Performance Testing the Scheibe SF 25B Falke

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1. Introduction

The object of this investigation was to measure the performance of the Falke with several different propeller and engine configurations, and hence to deduce the drag coefficients of the propeller and the engine cooling system. It is convenient do use a motor glider for this type of test since it can be launched by aerotow for measurements with the propeller removed.
The method used was the conventional one for glider performance testing; making a series of short straight glides at constant speed, recording height and speed as functions of time. An automatic recording system was used with computer analysis. The aircraft was in good condition and clean, but was not specially polished.
A G. A. drawing of the Falke is shown in fig. 1, and leading particulars are given in table 1.

2. The Performance Tests

The equipment and methods are more fully described elsewhere [1, 2]. The aircraft is climbed (or towed) to a convenient height, and made to descend in a series of short straight 'partial glides' at constant speed. The recording equipment records height and speed every 1.6 seconds, and speech from the observer to label the ends of the runs. The recording is played back into a digital computer which calculates for each run the equivalent rate of sink and the mean value of the equivalent air speed.
The recording system has a resolution of about 2 ft. (0.6 m) in height and 0.2 knots (0.1 m/s) in air speed. So runs of 45 seconds duration are long enough, giving typical random errors of 0.1 knots (0.05 m/s) in rate of sink and 0.2 knots (0.1 m/s) in air speed. The scatter in rate of sink due to vertical air movements [3] is much greater, typically 0.4 knots (0.2 m/s) in the current series of measurements, so many runs are needed to establish the polar with reasonable accuracy. Of course, measurements are only made when the air is stable, but standing waves are so common that they cannot be avoided.
The position error was measured using a trailing static head and an auxiliary pitot head mounted below the starboard wing on the leg of the outrigger wheel. The airspeed transducer was calibrated daily against a water manometer, and the height transducer was calibrated occasionally against a mercury barometer. The outside air temperature was measured at intervals during the climb on each day. The aircraft were weighed, and due allowance was made for the weight of pilots, equipment and fuel on each flight. When the propeller was removed it was replaced by a similar weight of ballast.

General arrangement drawing of the SF 25B Falke.

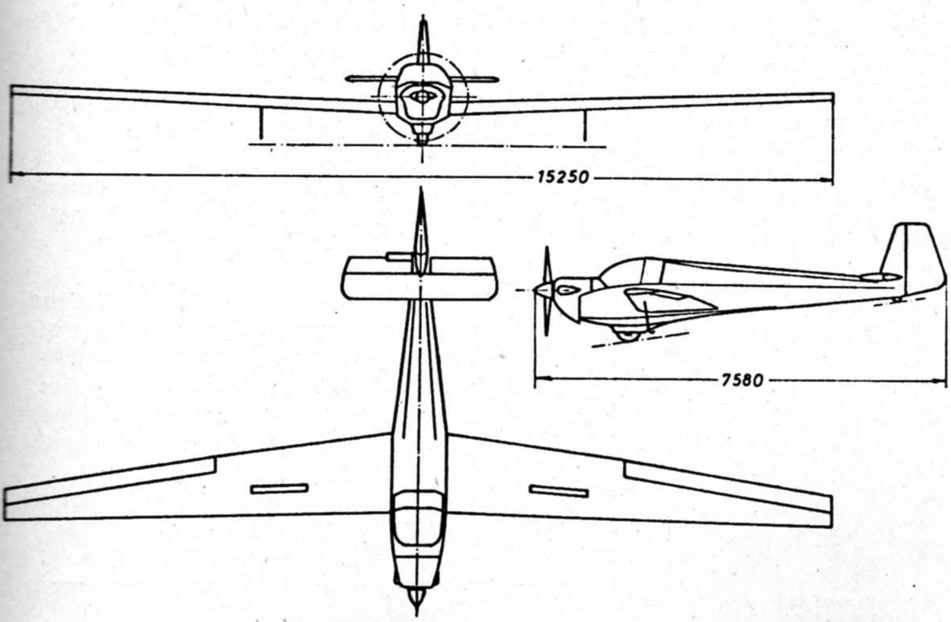


Table 1. Leading Particulars of the SF25B Falke

Wing Span	50.2 ft	15.3 m
Wing area	188 ft²	17.5 m²
Max. A. U. W.	1190 lbs	540 kg
Propeller diameter	5 ft	1.52 m

