Flight Handling Qualities of the Wright Brothers 1905 Flyer III

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The success of the first powered, controlled flights at Kitty Hawk on December 17th 1903 were a breakthrough, substantiating the Wright Brothers' research and design concepts. However, there was still much work to be done to improve the flying qualities of their aircraft to a practical standard ready to be marketed to the world. The years 1904-05 represent the period where the Wrights evolved the design of their powered aircraft, culminating in October 1905 with the Flyer III in which they were able fly significant cross country distances. The 1905 Flyer III was the Wrights first true practical design, flying 38km in 38 minutes (McFarland, 1953) –this was to be their last flight for nearly two years whilst they tried to sell their invention to the governments in Europe and the United States.

This paper reflects on that engineering challenge faced by the Wright Brothers and reports on recent research output of a project studying the Wright aircraft using modern flight science techniques. During the project, simulation models of the Wright 1901 and 1902 Gliders and the 1903/04 and 1905 Flyer powered aircraft have been developed and this paper details the challenges involved in developing these models and implementing them in real time piloted simulation.

This paper will focus specifically on the 1905 machine and will use results from wind tunnel tests, computational flight dynamics analysis and piloted simulation trials. It will also look back at the evolution of the Wrights' designs 1901-1905 and highlight how they developed efficient wings, a 3–axis control system, advanced propellers and a lightweight internal combustion engine, integrating them into an airframe strong enough for flight.

The critical innovation of flight-control and its effect on the handling qualities of the aircraft is a specific focus. The Wright Brothers, devoid of any stability theory, strove to overcome the pitch and roll instabilities of their canard-configured biplane aircraft. The Wrights had developed a ingenious warp-to-rudder interlink system on the 1902 Glider to overcome adverse yaw; however, this system was discovered to create undesired effects when a sustained turn was required in the later 1904 Flyer II aircraft.

The story of the Wrights technological journey is one of systematic analysis and rational, methodical development. They developed practices recognisable

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to modern aeronautical engineers and also became the first true 'test pilots'. In the proposed paper the aeronautical discoveries are re-evaluated and brought into new light by modern modelling and simulation techniques .The work acknowledges and celebrates the Wright brothers achievements in this in the centenary of flight period.

The paper will present the flight handling qualities analysis covering the following technical areas:

1. Wind Tunnel Testing and Aerodynamic performance and Static Stability

Wind tunnel tests of a 1/8th scale model 1905 Flyer III model were carried in order to obtain the obtain the aerodynamic characteristics for modelling and simulation use (see Figure 1). The experiments encompassed a wide range of angles of attack, sideslip and control surface deflections. Figure 2 and Figure 3 illustrate the lift coefficient and pitching moment coefficient versus angle of attack. Typical Wright aircraft characteristics are observed with a flat top stall, maintaining constant lift coefficient to high angles of attack (Padfield and Lawrence, 2003) and an pitch unstable C_{M_α} .

