

A METHOD TO FIND SURFACE DEFECTS WHICH MAY DISRUPT LAMINAR FLOW

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INTRODUCTION

The elegant wings of sailplanes in flight deflect noticeably and twist slightly. Accordingly, there must be a degree of distortion of the airfoil contour – which may have been close to perfect when measured while the aircraft was not subjected to flight loads.

This paper describes a technique for finding such localized distortions of the wing under simulated flight conditions, seeking those that can cause the airfoil boundary layer to transition prematurely from laminar to turbulent flow with consequent increase in drag.

The guided probe or short tool pictured in Figure 1 is described in Reference 1 (since the SSA has no more copies of this issue of *Soaring* the author will provide Xerox copies of the article upon request and receipt of

\$2.00 to cover expenses.) It is a calibratable, adequately accurate instrument in contrast to the roller-mounted device often used to measure wing smoothness, shown in Figure 2. Rolled chordwise over a wing, the latter shows slowly varying indications due to the gradual changes of radius of the airfoil. Rolled spanwise along a constant percent chordline of a perfect wing, almost no change

of reading should be observed. The first indication of a flat, a bump or dent, will show just half of the dimension of the actual defect.

Due to its 12 inch effective length, the short tool would probably require months of time to survey an average sailplane wing. A simple, inexpensive system, much less time consuming, has been a goal of the author since 1987.

This paper presents an accurate, calibratable device, see Figure 3, which should permit, along with the short tool, the thorough examination of a sailplane wing, top and bottom, tip-to-tip to at least 60% chord in one, or at the most, a very few days. Anomalous areas should be found and described dimensionally and in detail if they are of a magnitude that threatens transition from laminar flow in normal flight attitudes.

Critical surface waviness is a deep and complex subject, not addressed in this document. For a rough comparison of wings not under simulated flight loads:

1. Research models may attain 0.001 inch per inch waviness .
2. Some racing sailplanes claim 0.002 inch per inch waviness .
3. (Typically) production

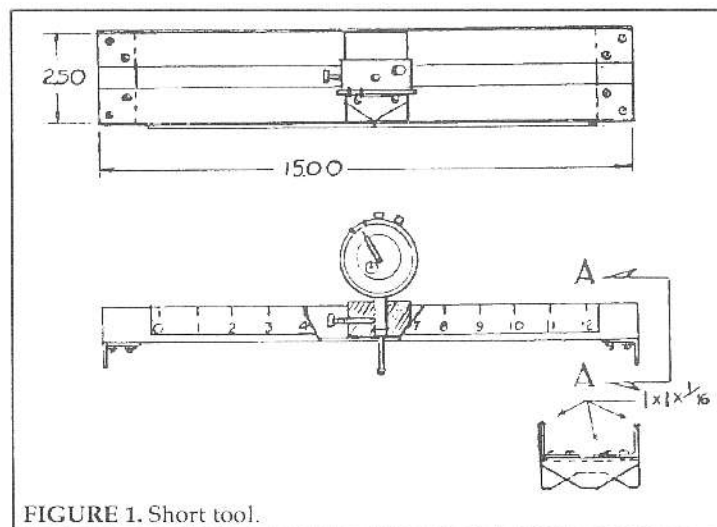


FIGURE 1. Short tool.

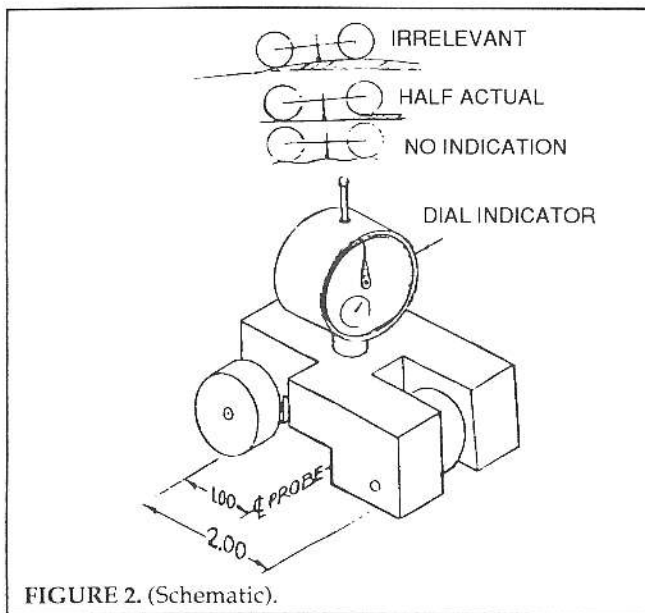


FIGURE 2. (Schematic).

sailplanes are thought to be 0.004 to 0.006 inch/inch.

