DESIGN AND ANALYSIS OF THE STANDARD CLASS TAILLESS SAILPLANE DUTAG

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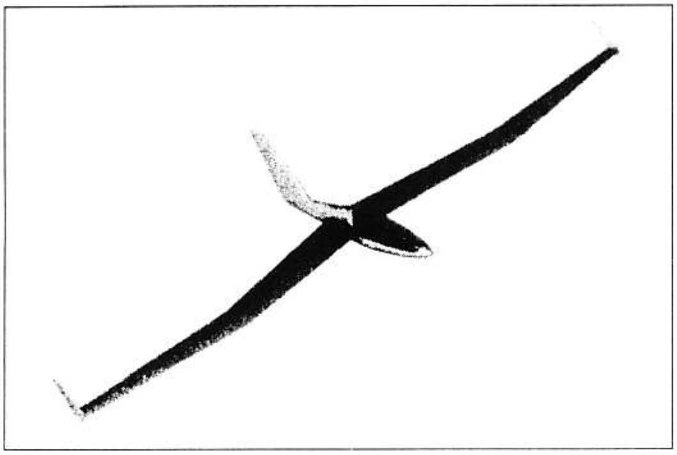
Summary

This paper focuses on the design and analysis of the tailless glider DUTAG. The design of an advanced tailless glider is only possible by means of a program that shows the effect of design decisions on all disciplines. The design philosophy (ICADS) implemented in these programs made the following conclusions possible:

- To be competitive a tailless glider needs a tail.
- The gull wing planform does offer gust alleviation and will probably be seen on gliders in the future.



Introduction

The design and optimization of a high performance tailless glider is a rather complex and highly iterative process, the more since the performance, stability and control as well as the loads are heavily affected by the aeroelastic and dynamic behavior of the flexible aircraft.

For this reasons wing planform, wing sections, wing twist, local bending and torsional stiffness have to be chosen interactively, with the utmost care, to reach the highest possible performance and the lowest structural weight.

Since the weight of the structure is directly related to the occurring loads, the wing is tailored in such a way that the occurring loads in the different design load cases are suppressed.

This load alleviation can either lead to a lower weight of the structure or to higher operational limits of the aircraft.

Because of the high flexibility of the wing, extra attention must be paid to dynamic divergence, aileron effectiveness and the occurrence of flutter. This design process, mostly referred to as aeroelastic tailoring, requires a very accurate design and a great amount of rather complex calculations. The determination of the operational limits and the limit loads on flexible aircraft is becoming much more complicated. In this case not only the static loads on the rigid aircraft but the dynamic loads on the flexible aircraft are becoming the defining loads for the design and the strength of the structure. As a result, the proof of compliance with the airworthiness requirements of the JAR 22 aviation regulations will become a more complicated matter.

The execution of such a complex design process as described above would be hardly possible without the use of modern computer facilities and an interactive design system. Such a system ICADS, Interactive Computerized Aircraft Design System, is at the moment developed by the faculty of Aerospace Engineering of the Delft University of Technology (reference 1)

The system in its present form was not suitable for the design of a high performance tailless glider like the DUTAG. Because of this a new program NUR (NUR fur die NURflugel) was set up for the design and analysis of the DUTAG. The NUR program closely follows the ICADS design philosophy and methodology as described in reference 2. For those readers who are not familiar with this design methodology a short explanation will be given in the next paragraph.

ICADS design philosophy and methodology.

The main goals of the ICADS design philosophy and methodology are to reduce cost, time, effort and risk in the design and development process of advanced, efficient and safe aircraft in order to reach a fast market response and to create more room for optimization.

In ICADS these goals are met by means of:

- A proper organization of the design process.
- An efficient use of computer facilities.
- A great amount of automation.

The ICADS design methodology is based on:

- System engineering.
- Interactive design.
- Parallel processing.
- Concurrent Engineering.
- Phased design.
- Closed loop design.
- Defined design procedures.
- Computer aided design.

ICADS is a highly integrated system, which means that the different design tasks and the design analysis are integrated wherever possible. In practice this means that the performance, stability and control, aeroelastic and dynamic behavior, dynamic loads and load spectra, operational limits, airworthiness and cost can be investigated by one and the same program! The analysis is automated, design decisions are left to the project manager (figure 1.)

NUR

The same methodology is used in the NUR program. The only difference is that in NUR there are no engines, only simple systems and no cost calculation routines since the sole aim of NUR is to reach the highest possible performance. A very short introduction to the NUR program will be given here, more technical details can be found in reference 3(The complete report). NUR is a purpose made interactive computer program for the design and analysis of a tailless glider. Although purpose made the program will be just as well suited to the design of any type of high performance glider in the very near future.

The backbone of the program is a simplified FEM computer model (only beam elements are used) that is given the same aerodynamic and structural properties as the real aircraft. This simulated model is not static, it can move and accelerate in any direction under the influence of the acting airloads, mass loads and reaction loads. In this way the NUR program can be used for flight path, motion and mission simulation.

During the simulation the program calculates all airloads, accelerations, mass loads and reaction loads on every part of the flexible aircraft. The attitude of the aircraft with respect to the gravity field is taken into account. The actual mass and stiffness distributions of the aircraft in a specific design phase are used.

The flight path simulation is used to check the performance, stability and control as well as the operational limits of the aircraft. The flight path simulation is also used to find the dynamic limit loads on the flexible and trimmed aircraft during take off, climb, cruise, maneuvering, gust, approach and landing. In the NUR program this process is completely automated.

The motion simulation is used to investigate aeroelastic and dynamic behavior. Mission simulation will be used in the future to investigate fatigue load spectra.

The program is used in three different modes:

Rigid: No aeroelastic effects are calculated with. Only static flight cases.

Flexible: Aeroelastic effects incorporated. Only static flight cases.

Free flying: The flexible airplane is flying in time space. Gust and dynamic behavior can be investigated.

