# EFFECT OF THE WING SECTION DRAG POLAR SHAPE ON THE DESIRABLE WING AREA AND ATTAINABLE AVERAGE CROSS COUNTRY SPEED OF STANDARD CLASS GLIDERS

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**Summary**

**The wing areas and corresponding wing loadings giving best average cross country speeds for four different types of wing section drag polar are determined and the cross country speeds are compared. In calculating the drag polars of the gliders the effects of the varying wing area on the drag coefficients of the body and empennage of the gliders are taken into account, a task which is usually neglected. Likewise, the effects of varying pitching moments of four profiles under study on the optimal center of gravity positions are calculated and taken into account.**
**The results show that, in contrast to assumptions made in some former papers, the wing section has a significant effect on the optimum wing area (or aspect ratio). Furthermore, the optimal wing section characteristics of a standard class glider seem to be significantly dependent on the competition weather.**

**1. Introduction**

The aerodynamic optimization of a sailplane is frequently discussed, most attention being given to the question of optimum wing aspect ratio. However, it seems to the authors that the effects of the wing profile characteristics are often considered incompletely. In some of the former studies the optimization has been restricted to a "local" problem instead of trying to find a "global" optimum. Either the wing section has been varied while the wing area has been fixed or vice versa (ref. 1,2 and 3). Reference 4 deals with the problem as a global optimization problem, but includes some assumptions that may implicate inaccurate results.
In this paper, the aerodynamic optimization of a standard class glider is dealt with in a comprehensive manner taking into account as many relevant factors affecting the sailplane performance as possible. Thus, added to the geometric factors mentioned above, practical attainable minimum weights of gliders with different wing areas, the use of water ballast and various atmospheric conditions (thermal distributions) were considered. The authors feel this is the only way to reach the global instead of a local optimum.

**2. Principles of the optimization procedure and methods of calculating lift and drag**

*2.1 General*

In order to study the effects of the aerodynamic parameters the optimum configuration for a glider is found by calculating the cross country performance for a number of different configurations and selecting the best one.
The main objective in this study was to compare four different wing section types. An equal treatment of these wing sections requires that for every wing section considered the wing area and the wing loading must be chosen in a way that maximizes the cross country performance. This has been fulfilled by calculating the cross country performance for every wing section with five different wing areas and with four or five different wing loadings. The total number of glider configurations dealt with is thus 95.
The determination of the cross country performance of a glider configuration consists of:

1. calculating the drag polar of the glider taking into account the contributions of wing, empennage, fuselage and interference;
2. calculating the speed polar from the drag polar;
3. using the speed polar for calculating the maximum cross country speed in different atmospheric conditions.

The drag polars of the 95 gliders were calculated in a manner which gave each the "best possible" speed polar in respect of other aerodynamic parameters, eg. c.g. position, wing planform and wing twist. Thus a meaningful comparison between the different configurations was assured. When maximizing the cross country performance the average cross country speed was determined according to the classical McCready theory neglecting the transient phases between the glides and climbs. The thermal models selected were those of Horstmann (ref. 5).

*2.2 Calculating the drag polar*

The total drag of the glider was divided into components as follows

$$C_D = C_{DiW} + C_{DpW} + C_{pH} + C_{DpV} + C_{DBody} + C_{Dinter} \quad (1)$$

where the subscripts have the following meanings
i = induced, p = profile, inter = interference
w = wing, H = horizontal tail, V = vertical tail
To calculate the total lift coefficient of the glider and the drag coefficients in eg. (1) a computer program package by Vanhanen (ref. 6) was utilized. This PASCAL-program is based on a vortex lattice method. Thus, it is possible to determine the downwash in the empennage area and hence the drag components caused by the horizontal tail with good accuracy. All the profile drag components were calculated using wind tunnel measurements (ref. 7) for the wing sections considered. The drag component caused by fuselage ($C_{DBody}$) was calculated with a half-empiric method described by Lehtonen (ref. 8).
The drag component due to the interference between the wing and body (fuselage) was determined using empirical data from the flight measurements of PIK-20, ref. 8, see fig. 1.
It should be noted that all the drag components of eq. (1) are considered as lift dependent. There is no "miscellaneous" or "restwiderstand" coefficient with a constant value.

*2.3 Calculating the maximum allowed lift coefficient in thermals*

The maximum allowable lift coefficient in thermal turns depends on the $C_{Lmax}$ of the glider and on the stalling characteristics. The total $C_{Lmax}$ may be considerably less than $C_{Lmax\ wing}$ due to wing body interference. Thus, calculating the maximum lift coefficient for the wing only may be useless.
In this study, the maximum allowed lift coefficient applied in thermals was chosen to be:

$$C_{Lallow} = c_{lmax} - 0.25, \quad (2)$$

where $c_{lmax}$ is the maximum lift coefficient of the wing section considered. This value is based on flight measurements (ref. 8) and is of limited accuracy. Strictly the decrement of the lift coefficient should have different values for different wing sections depending on the shape of the lift curve near the stall.

