INVESTIGATION OF THE SPEED REDUCTION METHOD FOR THE PERFORMANCE EVALUATION OF GLIDERS

by Andreas Albat, Akademische Fliegergruppe Braunschweig, Germany
and Dietmar Schmerwitz, Braunschweig, Germany

Presented at the XXIII OSTIV Congress, Borlänge Sweden (1993)

1. Nomenclature

CD	[-]	Drag coefficient
CL	[-]	Lift coefficient
D	[N]	Drag
g	[m / s^2]	Acceleration due to gravity
H_p	[m]	Pressure altitude
L	[N]	Lift
m	[kg]	Total mass of the glider in flight
5	[m^2]	Wing area
V	[km / h]	Airspeed
w_s	[m / s]	Aircraft rate of climb, + upward
g	[-]	Flight path slope
r	[kg/m^3]	Air density
instat		instationary
stat		stationary

2. Introduction

Currently the performance measurement of gliders is carried out using stationary methods. The Partial Glide Method and the Glider Comparison Method are the well-known methods.

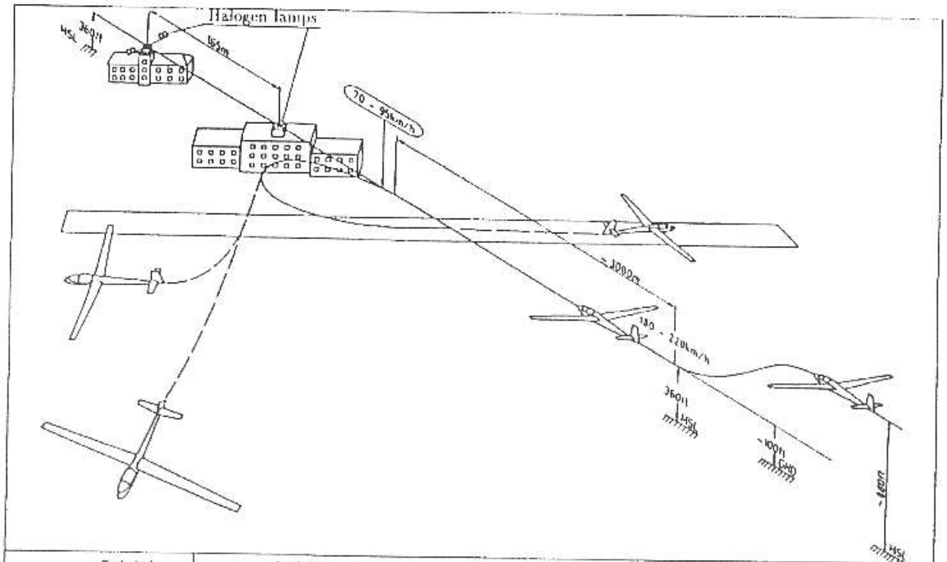
The advantage of an instationary method is the measurement of a polar within a short period of time. In 1984/85 first investigations of the Speed Reduction Method were conducted in Braunschweig with the Cirrus D-0471. In order to reduce the required equipment and to simplify the evaluation of the data a horizontal flight path close to ground was chosen. This particular flight path was indicated using three halogen lamps (Figure 1), which should stay at the same level from the pilots view. An exemplary determined polar, which is shown in Figure 2, was not satisfactory in comparison with the traditional methods. Disturbing turbulences lead to the unsatisfactory results. Furthermore the danger of flights at low altitude has to be considered. In 1992, new flight experiments using speed reduction and acceleration procedures were carried out with the research glider DG 300/17m of the DLR Braunschweig in altitudes varying from 3000 m to 200 m. As data gathering system the custom-madeVP3-1MA was used. The design criterions for the data recording system were lead by weight, compatibility to other gliders and a reduced number of sensors. Very important are the additional display functions, which offer the possibility to fly on a horizontal flight path.

3. Performance Measurement of Gliders

The Partial Glide Method is normally used for the determination of an absolute polar for a reference glider. The main problem concerning this method is the influence of the air movement even in a stable high pressure atmosphere. If the flights are carried out on several days with different stable weather conditions, the absolute error can be estimated to 8%. Because of the approximately 12 aero-tows to 4000 m and the required labour for the data evaluation this method is very expensive.

The Glider Comparison Method is used for the relative performance evaluation of other gliders with respect to the absolute polar of the reference glider. The influence of the weather is negligible due to the assumption that both gliders are affected by the same air movement, and the relative error is approximately 2.5%. The absolute error can be calculated by adding the polar error of the reference glider.

