06-09-2005, 07:11 PM #1

ChuckDickerson
Mentor / Bayou LRI
AKA: DeepWater
FRC #0456 (Siege Robotics)
Team Role: Mentor

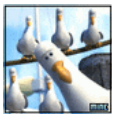
Join Date: May 2004
Rookie Year: 2004
Location: Vicksburg, MS
Posts: 815

Cheap Torque Measurement?

OK all you motorheads and gearbox designers, how do YOU measure torque? Not calculate a graph, I mean directly measure torque at the output shaft of the motor or gearbox. As in, I want something that works like a tachometer for RPM but for torque. I know that there are such things a torque sensors but what I find seem to be big heavy industrial stuff and/or VERY expensive. I would like to be able to take a motor of the size ranges we use in FIRST (FP, CIM, Globe, Drill, etc.) and apply a known voltage and current limit to it and clamp something on the output shaft and measure the torque. It could be a direct reading sort of like a torque wrench (i.e. ft-fbs, nM, etc.) or just some sort of analog output like a voltage range that is proportional to the torque that I read and convert. Do R/C hobby folks use anything like this? Even something that would output a 0-5V sensor type thing that could be read with the Robot Controller might be cool. Maybe even some sort of bar clamped to the output shaft with a linear strain gauge setup or something. It would, of course, need to be cheap! What am I looking for? I don't even know where to start. How about some search terms, maybe some direct links, or even just tell me that I am crazy and no such critter exists? Help! Educate me!

For example stuff like this: http://www.transducertechniques.com/...nt-Sensors.cfm is way too expensive for me!

06-09-2005, 07:29 PM #2



UFH 05 Jun 1-15

Gary Dillard
Generator of Entropy
AKA: you know, the old bald guy
FRC #2973 (The Mad Rockers)
Team Role: Engineer

Join Date: Nov 2001
Rookie Year: 1998
Location: Huntsville, AL
Posts: 1,499

Re: Cheap Torque Measurement?

There is an easy method, but it's not what you think:

Output torque of a motor is not a value, it's a graph that's a function of speed. At free speed there is no torque; at zero speed you get the stall torque. And unfortunately by applying a fixed voltage you don't get a given speed or output torque - the motor will run at whatever speed correlates to the applied torque. But there is a pretty simple way to plot the curve.

Mount/fix the motor so the shaft is horizontal and up in the air, like up on a table. Put a spool or pulley on the output shaft and attach a string or cord to the spool with a weight on the end. Apply voltage to the motor and determine the speed of the motor using a tachometer or by timing the speed that the weight moves up and dividing by the circumference. The torque is the weight times the radius of the spool. Change the weight and you will have several points on the speed curve - they should be linear (theoretically they are).

Now, if you want something you could do on the robot that correlates to torque, you could measure the current because it is linear with speed as well. But you would still need to know what torque correlates to what current.

_____
Close enough to taste it, too far to reach it

06-09-2005, 08:07 PM #3

Andy A.
Getting old
FRC #0095
Team Role: Coach

Join Date: Jun 2001
Rookie Year: 2001
Location: New Hampshire
Posts: 979

Re: Cheap Torque Measurement?

Ever throught about making your self a little adapter such that you could attach the end of the motor shaft to a torque wrench?

Crank up the motor and see how much torque it takes to stall it at a given voltage. Of course, if you let go you have a nice long torque wrench flinging around on the end of your motor, which strikes me as a bad thing. And if you don't let go, then your still stalling the motor for as long as it takes to get the reading, which also strikes me as being a bad thing.

Actually, the whole idea strikes me as being bad. but I like the notion of taking a measurement in such a blatantly inaccurate and hazardous manner.

-Andy A.

06-09-2005, 09:38 PM #4

ChuckDickerson
Mentor / Bayou LRI
AKA: DeepWater
FRC #0456 (Siege Robotics)
Team Role: Mentor

Join Date: May 2004
Rookie Year: 2004
Location: Vicksburg, MS
Posts: 815

Re: Cheap Torque Measurement?

Quote:

> Originally Posted by **Gary Dillard**
> *Mount/fix the motor so the shaft is horizontal and up in the air, like up on a table. Put a spool or pulley on the output shaft and attach a string or cord to the spool with a weight on the end. Apply voltage to the motor and determine the speed of the motor using a tachometer or by timing the speed that the weight moves up and dividing by the circumference. The torque is the weight times the radius of the spool. Change the weight and you will have several points on the speed curve - they should be linear (theoretically they are).*

That is exactly what I want to do but electronically. I know there are expensive torque sensors that do this but I am looking for a neat idea to do this on the cheap.

