Analyzing a Motor

I have in the past looked at several motors to get an idea as to how well they would work in our boats. I have concentrated on the larger motors that we would use in some of our larger boats. We all want know if the motor we have or the one we are thinking about buying will work well for our application. I have come up with a series of measurements that I hope will answer some of these questions.

First of all we need to know how we intend to use the motor. First of all I assume that we will be using the motor in a Tug that is 24 inches in length or larger and that the propeller is 2 inches in diameter or larger. Given these two numbers as a starting point we can make some assumptions of what we want in a motor. As I pointed out in an earlier article about scale speed that our boats look best when the top speed is between 2 and 3 1/2 miles an hour. Most of the propellers we get have a pitch between 2 and 3 inches. With this pitch that means a maximum operating RPM of around 2,000 RPM assuming a 25% slip. With the motor driving the propeller at about 2/3 its unloaded speed we are looking for motors that turn about 3,000 RPM unloaded.

The second question we have is how much current will the motor draw. I found when working with 500 series can motors that we use in our Springers that they can draw excessive amounts of current, often well over 10 amps. This can be too much if we intend to run the boat for any length of time. So I look at how much current the motor draws when running free, what is the resistance of the armature. This gives me some idea of the motor will perform under load.

Dave White gave me 2 pairs of motors he wants to use in a large, about 50 inch long, tug he plans to build. I thought I would use the testing of these 4 motors to illustrate how I test the motors and what conclusions I make. First of all I measure the free running RPM and current draw at several voltages up to the maximum he intends to use. Then I make a measurement of the armature resistance. In the case of Dave's motors he intends to use a 12 volt battery. I choose to measure the RPM and current at 1 volt increments from 1 to 12.

The setup I use is a variable DC power supply, a volt meter and an ammeter, see figure 1.

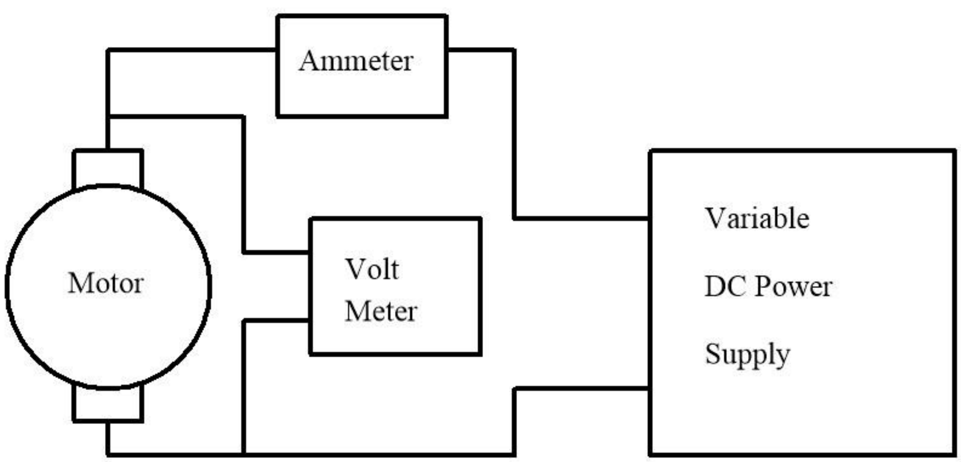

Figure 1

I connect the volt meter directly to the motor to measure the voltage supplied to the motor and avoid any errors because of voltage drops in the ammeter or wiring. I connect the ammeter in series with either power supply lead. I then adjust the power supply so the volt meter shows the voltage for the measurement and then record the current reading and RPM.

To measure the RPM I use a Hobbico Digital Mini-Tach. It is a simple optical tachometer. It seems to work rather well but there are some things to take into account. First the light source must be steady a standard incandescent or florescent flicker, we can't see it but it cause all sorts of strange readings. The tachometer will read a steady 3600 when pointing at a standard 60 watt light bulb. So I use an LED flashlight as a light source. Second since the tachometer is designed to be used with propellers I either attach a thin stick of wood to the motor shaft or if the shaft is reflective enough I put 2 thin strips of black tape on the shaft, this gives a suitable signal to the tachometer to give a reliable RPM measurement. I prefer the tape because it does not put any load on the motor but when using a piece of wood I try to pick a piece that is thin enough and short enough to provide as little load as possible. Figure 2 shows the tape on the shaft and figure 3 shows a thin piece of wood.

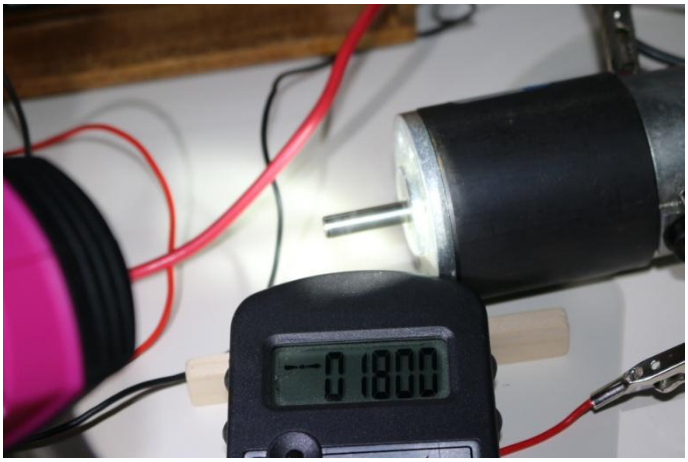

Figure 2

Figure 3

The Volt meter and Ammeter are meters that Earl Anderson had but had not finished mounting and setting up. I mounted the 2 meters in a single housing for convenience. Figure 4 shows the 2 meters connected and making a measurement.