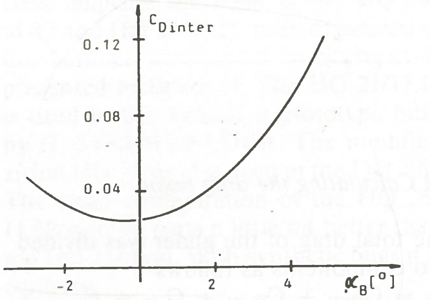


**Fig. 1. Wing-body-interference drag coefficient $C_{Dinter}$ as a function of body angle of attack $\alpha_B$. Reference area is maximum body section area, ref. 8.**

## 3. Determination of the design parameters of the glider configurations considered

### *3.1 The wing section drag polars*

The main objective of this study was to find out the effects of the wing section on the glider performance. Therefore, the four sections were chosen from ref. 7 to be as dissimilar as possible. The sections selected were:
FX 66-17AII-182,
FX 38-153 (with a modification in drag polar),
FX 60-157,
FX 60-157,
FX 61-184.
The modification of the drag polar of the section FX 38-153 (ref. 7) is shown in Figure 2. The modification was done to elevate the drag bucket an amount of 0.2 in $c_l$-axis direction, and corresponds to an increase in camber and consequently in moment coefficient. An increase of 0.2 in $c_l$-values implies a decrease of 0.05 in $c_{ml/4}$-values.
The drag polars of the selected wing sections for two different Re-numbers are presented in Figures 3a and 3b. The FX 66-17AII-182 represents a wide but shallow drag bucket and FX 38-153mod represents the opposite type with a deep but narrow drag bucket. The other two sections lie somewhere in between. It must be emphasized in this connection that the drag polars were selected to achieve as conspicuous trends as possible and there were no other factors involved.

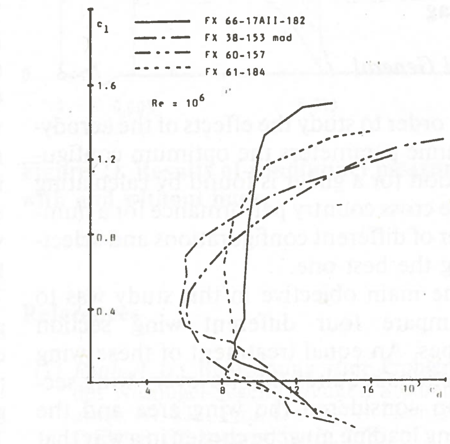


**Fig. 3a. Drag polars of selected wing sections, Re = $10^6$, ref. 7.**

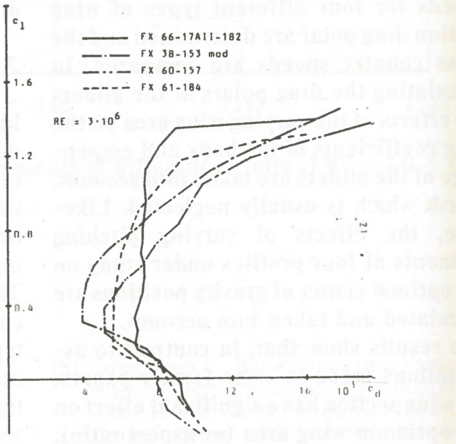


**Fig. 3b. Drag polars of selected wing sections, Re = $3 \cdot 10^6$, ref. 7.**

### *3.2 Selected wing areas and corresponding glider minimum weights*

To find the optimal wing area (aspect ratio) for each wing section the cross country performance was calculated for glider configurations with wing areas of 10, 11, 12, 13 and 14 $m^2$.
Empty weights were calculated with the help of Stender's formula (ref. 10), statistics of Thomas (ref. 11) and experiences gained from the use of carbon fibre in glider structures (ref. 8). A breakdown of the empty masses and corresponding wing loadings are shown in Table 1. All the versions had a maximum weight that corresponded to a wing loading of 450 $N/m^2$ to assure that the empty weights based on statistical data were valid. This means a maximum of 280 kgs water ballast in the case of a 14 $m^2$ wing.

### *3.3 Selecting the wing planform and twist; selecting the wing and horizontal tail incidence*

The main principles which were followed in this task were:

- for each combination of wing area and secting a combination of planform and twist was selected which ensured a wing Oswald's factor $e_w$ greater than 0.995 at $C_L$'s greater than the one corresponding to the maximum glide ratio;
- for each combination of wing area and section the wing incidence was determined in such a way that the sum of drag coefficients $C_{DBody}$ and $C_{Dinter}$ was a minimum at the $C_L$ corresponding to the maximum glide ratio;
- the horizontal tail incidence was chosen to give almost zero elevator deflection at the $C_L$ corresponding to the maximum glide ratio.

### *3.4 The tail areas and c.g. positions*

All the gliders were assumed to have 7.0 m long fuselages. The aerodynamic centres of the wings were all assumed to be located at the same point relative to the fuselage. The tail volume ratios of horizontal and vertical tails were chosen according to the statistics by Thomas (ref. 11). Thus $V_H = 0.58$ and $V_V = 0.028$ were selected. Tail areas are presented in Table 2. The aspect ratios were selected as 5.5 for horizontal tail and 1.4 for vertical tail. The wing section of both the vertical and horizontal tail was FX 71-L-150/20.