Quote:

> Originally Posted by **Gary Dillard**
> *Now, if you want something you could do on the robot that correlates to torque, you could measure the current because it is linear with speed as well. But you would still need to know what torque correlates to what current.*

The "what torque correlates to what current" is the part I am trying to get to (I think).

So here's the deal. I stumbled across these: http://www.medusaproducts.com/Other/...rs/PA-Main.htm Particularly the new "Pro" model which is due out next month. These are really nifty power analyzers used by the R/C airplane folks that hook up between your power source (battery) and load (speed controller & motor) and display voltage, current, power, amp-hours, and watt-hours. The Plus will connect to a PC and graph. The new Pro will also measure RPM, temperature, and thrust using a digital scale. Do any teams use these? So I emailed the company and it turns out the scale is just hooked up to an aux input which can accept any 0-2.6V signal. It seems to me that if a proper inexpensive "torque sensor" could be found and the right circuit developed this thing would be a really nice addition to a FIRST team tool box. I just don't know enough about electronic torque measurement to know where to start. I wonder if there is someone here on CD that would like a summer project.

-Chuck

06-10-2005, 08:46 AM #5

Gary Dillard
Generator of Entropy
AKA: you know, the old bald guy
FRC #2973 (The Mad Rockers)
Team Role: Engineer

Join Date: Nov 2001
Rookie Year: 1998
Location: Huntsville, AL
Posts: 1,499

Re: Cheap Torque Measurement?

OK, the instrument you are looking for is a dynamometer. Do a google search and you should find lots of types.

Close enough to taste it, too far to reach it

06-12-2005, 02:47 AM #6

ChuckDickerson
Mentor / Bayou LRI
AKA: DeepWater
FRC #0456 (Siege Robotics)
Team Role: Mentor

Join Date: May 2004
Rookie Year: 2004
Location: Vicksburg, MS
Posts: 815

Re: Cheap Torque Measurement?

Quote:

> Originally Posted by **Gary Dillard**
> *OK, the instrument you are looking for is a dynamometer.*

Exactly, but I am trying to figure out how to make one for the least cost.

So forget about the "torque sensor" idea. I guess what I am really looking for is a way to apply a known (but variable) rotational load/torque/resistance to a test motor and measure the power (voltage and current) it takes to overcome the rotational load/torque/resistance and keep the motor spinning. Like a mechanical brake but with a clutch that can be set to slip at a known torque. Something that can be clamped to a motor output shaft in some sort of a test stand.

Since I don't know where to get small mechanical rotary brake like thing with a user settable infinitely variable slip clutch but I do have a bunch of small DC motors laying around to play with what about this idea. First let me state that my assumptions are that for any DC motor the output speed is related to input voltage and the output torque is related to the input current. Someone please correct me if I am incorrect on this.

Lets say I hook two DC motors together end to end by the drive shaft using a coupler and secure the motors to some sort of test stand. I'll call motor "A" the TEST motor and motor "B" the LOAD motor. For this example, I am thinking a Fisher Price or drill motor as the test motor A and the well known CIM motor as the load motor B. If I apply power to the test motor A such that it gets both motors spinning I should be able to measure a voltage of some sort on the leads of the load motor B because motor B will act as a generator right? In fact, from what I understand you can actually use a small DC motor as a tachometer using a multimeter if you know the specs of the motor. Now if I were to apply power to the load motor B such that it wants to turn in the opposite direction as test motor A then the test motor A would have to start working harder to counteract the torque produced by the load motor B and thus

the test motor A would draw more current from the power source. It seems to me that in an ideal world if you knew all the power curves (torque vs. current & speed vs. voltage) of the load motor B and could measure all the power (voltage & current and calculate watts) going into the two motors then you could solve for the power curves of the test motor A. Although the measurements could be taken with a multimeter the Medusa "Power Analyzers" I mentioned above seem to be a nice purpose built reasonably priced product to do all the voltage, current, watt, RPM, and even temperature measurements for the "dyno" system and even connect to a PC for graphing, etc. What seems to me to be the unknowns in the test "dyno" setup are:

1) What happens to the energy created by the "generator effect" when you then apply a reverse voltage to the load motor B? How does this effect the measurement setup and calculations?

