BEHAVIOR OF RUBBER MOTORS, Part III

By Frank Rowsome

How long should our rubber motors be in order to optimize flight times? Years ago, I came to the conclusion that longer is usually beller - up to the point that the motor misbehaves. Long motors accept more turns and store more energy than short motors of the same strand width and strand count. If you get greedy and go for a motor that is too long, it will bind up in the nose or climb the rear peg, or the nose block may pop out, disturbing the balance and preventing some of the turns from being returned to the propeller in flight.

There are some tradeoffs to be considered in choosing to go with particularly long motors. A long motor is heavier than its shorter cousin, so the gross weight of the model goes up as we go to longer and longer motors. That means that the prop needs to work a lillie harder to fly the plane. As you progress from shorter motors to longer ones, the vigor of climb will decline a little, unless you increase the motor cross section a lillie - which further adds to the weight and cuts into maximum turns.

Part II of this series of articles reported some studies with Stew Meyers' Recording Torque Meter to measure the effect of motor length upon the twisting force - torque - that rubber motors deliver to the propeller during the cruise portion of the motor run, after the torque burst tails off.

The results showed that long motors - compared with the working length (distance between the prop hook and rear peg) - are a little less efficient in returning torque or energy to the prop than shorter motors of the same cross section. Thus, if you want to preserve the vigor of climb while trying longer and longer motors, the cross section must increase even more dramatically - some to haul the extra weight and still more to compensate for the decline Jn efficiency with lengthened motors. This effect is least pronounced with very skinny motors and is increasingly pronounced with greater motor cross section - more strand width or strand count.

What does this mean in practice? In peanuts and other very light, small models that can fly with very skinny motors, you may be able to get away with relatively long motors, e.g. with motor length ratios in the 4 to 6 range, maybe more. Light dimers and other ships in the 16" to 20" wing span range may tolerate motors having a motor length ratio of about 4. Larger models - which require huskier motors - tolerate motors with fewer multiples of the hook to peg distance. I have been using motors cut to R = 3 in some models up to 36" wingspan with success. It also accounts for the fact that old time cabin and stick models - with props up to 15" diameter and pitches up to 19" and requiring a very fat hank of rubber to fly at all - generally will not tolerate motors longer than about 2 times the hook to peg distance, no mailer how they are braided or anchored.

These suggestions about motor length apply to models with fuselages enclosing the motor - not motor stick models - and must be adjusted for the motor clearance in the fuselage. In a model with lillie interior motor clearance, motor jamming is more likely to occur, with the result that these models are less tolerant of long motors than models with ample interior room. Models of Gee Bees and Cessna racers can get away with higher motor length ratios than, e.g., Greeve racers or WW II fighters with inline engines, provided that the rear peg is far enough forward that the model does not become tail heavy in the process.

