BEHAVIOR OF RUBBER MOTORS, Part II

By Frank Rowsome

At first sight, we are tempted to think that twisting force of a wound rubber motor - that is torque -- is independent of length; it only depends on the turns and motor cross section - that is, the strand count, width and thickness of each strand of the motor, and maybe the batch of rubber -- but not on its length. On the other hand, if you braid in a very long motor - compared with the prop-hook-to-rear-peg distance - it must form more layers of spirals when wound than a short motor to fit in the same airplane. This layering or bunching may affect the average torque you can deliver to the prop during rundown. Then, too, long motors have normal modes of vibration different from shorter motors of the same cross section, so will vibrate differently in flight. This, too, can affect torque.

When Stew Meyers allowed me to use one of his Recording Torque Meters (RTM), I decided that my first goal would be to explore the effect of motor length upon torque delivered to the prop.

Let us define Motor Length Ratio, R as the ratio of the unstretched, unbraided motor in its final number of loops to the distance between the prop hook and the rear peg. That way, if a motor starts out three times as long as its working length in the airplane, it has a value of R = 3, and so forth. We could also call R the "compression ratio" of the motor.

I used a window fan blowing at the prop in the RTM to simulate an environment in which the airplane is fiying at 12 to 18 feet per second through the surrounding air, in order to more accurately reproduce actual fiight conditions on the test stand. I used Super Sport rubber from the September 2008 batch, lubed with Dow Corning 33 Molykote in all of the tests.

Figures 1, 2, and 3 document the results. Each point in the graphs refiects a single motor rundown.

The horizontal axis gives the motor length ratio of the rundown. That is, the points at R=2 were experiments in which the motor was tested with a hook to peg distance that was half of its initial, unstretched, unbraided length, whereas those at R=6 were taken with the hookto-peg distance reduced to one sixth of the initial motor length, under much more crowded conditions.

The vertical axis in these figures show the average torque of the torque plateau (discounting the initial torque spike upon prop release and the last few dozen turns). That gives a measure of how vigorously the motor is driving the prop during the cruise portion of the motor run. The energy delivered to the prop is proportional to this torque.

Each of these first three graphs reflect different rubber cross sections. Figure 1 is for motors composed of four strands (two loops) of 1/16 Super Sport. Figure 2 is for motors composed of four stands of 1/8" rubber, and Figure 3 shows the results for motors of six strands of 1/8".

All three graphs show that the average torque declines with increasing R. That means, e.g., if you braid a very long motor into your model, it will be less efficient in delivering torque to the propeller than if you had chosen to use a shorter motor. You do get more turns with the longer motor, but you will need to go to a slightly greater motor cross section if you want the same vigor of climb you were able to get with the shorter motor.

Notice that the drop-off of torque with increasing R is least with the skinny motor and greatest with the fattest motor. With four loops of 1/16" rubber, you lose about 3.3% of torque and energy delivered to the prop for each multiple of the hook-to-peg distance in the motor. That becomes 4.4% for motors of 4 strands of 1/8", and 4.7% for 6 strands of 1/8".

Note that the results are widely scattered at some points and less so at others. Most of the spread appears to be random. I have failed to find a way to predict whether any particular run is going to produce above- or below average results in terms of torque output. The same is true of energy output. I believe this is true of actual fiight conditions.

The motors of 4 and especially 6 strands of 1/8 were on the ragged edge of misbehavior at the larger values of R, and would have hung up and jammed in any but the most cavernous of fuselages.

I had a lot of questions about how consistent and reliable the patterns and numbers in the figures are. Would the results still apply if the motors were wound more or less aggressively?

I found that the average torque changes remarkably little with the aggressiveness of the wind, so I believe the results apply to most levels of windup. Aggressive winding gives you more turns and a longer torque plateau, but little or no change in the average torque in the torque plateau. More on this in the next installment.

Would the results still apply if a different batch of Super Sport were used?

I did these tests with Sept 2008 Super Sport, which is about .043" thick, 7% to 8% thicker than the . 040" standard. This should yield a boost in torque of about 11% to 12% over normal. I have not (yet) tested to see if other batches are consistent. I expect little change in the decline with R, but have not verified that with experiments.

Would the results still apply if a different propeller pitch or RPM had been used? Prop RPM affects the writhing and vibration of motors. I believe that this vibration --which has a large random component -- is responsible for most of the scatter in the graph points at particular values of R. I expect - but have not yet verified - that changing prop RPM would alter the scatter pattern in the data, but not the overall trends.

Would the results still apply if I had used a different lube? I used Dow Corning 33 Molykote in the tests reported here. I tried a silicon grease, Novagard 624, in some preliminary studies and it gave somewhat lower values of average torque than Molykote. Stew and Dan did some preliminary studies with the RTM that suggested that there is little difference among lubes in the energy and torque produced, but there is an anecdotal report that one "personal" lubricant greatly improve motor performance. So, this subject is worth further study.

Would the results still apply if I had used a different range for averaging torque?

I compared three ways of calculating the average torque: 1) true average from the first to last turn of the motor (which fully counts the torque burst), 2) an average of the middle BO% of the turns calculated from the point that 90% of the turns remain down to where 10% of the turns remain, and 3) an average over the middle 50% of the turn range, beginning when 75% turns remain down to the point where 25% remain. I found that the first measure is a little higher than the other two and is less consistent, as it is infiuenced strongly by the torque burst. The second two generally agree with each other within about 1 % and are more representative of the torque plateau. I chose to go with the second method, though I would have gotten nearly identical results if I had worked with the third method.

For those comfortable with the mathematics, the best linear fit for the three motor cross sections are:

T(R)4X1/16 = 0.253(1-0.033R) ounce-inches,
T(R)4X1/8 = .B20(1-.041R) ounce-inches, [Note that this seriously underestimates torque for R=4; the straight line fit is not a good predictor for this case.]
T(R)6X1/8 = 1.63(1-0.047R) ounce-inches.

A best fit for all the cross sections, treating motor cross section C (in square inches) as an independent variable, is TIR C) = 551*C 1.696 (1-.144*WC 0.325) ounce-inches.