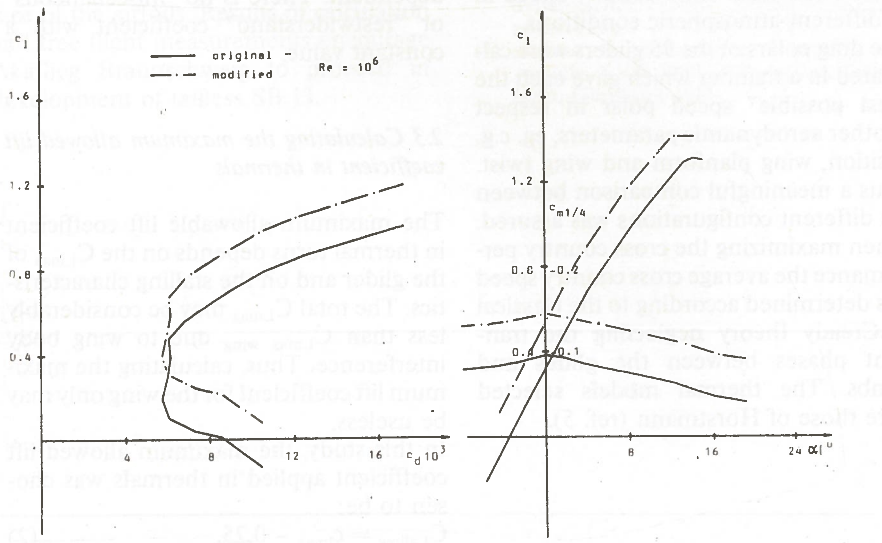


**Fig. 2. Modification of aerodynamic coefficients of wing section FX 38-153.**

The optimal c.g. position $h_{opt}$, calculated according to the method of Sachs (ref. 12), is a function of lift coefficient of the glider, see Fig. 4. Based on the analysis by Irving (ref. 13) the c.g. positions h of the glider configurations were selected to be equal to $h_{opt}$ at lift coefficient values $1.0 > C_L > 0.8$.

**Table 2.** Tail areas ($S_H$ and $S_V$) corresponding to different wing areas (S). Subscripts: H = horizontal tail; V = vertical tail.

| S [m²] | $S_H$ [m²] | $S_V$ [m²] |
|---|---|---|
| 10 | 0.97 | 1.02 |
| 11 | 1.17 | 1.12 |
| 12 | 1.40 | 1.22 |
| 13 | 1.64 | 1.33 |
| 14 | 1.90 | 1.43 |

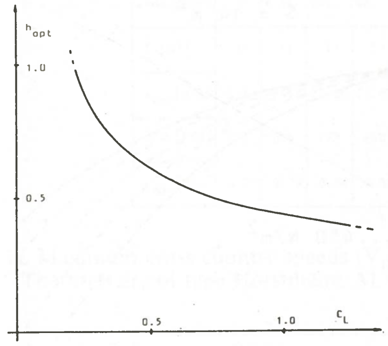


**Fig. 4. Effect of glider lift coefficient $C_L$ on optimal centre of gravity position $h_{opt}$.**

**Table 1.** The effect of wing area (S) on the masses of wing ($m_W$) and body + empennage ($m_{B+E}$) and attainable minimum wing loading ($(W/S)_{min}$). A pilot mass of 80 kgs is assumed.

| S [m²] | $m_W$ [kg] | $m_{B+E}$ [kg] | $m_{OE} = m_W + m_{B+E}$ | $(W/S)_{min}$ [N/m²] |
|---|---|---|---|---|
| 10 | 110 | 115 | 225 | 300 |
| 11 | 121 | 117 | 238 | 285 |
| 12 | 132 | 119 | 251 | 270 |
| 13 | 143 | 121 | 264 | 260 |
| 14 | 154 | 123 | 277 | 250 |

**Table 3.** The centre of gravity positions h (percent of MAC) for different wing section – wing area combinations.

| wing section | FX 66-17AII-182 | FX 38-153 mod | FX 60-157 | FX 61-184 |
|---|---|---|---|---|
| S [m²] | h | h | h | h |
| 10 | 0.40 | 0.50 | 0.45 | 0.48 |
| 11 | 0.40 | 0.49 | 0.46 | 0.48 |
| 12 | 0.40 | 0.48 | 0.46 | 0.47 |
| 13 | 0.40 | 0.47 | 0.46 | 0.46 |
| 14 | 0.40 | 0.46 | 0.46 | 0.45 |

The values selected are presented in Table 3. Notice that the c.g. positions in the cases of wing sections FX 66-17AII-182 and FX 60-157 could not be accepted as prescribed above because the stick free margin (according to ref. 14 and 15) restricted the c.g. position.