In contrast to these two methods the Speed Reduction



Indication of a horizontal flight path close to ground for the *Speed Reduction Method* (Ortgies 1985)

FIGURE 1

Method is an instationary method, which leads to an 'absolute' polar as well. A horizontal flight path is chosen to slow speed reduction in order to avoid instationary effects. It takes approximately 2 minutes to fly through the complete range of the lift coefficient. Important for the possibility to fly this particular path is the display of the difference of the present altitude to a reference altitude and the derivative of the altitude with respect to time. Essential is a stable atmosphere and a very good calibration of the data gathering system.

4. Theoretical Basis of the Speed Reduction Method

The evaluation of the speed polar is based on the equations for lift, drag and the derivative of the altitude with respect to time. To simplify the required equations only a slow speed reduction is allowed.

$$D = -m\dot{V} - m\,g\sin\gamma \qquad (4.1)$$

$$L = m\,V\dot{\gamma} + m\,g\cos\gamma \qquad (4.2)$$

$$\dot{H}_p = V\sin\gamma \qquad (4.3)$$

The flight path slope can be determined using equation (4.3). $\dot{V}$ and $\dot{g}$ are calculated by numerical differentiation. From these equations the lift and drag coefficients can be calculated:

$$C_L = \frac{2\,m\,g}{\rho V^2 S}\left(\frac{V\dot{\gamma}}{g} + \cos\gamma\right) \qquad (4.4)$$

$$C_D = -\frac{2\,m\,g}{\rho V^2 S}\left(\frac{\dot{V}}{g} + \sin\gamma\right) \qquad (4.5)$$

The basic idea of the Speed Reduction Method is the assumption that the lift and drag coefficients calculated from the instationary measured data are equivalent to those corresponding to the stationary airspeeds and rates of sink. Thus the equations for the stationary airspeed and rate of sink are expressed in terms of the lift and drag coefficient.

$$V_{stat} = \sqrt{\frac{2\,m\,g\cos\gamma_{stat}}{S\rho C_{L,stat}}} = \sqrt{\frac{2\,m\,g}{S\rho C_{L,instat}}}\frac{1}{(1+(\frac{C_{D,instat}}{C_{L,instat}})^2)^{\frac{1}{4}}} \qquad (4.6)$$

$$w_{s,stat} = V_{stat}\sin\gamma_{stat} = \sqrt{\frac{2\,m\,g}{S\rho}}\frac{C_{D,instat}}{C_{L,instat}^{\frac{3}{2}}}\frac{1}{(1+(\frac{C_{D,instat}}{C_{L,instat}})^2)^{\frac{3}{4}}} \qquad (4.7)$$

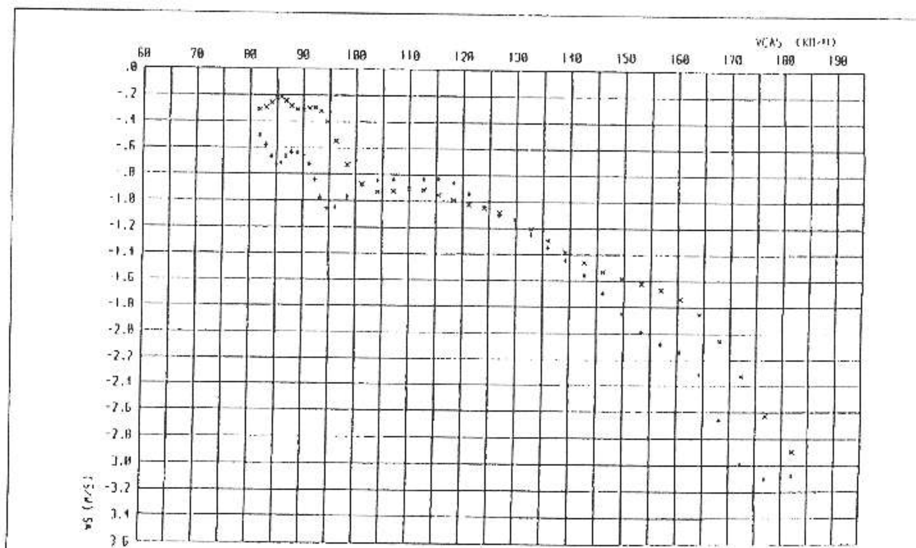
The necessary differentiations and a large standard deviation of the rate of sink (Figure 3) were improved using an interpolation function on the measured data (V, H_p, T).