The NUR program makes use of lifting line theory in

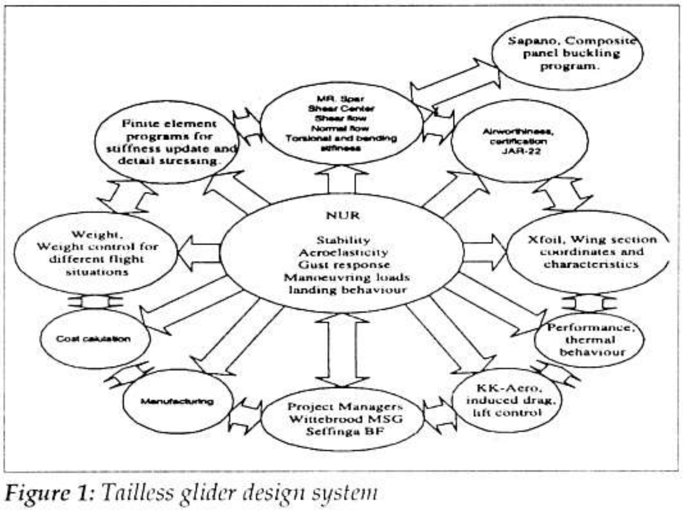


Figure 1: Tailless glider design system

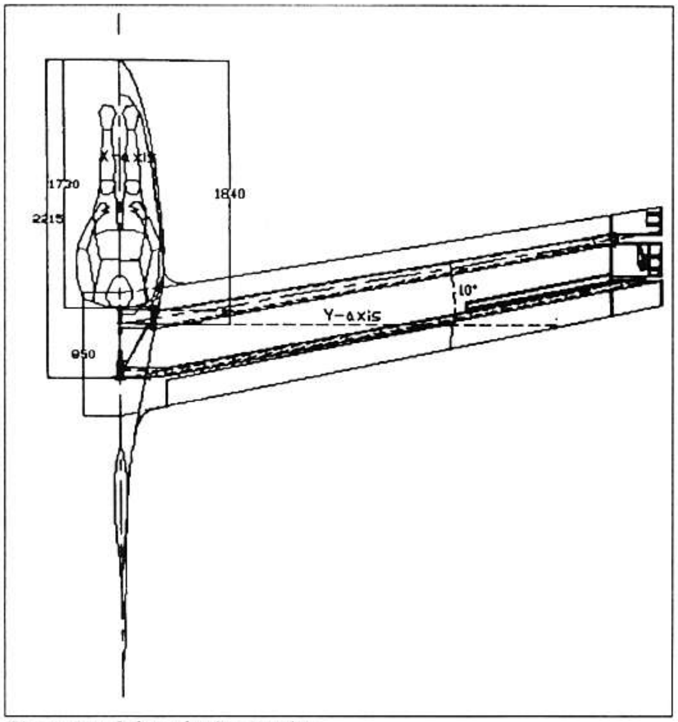


Figure 2a: Inboard wing section.

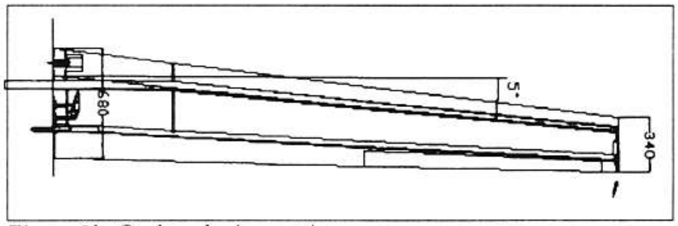


Figure 2b: Outboard wing section.

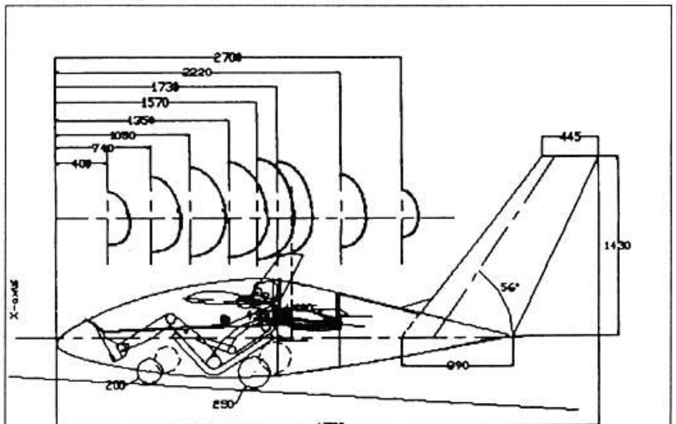


Figure 2c: Side view with cross sections.

combination with strip theory to calculate the aerodynamics. To make the time response possible the program makes use of modal residualization (reference 4). The aerodynamics used are quasi-stationary, thus the program can only predict flutter at low speeds with low frequency. The highest frequency that has dynamic influence in the modal residualization method is about 40 Hz for all calculations presented in this report.

Elevator control in a time response is accomplished by means of the mouse or keyboard. With a very fast computer pilot induced oscillations can be studied with NUR. Automatic pilot control can also be studied in the future if the algorithm that presents the pilot is programmed in the NUR program.

Only with a program like NUR it is possible to run what-if programs to investigate the effects of design decisions.

Design loop

The prime feature of ICADS is closed loop design. Design decisions are checked against all expertise's in short design loops as shown in figure 1, the design organization graph. By checking all expertise's it is possible to find design constraints in subjects that were often to hard to calculate: fatigue loading, flutter and strange dynamical behavior. The concept will never be frozen in what nowadays is called the initial design phase. In figure 1 all programs interfacing with NUR are depicted.

- Mr. Spar : This program calculates the stiffnesses of the local wing and fuselage sections by means of the thin membrane and engineer bending theory. All local sections are saved in a database for further processing. The loading on the wing that is calculated by the NUR program is returned to the Mr. Spar program to calculate the shear and normal flows. These flows are given to the panel-buckling program Sapano as shown in figure 1.
- Sapano: Composite panel buckling program developed by the TU Delft Faculty of Aerospace Engineering.
- Weight: Changes in lay-up for the local sections are given to the weight program "WEIGHT" to recalculate the mass distribution. The mass distribution is related to the most important parameters that define the wing planform. This means that planform changes can easily be accomplished.
- Xfoil: Two-dimensional wing section program to calculate the aerodynamic characteristics around the 0.25 chord point. The characteristics are given to the NUR program in table form to calculate the lift distribution.
- KK-Aero: Polish 3D panel program to check the lift distributions generated by the NUR program. Also used to calculate the induced drag for the performance calculations.
- MECHANICA: Finite element program used for a stiffness update of the NUR program finite element model. Mechanica is also used for detail stressing when the loading on the aircraft is known.

The DUTAG design.

This section considers the planform, material choice and other important features of the DUTAG. A three-view drawing is presented in figures 2a, 2b and 2c. Some technical data are in table 1,2 at the end of this report.

Considering the past.

Most features Mr. Seffinga put into the DUTAG were based on tailless wings from the past. All these wings were either back swept, forward swept or had no sweep at all. We now start with a very short survey of tailless wings from the past to discuss the problems involved. This information was taken from reference.5 and does not have the pretention to be complete.

Straight wings:
FAUVEL AV-36 (No sweep)

A rigid tailless glider with no sweep can only be stabilized by means of wing sections that have a positive moment coefficient. These wing sections have more viscous drag then what is considered normal and have a very low Cl_{max}. The glide polar optimum cannot be reached with these kind of tailless wings.

Back swept wings:
HORTEN II (backsweep 26°)

Back swept tailless wings can be stabilized by wash-out in the wing. All Horten sailplanes had a clock shaped lift distribution due to the extreme taper and wash-out. A lot of induced drag was the consequence.

