BEHAVIOR OF RUBBER MOTORS PT I

BY Frank Rowsome

Last fall, Stew Meyers allowed me to borrow one of his Recording Torque Meters (RTM) to run some motor tests, much to my delight. The RTM allows much more precise measurements and more realistic studies of what motors are up to than the kind of bench- and flight-testing we normally do. The recording of torque (twisting force) of the motor together with a count of turns of the prop as the motor is wound and then unwinds under the load of a propeller is more accurate and more true to actual flight conditions than the kinds of tests I have been doing for years, winding and unwinding motors in the shop with a torque meter attached.

I did a lot of exploratory testing to learn to use the RTM correctly and to figure out how best to simulate an actual model flight. I took videos of motors driving a propeller at RPM values close to those in flight. Some were slow motion videos. Along the way, I learned many things about rubber motor performance.

1. As you stretch-wind a motor, initially the rubber merely twists about its center line. After a good many turns are in, the motor pops into a new configuration at one spot, where the motor adopts a corkscrew shape: the first “knot.” As you wind further, more of these corkscrew “knots” form, usually moving like a zipper from the first down the length of the motor. They are not really knots, they are more like spiral versions of a Z bend. As you continue to wind, the motor strands are becoming longer and thinner. The extra length is accommodated by more and more spirals. As winding proceeds, a second layer of spirals of spirals appears and grows down the length of the motor. As you un-stretch the motor as you approach full turns, more and more layers of spirals of spirals appear, as the motor shortens to its final working length.

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2. The torque during the motor run-down shows the following pattern: initially, the torque starts out quite high – called the torque burst -- but it rapidly falls toward a level that remains remarkably constant while most of the turns come out of the motor, only dropping down to zero as the motor fully unwinds. A close look at the torque plateau shows that the torque is actually jumping up and down like the plot of a seismograph. 3.

3. We can see the result of this torque pattern in a typical flight of a well-trimmed model. It climbs vigorously just after launch as a result of the extra power in the torque burst. Then it settles down to a more gentle climb during the period in which the motor is delivering – in the average -- more or less uniform power. Then the model transitions smoothly into a glide at the end of the motor run, as the torque ramps down to zero.

4. Watching closely what the motor is doing during the run in the RTM reveals why this pattern occurs. When the prop is initially released, the whole motor begins to act like a single twisted spring, gradually unwinding evenly throughout its length. But the twists in the layers of spirals are locked in by the neighboring or overlying spirals, and cannot unwind until the outer layer of spirals begin to pop out in the reverse of the process when they formed during winding. The transition occurs locally in one spot on the motor. A short length of the outermost spiral – usually just one or two turns – pops out straight. When this happens, the torque jumps up as its twist become available to drive the prop. Then the torque subsides over the next 10 or 20 turns, until another pop occurs, straightening a little more of the motor. The sequence of pops during run-down also often goes in order like a zipper.
5. This pop – unwind – pop– unwind sequence seems to be responsible for the motor delivering more or less uniform power (in the average) over the "cruise" portion of the motor run, but with saw-tooth surges and slumps if you look closely at the torque plot.
6. The popping of segments of the motor as spirals jump to straight segments causes a lot of motor vibration which – in severe cases – leads to such things as the nose block popping out, the motor climbing the rear peg and bunching behind, or at the prop hook.
7. The local uncoiling of the motor causes the center of gravity of the motor to shift fore and aft a little, in a seemingly random and unpredictable fashion during the motor run. This effect is magnified when the uncoiling acts like a zipper running from one end of the motor to the other. We can see that in the flight pattern of some models that seem to drift out of trim at times during the motor run and then drift back into trim again.
8. The other major cause of motor vibration is harmonic resonance. No matter how perfectly you make your prop hooks, the motor will never stay precisely centered on the prop shaft axis, so it is being shaken – at least a little – by prop shaft rotation. At times, this sets the motor to swinging like a jump rope. If the prop rotational speed just matches one of the resonant frequencies of the motor, it will start to swing out of line.
9. Our motors act just like strings of a musical instrument – guitar, harp, piano, etc. or a jump rope. The underlying physics is just the same. There is a base note or frequency and higher-pitched multiples of that frequency. In motors running on the RTM with prop speeds similar to actual flight conditions, I have observed over one hundred instances of jump-rope behavior. Usually, these resonances are brief – lasting for only a few tens of turns of the prop – but rarely they persist for a substantial fraction of the motor run.
10. Typically, such jump-rope vibrations collapse quickly and then cease if the motor strikes a barrier such as the inside of the fuselage.
11. To my great surprise, I found that the torque being delivered to the prop during these episodes of resonant jump-roping almost always actually increases by roughly 10% above what it was before and after the jump-roping took place. I believe that the stretching and shaking of the motor is helping to free up the spiral packing, allowing the transitions to a straighter configuration – which unlock some of the stored turns – to occur more easily.
12. I do not believe it possible to put this process to work for us in our models. It is true that jump-roping almost always improves rubber motor power delivery. But achieving it and sustaining it consistently would require managing motor tension and prop RPM with a precision we could not hope to achieve.

In the next installment, I will report findings on how motor length affects torque and a preliminary report on mass launch winding sequences