A verification of the improved evaluation programs was done using the data from the Partial Glide Method. The difference in the rate of sink was less than 0.5%.

Important for any evaluation of the data is a very good calibration. First a temperature dependent calibration of the different sensors including the data recording system was done. A reasonable effort was made for the dynamic pressure calibration and for a calibration of the static pressure depending on the velocity.

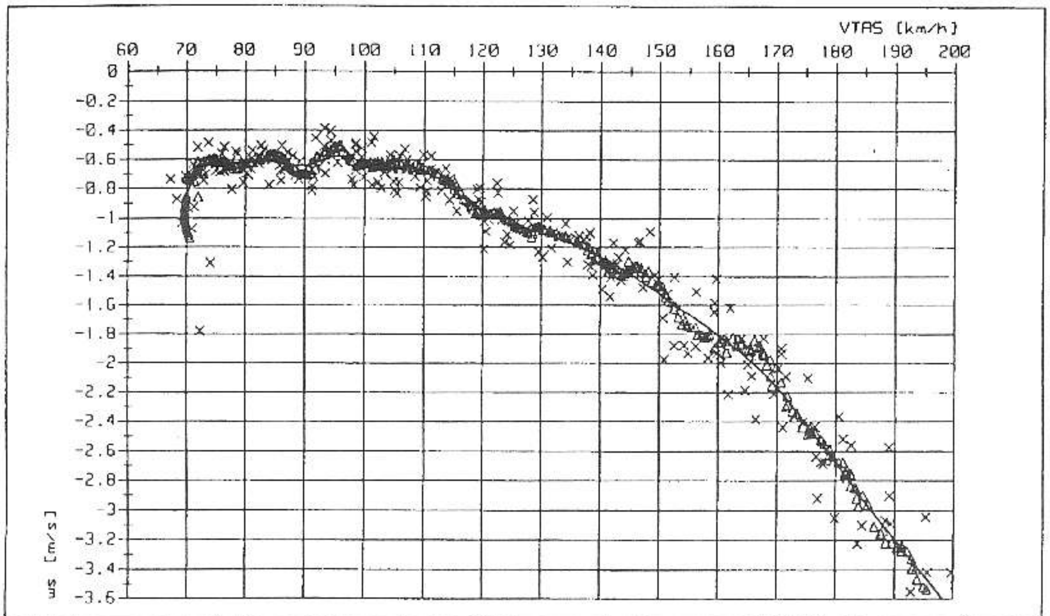
5. Flight Experiments and Evaluation of the Measured Data

Several flight procedures were tested in order to find an instationary manoeuvre which is easy to fly and can



Speed polar using the *Speed Reduction Method* (Ortgies 1985)
+ including H compensation

