EVALUATION OF CANOPY JETTISONING SYSTEMS FOR SAILPLANES

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1. INTRODUCTION

Over the past twenty years, there have been a number of glider accidents in which the occupants were killed either because they were unable to jettison the canopy, or because they did not jettison the canopy in time. For this reason, the West German Federal Ministry of Transport has ordered the Fachhochschule in Aachen to analyze such accidents, to evaluate the existing canopy jettisoning systems and to provide a data base for a future revision of the Joint Airworthiness Requirements 22. This paper includes an abstract of the accident analysis and of the inventory of the existing jettisoning systems. Furthermore, it presents some results of investigations into the determination of the time period required to operate the jettison levers and to leave the cockpit. In addition, wind tunnel tests have been carried out to provide an experimental verification of the aerodynamic forces and moments acting on the canopy.

2. ACCIDENT ANALYSIS

The analysis of sailplane accidents has been carried out using documents supplied by the LBA (Luftfahrtbundesamt, Federal Office of Civil Aeronautics). In most of these accidents the occupants were forced to bail out to survive. Between 1975 and the middle of 1988 there were 34 accidents involving 58 gliders of various types registered in Germany.

The main cause of the accidents was a mid-air collision particularly during thermal circling. The damage was severing of the fuselage, a part of the wing or a part of the tail followed by a total loss of control and a very high rate of descent, involving a vertical or spiral dive or a rotation around a body axis. In some cases, the g-load prevented, and in others facilitated the escape from the glider. The time between collision and impact on the ground was very short.

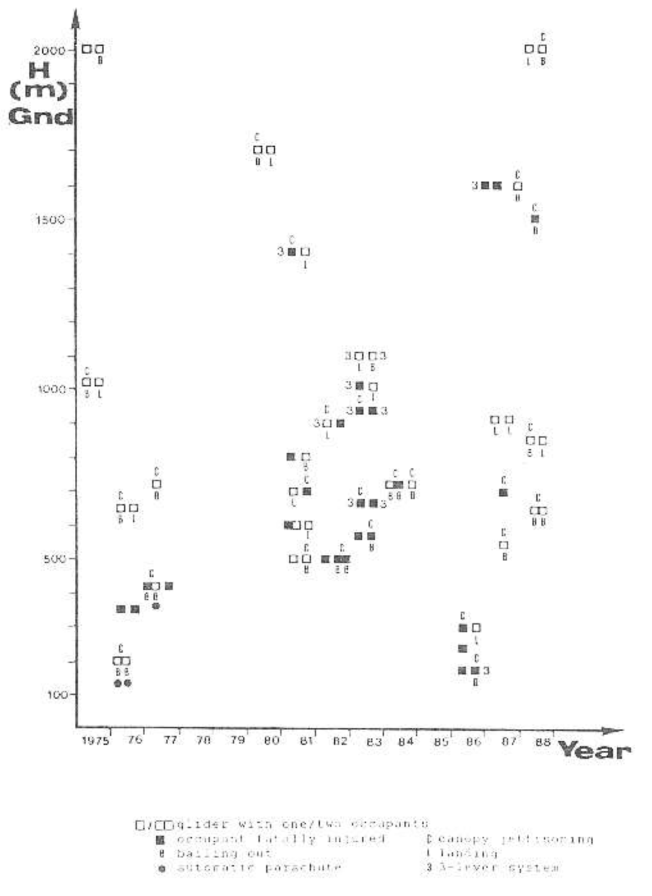

Figure 1. Heights of the accidents.

Figure 1 shows the heights of the accidents registered between 1975 and 1988. Each point represents an occupant, black indicating that the occupant was killed. 28 of the 64 occupants were fatally injured. For each accident, the figure shows whether the canopy was jettisoned (C), the occupant bailed out (B) or whether the pilot landed the sailplane (L). 14 of the 58 gliders were landed. 32 occupants jettisoned the canopy and tried to bail out. 13 of these were killed as a result of the low height or other difficulties. A malfunctioning of the jettison mechanism could not be proven.

It becomes apparent that most of the accidents occurred below a height of about 1200 m. The percentage of the persons killed below 1200 m is higher than that of the persons killed above 1200 m. The lowest height at which an occupant survived is about 200 m. It must be mentioned that this glider was equipped with automatic parachutes. Without an automatic parachute, the lowest height at which anyone survived was 500 m (1981). There is only one accident above 1200 m (1981/1400 m) in which the pilot was killed because the time to jettison the canopy and leave the cockpit was too short. But, there are many such accidents below 1200 m.