SB-13(backsweep 15°)

In the SB-13 project the extreme taper was removed. The wing sections had a very small moment coefficient. The lift distributions were more elliptic so that the induced drag losses were less, this resulted in a $(L/D)_{max}$ of 41. In the 15 meter standard class an $(L/D)_{max}$ of 43.5 is the maximum that can be achieved at this time. A flexible version of the SB-13 would have suffered from flutter at about 120 km/h. To control the flutter problem a lot of weight was added to the plane. The final flutter speed was 280 km/h, which is still not very high. The SB-13 has a very high landing gear that has broken 3 times. The SB-13 can only be flown by very experienced pilots, it cannot fly with water. Pilots feel every gust in their bones due to the very stiff wing.

Forward swept wing
GENESIS I (forward sweep 5°)

A forward swept plane will suffer from divergence at a certain speed. For this reason the GENESIS has very little forward sweep. To trim the glider a very small fixed horizontal stabilizer is placed on top of the vertical tail. The calculated LD is 43.2 at 120 km/h. The GENESIS is considered a serious competitor for the DUTAG.

Mr. Seffinga was looking for a tailless wing that would not have the unfavorable SB-13 characteristics and came to a forward swept design. After some hand calculations he considered the divergence effect a too big problem and decided in favor of the gull-winged planform as it is now. The back sweep of the outboard section will damp the divergence effect. The DUTAG can be rotated much further in ground effect and will thus have a much lower landing speed compared to the SB13. There will hardly be any cross coupling between the symmetric and anti- symmetric movements because the ailerons are in line of the airplane center of gravity. There is no reduction in elevator effectiveness due to aeroelasticity. Mr. Seffinga considered 4 lift distributions that would turn the DUTAG into a success. These lift distributions will be discussed in the coming paragraph focusing on aeroelasticity.

Aspect ratio.

To efficiently fly through different thermal areas the wing loading W/S of a modern glider can be varied between about 25 and 50 kg/m². As shown in table 2 the most modern sailplanes stay within these boundaries. If a glider has a high empty weight, the wing surface must be larger to reach the lower wing loading bound. The wing loading at the start of a contest is dictated by the thermal expectations.

The DUTAG empty weight is 150 kg at the moment. The gain in empty weight compared to the conventional standard class sailplanes (Mean empty weight: ~233 kg) is clear. The DUTAG has a wing surface of 9.5 m^2 and an aspect ratio of 23.7. The DUTAG wing loadings are on the lower bound from what is considered normal (Dutag 21 kg/m^2, normally 25 kg/m^2). This shows that the wing surface could probably be reduced to create an aspect ratio of about 25. If this would be a favorable decision must be investigated by means of a "what-if" program in the near future. The whole nose section of the DUTAG wing can be filled with water (125 kg) to reach the upper wing loading bound(Dutag 41 kg/m^2, normally ~45 kg/m^2).

Construction

- The DUTAG consists of 4 parts:
- Fuselage (length 4.3 meter).
- Inner wing section (length 7.5 meter).
- Two outboard wing sections. (length 4.25 meter).

The wing is divided in three parts to make transport possible. The wing could have been divided into 2 parts of about 8 meter each. It was decided not to do this because of the extra weight that would be needed to create a safe structure. The only way to justify this statement is to run a "what-if" program with NUR.

The DUTAG is an all composite CFRP airplane. This material was chosen because of the high specific stiffness and strength. No cost criteria were put on the design to simplify the design loops. The sandwich is only composed of layers lying under 0/90 and +/- 45° material seen along the line connecting the local 0.25 chord points at the moment. This still leaves some freedom for aeroelastic tailoring in the future by means of small lay-up changes.

Control surfaces.

The DUTAG elevator is located near the fuselage as shown in figure 2a. The elevator is located behind the airplane center of gravity line. In this way local pressure loads from the elevator are not working against the intended effect (reference 5).

The ailerons are located near the tips with a hinge at 20% of the local chord (figure 2b). The ailerons will perform better due to the presence of winglets. The aeroelasticity works against the aileron. If the aileron creates more lift, the wing is twisted in a way that creates less lift. The extra lift at the aileron location results in a twisting of the wing at the inner wing sections due to the bending -> torsion change at the wing partition. The aileron reversal speed will be lower then for straight wing gliders.

Directional control is accomplished by drag rudders. Drag rudders have been chosen because:

- Remain active while spinning.
- Have a very large moment arm to the airplane center of gravity.

The drag rudder and thus the drag force is standing above the wing. The resulting torsion moment wants to turn the local wing sections to a higher angle of attack that creates more lift and thus more induced drag. The extra drag adds to the dragrudder drag, which will speed up the turn. The extra lift is unwanted because the DUTAG could start to roll out of a turn. It may be clear that these cross coupling effects must be investigated in the same way as the symmetric movements. An analysis like this would be impossible with stability derivatives because of the aeroelasticity involved.

Aeroelasticity

Mr. Seffinga was looking for a wing plantorm that would have favorable aeroelastic features concerning:

- Lift distributions.
- Load alleviation.
- Dynamic behavior.

The objective lift distributions he had in mind relative to an elliptic lift distribution are shown in figure 3 for the following characteristic flight situations.

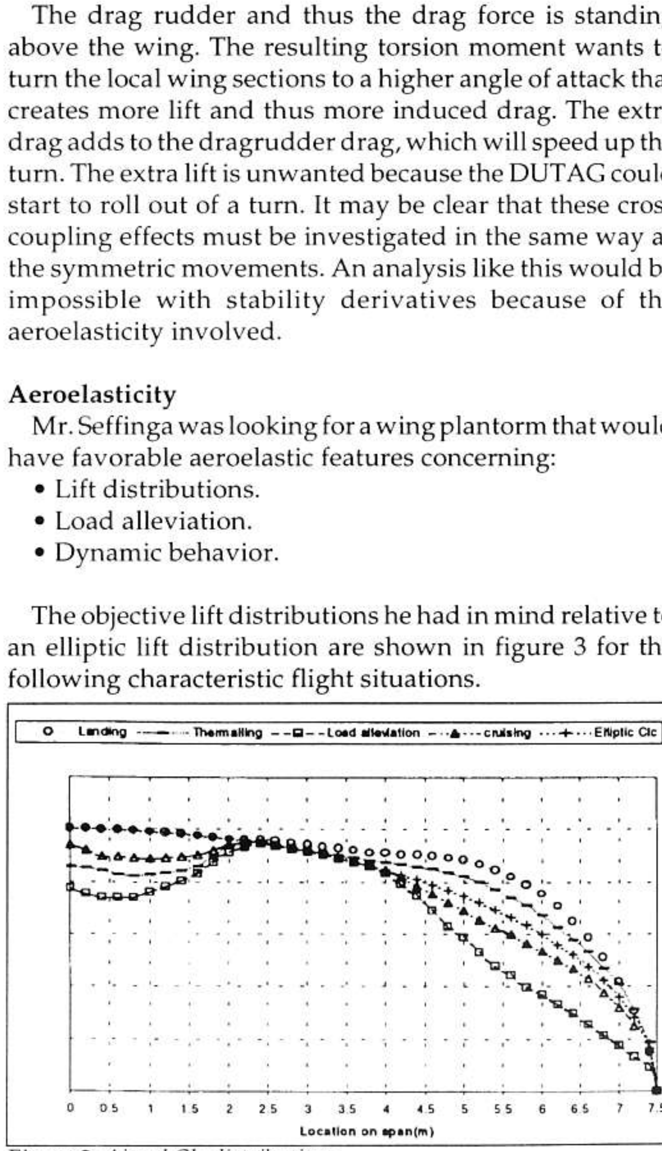


Figure 3: Aimed Clc distributions.