DESCRIPTION

The author found it natural but time consuming to examine wing surfaces for smoothness by causing the lines of scanning to run chordwise, the direction of fluid flow. Recently he recognized that a similar sensor following spanwise (approximately 90° to fluid flow) lines of constant percent chord would also be effective. The concept of measuring small dimensions related to a calibrated, accurate datum as noted in Reference 1 is kept, but the length of the datum was increased by a factor of 8. The problem is to get an accurate datum. This is not as difficult as had been feared.

The plan is to lay out on the wing lines of constant percent chord, about an inch (25mm) apart at the root, and to track each line at a fairly steady rate while observing the dial indicating gauge. Whenever

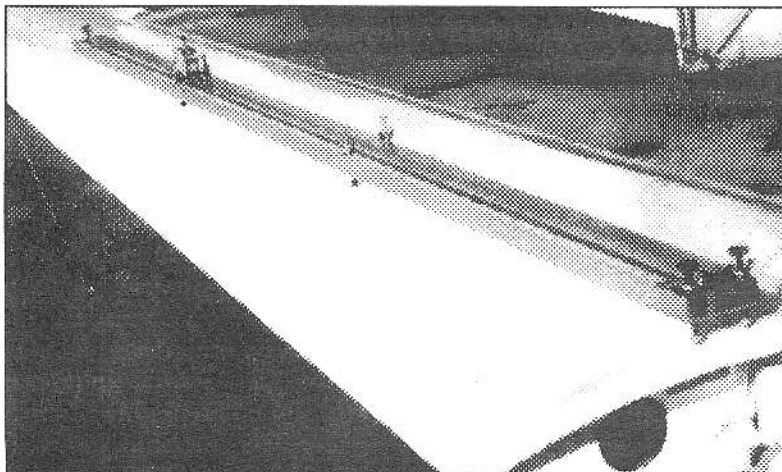


FIGURE 3. Long tool.

the slowly moving indicator pointer shows an increase, as by a bump, more than, say, 0.002 inch (0.005mm), in 1 inch. (25mm), a soft lead pencil mark, "O," is made. A similar decrease of 0.002 inch in 1 inch travel indicates a depression; here, with a lead pencil, "X," marks that spot. This should be followed (on wings with airfoils designed for extended laminar flow) to at least 60% of the chord.

To avoid wind-generated movement of the wing, measuring should be done in an enclosed space. The wing tips must be raised and held at a position that approximates wing deflection in the 45° bank condition. Wing twist should also be estimated and applied. The curvature of the wing, with or without water ballast, will not be identical to that which it assumes in flight, but lifting the tips will induce compression and possibly incipient buckling close to those in the critical flight condition. In a weak thermal in a "save", one wants the laminar flow to be retained then as much as possible at

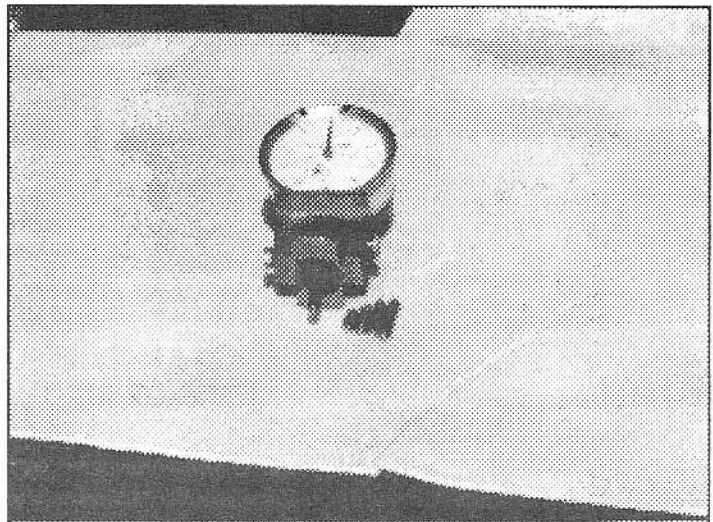


FIGURE 4. Dial indicator and probe extensions.

relatively low air speed. While the wings are still deflected each "X" and "O" should have several very closely spaced lines at, say, 0.25 inch (6mm) drawn, (soft pencil) for a few inches, parallel to and on both sides of those of the long, constant percent chords (spanwise).

