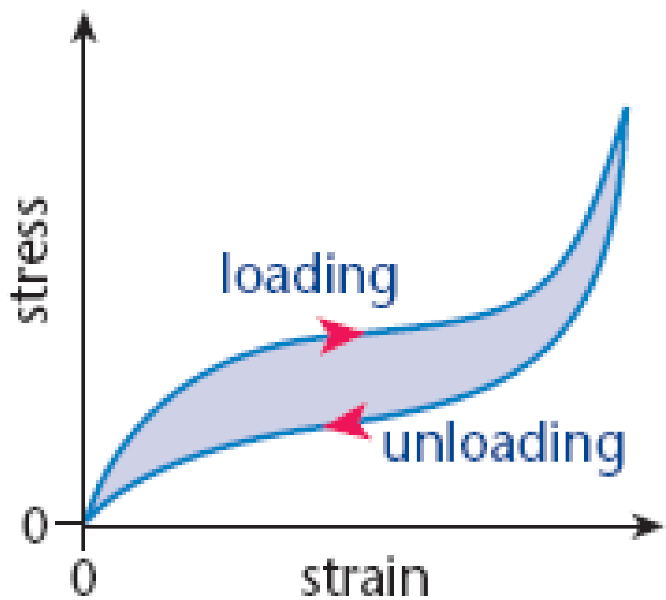
Rubber Motors for Wright Stuff

Overview:

A rubber loop is the storage media for energy to fly our planes. Rubber is elastic, meaning it can stretch a lot before it breaks, and it "unstretches", giving back a good bit of the energy put into stretching it. Thus, it is somewhat like a battery. In Wright Stuff, the amount of rubber is limited (1.5g), and so the size and winding plays a critical role in how long the plane will fly. The rubber must be matched to the characteristics of the plane, and to the propeller.

Hysteresis

Hysteresis is when something follows a different path moving in one direction than in the other. In terms of rubber, hysteresis means that the torque to wind the rubber is higher than the torque to unwind.



In this diagram, "strain" means stretching. In our case, while we stretch the rubber to aid in winding, the strain is caused by twisting the rubber. If you follow the "loading" curve, you see the rubber does not resist much at all in the beginning, then has a long period of accepting winds, or energy, and finally sharply increases in stress. If you kept adding energy after the sudden increase, the rubber breaks.

The area under the loading curve represents energy going into the rubber. Just like charging a battery. The area under the unloading curve is energy we get out, which is less than what we put in. Where does the extra energy go? It goes to heat in the rubber. Try stretching a rubber band quickly multiple times. It gets warm. This is the same reason a battery gets warm when you charge it. Some of the energy is wasted as heat.

If you stop winding anywhere on the loading curve, and begin to unwind, the stress quickly drops to the lower unwind curve. So if you wind to a specific torque, you do not get that torque as output very long! However, if you wind to the steep part of the curve, then back off to the torque you desire, then you have a lot more energy (area under the curve) in the rubber.

Rubber has a LOT of hysteresis. This is why winding tight and then unwinding is so important. It is also why we must know how much torque it takes to break the rubber. Otherwise, we leave energy “on the table”. Our current rubber is good to about 7-8, but we are winding to about 5 in practice to make the rubber last longer. Winding tight shortens the life of the rubber. In competition, we only need one run out of the rubber.

Cutting rubber

The rubber is made In large sheets, and cut into uniform strips by the seller. I have 3/32” and 3/16” nominal width. However, the rubber sheet is not perfect, and the thickness may vary as well.

In order to match the propeller and the plane, we vary the width of the rubber. A thinner rubber can fit a lot more winds, so can fly a lot longer. However, the torque (stress) is not as high, and you may not have enough power (torque) to fly the plane. Too thick, and you have too much power, the plane climbs and then flies “dead stick” (runs out of winds), dropping quickly. Ideally, you land with the propeller still turning, but use most of the winds.

We use a “Rubber Stripper” device to cut the rubber into strips. However, it is rather finicky to set up. After making a width adjustment, we slice a small length, weigh it, and measure the length. We divide the two to get grams per inch. This is the critical measurement, as a thinner but wider piece does the same as a thicker narrower piece when cut to the same grams per inch.

After cutting a piece long enough for a loop, we check another small cut to be sure the setup or rubber thickness has not changed too much, and adjust if it did.

Making the motor

We are limited to 1.5g of rubber. If too light, we lose energy storage. If too heavy, it will not pass inspection. We add the two rings for the ends, and tie a single overhand knot after lubing with a touch of water. At this point we check the weight, and trim the ends of the knot until the weight is very close to 1.5g. The knot is easily moved by pulling the ends. Once the weight is right, a second overhand knot is tied and pulled to the first knot. The two knots reinforce each other. A small drop of CA helps too.

The motor must be broken in to maximize energy capability. After lubing, the motor can be stretched to its limits for about 5 minutes. Alternatively, it can be wound once, which is a good way to ensure it does not have any nicks that might cause failure. After break-in, it is washed with warm soapy water to remove talc and lube, re-weighed, and labeled in a baggie. If it is not for a contest, it does not have to be washed.

The important parameters to record:

- Date, to keep track of batch and age
- Nominal width in g/in, as measured before cutting the strip to length
- Weight of the loop
- Length of the loop

The length of the loop is the most accurate measure of the width, because you have about 1m of rubber at 1.5g, so it is more accurate than the grams per inch measurement. It also accounts for any variation over the length of the rubber. If the post-cutting sample is dramatically different than the pre-cut sample, something changed and the rubber loop may be no good. It is only as strong as its weakest part.

Winding

The indoor rubber community has experimented over the years and found ways to jamb more and more energy into the band without breaking. We take advantage of that knowledge.