## 4. Calculated speed polars

The 95 speed polars required about 1400 $C_L$–$C_D$ points to be analyzed. Some of the speed polars are presented in Figures 5a–5b. The maximum glide ratio $E_{max}$, corresponding flight speed $V_{E=E_{max}}$ and speed at the sink rate of 2.0 m/s are presented in Table 4 for each wing area-wing section combination at both minimum and maximum wing loadings.

## 5. The atmospheric conditions

In the early studies on the average cross country speeds no attempts were made to give an unified representation where more than one type of thermal was represented, see e.g. ref. 16.

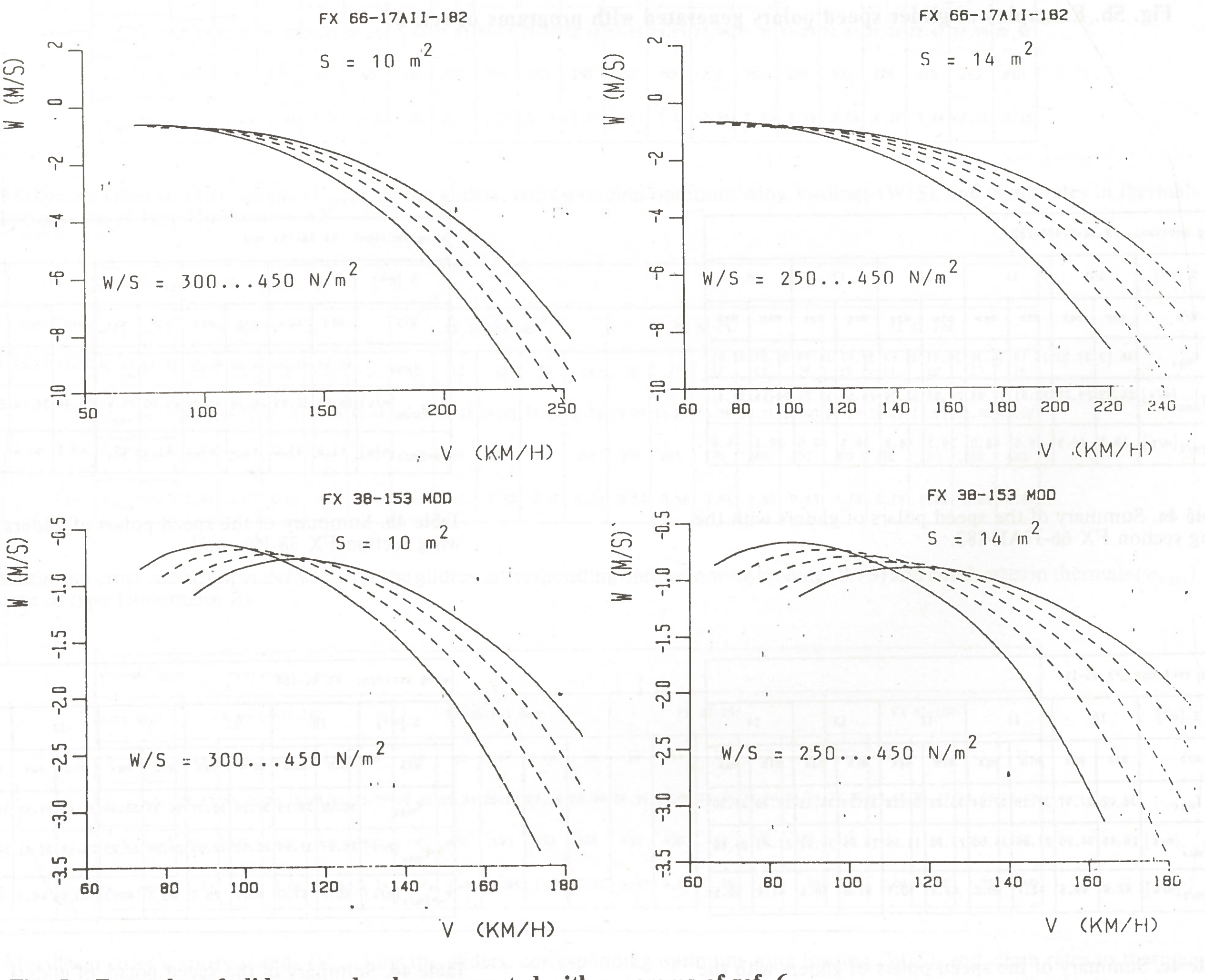


**Fig. 5a. Examples of glider speed polars generated with programs of ref. 6.**

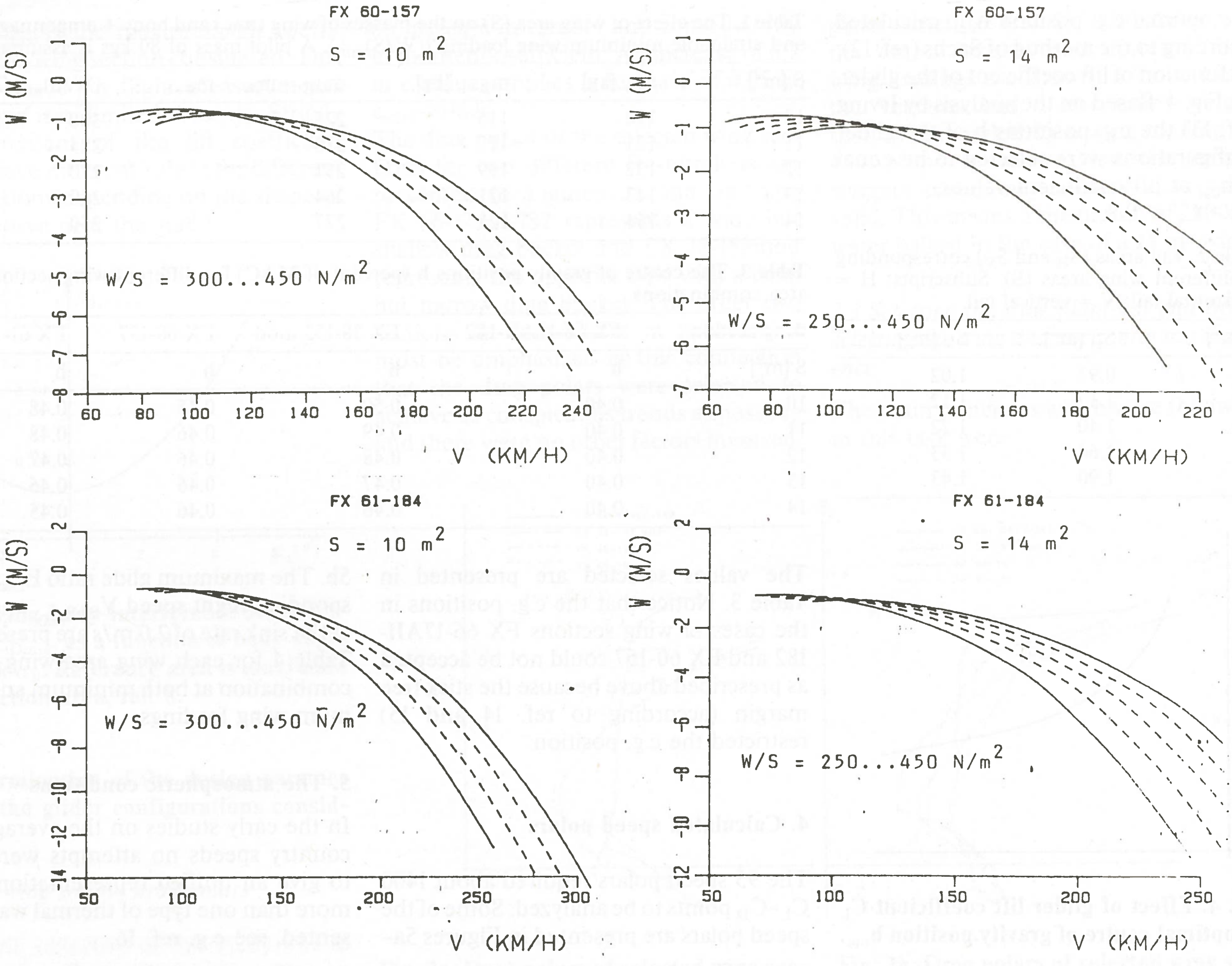


**Fig. 5b. Examples of glider speed polars generated with programs of ref. 6.**

| wing section: FX 66-17AII-182 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| S [m²] | 10 | | 11 | | 12 | | 13 | | 14 | |