Thermalling

Objective:

When thermalling the lift distribution should be as elliptic as possible. This is because of the induced drag that has a lot of influence on the glide ratio. To reach a high CL the elevator is pulled and there is less lift created at the location of the elevator. More lift is created outboard. This should result in a twisting of the wing that helps trimming the plane. The elevator is acting like a trim-tab on the wing planform.

At the moment:

The Cl and Clc distributions generated by the NUR program in flexible and rigid mode are shown for L/W = 1.4 in figure 4 and figure 5 respectively (in a thermal the L/W ratio is normally between 1.0 and 1.4). The rigid and non- rigid Cl distributions are almost the same, thus the flexibility effects are very marginal for thermalling behavior. The lift distribution is over-elliptic at the outboard wing sections and under-elliptic at the inboard wing sections. This resulted in more induced drag

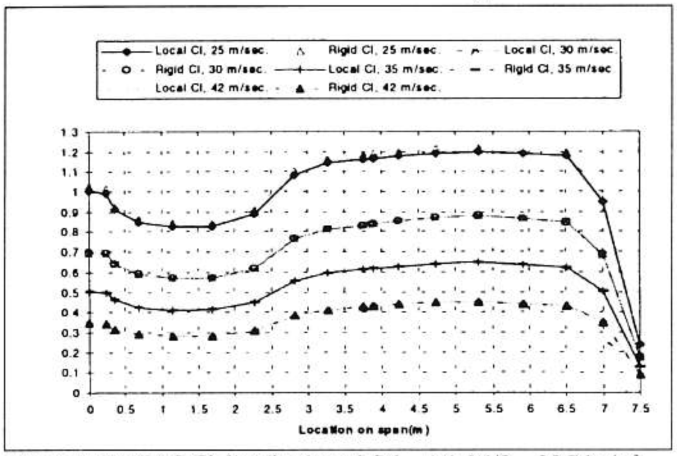


Figure 4: DUTAG Cl distributions. L/W = 1.4, W/S = 28.7 kg/m².

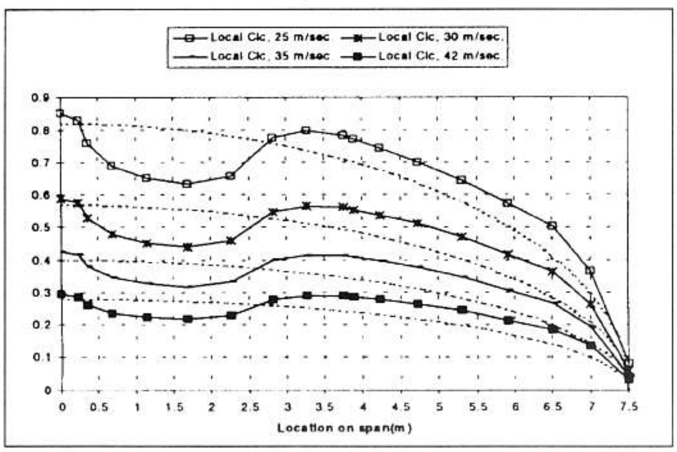


Figure 5: DUTAG Cl and elliptical Cl_c distributions. L/W = 1.4, W/S = 28.7 kg/m².

Cruising

Objective:

When flying between thermals the lift distribution should be a bit under-elliptic at the outboard wing sections. The elevator must stand in the wing section for minimum viscous drag. As a result, less lift is created outboard and the wing is untwisting somewhat in comparison to the thermalling situation. This should result in an under-elliptic lift distribution as shown in figure 3.

At the moment:

The Cl and Clc distributions generated by the NUR program in flexible mode for the L/W = 1 case are shown in figure 6 and figure 7 respectively. In figure 7 the elliptic Clc distribution is also plotted.

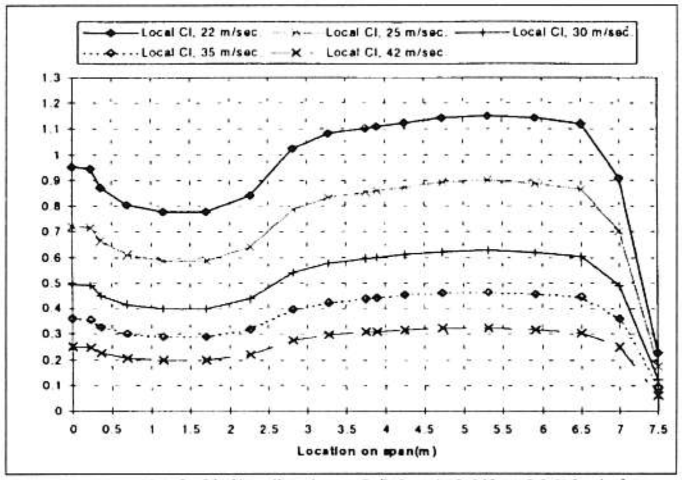


Figure 6: DUTAG Cl distributions. L/W = 1, W/S = 28.7 kg/m².

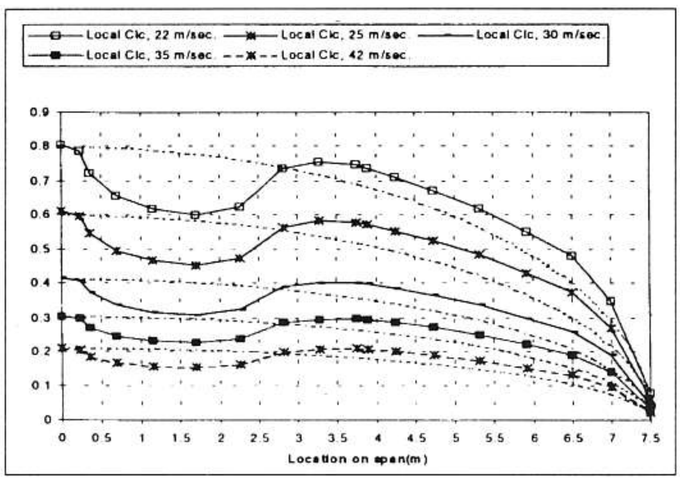


Figure 7: DUTAG Cl and ellptical Cl_c distributions. L/W/ = 1, W/S = 28.7 kg/m².

