TECH TIME

Helpful tips for the Avionics Technician

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This month we continue our series on autopilot theory and operation by examining the role of cable tension in aircraft performance. Why is cable tension important? Because when the pilot or autopilot commands a control surface to move, there must be no delay and the deflection must be a specific, measured response or the aircraft performance will be sloppy.

A properly adjusted cable precludes oscillating tendencies and fulfills the autopilot computer's need for control surface movement in direct proportion to its command. One simple test is to engage the autopilot and attempt to move the control surfaces. There should be no slop in the system. If you have an aircraft with loose controls and it is equipped with control rods, check the ball and socket joints. They can become worn and loosen, causing a delay in response from an autopilot servo command. Remember that a cable tension set too high will increase the system friction which can also result in a tendency to oscillate

If your aircraft has cables, you must consult temperature charts before making any measurements of tension. Remember that different metals expand or contract with temperature at different rates or have varying *temperature coefficients.* Since many aircraft are constructed of aluminum, with a temperature coefficient of 12.8 µinch/inch/ºF, and the control surfaces are deflected with steel cables, with a temperature coefficient of 9.6 µinch/inch/ºF, you are setting the stage for problems when there are large changes in temperature during the course of a flight. When you ascend in an aircraft, there is a temperature lapse rate of approximately 3 ½ ºF or about 2º C for every 1000 feet of climb. Therefore, at altitude the fuselage has shrunk more than the cables and the cable tension has decreased. The longer the fuselage is, the greater the problem. Some aircraft have cable tensioners that take up the slack during high altitude cruise. For aircraft with and without compensating mechanisms, it is best to set the tension at the high end of specifications.

To measure cable tension, the industry's standard tool is the *cable tensionmeter*. This device is attached to the control cable or bridle cable and a small hook then causes a portion of the cable to deflect. The resultant force measured is then compared to a master calibration table and the tension calculated. Another way to set the cable tension on the *bridle cables* is to use a fish scale to pull the cable in the same direction as the cable is installed and when the fish scale reads the proper force, the bolts on the attaching clamp are tightened. Remember that tightening a bridle cable can effect the tension of the main cable and vice versa. It is a good idea to check both after making any adjustments.

One simple method of calibrating a fish scale is to use a ladder or other support to hang a bucket of water to be measured. Since the weight of water is fundamental, at 8.3 lbs per gallon at room temperature, you can simply fill the bucket with water from a measured beaker and measure the resultant weight. To compensate for the weight of the bucket and cable, set up a teeter-totter and balance the bucket/cable mass with another light-weight water container filled until the teeter-totter is level. The weight of this quantity of water becomes your constant in future calculations.

But what about the cable tensionmeter? Is it as accurate as using the fish scale? We must remember that as an industry we measure numerous parameters in the course of our duties. Whether it is voltage, resistance, current, friction, tension, etc., we use equipment that impacts the device being tested in order to extract useful information. In other words, we have changed the system by measuring it. Figure 1 on the following page is a diagram of the cable tensionmeter mechanism. Note that the clamping action has the effect of *shortening* the cable.

Where lengths are great, such as in main control cables, this shortening effect causes only a small distortion in actual tension. But the shorter the cable measured, the greater the inaccuracy. It is possible for a calibrated cable tensionmeter to have a 50% error on a short bridle cable. This can result in an aircraft oscillation that is very hard to troubleshoot.

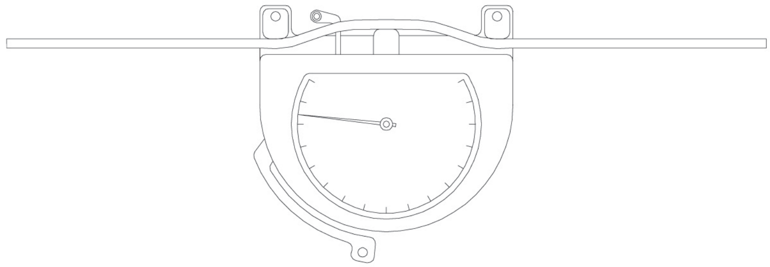

Figure 1. Cable Tensionmeter.

One reason for this inaccuracy is the small total distance between reference points, typically only 3”. Additionally, the tensiometers are calibrated with cables at least 36” long, allowing errors to increase in direct proportion to lengths shorter than this. From classical physics, we can turn this problem into a two dimensional equilibrium condition with applied forces. See Figure 2 below:

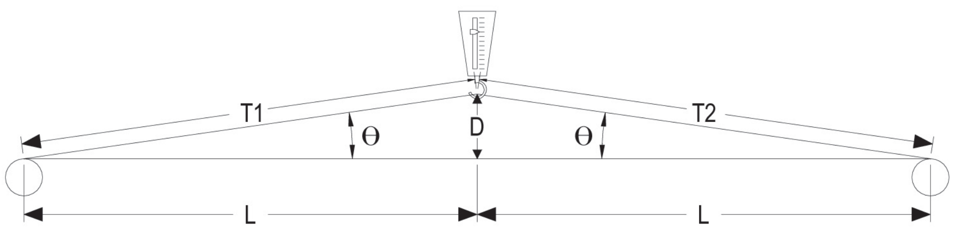

Figure 2. Forces applied to cable.

We attach the fish scale to the cable, in the middle of its run, and measure both the amount of force and the distance the cable was displaced. Since the two lengths of cable are symmetrical with respect to the fish scale, the tensions in both sides must be the same. This is found by summing the forces in the horizontal direction and setting them equal to zero.

Eq. 1 Forces in X axis = $Fx = T_1 \cos\theta - T_2 \cos\theta = 0$ given $T_1 = T_2 = T$ = Tension
Eq. 2 Forces in Y axis = $Fy = T \sin\theta + T \sin\theta$
$= 2T (\sin\theta)$ where $\sin\theta$ = deflection D / length L (assumes small angles)
Eq. 3 $\mathbf{T = Fy / 2 \sin\theta}$

Example: You wish to measure the tension of a bridle cable, 18” long. The fish scale measures 8 oz (0.50 lb) with 0.25” deflection.

$T = Fy / 2 \sin\theta \quad \sin\theta = D / L$

$$T = \frac{8\text{ oz}}{2(0.25''/9'')} = \frac{4\text{ oz}}{.028} = \mathbf{143\text{ oz or} \approx 9\text{ lbs}}$$

You may wish to measure tension using this method and compare the result with the industry accepted cable tensiometer’s calculated value. Use only the smallest amount of force (fish scale deflection) necessary to provide a reliable reading. This alternative procedure may prove to be invaluable in constricted spaces and/or with short cables.

This concludes this Tech Time series on autopilot theory, operation and troubleshooting.