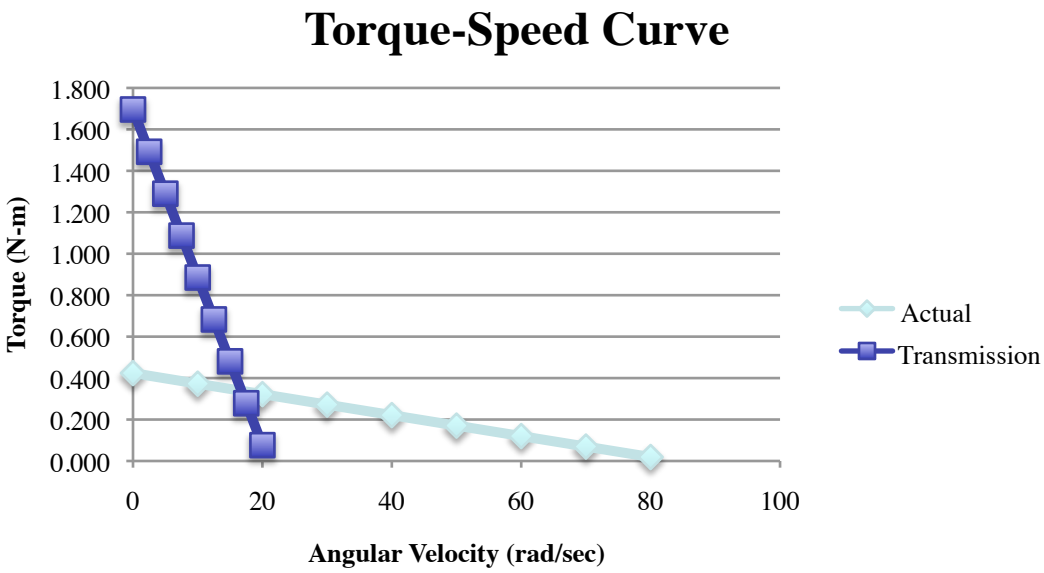
**Thus, the motor torque decreases linearly with increasing angular velocity.**



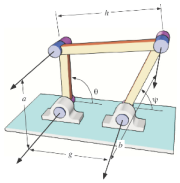
# Torque Speed Curve


The primary parameters used to characterize a DC Motor are its stall torque and its no-load speed.

The torque speed curve of the motor is a line that connects these two points.