Furthermore, the analysis shows that the percentage of persons killed with a 3-lever system is higher than that with a 2 or 1-lever system. In four accidents (1980/1400 m, 1983/1100 m, 1983/940 m, 1983/620 m) the occupants had difficulties operating the jettison levers. In all these cases, the gliders were equipped with a 3-lever system.

In the light of this analysis, it must be mentioned that after a mid-air collision there is normally a total loss of control and if the occupant has survived he must jettison the canopy and bail out immediately after the collision and pull the ripcord directly. There is no time for information or thinking. In order to improve the canopy jettisoning system it is necessary to shorten the time period for jettisoning and leaving the glider by constructive solutions. Furthermore, the occupant must be able to operate the jettisoning levers without delay, which presupposes familiarity with the jettisoning procedure.

3. INVENTORY

An inventory of the existing jettisoning systems establishes that sailplanes are equipped with different systems depending on manufacture and type of glider. There are a variety of jettison levers. One can find 1-, 2- or 3-lever systems. The pilot can operate them with either one or two hands. Sometimes a specific opening sequence is necessary. The method of opening may be different; in some gliders the levers must be pushed and in others pulled, or in a 2-lever system one lever must be pulled and the other pushed. The locations of the levers as well as their shapes are different. One can find knobs or handles on or above the instrument panel, on the right or left of the canopy or on the cabin wall. There is only one common denominator: all levers for jettisoning the canopy are red colored.

It must be emphasized that these levers are only used in an emergency. Such situations occur after a collision with an ensuing loss of control, and comes as a surprise to the occupant. The pilot is very excited and his arousal is very high. There is a considerable disorganization in thinking ability and a loss of memory occurs (1). The pilot has problems in remembering the correct operation to jettison the canopy. In this situation, when a quick and accurate operation is needed, the occupant is often unfamiliar with the jettisoning procedure because he often flies different types of gliders and does not inform himself of, nor practice the handling of the emergency system. This fact delays or prevents the correct operation of the jettisoning levers. Thus, a standardization of this emergency system is of prime importance.

In addition, the cockpit design differs in many sailplanes. there are various shapes of instrument panels, such as a fixed panel from the left to the right cabin wall, or a mushroom shaped panel, and in some cases the panel is raised when the canopy is jettisoned. In the case of a fixed panel, the occupant has to pull up his legs before he can bail out; with a mushroom shaped panel the pilot can swing his legs over both the panel and the cabin wall to leave the cockpit. There is no common bailing out procedure. Furthermore, the exit is complicated by protruding levers or pins.

4. PERIOD FOR JETTISONING AND EXIT

The average time period required to jettison the canopy and leave the cockpit was measured in an extensive test program in a cockpit of an LS-4. Approximately 25 test persons between the ages of twenty and sixty participated. The following parameters were tested with regard to the time needed to jettison the canopy and open the safety belt: number of levers, pushing away the canopy and age of the occupant. The time taken to leave the glider was measured with regard to the parameters: fixed panel, mushroom shaped panel, raised panel, age of the occupant, load factor and height of the cockpit wall.

Figure 2 shows the values of the periods and the spread with 1-, 2- or 3-lever system. It furthermore shows the time saved if the canopy does not have to be pushed away by the pilot, since it is pulled away by the airstream. The average period required to operate a 3-lever system and to push away the canopy is about 3.5 seconds. With a 1-lever system or a 2-lever system, which is operated simultaneously with both hands, this period can be reduced to about 2.5 seconds. If the canopy is pulled away automatically by the airstream, the time saved is about 1 second, irrespective of the number of levers. This means that a total of 2 seconds could be saved. An influence of the pilot's age could not be determined.

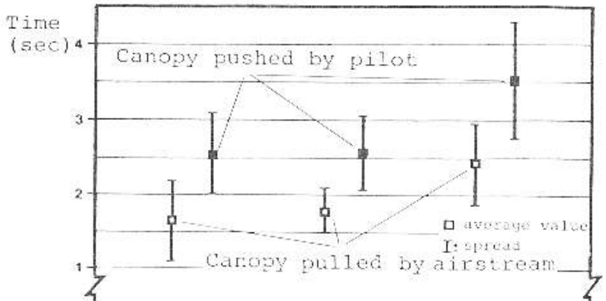

Figure 2. Average time period to jettison the canopy.