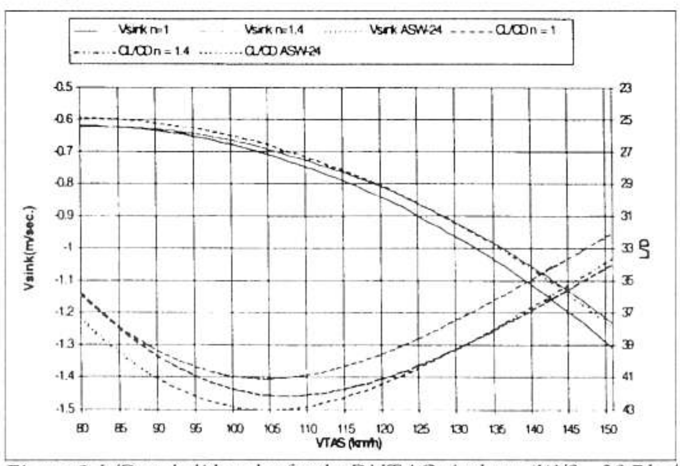


Figure 8: L/D and glide polar for the DUTAG airplane. (W/S = 28.7 kg/m². Xcg - Xac = 7%. L/W = 1 and L/W = 1.4

The lift distribution is over-elliptic for both the thermalling and the cruising flight situation. The aimed lift distributions are not realized yet. This could be modified by means of washout. The effects of such a design decision can be checked by means of a what-if program with NUR. The dragpolar is shown below in comparison to the ASW- 24.

The induced drag was calculated with a 3D-panelling program KK-Aero. The wing viscous drag by means of strip-theory. The fuselage viscous drag by means of a boundary layer program. The resulting Oswald factor was 0.65. The maximum glide ratio is still quite high because of the lack of the turbulent fuselage wake.

Gust and maneuvering

Objective:

In gust and maneuvering flight cases, the lift distribution should be under-elliptic to prevent high bending moments at the root. To make this scenario work the elastic axis should be far in front of the outboard nose wing sections. The wing is then twisted in such a way that creates less lift. A high maneuvering load factor can only be reached at very high velocities. A problem with the frontal location of the elastic axis will be the reduction in aileron effectiveness. At the moment: The DUTAG gust and maneuvering behavior will be discussed in a coming chapter.

Landing

Objective

When landing an over-elliptic lift distribution would be favorable. All wing sections should be working at the maximum local Cl. For a tailless wing like the DUTAG this lift distribution is possible because the DUTAG can be rotated much further than a conventional glider. To stop the rotation the elevator must be used like a landing flap. The FAUVEL AV36 and several soaring birds use this technique. It will be hard too prove this concept in a calculation.

At the moment:

No successful landing showing the above-mentioned features has been performed with NUR at this moment.

Gust and maneuvering loads

The gust alleviation of the DUTAG airplane has been one of the main objectives of the design. This behavior can be checked with the NUR program as described in the more extensive report reference3 In figure 9 and 10 the results are given for a gust +15 m/sec. and -15 m/sec. at the design gust speed of 55 m/sec. The reference that is used is the JAR formula for the N-factor due to a gust, this formula gives: N = 7.0 for a positive gust, N = -5.0 for a negative gust This N-factor can be calculated with NUR if linear wing sections are placed on the wing, no pitching is allowed and the plane is assumed rigid.

The loading for the 1-cos gust of 15 m/sec is minimal on the flexible wing as shown in figure 11. Also shown in this figure is the fact that even though the FAR N-factor for the linear wing sections is higher, the bending moment at the root is lower then the nonlinear wing sections. This is due to the fact that more lift is created on the outboard wing for the non-linear wing sections as can be derived from the transverse force build-up in figure 11.

The loading for the negative gust is shown in figure 12. For the negative gust only 0.5 sec. response is plotted in figure 10. The gust is hitting the airplane so heavily that it pitches into the stall at the positive N-factor. When a smaller gust of about 12 m/sec. is put on the wing the gust is damped the same way as a positive gust.

From these figures it may be clear that the FAR formula

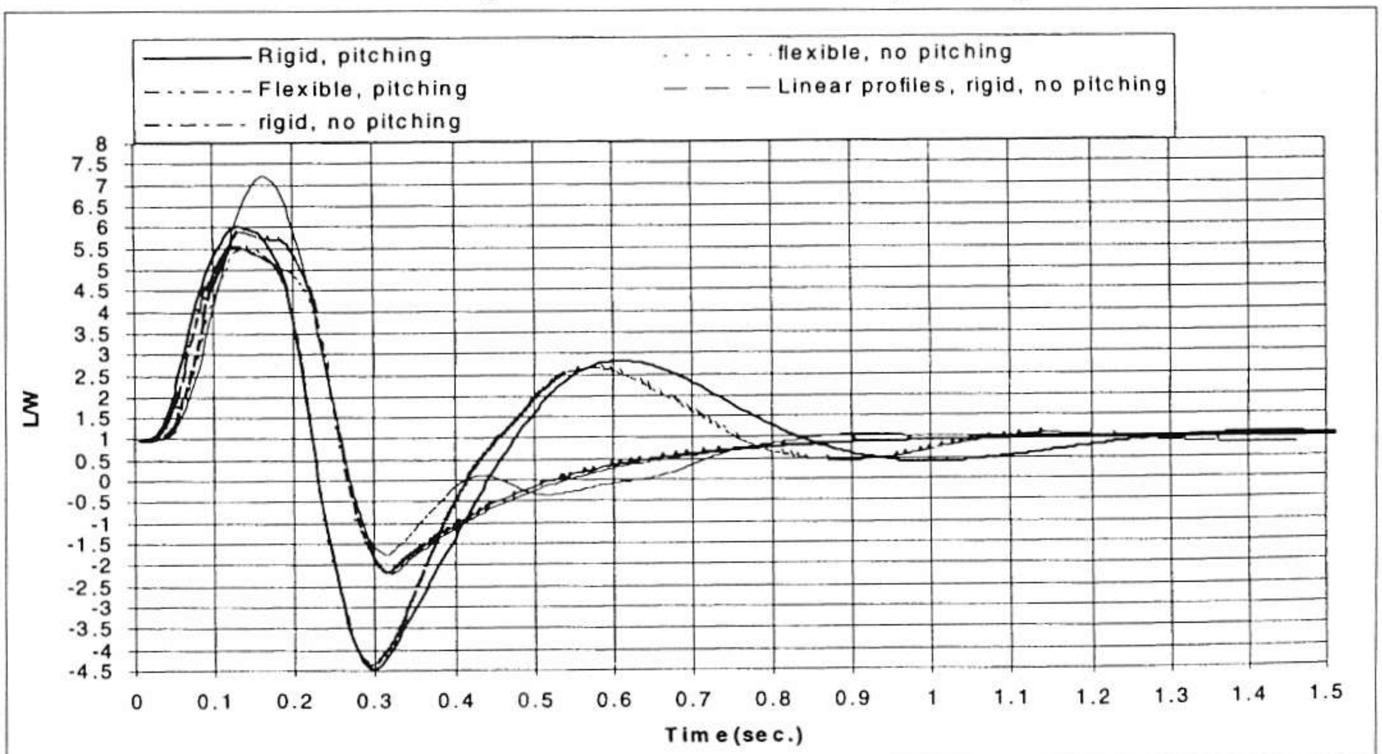


Figure 9: DUTAG response comparison for 1 - cos gust. Maximum wind speed 15 m/sec at 7.92 m in the gust, 1000 m ISA, VTAS = 55 m/sec.

