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A Handling Qualities Analysis of the Wright Brothers' 1902 Glider

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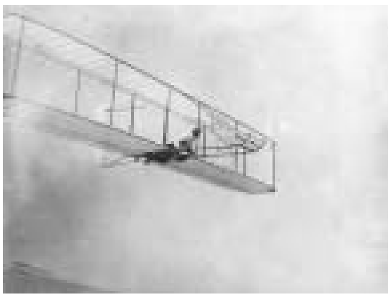
Abstract

This paper will present a handling qualities analysis of the aircraft on which 3-axis control was first implemented and tested in hundreds of glides during late October 1902. Results will be taken from a research project underway at the University of Liverpool where the technical achievements of the Wright Brothers in the period 1900-1905 are being assessed using modern analytical and experimental methods. In his book, 'Visions of a Flying Machine' (Ref 1), Peter Jakab writes "*If the Wright Brothers are to be cited as the inventors of the airplane based on having resolved all the fundamental problems of mechanical flight then it is not necessary to look beyond the 1902 glider… what was innovative about the (1903) Flyer was present in the early 1902 glider*". After struggling with performance and control problems in their 1901 glider and initially with control difficulties in the 2-axis control (pitch and roll) version of their 1902 design, the Brothers came up with the idea of interlinking the movement of the wing warp with the vertical rudder, hence providing a degree of turn co-ordination and largely counteracting the adverse yaw effects caused by the strong warp drag. As he prepared to return home to Dayton in late October 1902, Orville wrote to his sister Katherine, "*The past five days have been the most satisfactory for gliding that we have had. In two days we made over 250 glides, or more than we had made all together up to the time Lorin left…. we now hold all the records! …The largest machine we handled in any kind of weather, made the longest distance glide, the longest time in the air, the smallest angle of descent, and the highest wind!!!*" (Ref 2, p 279) From letters and diary notes we can judge that the Wrights were very satisfied with their achievements. Wilbur later wrote (Ref 2, p 323) "*With this improvement our serious troubles ended and thereafter we devoted ourselves to the work of gaining skill by continued practice. When properly applied the means of control proved to possess a mastery over the forces tending to disturb the equilibrium*." The control concept 'invented' on the 1902 glider (Fig 1) was to remain a fundamental part of the Wright aircraft designs for year to come.



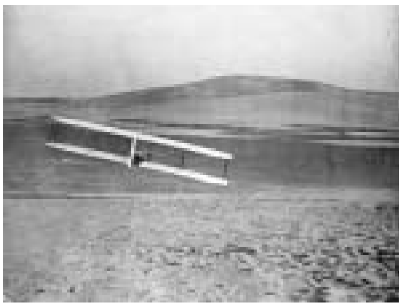


Fig 1 Wilbur and Orville Wright Flying the first aircraft with 3-axis control over the Kill Devil Hills in October 1902

Critical to the Wright Brothers' success in 1902 was their approach to solving the problems they had experienced with their 1901 glider. They embarked on a design review and conducted a series of wind tunnel experiments which were to equip them with data and knowledge on applied aerodynamics significantly in advance of the 'state-of-the-art.

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The paper will present the handling qualities analysis within the following themes:

1. **Aerodynamic performance;** Fig 2 shows a comparison of the Wright's measurement of lift coefficient of their aerofoil No 12 (aspect ratio 6) with that from a 1/8th scale model of the 1902 glider from the Liverpool project. With nearly twice the aspect ratio of the 1901 wing, the lift curve slope of the 1902 design was increased and the characteristic flat top after C_{Lmax} is shown in the Figure. Although the drag increased significantly, there was very little loss of lift at high incidence on the thin wings of the early Wright aircraft.