For convenience one next uses the short tool. Mark the location of the probe for every 0.001 inch (0.026mm) up and/or down to create a contour map of each local surface feature that was marked "O" or "X." This should reveal the extent, size and the character of the surface deformity and aid in evaluating its probable cause as well as give an appreciation of the repair for the defect.

In normal flight the lower surface is under considerable tension. Buckling, if it exists, may run spanwise. If possible, one might join the

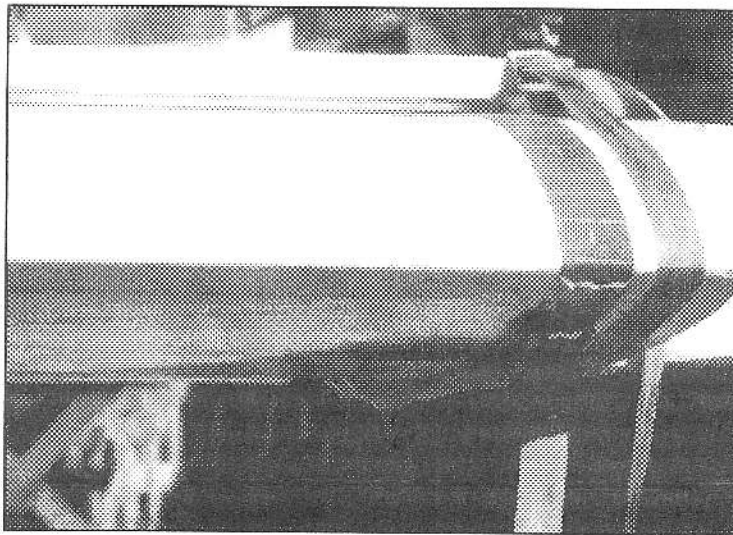


FIGURE 5. Marking constant percent chord, root.

left and right wings without the fuselage in place, then turn the joined wings over (with plenty of skilled help!) so that the parts of the spar that are normally inside the fuselage can be secured to a suitable support spaced at some convenient height, thus exposing the underside of the wing. One can now carefully weight and twist the extreme tips to approximate the desired "45° of bank." The lower surface can then be examined as has been described above. Experience may show that it is not required to so deflect the wings; then the lower surface of each can be examined when laid flat on a table.

Any unusual deformations should be examined by a licensed mechanic in the event that they were caused by damaged or weak structure.

DESIGN OF THE LONG TOOL

To be able to explore relatively small radius concavities such as a long, female mold, the long tool, Figure 3,

was kept quite narrow while achieving stiffness in bending and torsion. There are three adjustable pads (feet), one at one end and two at the other, on which the unit stands. Two pairs of auxiliary adjustable legs minimize deflection of the tubes by contacting the wing surface.

The 8 foot (2.4 meters, approximately) length of this unit was determined by the available stock in a local hardware store. These extruded shapes, 1.00 by 1.00 inch cross-section tubes (and angles, Figure 1), were found to be remarkably, but not perfectly, straight and accurate, quite light in weight and not unduly delicate or unwieldy to handle. The one inch (25mm) travel dial indicator has graduations of 0.001 inch (0.026mm). It is mounted in a block of flat, hard wood which slides on the 2 tube datum. This sliding element, carrying the dial indicator, Figure 4 is made about 0.040 inch (1 mm) narrower than the gap in which it moves and is

held in contact with the two square tubes by a spring loaded clip, so that it cannot twist or rock significantly as it traverses its datum plane. A thumbscrew locks the shank of the dial gauge to the sliding block. The slider is moved (pulled) by the string provided. This allows control from the leading edge of the wing when the tool is at the 60% or more chord location.

Extensions of the stem of the dial gauge, Figure 4, may be needed for wings that are more flexible.

To locate on a constant percent chord line of a wing, the ends of this tool are located by two adjustable straps that girdle the wing at each end of the tool, see Figure 5.

CALIBRATION

The long tool was calibrated on a 30 X 60 inch microflat table. The datum plane of the two square tubes was found to be adequate to detect variations as small as 0.001 inch per 2 inches, which was the objective.