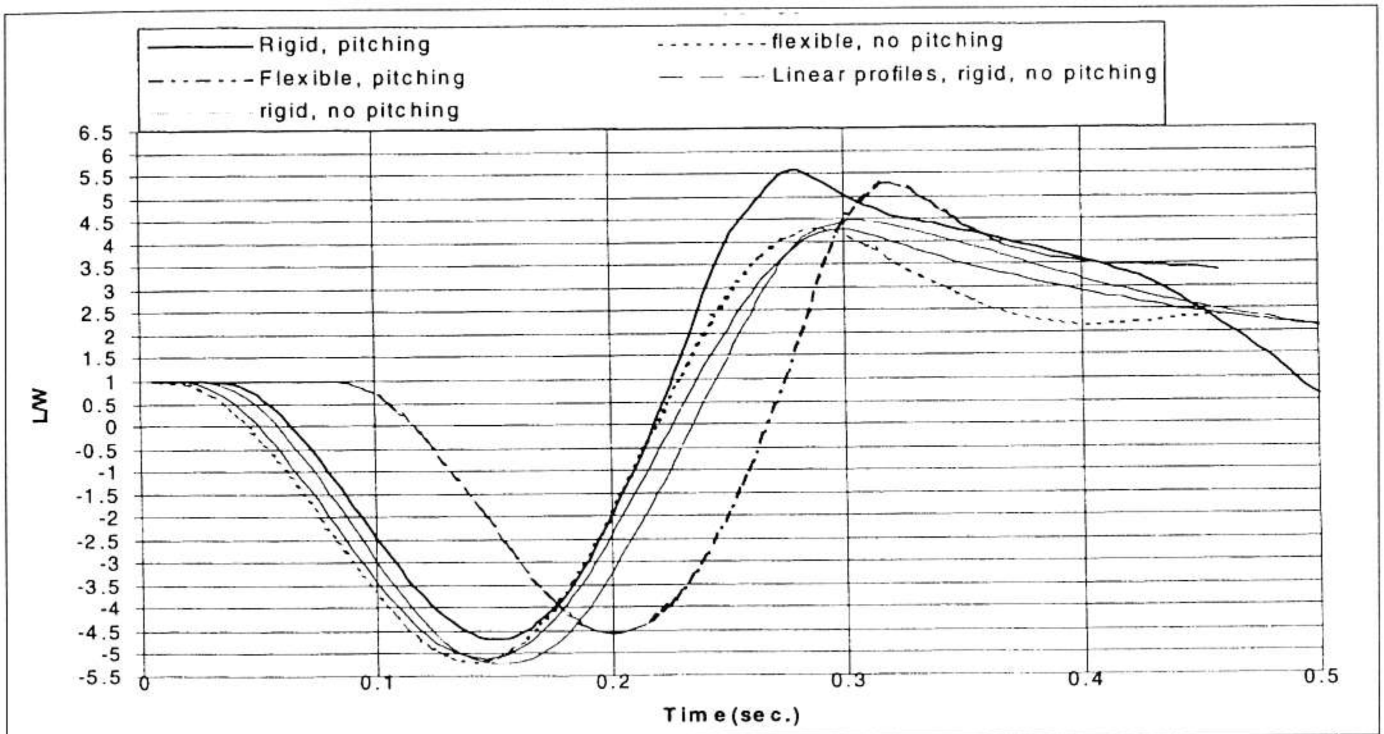


Figure 10: DUTAG response comparison for 1 - cos gust. Maximum wind speed -15 m/sec at 7.92 m in the gust, 1000 m ISA, VTAS = 55 m/sec.

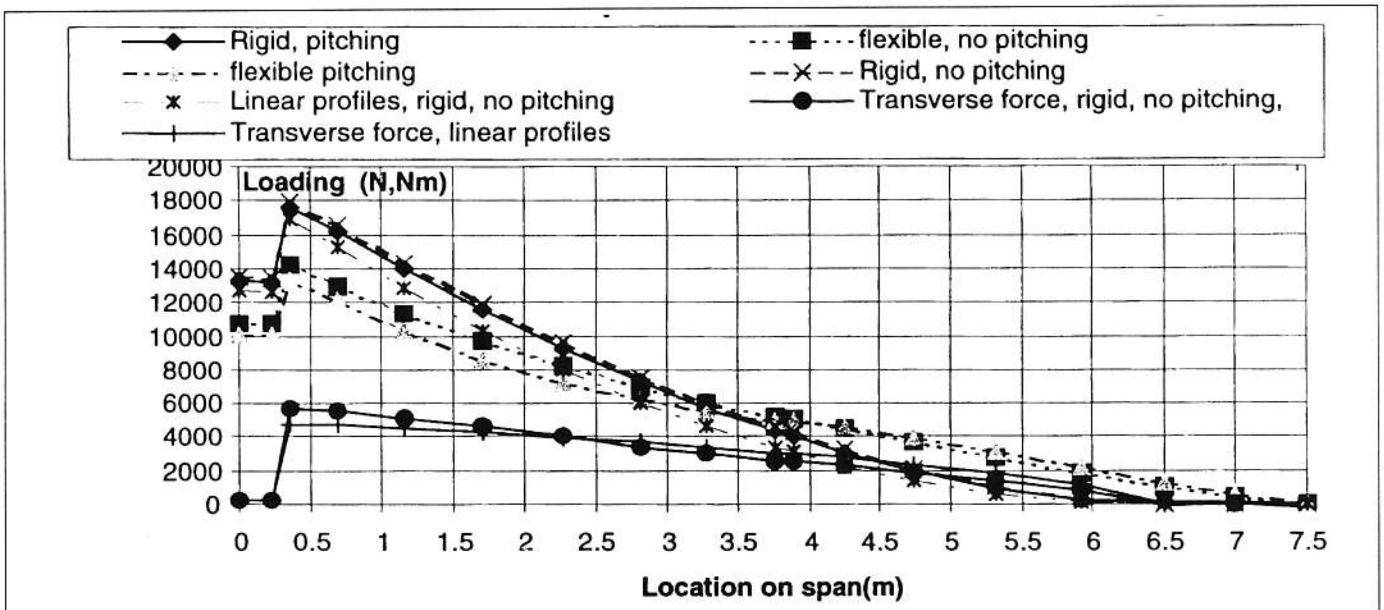


Figure 11: Maximum loading on the DUTAG wing for a 1-cos gust. Maximum wind speed 15 m/sec. at 7.92 m in the gust.

is probably to conservative for the DUTAG airplane. It could be possible that gust spectra exist that are not very friendly towards the DUTAG airplane. Because of this measured gust spectra will have to be crossed by NUR. Fatigue calculations can be performed very early in the initial design phase if the resulting loading sequence is saved.