2) Of course, there will be lots of energy lost to heat, friction, etc. How do you account for this when creating data points on the curves?

3) Would this motor to motor setup even be a good idea since you would basically not only be stalling the load motor B at all times but stalling it while it is being forced to turn in the opposite direction than it wants to turn. Seems like the whole setup might not last too long. Given this wouldn't it always be better to have a much higher power motor as the load motor B and barely drive it with a small amount of power relative to the test motor A so that it pulls a known amount of "drag" or "reverse torque" on the test motor A but minimizes the losses to heat, etc. from the stall?

4) The whole motor to motor test configuration is just an idea to be able to produce a known, measurable, and infinitely variable amount of reverse torque on the test motor. If the whole motor to motor setup is a really bad idea (I kinda think it might be) where would one find the small mechanical brake with infinitely variable torque calibrated slip clutch thingy that can be clamp mounted on the test motor output shaft? I guess it would have to be some sort of magnetic clutch type device just not a motor.

... N) What else have I not considered?

Now, given all of the above what about throwing a gearbox between the motors? Wouldn't a "dyno" setup of some sort like this be useful for team testing gearboxes? I am just throwing around some ideas I have floating around in my head right now and trying to an academic discussion on the topic so I might learn something. So does anyone have any thoughts?

Thanks,
Chuck

06-12-2005, 08:13 AM #7

UFH 05 Jul 15-31

Mike Betts
Electrical Engineer
no team
Team Role: Engineer

Join Date: Dec 2001
Rookie Year: 1995
Location: Homosassa, FL
Posts: 1,443

Re: Cheap Torque Measurement?

Chuck,

The following is not perfect but you don't need a load sensor to do it...

In your motor/generator pair:

(1) Make both the motor and generator the same type of motor.

(2) Wire a power resistor across the generator's electrical "outputs". Be careful to size the resistor properly.

(3) Measure the voltage and current at the "input" and "output". Also measure the speed at the spindle/coupler.

(4) Adjust the input voltage to a known value (in our case it's almost always 12.0V). Note that you do not need a precision high current power supply... Just use an Exide SLA and let it slowly discharge as you run the MG and take your readings at 12V.

Note also that you can ignore (4) depending on exactly the type of data you are going for...

For a given load resistance, you will take your readings:

Input Power (W) = Input Voltage (V) * Input Current (A)
Output Power (W) = Output Voltage (V) * Output Current (A)
Mechanical Power at coupler (W) = [Input Power (W) + Output Power (W)] / 2
Torque at coupler (N*m) = Mechanical Power (W) / Spindle Speed (radians/sec)
Power Lost in Motor (W) = Input Power (W) - Mechanical Power at Coupler (W)

et cetera...

Hope this helps...

Mike
_____
Mike Betts

Alumnus, Team 3518, Panthrobots, 2011
Alumnus, Team 177, Bobcat Robotics, 1995 - 2010
LRI, Connecticut Regional, 2007-2010
LRI, WPI Regional, 2009 - 2010
RI, South Florida Regional, 2012 - 2013

As easy as 355/113...

06-12-2005, 10:18 PM #8

ChuckDickerson
Mentor / Bayou LRI
AKA: DeepWater
FRC #0456 (Siege Robotics)
Team Role: Mentor

Join Date: May 2004
Rookie Year: 2004
Location: Vicksburg, MS
Posts: 815

Re: Cheap Torque Measurement?

Thanks for the info! I have questions:

> Quote:
> In your motor/generator pair:
>
> (1) Make both the motor and generator the same type of motor.

Why is it important to use to of the same type motor instead of an "unkonwn" motor as the test and a known motor (one you have power curves for) for the load motor/generator?

> Quote:
> (2) Wire a power resistor across the generator's electrical "outputs". Be careful to size the resistor properly.

What it the power resistor used for? Is this so that the generator now acts like a brake? Or am I missing the point and the point is not to actually load/brake the test motor. How do you determine the proper size power resistor? I am not an electronics person. I am more of a mechanical guy.