| W/S | min | max | min | max | min | max | min | max | min | max |
| $E_{max}$ | 36.12 | 37.03 | 35.14 | 36.36 | 34.33 | 35.63 | 33.57 | 34.79 | 32.87 | 34.01 |
| $V_{E=E_{max}}$ [m/s] | 24.33 | 29.79 | 23.81 | 31.94 | 24.85 | 32.09 | 24.50 | 32.24 | 24.16 | 32.41 |
| $V_{w=2m/s}$ [m/s] | 39.7 | 45.9 | 39.5 | 46.0 | 39.3 | 46.8 | 38.9 | 46.8 | 38.9 | 46.8 |

**Table 4a.** Summary of the speed polars of gliders with the wing section FX 66-17AII-182.

| wing section: FX 38-153 mod | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| S [m²] | 10 | | 11 | | 12 | | 13 | | 14 | |
| W/S | min | max | min | max | min | max | min | max | min | max |
| $E_{max}$ | 41.54 | 41.90 | 40.50 | 40.82 | 39.33 | 40.08 | 38.17 | 39.29 | 37.31 | 38.51 |
| $V_{E=E_{max}}$ [m/s] | 26.94 | 32.99 | 26.38 | 35.72 | 25.80 | 35.90 | 27.44 | 36.10 | 27.06 | 36.30 |
| $V_{w=2m/s}$ [m/s] | 41.9 | 49.0 | 41.5 | 49.5 | 41.0 | 49.8 | 40.9 | 50.4 | 40.6 | 50.8 |