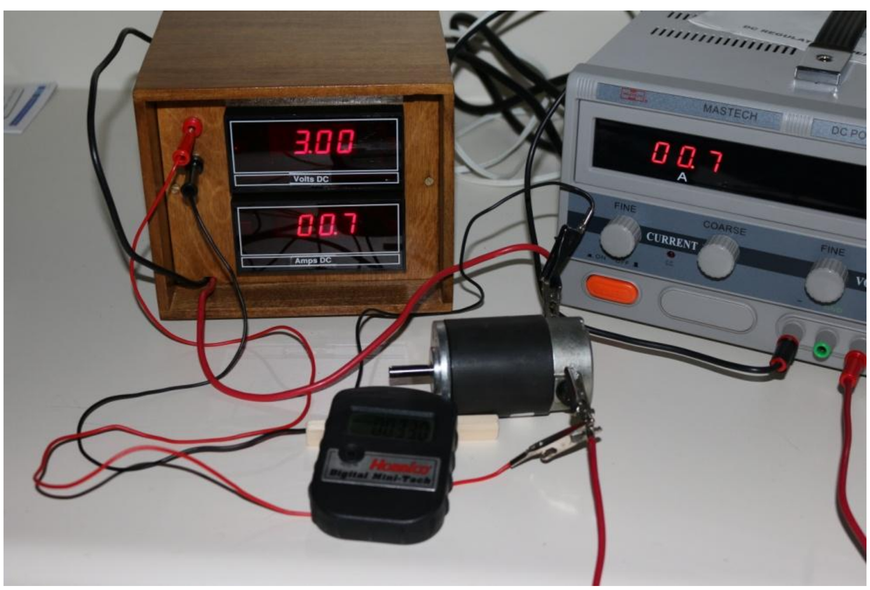

Figure 4

Now we will look at the results of the testing. I will start with the motor shown in figure 2. there are 2 identical Globe motors part number 537A229-1. Both motors tested the same with only slight variations at a couple of voltages. the results are as follows: (average values for the two motors)

Voltage	RPM	Current
1	500	0.6
2	1100	0.7
3	1800	0.7
4	2445	0.7
5	3135	0.7
6	3795	0.7
7	4480	0.7
8	5170	0.7
9	5880	0.8
10	6525	0.8
11	7190	0.8
12	7880	0.9

I then stalled the motors at low voltage to measure the armature resistance. At 1.8 volts the stall current was 4.8 amps giving a resistance of 0.4 ohms.

Now the question is what does all this mean. Well first of all the motor runs too fast for direct drive so some sort of reduction drive is necessary. If we look above and look for a propeller speed with the motor running at 2/3 free running speed a reduction of 2.5 to 1 would be a good choice. this would result of a maximum propeller speed of 2100 rpm. However with the low resistance (indicating strong torque) I would expect that the motor would run somewhat faster than 2/3 free run speed therefore a reduction of 3 to 1 would probably be a better choice. This would give high torque and with the reduction gear and the motor running 85 to90 % of free running speed the current draw would be in the range of 3 to 4 amps.

One of the second pair of motors tested is shown in Figure 3. I used a thin piece of wood to enable a tachometer reading. These 2 motors gave similar results to each other but markedly different than the Globe motors. The results are as follows: (again the average of the 2 motors)

Voltage	RPM	Current
1	0	0.2
2	200	0.3
3	450	0.3
4	700	0.4
5	930	0.6
6	1100	0.6
7	1335	0.6
8	1565	0.6
9	1800	0.6
10	2050	0.7
11	2290	0.7
12	2500	0.7

I stalled these motors with 3 volts applied and got a current of 1.5 amps giving a resistance of 2.0 ohms

With a maximum RPM of 2500 RPM these motors would have to be run direct drive. With a resistance of 2.0 ohms vs the 0.4 observed in the Globe motors I would expect that the propeller speed would be closer to 2/3 the free run speed or about 1700 RPM this would not give the performance of the Globe motors but the current draw would be about 2 amps which is less than with the Globe motors.

I will provide a bit of background to explain how I concluded what the current draw for the 2 pairs of motors would be. When a DC motor is spinning it generates an internal voltage proportional to the RPM. When we subtract the current draw times the armature resistance from the battery voltage we will get the voltage generated by the speed (RPM) of the motor. For example the globe motors ran 7880 RPM with 12 volts applied and drew 0.9 amps. Using this data we can calculate the voltage generated by the speed of the motor to be 12-(0.9 x 0.4) or 11.64 volts. This means that the motor generates 1 volt for every 678 RPM. Using this number and resistance of the armature we can calculate the current draw for any RPM the motor runs under load. To test this out I attached an 8 inch airplane propeller with a 7 inch pitch to the shaft of the globe motor. At 6 volts from the power supply the motor ran 3375 RPM which is slower than the free running speed of 3795 seen in the chart above. At 3375 RPM the motor generates 5 volts leaving one volt across the armature with a resistance of 0.4 ohms the current draw will be 2.5 amps. When I ran this in my test set up that is exactly what I measured for the current draw. This allows you to determine how the motor may be expected to operate in your boat.

Just as a interesting point the speed 600 we run in many of our Springers runs 3,000 per volt. that means the free run speed is about 18,000 RPM. When we put it in the water the propeller slows the motor down to about 12,000 RPM. With an armature resistance of 0.1 ohm this means the little motor will try to draw almost 20 amps. The draw ends up closer to 10 amps because of wiring resistance and the motor heating up and increasing resistance. That is why we drain a pair of 4.5 amp-hour batteries in 15 to 30 minutes.