The maneuvering loads have been checked by means of the static part in NUR. The loading for the N= 5.3 case is shown in figure 14. The Cl and Clc distributions, translation and rotation of the wing are shown in figure 13. The peaky CL distribution is due to the fact that wing section changes occur from station to station along the wing span as explained in reference.3.

The bending moment is much higher (16590 Nm) for the N=5.3 case compared to the maximum bending moment caused by the gust (13320 Nm), although the maximum FAR N-factor caused by the gust is higher (N= 5.55). To trim the airplane for the N=5.3 case the elevator destroys lift that must be delivered by the outboard wing sections. This means that most lift is created on outboard panels (see figure 12) and the bending moment will be higher then for a conventional wing. The objective Clc distribution for the N=5.3 case is not reached yet. The rotation of the wing is

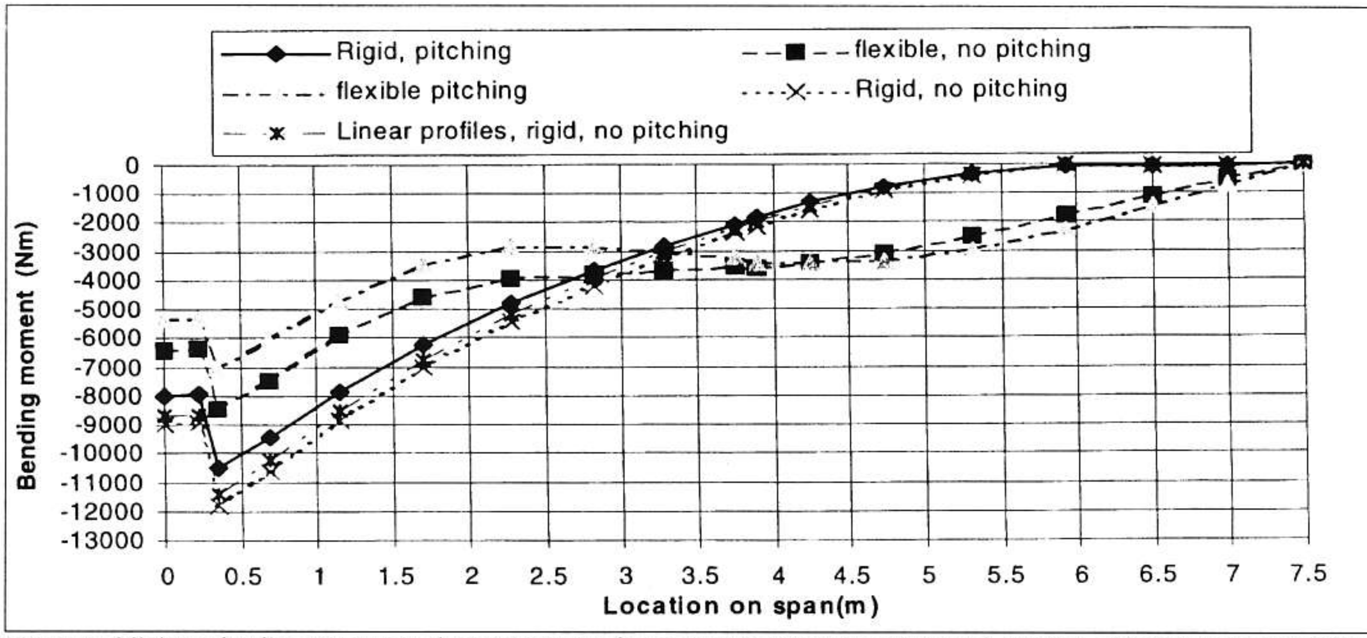


Figure 12: Minimum bending moments on the DUTAG wing for a 1-cos gust. Maximum wind speed -15 m/sec. at 7.92 m in the gust. 1000 m ISA. VTAS 55 m/sec.

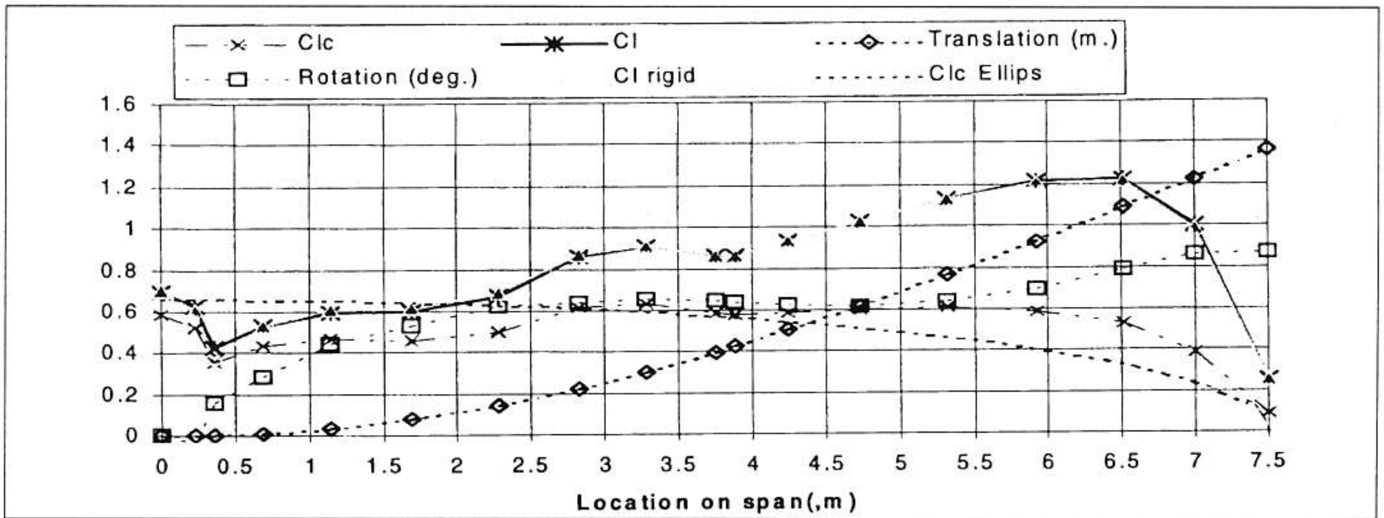


Figure 13: Characteristics on the DUTAG wing stations for the JAR N-factor 5.3 at 1000 m ISA. VTAS 55 m/sec.