Figure 3 shows the average time period and the spread to leave the glider after opening the safety belt with a load factor of 1 and 1.5. The period depends on the physical condition and the age of the occupant. A well trained young person needs about 2.6 seconds whilst an elder occupant needs about 4.5 seconds. This period increases with an increase of the load factor. The black points show average values with a positive load factor of 1.5 g which has been simulated by means of lead-weights distributed over the body. For trained young occupants, the average period increases to 3.5 seconds, and for occupants older than forty the time then needed is about 7.2 seconds. Some elder pilots were unable to leave the cockpit due to this load-factor.

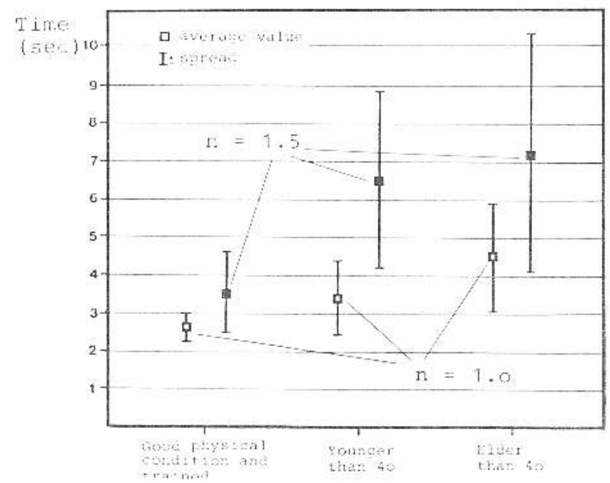

Figure 3. Average time period needed to leave the cockpit depending on age and physical condition.

Figure 4 reveals the differences due to the shape of the instrument panel. These values are only valid for young occupants. With no panel (the panel was jettisoned with the canopy) the period is reduced to 2.4 seconds, and a fixed panel which forces the pilot to retract his legs, increases the period to about 3.4 seconds.

A further essential factor can be seen in Figure 5, based on measurements with young persons. The height of the cockpit wall alters the time period. A reduction of the height to 22 cm reduces the period to 2.7 seconds and an increase in the height of the wall to 52 cm increases the period to 4.5 seconds.

These values show how a cockpit design may help reduce the time required to leave the glider.

5.0 WIND TUNNEL EXPERIMENTS

One of the major questions concerning jettisoning the canopy is the size of the aerodynamic force when opening the canopy. A wind tunnel test was carried out to determine the overall aerodynamic forces during the supposed initial opening phase. The tests were carried out in the Eiffel Wind Tunnel of the FH Aachen. The maximum dynamic pressure was about

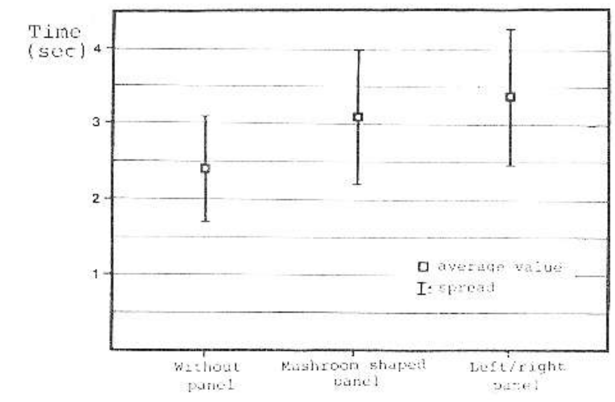

Figure 4. Average time period nedded to leave the cockpit depending on shape of the instrument panel.

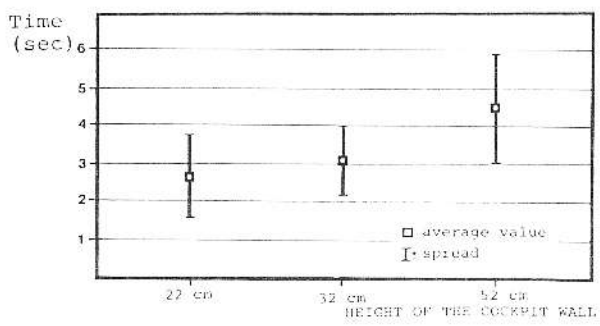

Figure 5. Average time period needed to leave the cockpit depending on height of the cockpit wall.