The computer was programmed to insert all the calibrations and corrections and to reduce each run to mean sea level conditions, at the aircraft's maximum all up weight of 1190 lbs (540 kg). These points, the raw data of the final analysis, are plotted in fig. 2, for one of the configurations tested. The analysis technique [2] is to fit a polar of the theoretical form [4]

$$S_o = AV^3 + B/V$$

to the measured points by a 'least squares' method. The output (fig. 3) is the polar reduced to mean sea level and corrected to an AUW of 1190 lbs. The dotted lines are error limits at ± two standard deviations. There is a 5% chance of the true polar lying outside these limits. All the other results are calculated from this fitted curve, including the coefficients k and C_{DO} of the drag equation.

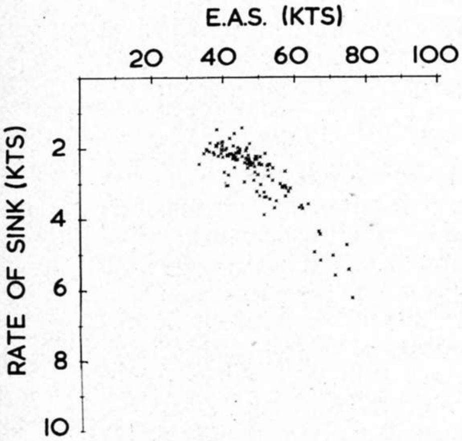
$$C_D = C_{DO} + k\, C_L^2/\pi A$$

Usually this fitted polar has to be corrected manually at low speeds, as the rate of sink increases near the stall. With the Falke this was not so; the rate of sink decreased with airspeed until the aircraft stalled and could not be flown steadily.

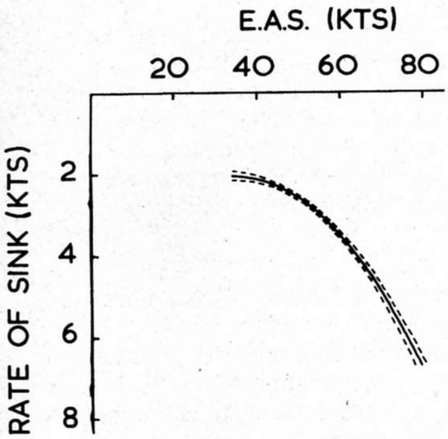
3. Results

The following sets of tests were made:
(a) Engine idling
(b) Propeller stopped, horizontal
(c) Propeller stopped, vertical
(d) Propeller removed and holes in spinner faired
(e) Propeller removed and cooling air intakes sealed
(f) Propeller windmilling, with engine switched off (50 knots IAS only – propeller rotates at 600 rpm).
Of these sets, (f) propeller windmilling, was not a complete polar, because the propeller stops windmilling below about 50 knots, and its drag is likely to vary markedly with propeller rpm. Sets (d) and (e), propeller removed, with and without sealing the cooling inlets, were not significantly different, so they have been combined. The fitted polars for two configurations are shown in figs. 3 and 4 with error limits at ± two standard deviations. All the fitted polars are drawn together, for comparison, in fig. 5. It can be seen that, as one would expect, the low

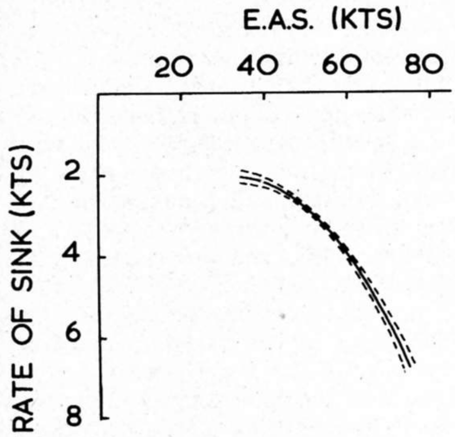
speed performance is independent of the state of the engine and propeller, but there are significant differences at higher speeds.
To show the magnitude of the errors, fig. 6 shows the rate of sink at 50 knots with its standard deviation, in each configuration. The errors are fairly large, but the differences are clearly significant.
Numerical values of the performance parameters are given in table 2 for each configuration. The table also gives weighted means of minimum sinking speed and k for configurations (b), (c), (d) and (e). Since these parameters depend little on profile drag, the means should be more accurate than the individual measurements.