**Table 4b.** Summary of the speed polars of gliders with the wing section FX 38-153 mod.

| wing section: FX 60-157 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| S [m²] | 10 | | 11 | | 12 | | 13 | | 14 | |
| W/S | min | max | min | max | min | max | min | max | min | max |
| $E_{max}$ | 38.02 | 37.97 | 37.19 | 37.04 | 36.22 | 36.10 | 35.19 | 35.15 | 34.30 | 34.30 |
| $V_{E=E_{max}}$ [m/s] | 28.46 | 34.90 | 27.86 | 35.00 | 27.23 | 35.15 | 26.85 | 35.31 | 26.43 | 35.48 |
| $V_{w=2m/s}$ [m/s] | 42.9 | 49.6 | 42.7 | 50.0 | 42.2 | 50.4 | 41.8 | 50.5 | 41.4 | 50.5 |

**Table 4c.** Summary of the speed polars of gliders with the wing section FX 60-157.

| wing section: FX 61-184 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| S [m²] | 10 | | 11 | | 12 | | 13 | | 14 | |
| W/S | min | max | min | max | min | max | min | max | min | max |
| $E_{max}$ | 38.02 | 39.15 | 37.26 | 38.31 | 36.35 | 37.39 | 35.41 | 36.42 | 34.51 | 35.55 |
| $V_{E=E_{max}}$ [m/s] | 26.07 | 31.94 | 25.52 | 32.06 | 24.96 | 32.23 | 24.64 | 32.41 | 24.29 | 32.59 |
| $V_{w=2m/s}$ [m/s] | 40.7 | 47.0 | 40.7 | 48.1 | 40.3 | 48.3 | 40.0 | 48.9 | 39.7 | 49.0 |

**Table 4d.** Summary of the speed polars of gliders with the wing section FX 61-184.

However Quast (ref.17) modelled thermal distributions which might be encountered in Central Europe. The present study considers an average thermal distribution during a soaring contest, based on the Finnish championship contests during the 1970's, (ref. 8) representing an average contest. According to this model the days characterized by Horstmann thermals A1 and B1 (weak thermals) are as common as days with thermal types A2 and B2 (strong thermals) prevailing. The occurrence of wide and narrow thermals is assumed in the present study to be equally frequent. Thus, the present model of thermal distribution contains equal number of A1, A2, B1 and B2 days. In order to study the effects of the atmospheric model on the cross country performance two other models were considered. The first one is a "Quastian" model including 8% of A1, 42% of A2, 8% of B1 and 42% B2 days. The second model is an "anti-Quastian" model with 42% A1, 8% A2, 42% B1 and 8% B2 days.

## 6. Results of the cross country performance calculations

The maximum attainable cross country speeds according to the classical MacCready theory for all the glider configurations considered are collected into Tables 5a–5d.

Contest scores for each wing section wing area combination were calculated. Thus the optimal wing areas for each wing section were found. The results of this process are given in Table 6a. Among other things one can deduce that an optimal wing area for the profile FX 61-184 is

| thermal type: Horstmann - A1 | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| wing sect. | FX 66-17AII-182 | | | | | FX 38-153 mod | | | | | FX 60-157 | | | | | FX 61-184 | | | | |
| S [m²] | 10 | 11 | 12 | 13 | 14 | 10 | 11 | 12 | 13 | 14 | 10 | 11 | 12 | 13 | 14 | 10 | 11 | 12 | 13 | 14 |
| $V_{max}$[m/s] | 13.43 | 13.66 | 13.86 | 13.82 | 13.81 | 8.97 | 10.43 | 11.53 | 12.13 | 12.51 | 9.60 | 10.75 | 11.70 | 12.11 | 12.50 | 11.34 | 11.87 | 12.28 | 13.04 | 13.14 |
| W/S [N/m] | 300 | 285 | 270 | 260 | 250 | 300 | 285 | 270 | 260 | 250 | 300 | 285 | 270 | 260 | 250 | 300 | 285 | 270 | 260 | 250 |
| $w_{max}$[m/s] | 0.75 | 0.79 | 0.84 | 0.86 | 0.88 | 0.32 | 0.41 | 0.50 | 0.57 | 0.62 | 0.38 | 0.46 | 0.55 | 0.60 | 0.65 | 0.52 | 0.58 | 0.63 | 0.73 | 0.76 |

**Table 5a.** Maximum cross country speeds ($V_{max}$) for the gliders, corresponding optimum wing loadings (W/S) and climb rates in thermals ($w_{max}$). Thermals are of type Horstmann A1.

| thermal type: Horstmann - A2 | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| wing sect. | FX 66-17AII-182 | | | | | FX 38-153 mod | | | | | FX 60-157 | | | | | FX 61-184 | | | | |
| S [m²] | 10 | 11 | 12 | 13 | 14 | 10 | 11 | 12 | 13 | 14 | 10 | 11 | 12 | 13 | 14 | 10 | 11 | 12 | 13 | 14 |
| $V_{max}$[m/s] | 22.59 | 22.56 | 22.50 | 22.42 | 22.30 | 22.60 | 22.81 | 22.92 | 23.22 | 23.23 | 23.15 | 23.29 | 23.38 | 23.35 | 23.28 | 22.27 | 22.32 | 22.47 | 22.59 | 22.52 |
| W/S [N/m] | 300 | 285 | 270 | 260 | 250 | 300 | 285 | 270 | 260 | 250 | 300 | 285 | 270 | 260 | 250 | 300 | 285 | 310 | 260 | 250 |
| $w_{max}$[m/s] | 2.52 | 2.58 | 2.64 | 2.67 | 2.70 | 2.05 | 2.16 | 2.27 | 2.36 | 2.42 | 2.13 | 2.23 | 2.34 | 2.40 | 2.46 | 2.24 | 2.32 | 2.14 | 2.51 | 2.55 |

