Inflight Measurements in Circling Flight and Validation Calculations

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Abstract: Circling flight is an important part of the design of sailplanes or other slow flying and circling aircraft. The design and calculation tools for sailplanes are very well validated for straight flight conditions and plenty of validation data exists. In order to improve circling flight, better prediction tools are needed that also need to be validated using flight test data, see [3]. Especially the rudder angles in circling flight have a strong influence on the lift distribution of the wing and the horizontal and vertical fin. While the straight flight is very stable, under circling conditions trimmed flight states at different angles of side slip can be achieved and the measurement is not as stable as in straight flight. The measurement at a defined bank angle is unstable, because the aircraft tends to leave this condition in most cases automatically. Only limited data is available in literature for sailplanes in turning flight or the data is simplified, e.g. [2]. Measurements with the research aircraft Discus-2c DLR were conducted (see [4]), to collect data of rudder angles and to measure sink rates at defined circling flights. The data measured will be used, to validate prediction tools for future sailplane designs, especially calculations of the rudder deflections under fully trimmed circling conditions. 3D scan data for the geometry of the Discus-2c DLR [5] was used for first validation calculations with the multiple vortex-line method LiftingLine V3.1, which is capable of calculating circling conditions, see [6].

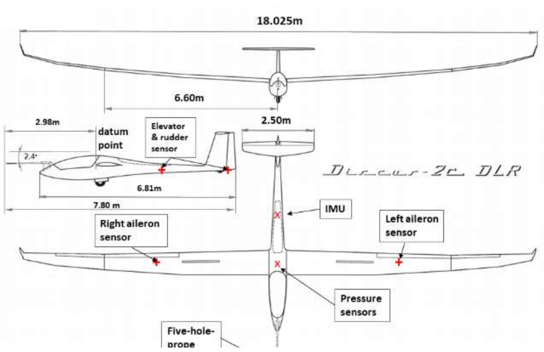

Figure 1: Discus-2c DLR: Dimensions and Rudder-Angle-Sensor Positions [4]

Keywords**:** circling flight, turning flight, validation calculations, inflight measurement, sailplane,

Introduction

The Discus-2c DLR is a modern 18m class sailplane with winglets and without flaps, built by the german manufacturer Schempp-Hirth. The type depends on the Discus-2c sailplane and was modified with a nose boom and a large equipment bay in the fuselage. It is also equipped with rudder sensors near to each rudder, high resolution pressure sensors connected with the five hole probe in the nose boom and actuators inside the fuselage connected to the steering rods of the ailerons and the elevator, (see figure 1).

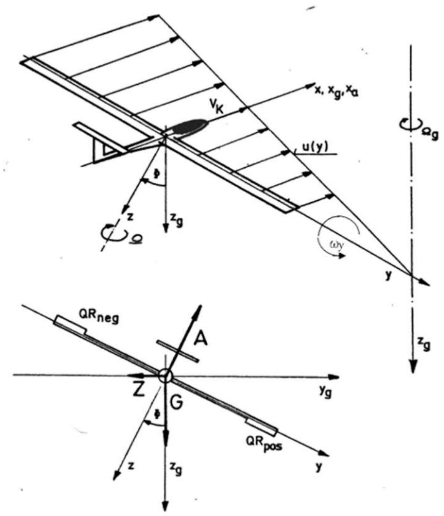

Figure 2:Varying flow conditions while circling, from [7], modified

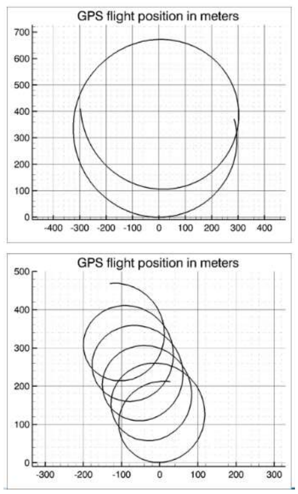

Figure 3: GPS positions of two test points at different bank angle: upper fig. +19°, lower fig. -50°

An experimental autopilot is capable of stabilizing the bank angle and the airspeed, so all measured values are averaged for each quasi static bank angle. The straight flight polar of the aircraft is well known and can be taken into account for validation of sink speed calculations in circling flight, with the methodology used in [1] and [2]. The measured values are compared to calculated values and the differences are shown and discussed.

Methodology

The research sailplane Discus-2c DLR was used for two test flights in July 2019 at measured weight and balance condition. The test flights took place at the Research Airport Braunschweig in the morning in calm air conditions. The sailplane was towed to FL95 and the test program depended of 22 circling flights at different bank angles and 5 straight flights for air mass movement correction at all. The bank angle while circling and the prescribed airspeed were stabilized by the two-axis experimental autopilot. The side slip angle was stabilized by the pilot by rudder input. Each test point was stabilized for at least 90 seconds. The airspeed flown in the experiment, was prescribed to be near a lift coefficient of 0.8, to avoid detached flow and nonlinear conditions. This requirement resulted in different airspeed for each bank angle, due to changing acceleration forces in circling flight. The GPS flight path in 2D for two test points are shown in figure 1. The differences in turning radius, the amount of turns in the same time and the influence of varying flow conditions in circling flight, see figure 3, show the need for calculation tools for circling conditions capable to optimize the design for future aircraft.

The calculations with LiftingLine are done with the scanned geometry data of the Discus, in order to have nearly no influence of the differences in geometry between calculation and measurement. The influence of changing air density with flight altitude must also be considered, see [8], because of changes in radius at different TAS (TrueAirSpeed).

Sensors and Data

The data measured consisted of several sensors. Air data was measured at the five-hole probe at the nose boom and a temperature/humidity sensor mounted at the fuselage under the right wing. The rudder deflections were measured by four rudder sensors, mounted close to each rudder. The inertial motion and acceleration were measured by an inertial measurement unit (IMU), mounted in the equipment bay and additionally used for the correction of the air data. The measured data of all test points in detail and the formulas used for correction in circling flight will be shown. The geometry of the Discus-2c DLR was optically measured and its 3D geometry is used for validation calculations.

Conclusion

Two test flights including 27 test points were conducted and data for circling flights between +50 and −54 degree bank angle at an lift coefficient approximate 0.8 were measured. The bank angle and the airspeed were stabilized by the experimental autopilot. The sideslip angle was steered manually by the pilot. The test points were stabilized over a period of at least 90 seconds. The air data measured was partly corrected for circling motion and the data and formulas will be shown. The data is used for the validation of new prediction tools, which are able to optimize the design of future sailplanes and motor gliders under circling conditions. For validation, the deflections of the ailerons, elevator and the rudder are calculated for the flight parameters flown in the experiment and the deviations between measurement and calculation are shown and discussed.

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