2. All measured points, configurations (d) and (e) (propeller removed).



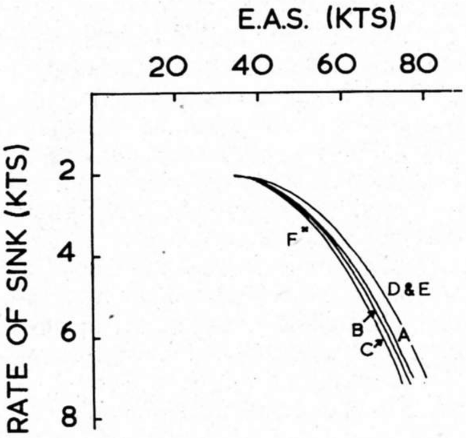
3. Fitted polar with limits at ±2 standard deviations, configurations (d) and (e) (propeller removed); a. u. w. = 1190 lb.



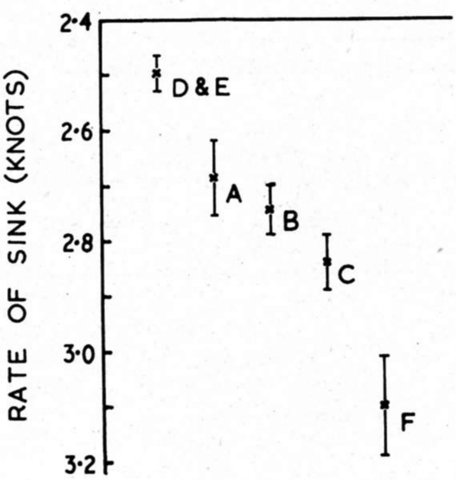
4. Fitted polar with limits at ±2 standard deviations, configuration (b) (propeller horizontal); a. u. w. = 1190 lb.

4. The Drag of the Propeller

The drag of the propeller expressed as a drag coefficient $C_{D\ prop.}$ referred to the wing area, can be calculated by subtracting the drag coefficient of the clean aircraft from that of the aircraft in the appropriate configuration. This can be done with C_{DO}, which is preferable when the propeller is stationary; or with C_D at a particular airspeed, which must be used when the propeller is rotating. Results of both methods are given in table 3.
The drag of the propeller can be calculated from the formulae given by Hoerner [5]. In applying these, the dimensions shown in fig. 7 have been used, and parts of the propeller blade that lie close in front of parts of the cowling have been ignored.
(a) Engine idling. This was not calculated, due to lack of the necessary engine performance curves.
(b) Propeller stopped, horizontal. The total area of blade projecting beyond the cowling is approximately 1.1 sq. ft.



5. All the fitted polars:
(a) engine idling.
(b) propeller horizontal.
(c) propeller vertical.
(d) and (e) propeller removed.
(f) propeller windmilling.

