TECH TIME

Helpful tips for the Avionics Technician

B Y   A L   I N G L E

This month we continue our series on autopilot theory and operation by examining the role of cable friction in aircraft performance.

Does the aircraft in question have friction specifications? Most aircraft manufactured today do have specifications and procedures for measuring friction and in these instances the technician may simply follow their instructions. But what if the aircraft has no published specifications and procedures? What is needed is a repeatable and universal way of measuring the friction so that multiple aircraft can be tested and their serviceability determined. It is important to note that most airframe manufacturers do not specify the *minimum* friction-only the maximum. It is therefore possible for an aircraft to exhibit symptoms that mask this condition. We will cover this scenario later.

All tests are to be performed with a calibrated spring scale, denominated in ounces or pounds. We are not talking about a lot of force here, probably on the order on 1-2 lbs. at most. We will first cover *how* to measure the friction, then explain *why* this is so important. Starting with the roll axis, you want to apply a torque to the control yoke. Attach a piece of safety wire to the outside of the yoke's left horn and to the other end of the wire attach the spring scale. Next slowly and consistently pull up on the spring scale and record the scale's reading as the yoke passes through the neutral position. Do this three times and record the average. Now repeat this procedure after attaching the safety wire to the right hand side of the yoke. The friction levels measured in both directions should not vary by more than 10%. See Figure 1 below for a diagram of what is happening.

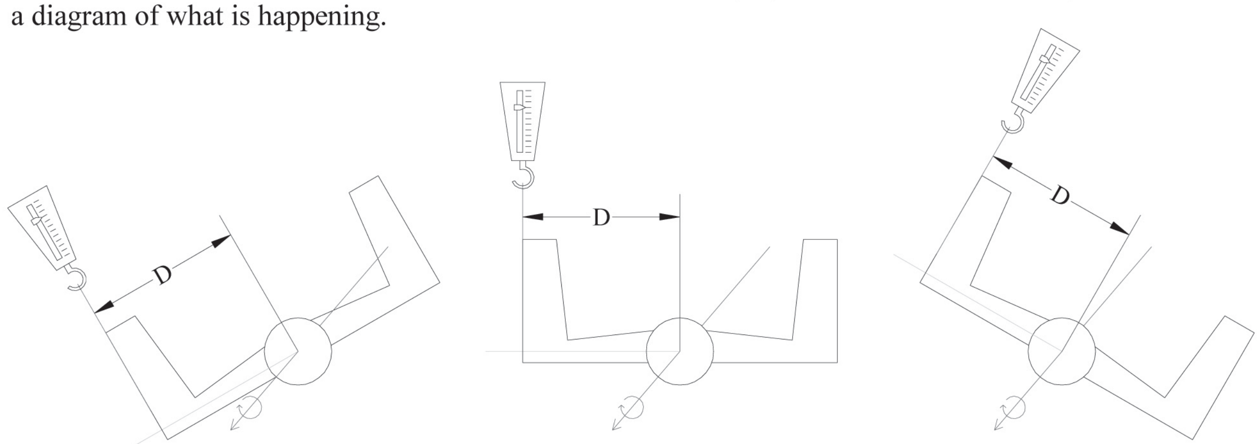

Figure 1 Measure torque required to rotate yoke.

Torque is calculated from the relation: $\mathbf{T = F \times D \times \sin\theta}$
Where T = Torque, F= Force in ounces or pounds, D= Distance in any unit i.e. inches, centimeters, etc., Sin θ = angle between the applied force and the arm

It is of paramount importance that the measurements be consistent in all subsequent tests in similar aircraft so that a baseline can be established. Remember to apply the spring scale's force at a right angle to the control yoke's body or the measurement will be too high (at a right angle, the Sin θ = 1 and drops out of the equation). It will help if a table is created listing the distance from center in which the test was performed, or at least the friction found. For example, if one measures friction as 16 ounces at 8.5 inches from yoke center in one aircraft (or 136 in-ounces of torque), and in another aircraft of similar model finds friction to be 17 ounces at 8 inches (or 136 in-ounces of torque), they are identical. Test aircraft with good functioning autopilots to act as a standard. Keep good records.

To measure the pitch axis, one must first balance the elevator with a counterweight forward of its rotational axis. Refer to Figure 2 on the following page. One method is to attach a piece of safety wire to a screw or rigging hole with an "S" hook. In aircraft without either of these attachment points, a "V" fixture can be fabricated such that it is placed on the elevator with an extension protruding forward, providing the opposing force to balance the elevator.

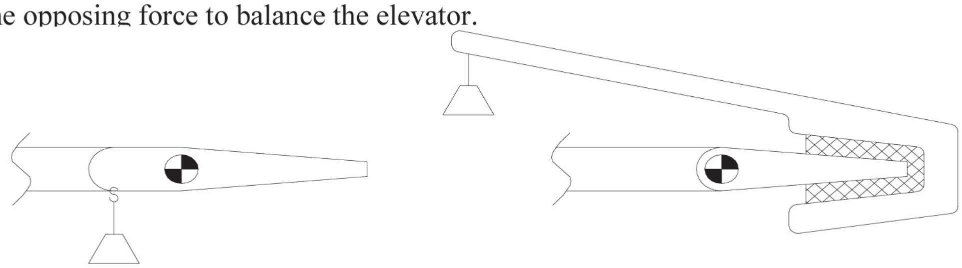

Figure 2 Attach weight to balance the elevator.

After balancing the elevator, attach the spring scale to the center of the yoke and pull the elevator through neutral in both directions three times, then average. They should not vary more than 10%.

For the yaw axis, because the rudder may be interconnected with the nose wheel, you must place the aircraft on jacks and retract the gear if retractable. Attach the spring scale first to one rudder pedal, pulling through center and then the other pedal, pulling through center. Again, measure the force three times per side, then average. The difference in forces yawing right and left should not exceed 10%.

Knowing how to measure the friction, let us now discuss the *why*. First of all, a commanded autopilot servo must first overcome the friction, then the air resistance of the control it is moving. In most equations, 10% is not considered a significant quantity. Therefore, if the friction constitutes less than 10% of its total load, it may not be considered relevant. Conversely, if the torque needed to overcome cable tension is more than 10%, it becomes relevant.

Consider that aircraft manufacturers typically use the second constructed aircraft for certification of the autopilot. If in later manufacturing the friction levels change due to differing assembly practices, the autopilot performance is going to suffer. This is a scenario where the friction can actually go down as more aircraft are produced.

A symptom of too much gain is an approximately one second periodic oscillation. This can be from a malfunction of the autopilot system or from cable friction that is *too low*. The movement of the yoke will be barely perceptible, less than 1/8 inch. In this instance, the technician can place his hand around the yoke where it enters the instrument panel and gently squeeze, thereby adding friction to the system. If the oscillations stop, you know that you have too much gain. Another way of determining this is to dampen the oscillation by any means (i.e. perhaps engaging the CWS mode). Then an abrupt input may be added to that axis and see if the oscillation reappears.

Conversely, a long duration oscillation of 10-30 seconds could be caused by a malfunction of the autopilot system or friction that is *too high*. Autopilot manufacturers typically start their certification process with too much gain, then back off just enough to prevent the fast oscillation. The key to knowing that you have a gain problem is that the oscillations are periodic, not erratic.

Erratic motion on the other hand can be due to gyro slip ring or motor brush intermittencies, to name a few. Recognize whether the fault is periodic or not and start the process of elimination.

Note: One source of high quality spring scales is Wagner Instruments, POB 1217, Greenwich, Connecticut, 06836, telephone (203) 869-9681.

Next Month: More Autopilots