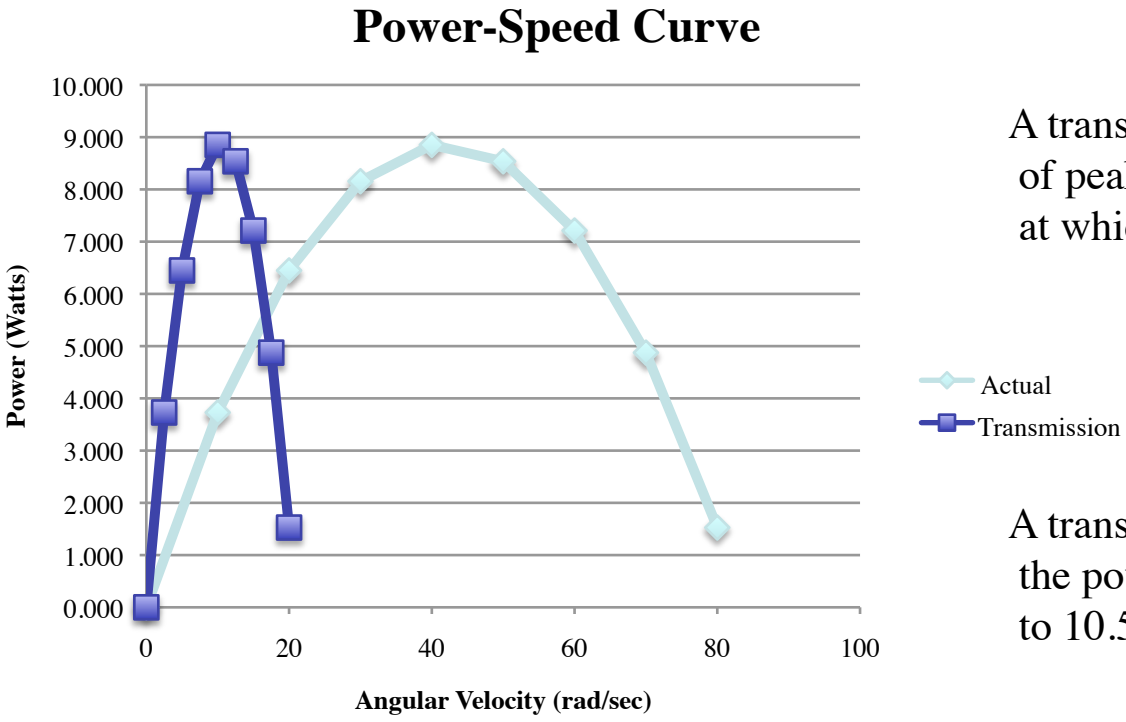



A transmission (4:1 reduction plotted above) decreases the output speed and increases the output torque.



# Power-Speed Curve

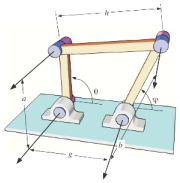
The power delivered by the motor is the product of its torque and angular velocity, $P=T\omega$. Notice that the power peak is at one-half the no-load speed.




A transmission does not change the value of peak power, but it does shift the speed at which it occurs.

A transmission with speed ratio R=4 shifts the power peak from 42 rad/sec (400rpm) to 10.5 rad/sec (100rpm).

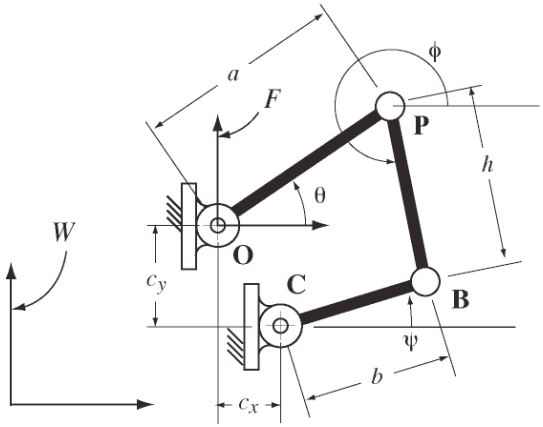
A transmission shifts the peak of the power-speed curve to the desired range of the output.

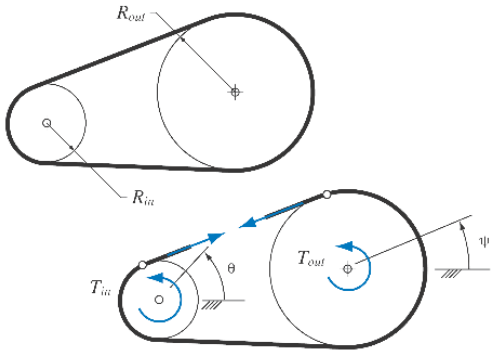


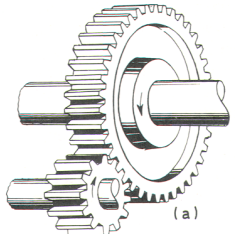
# Transmission

The choice of transmission components depends on the desired speed ratio:

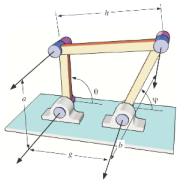
- up to 2:1 can be achieved using a **linkage**. The links are stiff, and have low but variable inertia and low joint friction;
- up to 6:1 can be achieved by a **belt**, chain and cable drives. The pulleys of these drives have higher but constant inertia, and the belt, chain or cable introduce elastic and friction losses; and
- up to 8:1 and higher can be achieved by **gear trains**. Gears have constant inertia, and tooth flexibility introduces elastic and friction losses.




Linkages, belt drives and gear trains can be combined to achieve a desired speed ratio.



# Summary

- The torque of a DC motor decreases linearly with increasing angular velocity.
- A motor's stall torque and no-load speed define its torque-speed curve.
- The power peak of a DC motor occurs at one-half of its no-load speed.
- A transmission shifts the peak of the power-speed curve to the desired range of the output.
- A linkage, belt-drive, gears or a combination of these components can provide the speed-ratio that matches the motor to the desired application.
- Transmission losses arise from inertia, elastic and friction effects.