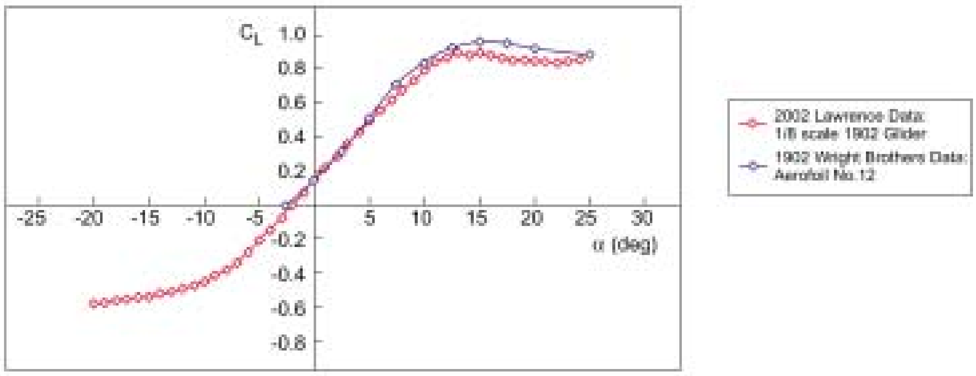

Fig 2 Comparison of Lift Coefficient (Wright aerofoil No 12 with Liverpool 1/8th scale wind tunnel model)

2. **Longitudinal Control and Stability**; Pitching moment coefficients derived from wind tunnel measurements on the 1902 glider configuration for 3 canard settings are shown in Fig 3. Strong nonlinearities are clearly present, particularly at high incidence and at maximum canard settings, but the basic pitch instability caused by the positive slope of $dC_m/d\alpha$ at zero canard can clearly be seen. At incidences above 10deg the slope of the pitching moment curve is seen to reverse, indicating a reversal of the movement of centre of pressure with incidence. With the relatively high camber of the wing sections used by the Wrights, they were continually plagued by strong movements of the centre of pressure, but at high alpha the reversal came as a relief as it resulted in a stable pitch motion, leading to a safe stall characterised by a flat descent at very low speed.

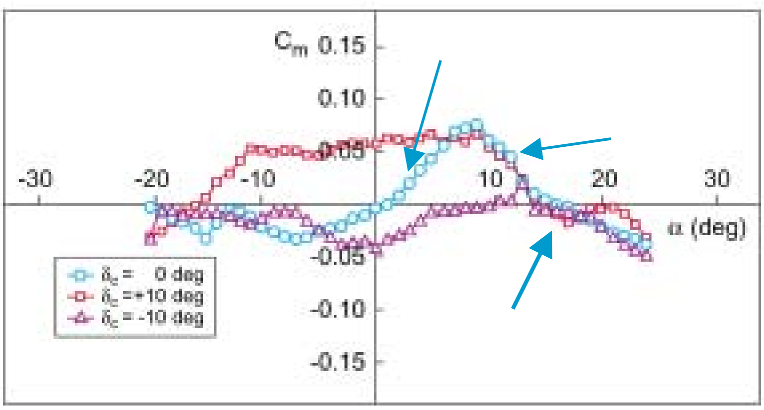

Fig 3 Pitching Moment Coefficient measured on the 1/8th scale wind-tunnel model of the 1902 glider

3. **Modelling and Closed-Loop HQ Analysis**: The paper will describe how the aerodynamic data has been assembled together with structural, inertial and control system components into a FLIGHTLAB simulation and how this has been used to conduct a detailed handling qualities analysis of the aircraft. Figure 4 shows root loci for the longitudinal characteristics with a simple pure gain pilot controlling pitch angle. The open loop divergence is suppressed but at the expense of reducing stability in the 'new' short period mode. This weakly damped oscillation was to feature in many of the Wright flight tests for years to come.

