Measurement of Glider Aerodynamics

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Introduction

The glider performance measurements of to-day do not have sufficient accuracy. The results are not repeatable and the measured points of the speed polar have considerable scatter.
The accuracy of speed polars measured in the classic way is not greater than 2 units of best glide angle for gliders having values of about 30. The likely error value increases with increase in the measured value.
The present measuring methods do not give the important information on incidence and flying path angle of the glider. The measurement of these parameters will enable the glider characteristics C_L and C_D versus incidence to be defined. These data permit the glider performance to be determined within close limits.
The method described here depends on the measurement of incidence and flight path angle of the glider.

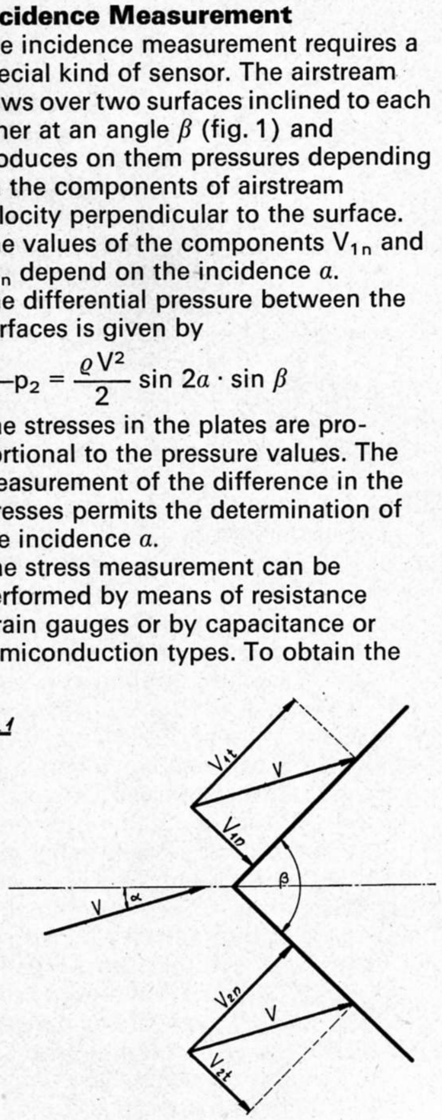
Incidence Measurement

The incidence measurement requires a special kind of sensor. The airstream flows over two surfaces inclined to each other at an angle β (fig. 1) and produces on them pressures depending on the components of airstream velocity perpendicular to the surface.
The values of the components V_{1n} and V_{2n} depend on the incidence a.
The differential pressure between the surfaces is given by

$$p_1 - p_2 = \frac{\varrho V^2}{2} \sin 2a \cdot \sin \beta$$

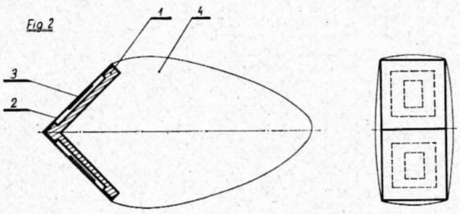
The stresses in the plates are proportional to the pressure values. The measurement of the difference in the stresses permits the determination of the incidence a.
The stress measurement can be performed by means of resistance strain gauges or by capacitance or semiconduction types. To obtain the smallest error it is recommended that resistance types are used. The strain gauges should be glued on the internal surfaces of the plates and connected in a semibridge arrangement. This connection allows for the measurement of stress differences and at the same time ensures temperature compensation.

Fig. 1



The sensor (fig. 2) consists of the body (1) on which are glued membranes of an elastic material (2) and strain gauges (3). The special housing (4) fairs the whole unit to an aerodynamic shape.

Fig. 2

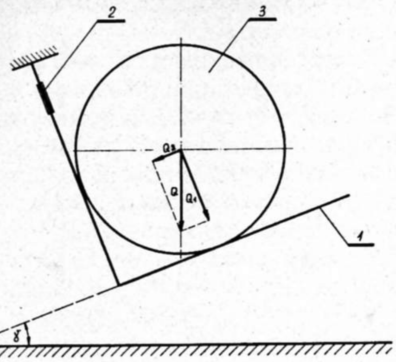


Since it is difficult to calculate the pressure upon the membranes the calibration of the sensor should be performed in a wind-tunnel. The calibration depends on defining the constant "A" (see below) and plotting the characteristics over the required range of incidence a. In the case of non-linearity of the characteristic it is necessary to define it in the form of $A = f(a)$.
The accuracy of measurement will depend mainly on the range of measured incidence (it is assumed that the bridge works only on one range). Taking into account the fact that the measurement is restricted to a maximum incidence value of 15° the reading error Δa is 4. This error will be enlarged by the instrumental-error of 1% of measured value, but this can be neglected. Other errors resulting from the calibration errors of the wind-tunnel can also be neglected. In this way it can be assumed that in the measuring range of 15° of incidence the error is about 4′.

Flight Path Measurement

For the measurement of flight path angle another kind of instrument is required (fig. 3).
The force applied by means of metal sphere (3) acts on a plate (2). The value of the force depends on the slope of the support (1) with respect to the ground level (angle γ). The sphere weight component Q_2 acts on the plate (2) resulting in stresses depending on the value of γ. Measurement of these stresses enables the flight path angle to be determined.

Fig. 3



The stresses are measured by means of strain gauges glued on both sides of the plate and connected in a semi-bridge arrangement.
The calibration of the instrument should be performed in a laboratory where the stresses σ are determined as a function of the angle γ. The measurement accuracy is the same as for the incidence sensor.

Results of Measurements

When the longitudinal axis of the measuring head is parallel to the longitudinal datum of the glider the following formula applies:

$$\sin 2a' = \frac{M_1}{q\,A_1}, \text{ where}$$

q = dynamic pressure
A_1 = constant obtained in wind-tunnel calibration
M_1 = reading on the bridge.

The incidence (see fig. 4) is

$a = a' + \delta$, where
δ = the angle between the longitudinal datum and the mean standard chord.

The flying path angle is

$\gamma = \gamma' - a'$, where
$\gamma' = A_2 \cdot M_2$
A_2 = constant obtained in calibration
M_2 = reading on the bridge.

The characteristic of $C_L = f(a)$ is defined as

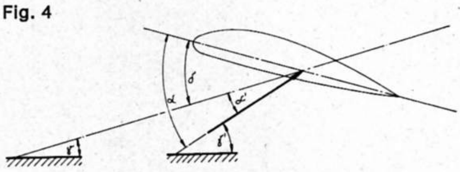
$$C_L = \frac{Q}{\frac{\varrho}{2} S} \cdot \frac{\cos \gamma}{V^2}$$

and similarly

$$C_D = \frac{Q}{\frac{\varrho}{2} S} \cdot \frac{\sin \gamma}{V^2}, \text{ where}$$

ϱ = air density.

Fig. 4



The airspeed polar is defined as follows:

$$\frac{V}{w} = \cot \gamma, \text{ where}$$

W = sinking speed of glider.