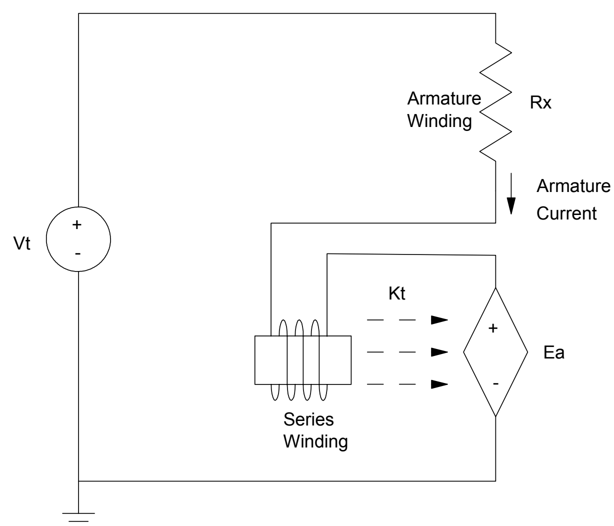
DC Series Wound Motors:



For DC motors, the starting current tends to be very large. If you use this current to strengthen the stator field, you get larger torque constants (Kt), meaning large starting torques. This makes series-wound motors useful for things like starters for cars.

Series-wound motors tend to have large currents - meaning they are not designed to be operated continuously. This works well for a starter - it's supposed to be a motor used only for a short time.

Series wound motors also are designed to work under load. If you remove the load, they try to speed up to infinity.

Things to note:

Series wound motors are designed to be used intermitently (not continuously)

Series wound motors need a load. It can be dangerous to remove the load.

Example: Let's use the same motor as before but with a series winding.

- Vt = 120V
- Ra = 1 Ohm
- Kt = 0.0027 Ia

Like all DC motors, it all comes down to the torque constant. For shunt-wound motors,

Kt = f(If) = constant.

For series-wound motors

Kt = f(Ia) = proportional to Ia

This creates a little odd behavior.

Problem: Find the operating speed for this motor when loaded with T = 1Nm

T = 1Nm:

$$T = 1Nm = K_t I_a = (0.0027 \cdot I_a) I_a$$

$$I_a = 19.24A$$

The torque constant is then

$$K_t = 0.0027 \cdot I_a = 0.0519 \frac{Nm}{A}$$

The back EMF is

$$E_a = V_t - I_a R_x = 100.76V$$

$$E_a = K_t \omega$$

$$\omega = 1939 \text{ rad/sec}$$

The power the motor is producing is

$$P = T\omega = 1939W$$

Problem: What happens if you increase the load?

Increase the load to 10Nm

$$T = 10Nm = (0.0027 \cdot I_a) I_a$$

$$I_a = 61.4A$$

The torque constant is

$$K_t = 0.0027 \cdot I_a = 0.1658 \frac{Nm}{A}$$

Note that as the load increases, the armature current increases as does the torque contant. The back EMF is

$$E_a = V_t - I_a R_x = 58.6V$$

The back EMF drops with load - which is what happens with shunt motors. No surprise here. The speed is

$$\omega = \frac{E_a}{K_t} = 353$$

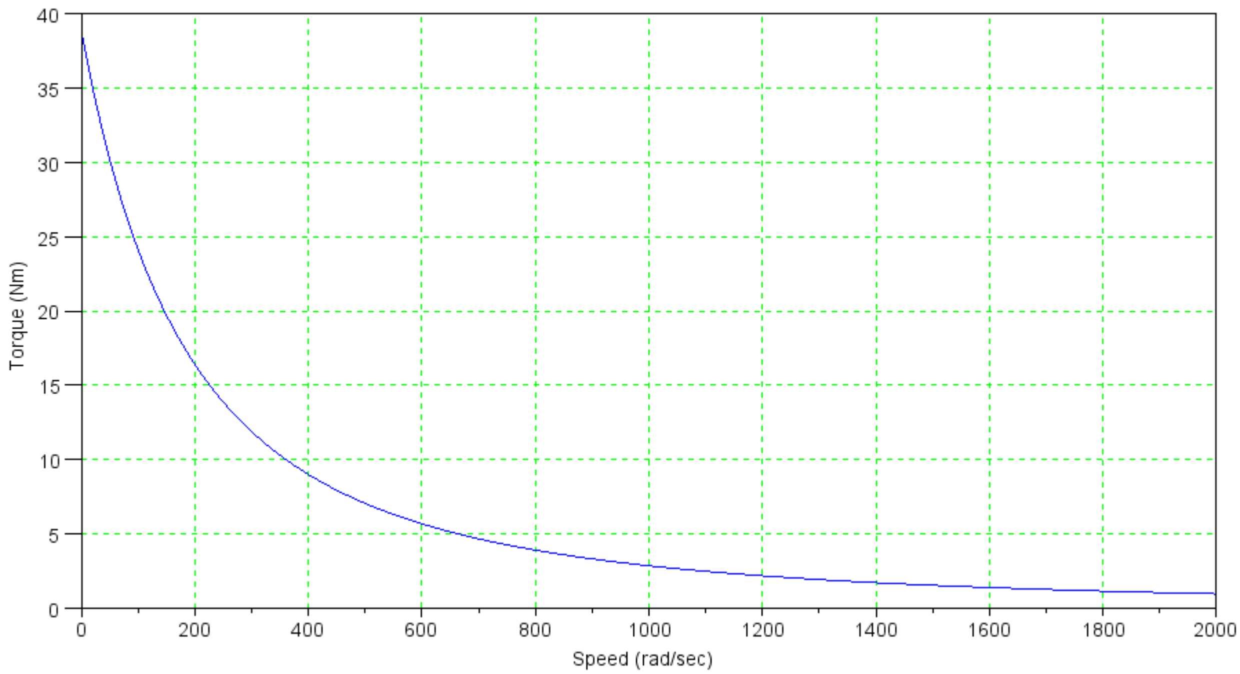
The motor slows down significantly as you load it. The power output is approximately constant.