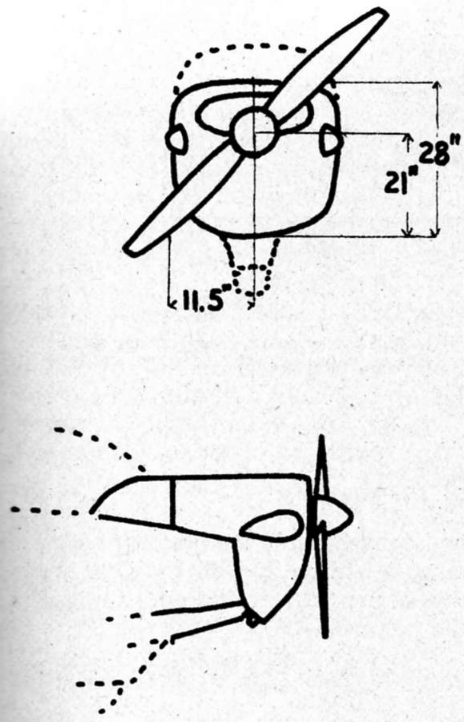


6. The rate of sink at 50 kts. The identifying letters are the same as in figure 5.

Hoerner, p. 13–21, gives C_D for the blade (at the pitch angle of 12°) of 1.05 based on frontal area. Hence, referred to wing area, $C_{D\ prop.}$ = 0.0061.
(c) Propeller stopped, vertical. The projecting area is increased to 1.5 sq. ft. increasing $C_{D\ prop.}$ to 0.0084.
(d) Propeller windmilling at 50 knots. Hoerner, p. 13–22, suggests that the power absorbed by a windmilling propeller is about twice the power output of the engine at the same rpm. The propeller windmilled at 600 rpm, at which speed a Volkswagen engine produces 1.2 HP. Hence on this basis the drag is 15.6 lb, and $C_{D\ prop.}$ is 0.0098.
(e) Cooling drag. This is difficult to estimate. Hoerner, p. 13–27, suggests a component C_D of 0.1 for the internal drag of cowled radial engines. On this basis, taking the frontal area of the Stamo engine as 1.5 sq. ft. we find $C_D = 0.0008$. The external drag of the cowling will certainly exceed that of a well designed glider nose, but it has not been estimated.

5. Conclusions

The performance of the Falke is not particularly good by glider standards, as would be expected from the low aspect ratio (for gliders) and the general lack of aerodynamic refinement. In particular, C_{DO} of the bare aircraft is 0.0227, whereas modern gliders lie between 0.017 and 0.010. In general, performance has been sacrificed for convenience, and the resultant compromise is excellent for glider pilot training. The gliding angle and minimum sinking speed are of course far better than those of typical light aircraft.
The drag of the propeller varies considerably. It is least when the propeller is horizontal, and partly blanketed by the cowling close behind it. So glider pilots should fly the Falke with the propeller horizontal. The drag is higher with the propeller vertical, and higher still when it is windmilling. The measured drag coefficients are all 10–20% below the theoretically predicted values.
However, the drag of the propeller is a significant part of the total drag of the aircraft, more than 10% at high speeds. This is surprising in view of the small size of the propeller and the high profile drag of the aircraft. Cooling drag on the other hand should be about 1/6 of the drag of the propeller; this was near the limit of measurement of the present set of tests and was not, in fact, detected.
The main conclusion therefore, is that a feathering or folding propeller is highly desirable on motor gliders, especially those of high performance. Moveable flaps or gills to seal the



7. The engine cowling. Propeller diameter 60″ (1.5m). Maximum chord 5.75″ (14.5cm).

cooling system are much less important. Alternatively, for the best possible performance, the entire engine and propeller can be retracted into the glider, giving a good aerodynamic shape. But such systems tend to be complex, and make it difficult to restart the engine quickly in flight.

This method of measuring propeller drag is reasonably satisfactory, giving the drag within about ±20%. It would be more accurate if the propeller were larger; the drag of a 10 ft. diameter propeller could be measured readily to ±5%. It would not be necessary for the engine to drive the propeller (or even to have an engine at all) since the aircraft could be launched by aerotow. The best method would probably be to fit a suitable hub, with a dynamometer and brake, to the nose of a pure glider. Then propellers of all reasonable sizes could be tested, both stationary and windmilling. The undercarriage would not have to be extended, as the propeller could be set horizontal before landing.