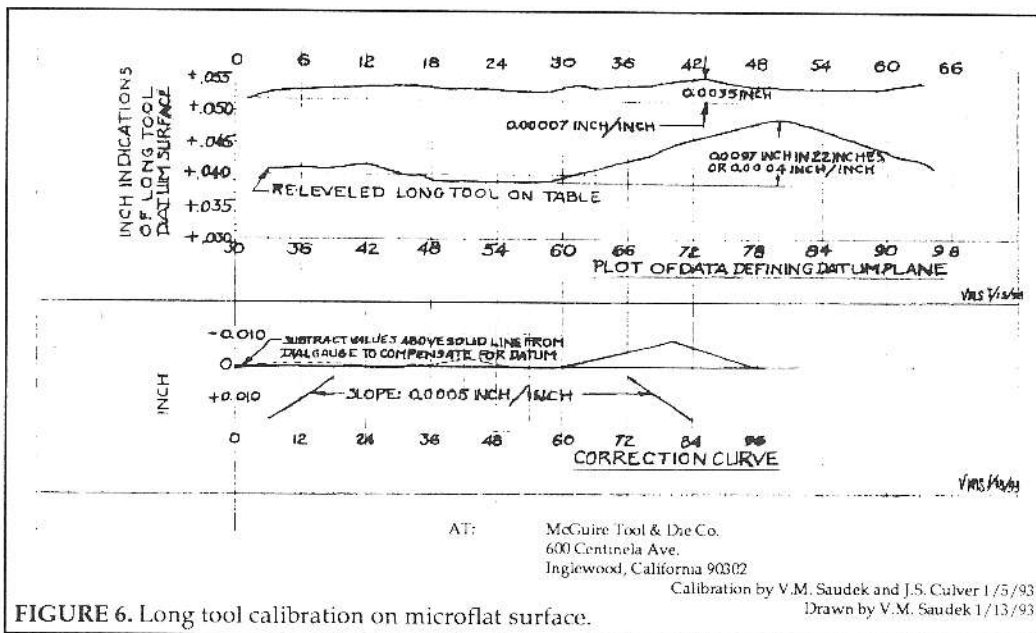


FIGURE 6. Long tool calibration on microflat surface.

Figure 6 indicates the result. The "hump" of 0.0097 inch which lies between the stations 58 and 95 shows a peak at station 80. Further examination showed that this was due to a deformation of 0.02 inch in one of the two square tube datum surfaces. As the slider moves across this "sag" in that datum, the dial indicator probe is pushed upwardly, increasing the readings as shown for the distance 58 to 80 and decreasing them from 80 to 95 as the tube curves upwardly again.

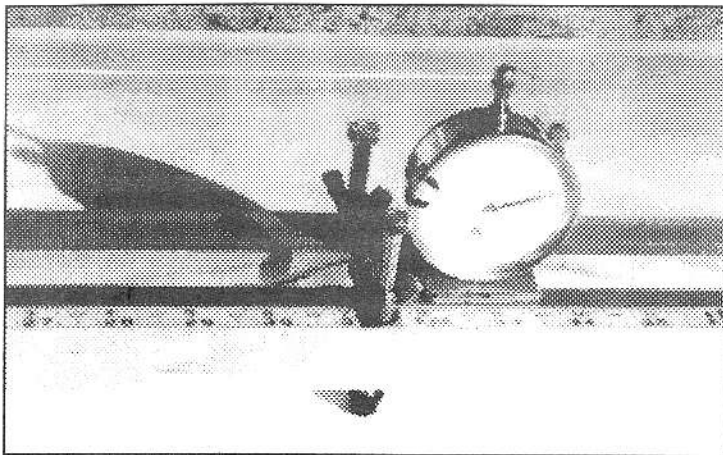


FIGURE 7. Adjusting auxiliary supports.

An attempt to correct the "sag" deformation was not done. However, when time permits the deformed tube will be rotated at $\pm 90^\circ$ and the tool will be recalibrated. Meanwhile, the influence of the "hump" in the calibration curve has been considered in a preliminary survey of a sailplane wing to explore that aspect of tool use.

Further examination of the tool found a twist of 1.8° between stations 65 inch and 96 inch. This results in a sideways rotation of the probe causing a total error between these stations of just under 0.001 inch or 0.00003 inches per inch, which is well beyond the limit of accuracy of individual readings.

The data used to draw the Figure 6 calibration were the average of three individual readings. In 7 of 130 cases "wild" readings of over 0.0003 inch from the mean of the other two were re-examined before any change of the set-up was made. In all such cases a fourth reading was closer to two of the first three and the "wild" reading was discarded. In the future a magnifying glass will be used to improve the estimate of the fourth digit after the decimal.