**Table 5b.** Maximum cross country speeds ($V_{max}$) for the gliders, corresponding optimum wing loadings (W/S), and climb rates in thermals ($w_{max}$). Thermals are of type Horstmann A2.

| thermal type: Horstmann - B1 | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| wing sect. | FX 66-17AII-182 | | | | | FX 38-153 mod | | | | | FX 60-157 | | | | | FX 61-184 | | | | |
| S [m²] | 10 | 11 | 12 | 13 | 14 | 10 | 11 | 12 | 13 | 14 | 10 | 11 | 12 | 13 | 14 | 10 | 11 | 12 | 13 | 14 |
| $V_{max}$[m/s] | 14.47 | 14.30 | 14.11 | 13.88 | 13.66 | 14.13 | 14.11 | 14.03 | 13.86 | 13.70 | 13.28 | 13.27 | 13.26 | 13.11 | 13.00 | 14.19 | 14.09 | 13.95 | 13.78 | 13.62 |
| W/S [N/m] | 300 | 285 | 270 | 260 | 250 | 300 | 285 | 270 | 260 | 250 | 300 | 285 | 270 | 260 | 250 | 300 | 285 | 270 | 260 | 250 |
| $w_{max}$[m/s] | 0.86 | 0.87 | 0.87 | 0.87 | 0.87 | 0.68 | 0.70 | 0.72 | 0.72 | 0.73 | 0.64 | 0.66 | 0.68 | 0.69 | 0.69 | 0.78 | 0.79 | 0.80 | 0.81 | 0.81 |

**Table 5c.** Maximum cross country speeds ($V_{max}$) for the gliders, corresponding optimum wing loading (W/S) and climb rates in thermals ($w_{max}$). Thermals are of type Horstmann B1.

| thermal type: Horstmann - B2 | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| wing sect. | FX 66-17AII-182 | | | | | FX 38-153 mod | | | | | FX 60-157 | | | | | FX 61-184 | | | | |
| S [m²] | 10 | 11 | 12 | 13 | 14 | 10 | 11 | 12 | 13 | 14 | 10 | 11 | 12 | 13 | 14 | 10 | 11 | 12 | 13 | 14 |
| $V_{max}$[m/s] | 24.47 | 24.34 | 24.16 | 24.12 | 23.71 | 25.33 | 25.34 | 25.27 | 25.14 | 24.99 | 24.96 | 24.86 | 24.66 | 24.46 | 24.24 | 24.84 | 24.85 | 24.77 | 24.62 | 24.42 |
| W/S [N/m] | 450 | 450 | 450 | 450 | 400 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 400 | 400 | 400 | 450 | 450 | 450 | 450 | 450 |
| $w_{max}$[m/s] | 2.14 | 2.10 | 2.06 | 2.05 | 2.14 | 1.91 | 1.88 | 1.84 | 1.80 | 1.76 | 1.87 | 1.84 | 1.96 | 1.92 | 1.89 | 2.07 | 2.04 | 2.00 | 1.95 | 1.90 |

**Table 5d.** Maximum cross country speeds ($V_{max}$) for the gliders, corresponding optimum wing loading (W/S), and climb rates in thermals ($w_{max}$). Thermals are of type Horstmann B2.

13 m². This result is in accordance with Helwig (ref. 4).

The corresponding results using the two additional atmospheric models are presented in Tables 6b and 6c.

If the atmospheric model used in the Table 6a is considered as a good approximation of an average contest weather the following conclusions can be made:

- in a contest held in weak atmospheric conditions (Table 6c) the "average-optimum" wing area (ie. optimum wing area in the average contest of ch. 5) is too small for the wing section FX 66-17AII-182 while it is suitable (13 m²) for the wing section FX 61-184
- in a contest with strong atmospheric conditions (Table 6b) the "average-optimum" wing areas are too large for the sections FX 38-157mod and FX 60-157.

The final comparison between the wing sections, in order to find the global optimum, was accomplished using the local optimum data from Tables 6a–6c. The results for all the three atmospheric models considered are presented in Table 7. The significant effect of the atmospheric conditions, not only on the optimal wing areas for a particular wing section but also on the optimal wing section (global optimum) is apparent. For instance when strong thermals prevail it seems that a wing section with a drag polar having a narrow but deep drag bucket (as FX 38-153mod) would be better than a section with a wide but shallow drag bucket (FX 66-17AII-182). This result differs from the conclusions made in ref. 1.