670 N/m² approximately 120 km/h with a nozzle area of 3 m².

The measurement of the pressure distribution around the fuselage is insufficient for these experiments since the pressure inside the cockpit also influences canopy forces. For this test, force transducers measuring the whole aerodynamic forces in x- and z- direction were used.

The z- force transducer can move in the x- direction while the x- force transducer can move in the z- direction. The canopy itself is aligned along the y-axis to balance the side force. The mechanism allows less jamming in the case of side force.

The aerodynamic forces were measured with the canopy in a closed position and when the front part was raised. The angle of attack was varied from -5 to +10 degrees and side slip angle from -15 to +15 degrees.

5.1 Aerodynamic forces in the closed position

The results are shown in the following figures. Figure 6 shows the normal and tangential forces (relative to the canopy weight) with the angle of attack. The opening of the cockpit ventilation and canopy window has an important influence. An opening of the ventilation and closing of the window increases the force to 120 percent of the canopy weight, due to the increase in the pressure inside the cockpit, and an opening of the cockpit window descreases the force due to a pressure reduction inside the cockpit. The tangential force alters slightly by changing the angle of attack, though to a lesser extent of about 8 percent of the canopy weight. The influence of cockpit ventilation and canopy window is obvious, though not so important owing to the low force. The direction of the force, which pulls the canopy to the front part of the fuselage, may be of greater interest.

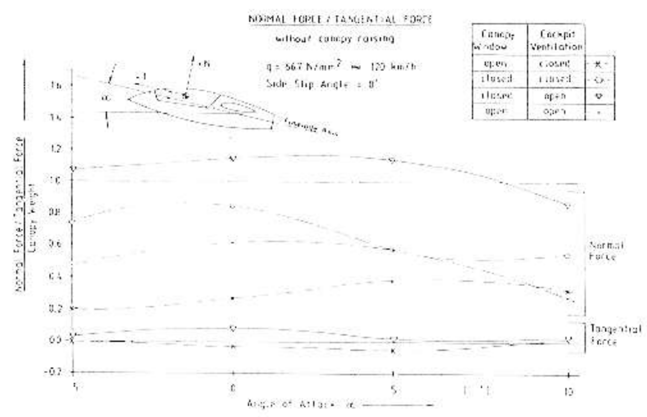

Figure 6. Normal and tangential forces acting on the closed canopy.

Figure 7 shows the normal forces with an alteration to the side slip angle at an angle of attack of 0 degrees. The normal force increases with an increase of the side slip angle, whereby the values are nearly symmetrical. With a closed window and an open ventilation they increase from 105 to 180 percent whereby with an open window and closed ventilation they increase from 30 up to 130 percent.

Figure 8 gives an impression of the moments acting on the canopy. Between an angle of attack of -5 degrees to +15 degrees, the measured moments are totally negative, i.e. nose heavy. The consequence being that in this region the moments try to close any forward opening.

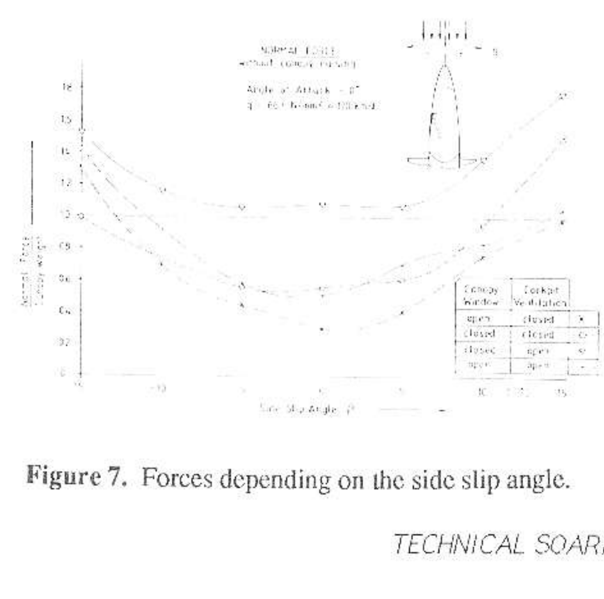

Figure 7. Forces depending on the side slip angle.