Table 2. Falke Performance Summary

Configuration	Best gliding angle at	(kt)	Minimum sink (kt) at	(kt)	k	C_{DO}
(a) Engine idling	18.6±0.6	44	2.08±0.12	34	1.18±0.10	0.0261±0.0009
(b) Prop. horizontal	18.3±0.4	43	2.07±0.08	34	1.15±0.07	0.0273±0.0008
(c) Prop. vertical	18.1±0.4	43	2.04±0.09	34	1.09±0.08	0.0295±0.0010
(d) Prop. off					1.20±0.07	0.0224±0.0008
(e) Prop. off and cooling sealed					1.24±0.09	0.0231±0.0010
d and e combined	19.6±0.3	47	2.06±0.06	35	1.22±0.05	0.0227±0.0006
b, c, d and e combined			2.06±0.04	34	1.17±0.03	

Note: 1 Kt = 0.515 m/s = 1.86 km/h

Table 3. Propeller Drag Coefficient

Configuration	From C_{DO}	From C_{DO} at 50 kts.	Calculated value
(a) Engine idling	0.0034±0.0010	0.0028±0.0012	
(b) Prop. horizontal	0.0046±0.0010	0.0040±0.0009	0.0061
(c) Prop. vertical	0.0068±0.0012	0.0053±0.0009	0.0084
(f) Prop. windmilling at 50 kts. (600 rpm)		0.0089±0.0015	0.0098
Internal cooling drag ∠0.0010			0.0008

Résumé

Determination des performances du Scheibe SF25B Falke

Les performances du Falke ont été mesurées par la méthode du palier décéléré pour cinq configurations de l'hélice, y compris l'hélice escamotée; dans cette dernière configuration, il a été procédé à des mesures après obturation des prises d'air de refroidissement.

L'obturation des prises d'air de refroidissement n'ayant pas d'effet significatif, les résultats correspondant aux deux configurations «hélice escamotée» ont été groupés. Les points individuels pour ces cas sont donnés sur la fig. 2 et la courbe moyenne et les courbes à 95% niveau de confiance sur la fig. 3. Les courbes moyennes pour tous les autres cas sont données sur la fig. 5; elles montrent que la meilleure configuration d'hélice est obtenue quand les pales sont horizontales. Les courbes à 95% niveau de confiance pour ce cas sont données sur la fig. 4.

Les mesures de performance sont résumées par le tableau 2 et une comparaison des augmentations de traînée, dues à l'hélice, théoriques et expérimentales sont données dans le tableau 3.

Zusammenfassung

Leistungsvermessung des Scheibe SF25B Falke

Die Leistung des Falke wurde mit Hilfe der «Höhenstufenmethode» für 5 verschiedene Propeller-Bedingungen gemessen, wobei auch der abgenommene Propeller eingeschlossen war, und in diesem Falle auch die Kühlluftöffnungen verschlossen wurden.

Das Schliessen der Kühlluftöffnungen hatte keinen bedeutenden Einfluss, weshalb dann die beiden Ergebnisse mit abgenommenem Propeller zusammengefasst wurden. Die Einzelpunkte für diese Fälle sind in Figur 2 und die mittlere Kurve mit 95% Wahrscheinlichkeit in Figur 3 dargestellt. Die mittleren Kurven für alle Fälle zeigt Figur 5, aus der auch zu ersehen ist, dass die beste Propellerstellung diejenige ist, bei der die Blätter horizontal stehen. Die 95% Wahrscheinlichkeitsgrenzen für diesen Fall sind in Figur 4 angegeben.

Die Leistungsdaten sind in Tabelle 2 zusammengefasst; ein Vergleich der gemessenen und geschätzten Widerstandsveränderungen in bezug auf den Propeller ist aus Tabelle 3 zu ersehen.

References

1. G. R. Whitfield, A simple data recording system with computer analysis, Radio and Electronic Engineer, Vol. 40, pp. 255–258, November 1970.

2. G. R. Whitfield. Automatic recording and analysis for glider performance testing, XII OSTIV Congress, Alpine, Texas, June 1970. Aero Revue, April 1972, pp. 203–206.

3. K. E. Machin. The performance testing of the Slingsby Sky, J. Roy. Aero. Soc., Vol. 58, p. 470 July 1954.

4. A. Welch, L. Welch and F. G. Irving. New soaring pilot, pp. 36–44, John Murray, London 1968.

5. S. F. Hoerner. Fluid dynamic drag, 2nd Edition. Published by the author, Midland Park, New Jersey 1964.