> Quote:
> (3) Measure the voltage and current at the "input" and "output". Also measure the speed at the spindle/coupler.
>
> (4) Adjust the input voltage to a known value (in our case it's almost always 12.0V). Note that you do not need a precision high current power supply... Just use an Exide SLA and let it slowly discharge as you run the MG and take your readings at 12V.
>
> Note also that you can ignore (4) depending on exactly the type of data you are going for...
>
> For a given load resistance, you will take your readings:
>
> Input Power (W) = Input Voltage (V) * Input Current (A)
> Output Power (W) = Output Voltage (V) * Output Current (A)
> Mechanical Power at coupler (W) = [Input Power (W) + Output Power (W)] / 2
> Torque at coupler (N*m) = Mechanical Power (W) / Spindle Speed (radians/sec)
> Power Lost in Motor (W) = Input Power (W) - Mechanical Power at Coupler (W)
>
> et cetera...

Easy enough! I can handle that!

> Quote:
> Hope this helps...

A BUNCH! Thanks Mike!

06-12-2005, 11:56 PM #9

Al Skierkiewicz
Broadcast Eng/Chief Robot Inspector
AKA: Big Al WFFA 2005
FRC #0111 (WildStang)
Team Role: Engineer

Join Date: Jun 2001
Rookie Year: 1996
Location: Wheeling, IL
Posts: 10,183

Re: Cheap Torque Measurement?

I was thinking along the same lines as Mike but by using a variable resistor on the output of the generator. (Or switched resistors works as well) I think if you throw in a fudge factor for efficiency of each of the motors (I am guessing between 90 and 95%) all of the available input power passes straight through to the output electrically. Measuring voltage and current in the load ought to give you the numbers you need to make a pretty good guess. By using two identical motors you only have to calculate the efficiency for one since they should be the same.
Please remember that trying to duplicate the published specs will get you frustrated. The power supply and instrumentation used by the manufacturers is high quality (read "expensive") so that all data can be tested and repeated.

Good Luck All. Learn something new, everyday!
Al
WB9UVJ
www.wildstang.org

All is better now, NOS parts are working fine. Why does this year's game remind me of Violet in Willie Wonka? Hmmmm, I see blueberries!

06-13-2005, 02:11 AM #10

Mike Betts
Electrical Engineer
no team
Team Role: Engineer

Join Date: Dec 2001
Rookie Year: 1995
Location: Homosassa, FL
Posts: 1,443

Re: Cheap Torque Measurement?

Quote:

> Originally Posted by **DeepWater**
> *...Why is it important to use to of the same type motor instead of an "unkonwn" motor as the test and a known motor (one you have power curves for) for the load motor/generator?...*

As I noted in my first post, we are sacrificing some accuracy for expediency here... The efficiency of a motor as a motor may not be exactly equal to a motor as a generator. However, for the purposes of this experiment we can assume that a motor is a perfect bidirectional conversion device.

As Al Skierkiewicz stated, your measuremnts will not be as accurate as a manufacturer's lab. By using two identical motors, you are signifigantly reducing errors caused by your instrumentation being exactly the same as a lab's equipment.

Using the same motor for both motor and generator makes the math a lot easier... You will find that losses in a motor are not linear and are dependent on speed, torque, voltage and current.

Lastly, by using the same motor, you are assured that you are using the generator within it's operating range (the max speed of a CIM is not the same as a FP, for example).

Quote:

> Originally Posted by **DeepWater**
> *...What it the power resistor used for? Is this so that the generator now acts like a brake?...*

Exactly. You need both voltage and current to have power (P=V*I). Without a resistor, your output power is zero therefore your mechanical power is only the losses in the generator (fairly small in a good motor).

Mike

_____
Mike Betts

Alumnus, Team 3518, Panthrobots, 2011
Alumnus, Team 177, Bobcat Robotics, 1995 - 2010
LRI, Connecticut Regional, 2007-2010
LRI, WPI Regional, 2009 - 2010
RI, South Florida Regional, 2012 - 2013

As easy as 355/113...

06-13-2005, 02:27 AM #11

ChuckDickerson
Mentor / Bayou LRI
AKA: DeepWater
FRC #0456 (Siege Robotics)
Team Role: Mentor

Join Date: May 2004
Rookie Year: 2004
Location: Vicksburg, MS
Posts: 815

Re: Cheap Torque Measurement?

Ahh! I think the light bulb is starting to glow! Thanks for all the great info guys!