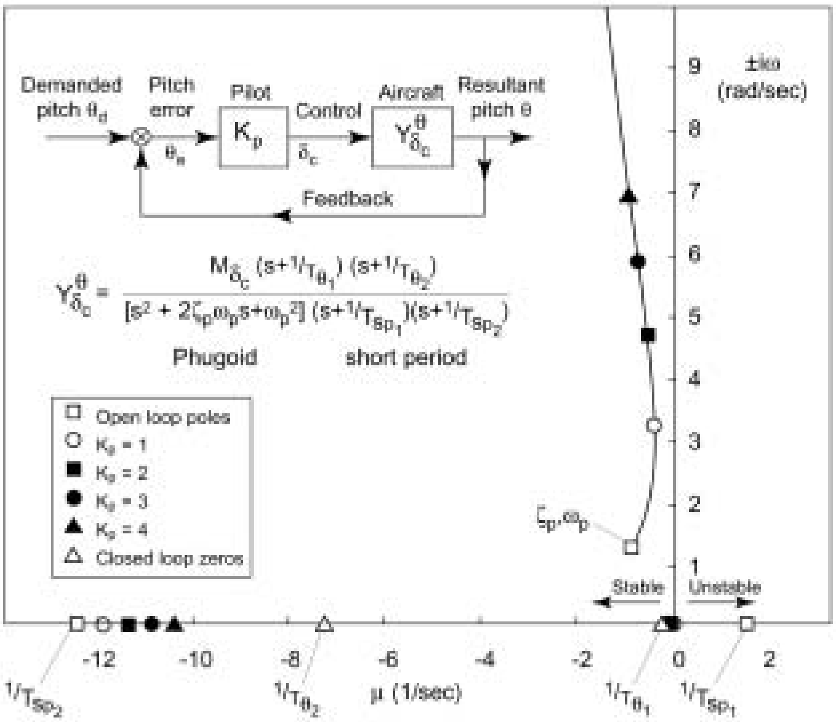

Fig 4 Closed-loop analysis of the Pitch Dynamics of the 1902 Glider

4. **Lateral-Directional Control and Stability**; Similar results will be presented for the lateral-directional dynamics. Here the Wrights also opted for an unstable configuration to enhance the manoeuvrability.

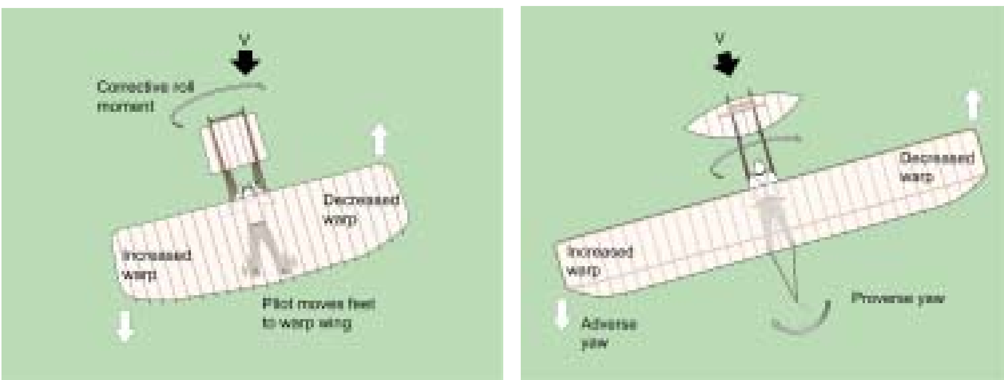

Fig 5 Comparison of the yaw response of the Wright's 1901 (2-axis control) and 1902 (3-axis control) configurations to corrective warp control

Fig 5 illustrates how the Wrights' warp-rudder inter-connect provided a proverse contribution to the yaw motion. The paper will discuss this control solution within the context of the October 1902 flight tests described by the Wrights.

5. **Piloted HQ Tests**; Finally, the paper will present results from handling tests conducted on the Liverpool Flight Simulator, featuring six motion axes and six visual channels (Ref 3). This aspect of the project brings us most closely to the experience of the Wright Brothers (where, as Orville says, "..*in two days we made over 250 glides*"), as they developed their flight control concept, preparing the way for the 1903 Flyer.

6. **Centenary Celebration**; It can be argued that the Wright Brothers work defined them as the first aeronautical engineers and first test pilots. The Liverpool project is an celebration of their excellence, interpreted within the framework of modern handling qualities systems engineering.

References

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