The first thing is to have accurate knowledge of your status. This means having instrumentation. We use a torque meter to know exactly how much torque we have on the rubber, and most importantly, how much torque remains after unwinding a bit. This value is critical to setting the altitude of the plane. You can wind by feel, but unwinding requires a torque meter. The second valuable instrument is a counter, as it is too easy to lose track of counting while winding.

The following steps, and reasons, are taken:

1. Lube with AmourAll. The rubber, when winding, will rub against itself and abrade, or cut. The lube allows it to slide, and can help get 50% more winds into the rubber.
2. Stretch 7X original length. Stretching allows an orderly formation of knots, rather than a balled up mess, and thus allows more knots, and substantially more winds to be put in.
3. Wind about half at full stretch. Experience based.
4. Walk in while winding. Controls the knot pileup, and converts linear stretch to final winds
5. Unwind to torque. Maximizes winds in the rubber for a given launch torque

Torque Burner

More torque at launch converts to more altitude in the flight. However, under a low ceiling, the torque to reach the ceiling is rather low, meaning a lot of unwinds, and lost energy. The taller the ceiling, then, the more time in the air is possible.

The torque burner allows us to fly multiple partial rubber lengths in one flight. The first unwinds until almost completion, and then releases and the second starts to unwind, etc. Thus, the plane climbs a total of perhaps twice the height of the gym, without hitting the ceiling. The second portion of the motor does not reach full torque since it is “combined” with the first part of the motor that is already unwound. Therefore, we put about 1/3 of the motor on the first pass, and 2/3 on the second. We can put more torque in the second motor by hooking up the tail hook and pin without unwinds, and then unwind the front a few turns. However, no torque reading is available when doing this.

The torque burner is risky. There are many variables, such as pin height, pin stiffness, torque in the second motor, etc. While ideally the pop time of the second motor would be the same every flight, that appears to be difficult to accomplish. If it pops early, the plan can end up in the ceiling. If it pops late (or not at all), the plan ends up in the floor. By all accounts, if you are skilled and experienced, the TB will still only work 80% of the time. This is a difficult aspect when you only get 2 official flights.

The trick to success is to implement a more accurate means of controlling the release of the TB. We will test a little more, but may need to return to traditional methods of altitude control. When the TB does work as planned, the times achieved can be substantially better than those with other methods.

Flaring Prop

The flaring prop is another method to control the release of torque (energy) from the rubber. The idea is that at high torque, the prop flares to a higher pitch, slowing down the unwinds. Unfortunately, with the rather small props this year, this capability appears limited. If the prop flexes too much, it stalls (just like a wing), and then energy is wasted smashing the air around without driving the plane. But with the small prop size, on the verge of stall we still unwind too fast.

As the torque goes down, the prop pitch goes down, and so the prop spins faster. Power is actually torque times rotational speed, so the power stays higher as the rubber unwinds. This helps to make a consistent and long cruise period after climbing.

It is a balancing act to get the prop pitch and flare to match the rubber, the air conditions (temperature, altitude), and the plane (drag, power needed to climb). However, once conditions are set, the balance appears somewhat repeatable, perhaps moreso than the TB.

LPP and other AAHS group flying

The rubber slips specify an approximate torque and winds for each piece of rubber. These numbers are derived form my “break-in” wind of the rubber, and are guides only. The following is given:

- Torque, two numbers.
  - First number is torque at full pull. This is generally half the max torque
  - Second number is torque at “landing, when winding is finished
- Winds, two numbers
  - First is winds at full pull. This is generally 50-60% of full winds. You may get more or less, depending how tight you pull the rubber.
  - Second is winds at landing. You may get more. Rubber will take more winds after its been used.

The winding process currently is as follows:

- Stretch the rubber until you feel a “wall” pulling it. This is typically about 8X stretch
  - Some say to stretch anywhere from 3 to 6X
  - I find stretch “to the wall” is most consistent
- Wind staying at full pull. Watch the torque and the winds
  - “Feel” the rubber. It will suddenly get higher torque, and harder to wind, and more pull. This is your key to move in
    - Note the torque at this point. This is your ½ torque. Ex, 4.
    - Double this torque, and your goal is to “land” at this doubled number. Ex, 8
    - The winds and the torque should resemble the sheet, but the feel is more important
    - If you go substantially over the winds on the sheet (20%), you may not have pulled enough, but you may want to start walking in.
- Walk in while winding. Watch the torque. You want to keep it at or above the ½ torque level
  - If dropping too fast, stop walking, keep winding
  - If ramping up, walk in faster
  - Continue like this to about halfway in
- Walk to landing, keep on winding
  - Torque will ramp up, sometimes steeply.
  - Control the ramp rate by controlling your walk-in speed, while continuing to wind
  - You may slow the winding for a bit more control. Coordinate winding and walking to maintain an increasing torque
  - Keep in mind the turns and torque desired at landing
  - Walk in speed will increase as you get closer. Keep “feeling the pull”
- Landing
  - If you get to the desired winds and have not landed, slowly crank in a few more turns as you bring the winder in. Never bring in without turning the crank. But you will need to get there quickly, especially if torque is high

- Failure to wind while walking in results in long stringy knots
- Lock the winder and record peak torque and winds
- Unwind to desired launch torque. Launch torque is set by gym height. (And plane capabilities). Generally, Scraps won't be above 0.5, LPP 5

In order to maximize energy stored, you need to develop a "feel" of the rubber. It will pull, telling you to move in quicker. The torque will also tell you to speed up or slow down your walk.

Always remember the rubber notes are a guide. Likely the torque will be lower and the winds higher than the sheet. If the winds are substantially higher, the rubber may be on its last legs. If you are just testing, and not competing, you can use the winds as gospel (torque will be lower), and that will make rubber last longer.