FIGURE 2



Technische Universität Braunschweig Institut für Flugführung DLR

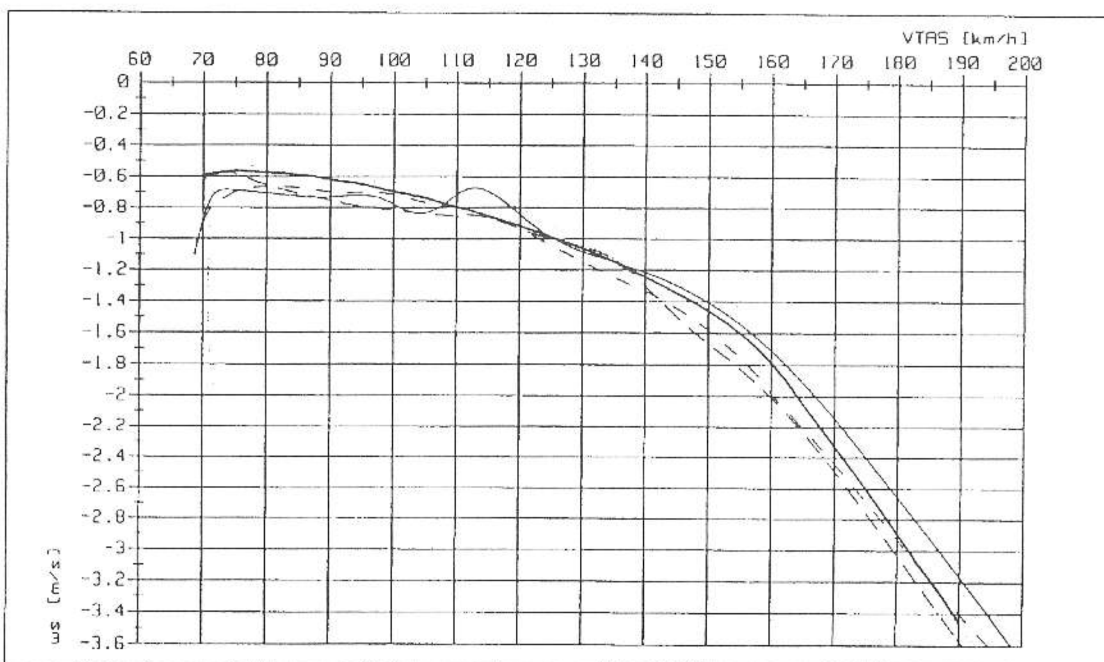
FIGURE 3

Application of the *Speed Reduction Method*
x ws - unsmoothed data (Flight No. 11, 22.11.91)
△ ws - smoothed data (Flight No. 11, 22.11.91)
— ws - smoothed polar (Flight No. 11, 22.11.91)

be reproduced. The Speed Reduction Method uses a horizontal flight path, which is indicated by the VP3-IMA. The speed at the beginning of the experiment is approximately 250 km/h. The advantage to prior tests close to ground is the speed reduction till stall speed. The investigation by Ortgies [3] showed that the stick movement should be restlicted to one way. If the horizontal flight path is left upwards, the pilot should not move tlle sticl; ulltil he enters the desired horizontal path again.

To be able to perform the required task (horizontal flight path) the pilot needs information about the difference between the altitude at the beginning of the experiment and the current altitude and the derivative of the altitude with respect to time. These are displayed on Peschges VP3 digital vario/ speed to fly displays. The difference between the altitude at the beginning of the experiment and the current altitude during the maneuver can be displayed within a range of 10 m. This range can be easily left due to small movements of the stick by the pilot when starting the data recording. It still requires some practice to stay within this range. If the display limit of 10 m is exceeded, the derivative of the altitude can be used to maintain a parallel horizontal flight path. Compared to other instationary procedures this manoeuvre proved to be most efficient due to the long time interval of approximately 200 seconds for each experiment in order to avoid instationary effects. Training improved entering the horizontal path and to keep the altitude more precisely.

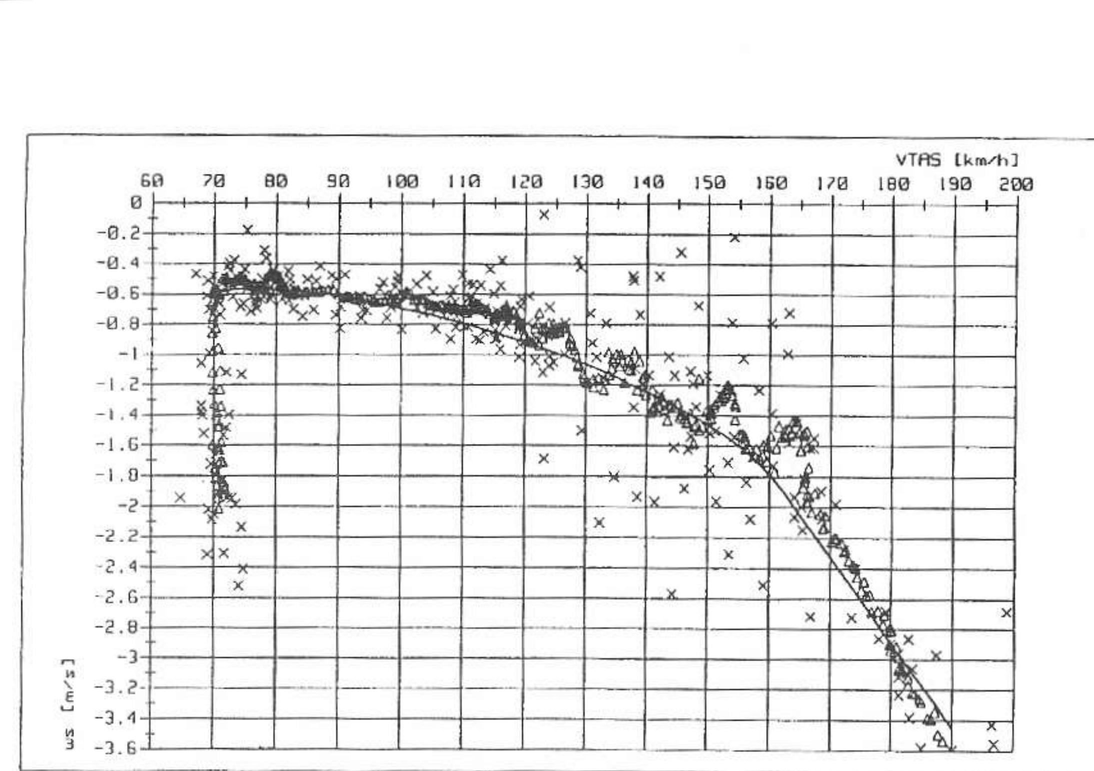
Figure 4 shows an example of the evaluated polars using the Speed Reduction Method in comparison to the Partial Glide Polar. The difference from the polar determined using the Partial Glide Method can be explained by the characteristic of the atmosphere. A different