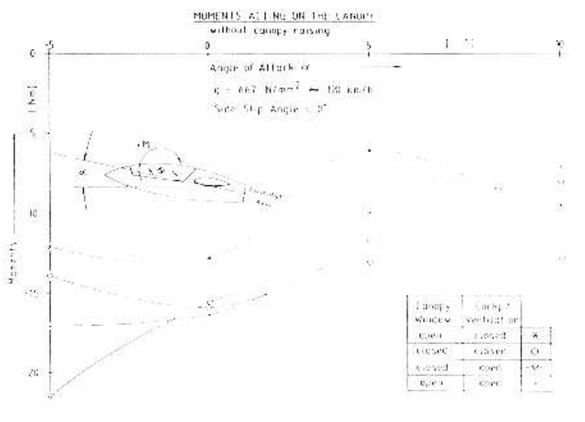

Figure 8. Moments on the closed canopy.

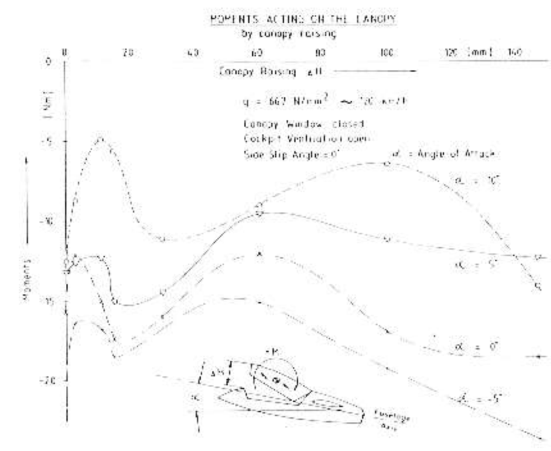

Figure 10. Moments on the raised canopy.

5.2 Aerodynamic forces in a raised position

In these experiments the front part of the canopy was raised up to 150 mm. As in the closed position (normal flight), the influence of the cockpit ventilation and the canopy window had an effect up until an opening of about 60 mm.

Figure 9 shows the normal and tangential force in relation to the forward opening (ventilation open, window closed). The most important factor is the decrease in force with a small opening less than 30 mm. If the gap is greater, the force increases with the opening. If the canopy is open so that there is a small gap between fuselage and canopy, the airflow surrounding the fuselage will produce a low pressure inside the cockpit. This underpressure tries to keep the canopy on the fuselage. The size of the force depends on the angle of attack. Apart from the angle of -5 degrees, the normal force is always greater than the canopy weight.

The tangential force does not change very much between an angle of attack of -5 and +10 degrees. These forces pull the canopy forward until the opening is approximately 60 mm, as in the closed position. The direction then changes and the tangential force pulls the canopy backwards.

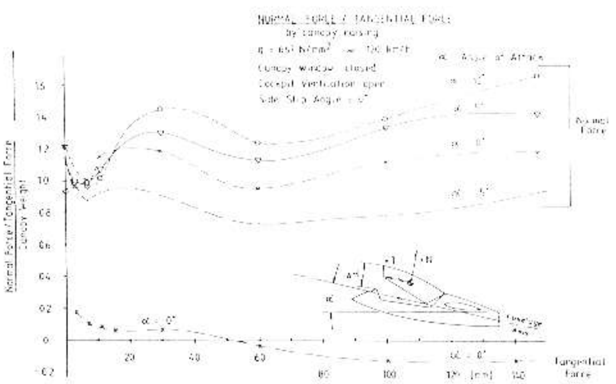

Figure 9. Normal and tangential forces on the raised canopy.

Figure 10 shows the moments acting on the canopy. As in the closed position, the overall moments are nose-heavy. This means the center of pressure lies behind the center of gravity. With a low raised canopy the forces and, therefore, the negative moments descrease. In the case of an increase of the angle of attack, the measured values clearly decrease, which indicates that the distance between the centers is reduced.

6. CONCLUSION

The accidents requiring a parachute jump were normally caused by a mid-air collision and occurred below a height of about 1000 m above ground. The time between collision and impact on the ground is very short, whereby each second is of crucial importance. The sailplanes are equipped with different jettisoning systems which delay or prevent the correct operation of this emergency system. Thus, a standardization of the numbers, the location and the method of opening is of prime importance so that the pilot is always familiar with the jettisoning procedure. There should not be more than 2 levers for jettisoning and the panel should be raised with the canopy to speed up the canopy jettisoning. The canopy itself should be pulled away automatically by the airstream. For this, the front part of the canopy should be raised by at least 60 mm. The investigation program has not finished yet and the final results will be shown later.

7. REFERENCES

(1) Beaty, D. 1969: The Human Factor in Aircraft Accidents, London, Secker & Warburg