## 7. Conclusions

In the present study the effects of the wing section drag polar characteristics on the optimum wing area and cross country performance of a glider have been analyzed in a comprehensive manner. The results show that in contrast to assumptions made in some former papers the wing section selection has a significant effect on the optimum wing area (or aspect ratio). Furthermore, the optimal wing section characteristics of a standard class glider seem to be significantly dependent on the competition weather.


## Acknowledgements

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| | A1 | A2 | B1 | B2 |
|---|---|---|---|---|
| thermal distribution during the contests: | 25 % | 25 % | 25 % | 25 % |

| wing section | FX 66-17AII-182 | | FX 38-153 mod | | FX 60-157 | | FX 61-184 | |
|---|---|---|---|---|---|---|---|---|
| place in contest | S [m²] | total points | S [m²] | total points | S [m²] | total points | S [m²] | total points |
| 1st | 10 | 11906.4 | 14 | 11866.8 | 14 | 11836.8 | 13 | 11863.2 |
| 2nd | 11 | 11901.6 | 13 | 11826.0 | 13 | 11804.4 | 14 | 11818.8 |
| 3rd | 12 | 11875.2 | 12 | 11695.2 | 12 | 11767.2 | 12 | 11727.6 |
| 4th | 13 | 11803.2 | 11 | 11443.2 | 11 | 11553.6 | 11 | 11653.2 |
| 5th | 14 | 11689.2 | 10 | 11068.8 | 10 | 11274.0 | 10 | 11545.2 |

**Table 6a.** Results of four fictional soaring contests for the four fixed wing sections. The maximum score is 12000 points for each contest.

| | A1 | A2 | B1 | B2 |
|---|---|---|---|---|
| thermal distribution during the contests: | 8 % | 42 % | 8 % | 42 % |

| wing section | FX 66-17AII-182 | | FX 38-153 mod | | FX 60-157 | | FX 61-184 | |
|---|---|---|---|---|---|---|---|---|
| place in contest | S [m²] | total points | S [m²] | total points | S [m²] | total points | S [m²] | total points |
| 1st | 10 | 997.5 | 13 | 992.5 | 12 | 989.7 | 13 | 993.2 |
| 2nd | 11 | 995.1 | 14 | 991.8 | 13 | 987.5 | 12 | 989.8 |
| 3rd | 12 | 991.0 | 12 | 986.4 | 11 | 985.4 | 14 | 988.2 |
| 4th | 13 | 987.3 | 11 | 979.0 | 14 | 984.4 | 11 | 986.7 |
| 5th | 14 | 976.8 | 10 | 965.8 | 10 | 977.3 | 10 | 982.9 |

**Table 6b.** Results of four fictional soaring contests for the four fixed wing sections. The maximum score is 1000 point for each contest.

| | A1 | A2 | B1 | B2 |
|---|---|---|---|---|
| thermal distribution during the contests: | 42 % | 8 % | 42 % | 8 % |

| wing section | FX 66-17AII-182 | | FX 38-153 mod | | FX 60-157 | | FX 61-184 | |
|---|---|---|---|---|---|---|---|---|
| place in contest | S [m²] | total points | S [m²] | total points | S [m²] | total points | S [m²] | total points |
| 1st | 11 | 988.5 | 14 | 986.1 | 14 | 988.5 | 13 | 983.9 |
| 2nd | 12 | 988.2 | 13 | 978.6 | 13 | 979.8 | 14 | 981.5 |
| 3rd | 10 | 987.0 | 12 | 962.8 | 12 | 971.5 | 12 | 964.7 |
| 4th | 13 | 979.9 | 11 | 928.1 | 11 | 940.3 | 11 | 955.5 |
| 5th | 14 | 971.5 | 10 | 878.9 | 10 | 901.8 | 10 | 941.3 |

**Table 6c.** Results of four fictional soaring contests for the four fixed wing sections. The maximum score is 1000 points for each contest.

| | "average" | | | "Quastian" | | | "anti-Quastian" | | |
|---|---|---|---|---|---|---|---|---|---|
| | A1 25% A2 25% B1 25% B2 25% | | | A1 8% A2 42% B1 8% B2 42% | | | A1 42% A2 8% B1 42% B2 8% | | |
| placed as | wing section | S [m²] | points | wing section | S [m²] | points | wing section | S [m²] | points |
| 1st | FX 66 | 10 | 987.4 | FX 38 | 13 | 986.0 | FX 66 | 11 | 995.4 |
| 2nd | FX 61 | 13 | 969.7 | FX 60 | 12 | 975.0 | FX 61 | 13 | 962.1 |
| 3rd | FX 38 | 14 | 969.0 | FX 66 | 10 | 974.6 | FX 38 | 14 | 946.8 |
| 4th | FX 60 | 14 | 949.8 | FX 61 | 13 | 971.0 | FX 60 | 14 | 923.8 |

**Table 7.** Results of three meteorologically different fictional soaring contests for the local optimum wing section – wing area combinations of tables 6a, b and c. Maximum score per contest is 1000 points. Notations: FX 66 = FX 66-17AII-182; Fx 61 = FX 61-184; FX 60 = FX 60-157; FX 38 = FX 28-153 mod.

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