Technische Universität Braunschweig Institut für Flugführung DLR

FIGURE 4

Comparison of speed polars determinated using the *Speed Reduction Method* and *Partial Glide Method*
— ws - smoothed polar (Flight No. 12, 22.11.91)
ws - smoothed polar (Flight No. 5, 28.02.92)
— ws - *Partial Glide Polar*
- - ws - smoothed polar (Flight No. 6, 24.02.92)
-·- ws - smoothed polar (Flight No. 7, 24.02.92)



Technische Universität Braunschweig Institut für Flugführung

DLR

FIGURE 5 Performance evaluation of the stall using the *Speed Reduction Method*
x ws - unsmoothed data (Flight No. 5, 28.02.92)
Δ ws - smoothed data (Flight No. 5, 28.02.92)
— ws - *Partial Glide Polar*

global rate of sink is the main reason for this difference. Therefore it is obvious that the measurements for a polar using the Speed Reduction Method should be done on different days. After eight experiments slight changes should still be expected, and the error of the Speed Reduction Method is approximately 8%, which is similar to the error of the Partial Glide Method.

The general field of application is similar to the Partial Glide Method. Because of the required work and expenses to measure small differences, e.g. through the use of winglets or turbulators, the Speed Reduction Method is not appropriate for this purpose. Instead the Glider Comparison Method should be used due to the small error for relative performance measurements. But the Speed Reduction Method offers new applications. Figure 5 shows the performance evaluation of the stall, also the influence of a turbulent atmosphere. The standard deviation increased during the experiment in the speed range from 110 to 170 km/h.

Additionally this method offers the possibility to evaluate a speed polar for flights in rain. Approximately 10 experiments should give a reasonable 'rain polar'. To achieve reproducible results a 'defined rain' is necessary. The main problem will be to have similar rain conditions for all flights in a stable atmosphere.

6. Conclusion

An account of the capabilities of the DLR's data gathering system VP3-IMA pilots were able to perform with the research glider DG 300/17m an almost horizontal flight path. Instationary experiments utilizing the Speed Reduction Method were conducted in altitudes between 3000m and 200 m. Based on the experiences of old flight tests the stick movements are restricted to one way.

The experiments showed the advantage of the Speed Reduction Method compared to other instationary methods due to quasi-stationary conditions and flyability. The evaluation of only eight flights lead to a polar which differs less than 5% from the polar gained by the Partial Glide Method. The Method also offers the possibility to measure the performance within the stall and in rain.

The problem concerning this method is the use of differentiations and the related error. Additional work for an interpolation function based on a Least-Squares Polynomial was done to minimize the error. The error including the weather influence can be estimated to 8%. For the investigation of small performance differences, e.g. winglets, many flights are necessary to reduce the weather influence. The Glider Comparison Method is more suitable for this purpose due to the small influence of this error.

7. References

[l]. Albat, A.,1992, Untersuchung der AusschieBmethode mit veranderlichem Bahnwinkel fur die Flugleistungsvermessung von Segelflugzeugen Studienarbeit am Institut fur Flugfuhrung, TU Braunschweig

[2]. Berns, H.J., 1987, Unter-suchungen und MaBnahmen zur Stabilisierung des Leistung-sverhaltens des Kalibrierseg-ẹlflugzeuges DG 300/17 Studien-arbeit am Institut fur Flugme-chanik, TU Braunschweig.

[3]. Ortgies, C., 1985, Entwicklung eines Datenverarbeitungspro-grammes fur die Leistungsver-messung von Segelflugzeugen nach der AusschieBmethode. Studienarbeit am Institut fur Flugfuhrung, TU Braunschweig

[4]. Quellmann, W., 1984, Unt-ersuchungen zur Ausschie-Bmethode fur die Leistungsver-messurlg von Segelflugzeugen. Studienarbeit am Institut fur Flugfuhrung, TU Braunschweig