# Understanding motor constants Kt and Kemf for comparing brushless DC motors

So for a practical definition, the torque constant Kt specifies how many Nm of torque you'll get from the motor at a certain current? Is a bigger Kt always better?

I am more confused about the backemf constant Kemf. This is the amount of back EMF produced by the motor running at a certain speed. Does the back EMF limit the voltage the motor can accept and hence it's speed?

Would an ideal motor have a very high Kt and very low Kemf?

What happens if the back emf voltage reaches the input voltage, does the motor stop running?

Thank you for any answers, Fred

motor brushless-dc-motor

edited Aug 1 '12 at 17:24
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asked Jun 5 '12 at 15:46
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## 4 Answers

> Does the back EMF limit the voltage the motor can accept and hence it's speed?

Hmm. I think you're a little confused. Back-emf limits the motor speed because it dictates how much voltage you need to achieve a given speed.

> Would an ideal motor have a very high Kt and very low Kemf?

No. (The symbol $K_e$ is usually used for the back-emf constant, by the way.)

If you use SI units (Nm/A for $K_T$, V/(rad/s) for $K_e$), then $K_T = K_e$ for DC motors and permanent-magnet synchronous motors (aka "brushless DC"), and depending on the type of motor and how you define $K_T$ and $K_e$, the ratio of the two should be a fixed proportionality constant.

Proof of why this is true for DC motors:

At constant operating point (constant speed, voltage, current, torque):

- $V_T = K_e \omega_m + IR$
- $T_m = K_T I$

($V_T$ = terminal voltage, $\omega_m$ = motor angular velocity, $I$ = motor current, $R$ = motor resistance, $T_m$ = torque, including frictional losses)

Electrical power in = $V_T I = K_e \omega_m I + I^2 R$

mechanical power out = $T_m \omega_m = K_T I \omega_m$

Losses = $I^2 R$

Conservation of energy means electrical power in = mechanical power out + losses

This is true if and only if $K_e = K_T$.

> What happens if the back emf voltage reaches the input voltage, does the motor stop running?

No -- what happens is that the ability of the motor to produce torque decreases with speed. Back-emf voltage "uses up" voltage from the electrical power source; the will increase to match that torque as speed slows down, making more IR drop voltage available.

> Is a bigger Kt always better?

No. Rule of thumb with DC motor selection (also true for brushless DC motors to a large extent) -- pick a motor with a $K_T$ and back-emf constant such that the supply voltage you have available is well-matched with the back-emf at your maximum speed. You usually want back-emf voltage to be 80-95% of the supply voltage, but the exact number depends on the load torque and the IR drop in the motor at that operating point.

If you pick a $K_T = K_e$ too high, you'll run out of voltage and won't be able to achieve the speed you need. If you pick a $K_T = K_e$ too low, the current needed to achieve the torque you need will be higher than necessary.

edited Dec 11 '15 at 18:58 answered Jun 5 '12 at 18:20
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Kt is the ratio of torque output to current input so your initial definition is correct.

Is a bigger Kt *always* better? Not really. It depends on your application. You could conceivably need lower torque for some application. For instance an application where you wanted a higher speed. Typically the faster a motor spins, the less torque it generates.

This is due to the Back EMF generated. With the power supply voltage remaining constant, as you commutate the motor faster, the Back EMF increases and the current decreases thereby lowering the torque. This is to satisfy Newton's third law. The Back EMF doesn't really limit the voltage a motor can accept (though it is limited). But in general, you need a higher input voltage to overcome the Back EMF and attain higher speeds.

There is no such thing as an *ideal* motor. It depends on your application. You may want a high Kemf in the case of sensorless operation where you are using the Back EMF for position and speed feedback. But a high Kemf limits you in other areas. It's always a trade off.

The input voltage is the sum of the Back EMF and the voltage drop across the motor so the motor will most likely stall before the Back EMF reaches the input voltage level.

Further reading:

http://www.aveox.com/DC.aspx

http://www.micromo.com/motor-calculations.aspx

answered Jun 5 '12 at 18:02
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Motor and speaker are perfect linear translators of voltage to velocity, current to torque. Exact positive voltage will cause exact positive speed. For negative - the same. Exact load will cause torque and will be seen as exact current. Exact antiload will cause opposite torque and will be seen as reverse current.

- What is back EMF ? It is voltage generated by motor as if it was a generator.
- How high back EMF is ? For mechanically lossless motor it is same as applied voltage.
- When back EMF is same as input voltage ? When motor is free spinning with zero torque, doing zero work, consuming zero current.
- So what if motor is mechanically loaded ? The motor will slow down exactly to equilibrium of torque and load. Back EMF will be less than voltage. The voltage difference divided by current will be like a resistor, but heat will dissipate mechanically, not electrically.

**Ideal motor is as small, strong, fast and lossless as law of energy conservation allows**.

2 examples and 1 mystery:

Example 1: Load with constant mass and no friction. This is most common and practical. Motor translates current into acceleration.

Example 2: Magnet levitates over superconductor. The torgue is equal to weight. Means there is constant circular current in superconductor with zero voltage, opposite zero emf, zero velocity.

Mystery of Speaker: To cause exact and local air pressure of acoustic wave it needs exact what ? Travel distance, velocity, acceleration or torque ? There is some fluid dynamics or something there.

edited Jun 6 '12 at 3:52

answered Jun 6 '12 at 3:26

user924

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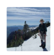
In addition to Kt = Ke (true for SI units, Torque in Nm, Ke in volts/rad/sec), be aware that for a sinusoidal back EMF, the driving voltage for the motor (from a 3-phase bridge) is approximately 1/3 of the DC link voltage. Thus, if the DC link voltage available is 300V, the motor should be rated for 100VAC at the desired operating speed. (Applies to PMAC motors - some (non-sinusoidal back EMF) Brushless motors are speed rated for the DC link voltage). The torque and speed formulae are also approximately correct for induction motors.

answered Jul 14 '17 at 7:39



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