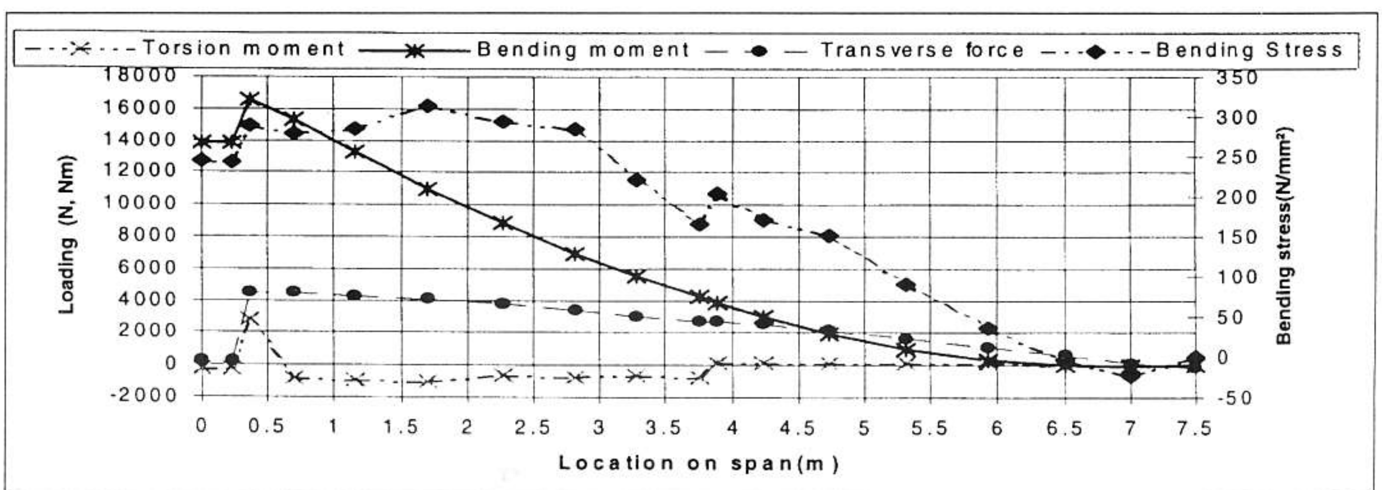


Figure 14: Loading on the DUTAG wing stations for the JAR N-factor 5.3 at 1000 m ISA. VTAS 55 m/sec.

Table 1: Technical data of the Standard Class Sailplane DUTAG.

Airworthiness in accordance with JAR-22, Category U.

Use : Competition flight in the FAI standard class.

Span	15 m	
Wing area	9.5 m^2	
Aspect ratio	23.7	
Fuselage length	4.3 m	
Cockpit seating height	0.81 m	
Cockpit width	0.64 m	
Height at fin	1.7 m	
Empty mass	151 KG	
Max. flight mass	390 kg	
Mass of wing	515 kg	
Max. wing loading	41 kg/m^2	
Min. wing loading	21 kg/m^2	
Waterballast	125 kg	
Cockpit useful load	120 kg	
Best L/D	41.3 at 105 km/h	W/S = 28.7 kg/m^2
Min. sink	-0,62 m/sec.	W/S = 28.7 kg/m^2
Min. speed	77 km/h	W/S = 28.7 kg/m^2
Max. speed (aimed)	300 km/h	
Maneuvering speed	198 km/h	W/S = 28.7 kg/m^2
Max. speed for strong turbulence	198 km/h	W/S = 28.7 kg/m^2
for aero tow	-	
for winch launch	max. -	
for landing gear extended	-	
for airbrakes extended	-	

still positive on the outboard wing sections as can be seen in figure 13. If the rotation of the wing would be negative on the outboard wing sections (more backsweep or forward location of the elastic axis at the outboard wing sections), the N-factor 5.3 can only be reached at a higher speed. The stall protects the airplane.

If the airplane cg is lying forward of 7 % MAC, the N-factor 5.3 cannot be reached in a static calculation due to premature stall. Again the stall protects the airplane. The JAR-formula due to a gust does not take this protection into account! Because the bending moments due to the maneuvering loading are much higher, the gust maneuvering speed Vb. can be chosen higher until the loadings are leveled. This opportunity has not been investigated yet.

Conclusions and future prospectives.

In present form the DUTAG glider is not performing better then conventional gliders like the ASW-24. The DUTAG tailless wing is probably an aero-elastic success concerning gust-alleviation behavior, "probably" because real gust spectra will have to be crossed by means of the NUR program and a flutter calculation still has to be done by means of a more advanced program.

The DUTAG is not flexible enough to show improvement in thermalling and cruising behavior compared to a rigid airplane. To improve this behavior the back sweep of the outboard wing section could be enlarged. How many degrees can only be investigated by means of "what-if" programs to respect all other constraints that can become active. The same effect can probably be created with a more forward elastic axis location at the outside wing sections. Due to these decisions, aileron reversal could become an important constraint, symmetrical movements will have to be incorporated in NUR.

To turn the DUTAG into a successful glider it will need a small fixed horizontal stabilizer on top of the vertical tail. The NUR program will have to be adapted to check design decisions concerning this horizontal stabilizer.

Because the aeroelastic effects have been controlled almost geometrically, there is still much design freedom regarding lay-up and placement of the main longeron.

The DUTAG proves that the development of this glider would not be possible without the ICADS philosophy that resulted in NUR, Mr Spar and the WEIGHT program.

References

1 G.J. Ransijn, Programs for ICADS,TU Delft, Faculty of aerospace engineering, Delft, 1995

2 B.F. Seffinga, Memorandum M-706, ICADS 0.1,TU Delft, Faculty of aerospace engineering, Delft, 1995

3.M.S.G.Wittebrood, Design, analysis and development of a high performance tailless glider by means of an Interactive Computerized Aircraft Design System, TU Delft, Faculty of aerospace engineering, Dem, 1997

4 R.J. Zwaan, Aeroelasticity of aircraft. TU Delft, Faculty of aerospace engineering, Delft, 1990

5 K.Nickel,M.Wolfahrt, Schwanzlose Flugzeuge: ihre Auslegung und ihre Eigenschaften. Birkhauser, Basel 1990

Table 2 : Table comparing some airplane wing loadings. The minimum weight is the empty weight plus a 50 kg. pilot.

Aeroplane	A	S(m^2)	weight(kg) empty	min.	max.	wing loading.(kg/m^2) min.	max.	Cl/Cd_{max}
SB-13	19.4	11.6	285	335	425	29	36	41.5
AK-5	21.1	10.6	245	295	485	23	46	41
AFH 24	21.8	10.2	225	275	475	27	46	42
ASW 24	22.5	10.0	220	270	500	27	50	43
SZD-55 *	23.4	9.6	210	260	500	27	52	48.7
DUTAG	23.7	9.5	150	200	390	21	41	41.3
ASW 27*	25.0	9.0	225	275	500	30	55	48
GENESIS I	20.1	11.2	222	272	525	27	47	43.2 (calculated)

* is not standard class