$$P = I_a E_a = T\omega = 3598W$$

Note that series wound motors are essentially constant-power motors. When the load goes to zero, the speed tries to go to infinity to keep the power out constant (or nearly so.)

```
-->Vt = 120;
-->Ra = 1;
-->Kt = 0.3183;

-->T = [1:50]';

-->Ia = (T / 0.0027) .^ 0.5;
-->Ea = Vt - Ia*Ra;
-->Kt = 0.0027*Ia;
-->w = Ea . / Kt;

-->plot(T,w)
-->xlabel('Torque (Nm)')
-->ylabel('Speed (rad/sec)')
-->xgrid(3)

-->plot(T,Kt)
-->xlabel('Torque (Nm)')
-->xgrid(3)
-->ylabel('Torque Constant (Kt)')

-->plot(w,Ea.*Ia)
-->xgrid(3)
-->xlabel('rad/sec')
-->ylabel('Power')
-->ylabel('Power (Watts)')
```

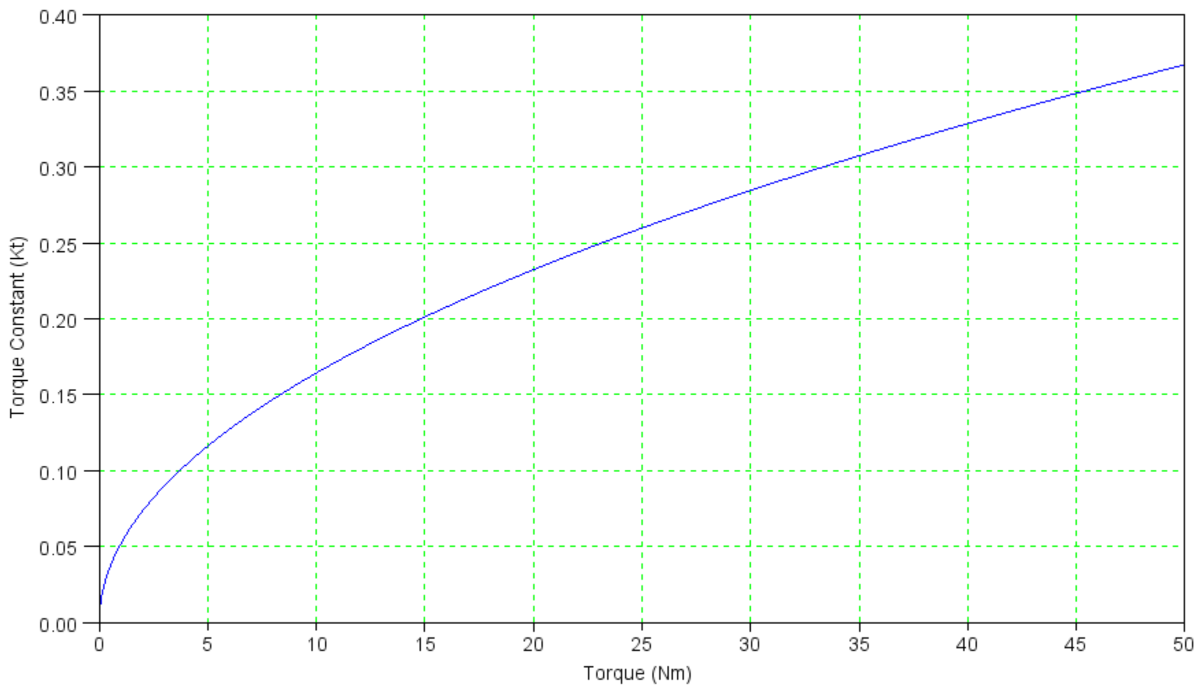
Speed vs. Torque



This is probably the most inportant curve. Note that

- The starting torque can be very large. Shunt wound motors make good starters for cars and engines.
- The torque drops quickly as speed increases.
- **As the torque (load) goes to zero, the speed goes to infinity. If you take the load off of a shunt-wound motor, it tries to fly apart.**

Torque Constant vs. Load (Torque)

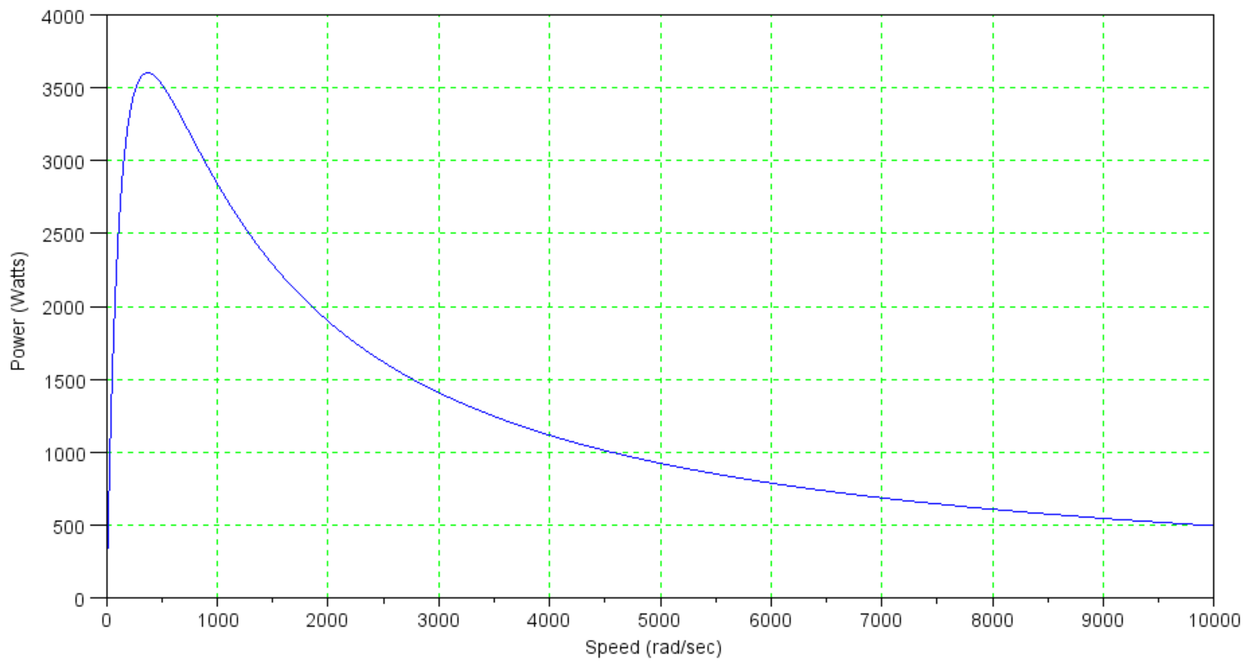


Series-wound motors have a neat property that the torque constant increases as the load increases. These motors work very well when you have a large load, such as starting a car when it's -30F.

The torque constant also goes to zero as the torque goes to zero. This results in the no-load speed trying to go to infinity.

- If there is residual magnatism in the stator field, the torque constant will not go all the way to zero. This might limit the no-load speed of the motor. It's kind of risky to try it though.
- In test cells, the test engineers usually (always?) have the authority to shut down an experiment if they feel it's unsafe.

Power vs. Speed



Series-wound motors are essentially constant-power motors. The power it delivers *does* change with speed, and *does* go to zero at zero speed (it has to), but over most of the operating range the power out is approximately constant.

This means

- The torque is lousy at high speeds. Series-wound motors are not meant for running constantly.
- There is still torque at high speeds. They try to take off to infinity if you don't load them.

Typically, series-wound motors do not have enough cooling to be run continuously. This saves copper (and reduces the cost of the motor). This means they work well when they are turned on for short bursts (such as run a compressor for an cooler, turn over a diesel engine, etc.).