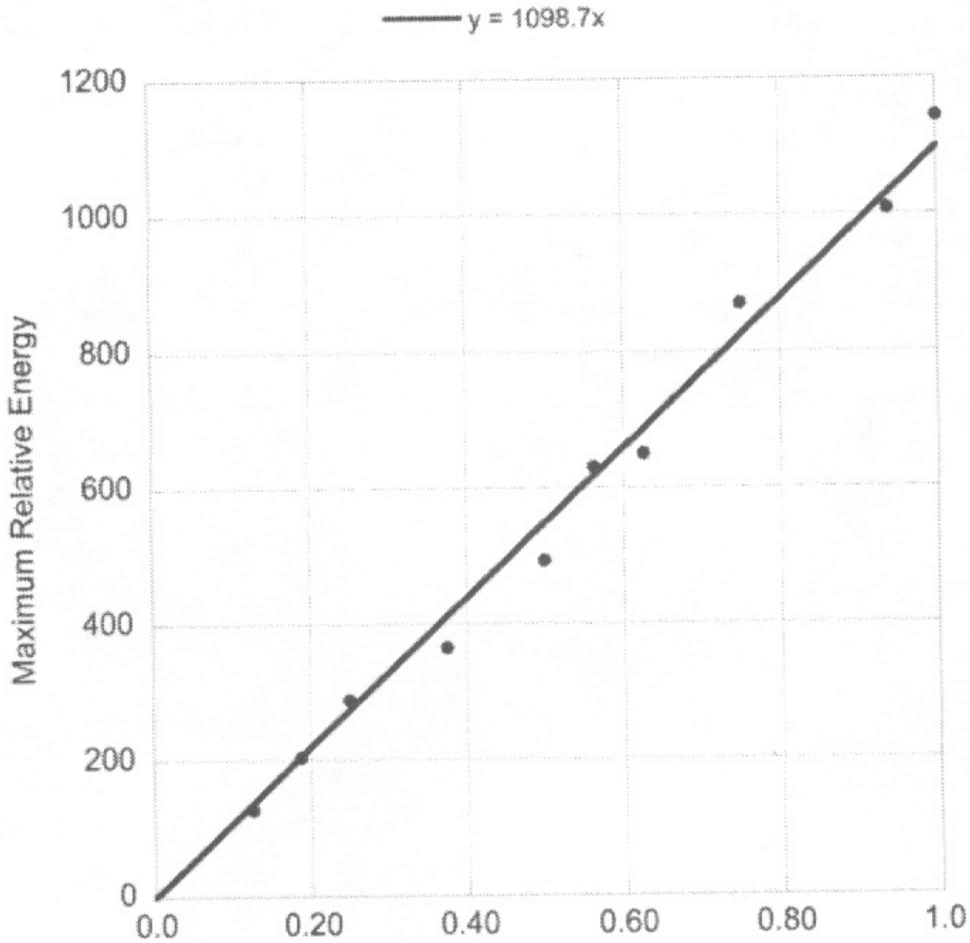
This effect also helps account for a mystery that has been puzzling me for years. Theory suggests that high pitch props - those with a P/D of up to 1.3 - should consistently out-perform low pitch props - those with P/D of less than 1 - such as stock Peck props. However, FAC competition seems to show no clear, consistent advantage to either prop choice. The argument goes as follows. The high-pitch prop screws itself through the air taking a bigger bight than the low pitch prop, which needs more turns to screw as far. To be sure, the high pitch prop requires more torque to do this - so its motor must have a greater cross section to give the same vigor of climb. The fatter motor required for high pitch props thus tolerates fewer turns than the motor used by the low-pitch prop, but if you do the measurements and work out the numbers, the higher pitch prop still screws itself through a longer column of air than the low pitch prop -- even taking into consideration the difference in the maximum number of motor turns, so the prop and motor combination with the longer screw distance (turns multiplied by prop pitch) should climb higher and last longer in flight than the prop and motor combination with the shorter screw distance. Or so I thought. Experience shows that it is closer to a tie. But if you take into consideration that the huskier motor required for the highpitch prop also needs a bit more cross section to account for both the extra weight and still more for the diminished efficiency in delivering torque, it is clear that the advantage in going with high-pitch props is less clear cut.

There is one more factor to consider. Wing loading may exact a penalty for going to heavy motors in increased drag. We like to employ flat-bollomed airfoils, mostly because they are particularly easy to build and align. The late Dave Rees showed that such wings work extremely well, even with skinny leading edges, if the wing loading is very low. The 'coconuts he was building in his later years were extraordinary for their slow, floating flight that seemed to go on forever. He built very light. He used very low-pitch propellers, and operated them with very skinny, low-torque, weak motors that barely produced a scale-like rate of climb even during the torque burst. He chose to use motors that were much shorter than he could have successfully braided into his models, and still he did a lot of winning just by just keeping everything extremely light and slowing everything down. In low wind conditions, very few of us could come close to his flight times.

He showed that longer motors are not always better. We saw some other clues when the FAC experimented with limiting the weight of motors in mass launch contests to 15% of the empty weight of the model. Meeting the weight limit meant using much shorter motors than we had been using. The objective of the motor weight limitation was to keep more of our flights within our generally undersized flying fields. It did not work as well as its proponents had hoped. Our models became lighter in gross weight, with the result that they floated better and flight times and drift distances were not reduced consistently. Our flight times came to reflect the luck of the lift more than it had before, so the 15% rule fell into disfavor.

I believe that our preferred flat-bottom airfoils lose efficiency as the wing loading goes up, so that there is yet another penalty in having a very long, heavy motor. What I am learning with Stew's recording torque meter is bringing the theory into better alignment with experience: lowpitch props may work as well as high pitch props in many of our models - particularly those with flat-bottom airfoils - and going to the longest motor you can get to work successfully in your model may not give you much of an advantage, if any. We have a much broader sweet spot in our choice of propeller pitch and motor dimensions than I once believed. We are back to where we were before, with experience, trial and error the best guide to picking props and motors.

Here is a plot by Mike Copeland of the energy stored in a rubber strip as a function of width. The energy units are inch- ounces and the width is in inches. The take away fact is it's linear.


y = 1098.7x
Maximum Relative Energy
1200
1000
800
600
400
200
0
0.0
0.20
0.40
0.60
0.80
1.0