PROCEDURE

The following is one method for designating constant percent chords, root-to-tip: With $3/4$ inch to 1 inch wide expandable (i.e., elastic) tape with the following lengths: 45, 35, 25, 20 and 15 inches, which allows for 40, 30, 20, 15 and 10 inches of elastic leaving 2-1/2 inches for attaching an adjustable belt strap to each end; mark the 40 inch elastic piece, unstretched, to make 40 spaces at 1 inch intervals, similarly, 40 spaces at $3/4$ inch on the 30 inch piece, and so on, and finally 40 at $1/4$ inch on the 10 inch piece.

Immediately outboard of the wing root fillet wrap the elastic band with 1.00 inch spacing (Figure 5) around the wing with the line marked "1" at the very leading edge and normal to the center line of the main spar. The elastic tape with $3/4$ inch spacing lines is similarly applied about 100 inches outboard (8.3 feet) from strip No. 1. This is strip No. 2. The number at the strap at the trailing edge must be made to be, by stretching it, the same as at the root, strap No. 1, within $1/8$ inch (3mm). If the wing

has multiple planform taper, an elastic, appropriately spaced and numbered tape is applied, chordwise, at each taper change location. The wing should thus be subject to examination by the 8 foot long tool, on constant percent chord stations so indicated, root to tip. In some areas the 8 foot tools spanwise spacings due to a change in planview taper may overlap, but the actual survey need not overlap.

One next aligns the long tool along the first constant percent chord line which will accept the adjustable feet at the ends, two at one end, one at the other. Girdle the wing with the adjustable belt. Secure these feet to the wing by tightening the belt around the wing chord (Figure 5) to fasten the tool to the wing firmly. Install and lock the dial gauge (in the slider) to the parallel square tubes by its rotating lower clip. Move the slider to one end and read it, then to the other end and read it. Using the single and double adjustable end feet, bring these two readings to the same value well within 0.001 inch with the three end wing nuts locked. Verify and readjust as required. With the dial gauge at the intermediate, auxiliary legs, adjust these legs (Figure 7) to contact the wing and so stabilize the square tubes that the dial shows no change when the tubes are (gently) pressed; lock with wing nuts.

Along each constant percent chord line in turn, move the dial gauge at a steady rate using the pull string, from the root outboard and read. The needle will move slowly as the gap between the square tubes datum and the wing changes, but slowly and, hopefully, steadily. What one looks for is a repeatable, unusual rate of change of indication, increase or decrease over a limited spanwise, say one inch, distance. Mark (with lead pencil) such areas with "X" for depression, "O" for bump, and continue the survey. Near the tip one may use every corresponding second or third constant chord line, i.e., every three eighths, half, or three-quarters inch.

The areas of the wing surface which are suspected of being potentially destabilizing for laminar flow are designated by the X's and O's. It is now possible with the short tool to measure with some exactitude the size of the suspect defects.

One can now fill wing surface depressions as with polyester gel-coat or micro-balloons and epoxy, then sand the areas which protrude, in accord with good practice to protect the wing skin structure integrity as defined by the manufacturer.

CONCLUSIONS

With the use of the relatively easy to make, yet adequate instruments here described, it is possible to find discrepancies of the contour of templates, plugs, female molds and the surfaces of the wings made from them. It should take fewer hours to define those errors of surface curvature which could cause transition to turbulent flow than any other method known to the author. The critical measurements should be made with the wings

deflected, ballasted and not ballasted, approximating flight loads.

These devices do not measure the coordinates of the airfoil, instead, they do locate faults and define them so they may be eradicated by repair or redesign.

It would be improper to examine the top side of wings that are not deflected to simulate at least the "one g" flight condition. Until the "inverted and deflected condition" is found to be impractical or unnecessary, the bottom-side-up wing with weighted tips ideally should be set up to the same "45° bank/twisted deflection."

The exploration of a deflected ("45° bank" right-sideup), twisted and ballasted wing will probably differ significantly from an examination of that wing's plugs, molds and non-flight deflected (e.g., drooping wings).

With the method and tools described in this paper and the improvements that might be developed with practice in the years to come, it should be possible to create wing surfaces to further extend laminar flow, to learn

more about what causes it to break down and, by this survey practice, possibly, to enhance performance by establishing the skin stiffness requirements to avoid surface buckling due to at least 45° of bank.

ACKNOWLEDGEMENTS

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REFERENCES

1. Saudek, V.M., "Airfoil Smooth Curve Measuring", *Soaring*, December 1987.