06-13-2005, 03:41 AM #12

Mike Betts
Electrical Engineer
no team
Team Role: Engineer

Join Date: Dec 2001
Rookie Year: 1995
Location: Homosassa, FL
Posts: 1,443

Re: Cheap Torque Measurement?

Quote:

> Originally Posted by **Al Skierkiewicz**
> *...I think if you throw in a fudge factor for efficiency of each of the motors (I am guessing between 90 and 95%)...*

Al,

The efficiency of DC motors is dependent on speed and is usually much less. Take the CIM for example:

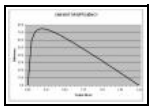
Stall Current = 114A
Stall Torque = 2.45 N*m
Free speed = 5342 RPM = 559 radians/sec

Efficiency at Max Power = (1.23 N*m * 280 rad/sec) / (12V * 57A) = 50%

Therefore, the mechanical power at the spindle will be 343W and I would expect the power dissipated in the generator's brake resistor to be about 172W or so…

Mike

Attached Thumbnails



Mike Betts

Alumnus, Team 3518, Panthrobots, 2011
Alumnus, Team 177, Bobcat Robotics, 1995 - 2010
LRI, Connecticut Regional, 2007-2010
LRI, WPI Regional, 2009 - 2010
RI, South Florida Regional, 2012 - 2013

As easy as 355/113...

06-13-2005, 07:10 AM #13

Al Skierkiewicz
Broadcast Eng/Chief Robot Inspector
AKA: Big Al WFFA 2005
FRC #0111 (WildStang)
Team Role: Engineer

Join Date: Jun 2001
Rookie Year: 1996
Location: Wheeling, IL
Posts: 10,183

Re: Cheap Torque Measurement?

Mike,
You got me again. I keep thinking of efficiencies at their peak and not at the operating point. I have got to get out of this rut.
Now what are you doing up at 2AM.?

Good Luck All. Learn something new, everyday!
Al
WB9UVJ
www.wildstang.org

All is better now, NOS parts are working fine. Why does this year's game remind me of Violet in Willie Wonka? Hmmmm, I see blueberries!

06-13-2005, 12:34 PM #14

ChuckDickerson
Mentor / Bayou LRI
AKA: DeepWater
FRC #0456 (Siege Robotics)
Team Role: Mentor

Join Date: May 2004
Rookie Year: 2004
Location: Vicksburg, MS
Posts: 815

Re: Cheap Torque Measurement?

Quote:

> Originally Posted by **Mike Betts**
> *Efficiency at Max Power = (1.23 N*m * 280 rad/sec) / (12V * 57A) = 50%*
>
> *Therefore, the mechanical power at the spindle will be 343W and I would expect the power dissipated in the generator's brake resistor to be about 172W or so…*

Mike,

What is your source for these numbers? The only source I have seen for the CIM motor specs is from the FIRST web site but some of the numbers don't quite match: http://www2.usfirst.org/2005comp/Specs/CIM.pdf

I am by no means trying to nit pick and I understand your numbers were just an example of the calculation but I am just wondering if there is another better source for the CIM motor specs that I should be using that I don't know about.

Using your example but taking the numbers for max power directly from the FIRST PDF spec sheet above I get that the efficiency is even worse (41%).

Torque = 171.7 Oz-In = 1.21 N*m
Speed = 2655 RPM = 278 rad/sec
Current = 67.9 A
Power = 337 W
Efficiency = 41% = (1.21 N*m * 278 rad/sec) / (12V * 67.9A)

The should be at least 337 W * 41 % = 138 W.

Thanks,
Chuck

06-13-2005, 01:05 PM #15

sanddrag
back to school ;-)
TBA FRC #0696 (Circuit Breakers)
Team Role: Teacher

Join Date: Jul 2002
Rookie Year: 2002
Location: Glendale, CA
Posts: 7,939

Re: Cheap Torque Measurement?

Here's some specs that FIRST gave us on the CIM in 2002 if these are of any help.
Stall Torque: 2.22 N-m
Stall Current: 107 A
Free (no load) speed: 5,500 RPM
Free (no load) current: 2.3 A
Peak Power: 321 W

_____
Teacher/Engineer/Machinist - Team 696 Circuit Breakers, 2011 - Present
Mentor/Engineer/Machinist, Team 968 RAWC, 2007-2010
Technical Mentor, Team 696 Circuit Breakers, 2005-2007
Student Mechanical Leader and Driver, Team 696 Circuit Breakers, 2002-2004

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