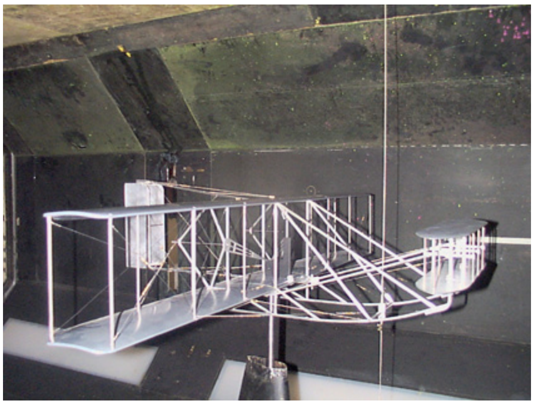

Figure 1. 1905 Flyer model in wind tunnel

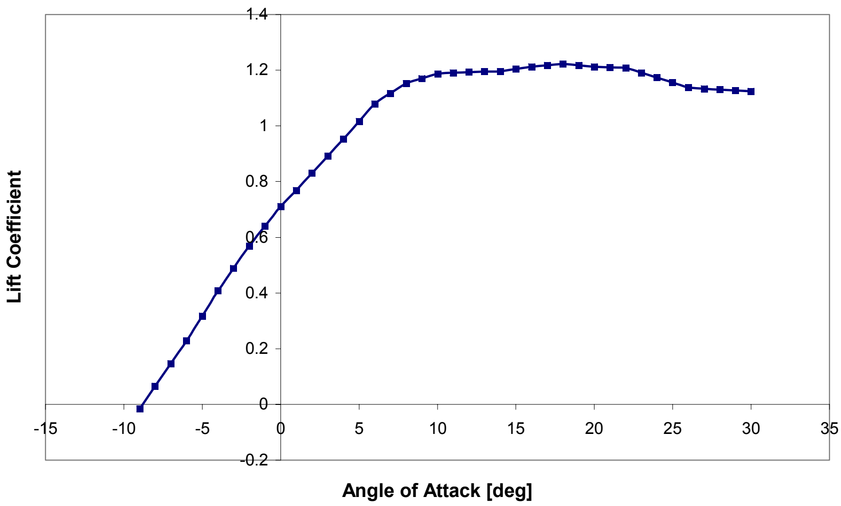

Figure 2. C_L vs. alpha, 1905 Flyer III

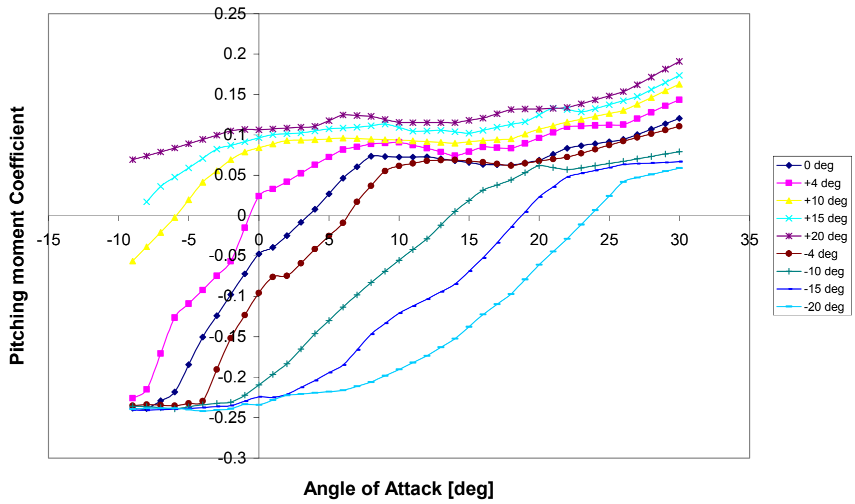

Figure 3. C_M vs. alpha 1905 Flyer III (c.g. @0.128c)

The 1905 Flyer III exhibits a 29% negative static margin, H_n for a c.g. position of 0.128c (from leading edge) - a greater static instability than the famously pitch unstable 1903 Flyer (H_n =-0.25).

2. Longitudinal Flight Dynamics

Although the 1905 Flyer III was more unstable, it was easier to fly than its 1903/04 predecessor. This was due its increased damping in pitch, C_{m_q}, a result of the much larger canard of 83ft^2 being installed in a further forward position (Culick and Papachristodoulou, 2003). This configuration also conferred greater control power in pitch improving the pitch control characteristics. Figure 4 and 5 present longitudinal root loci (pitch attitude to canard) showing the effect of closed loop control on the 1902 glider and 1903 Flyer respectively (Lawrence and Padfield, 2003). The action of pilot as a simple proportional gain in a feedback loop stabilises the pitch divergent mode but reduces the stability of the oscillatory mode.

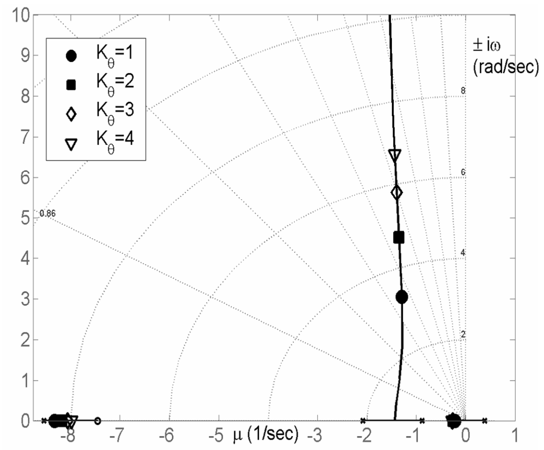

Figure 4. Closed loop root locus pitch attitude to canard, 1902 glider (c.g. @0.24c)

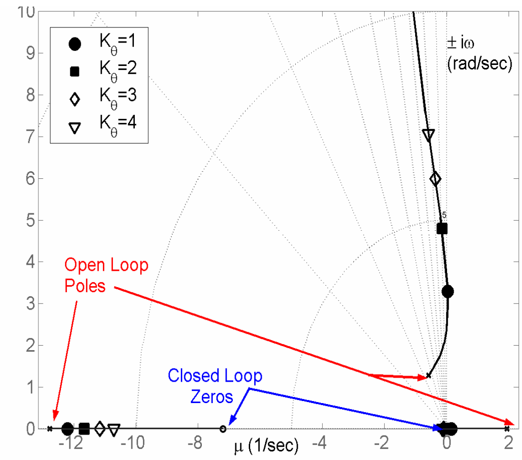

Figure 5 Closed loop root locus pitch attitude to canard, 1903 Flyer (c.g. @0.3c)

We see how the instability increased from 1902 to 1903 leading to poorer flying qualities in pitch. The development of the 1905 Flyer simulation model in the FLIGHTLAB environment will be presented. Using the FLIGHTLAB simulations the 1905 Flyer is compared and the pitch axis dynamics are assessed accompanied by a reflection on the previous designs.

3. Lateral-Directional Flight Dynamics

A number of modifications to improve the lateral characteristics of the 1905 Flyer III were made in comparison to the 1903/04 design. The anhedral wingtip droop was discarded in favour of a slight dihedral angle, and a larger, more powerful vertical tail was installed. These changes were made to improve the turn performance, reducing the spiral instability induced by the anhedral. Later, during their 1905 tests the Wrights removed their warp-rudder interlink system and provided a separate lever for rudder control – the first fully independent 3-axis control system.

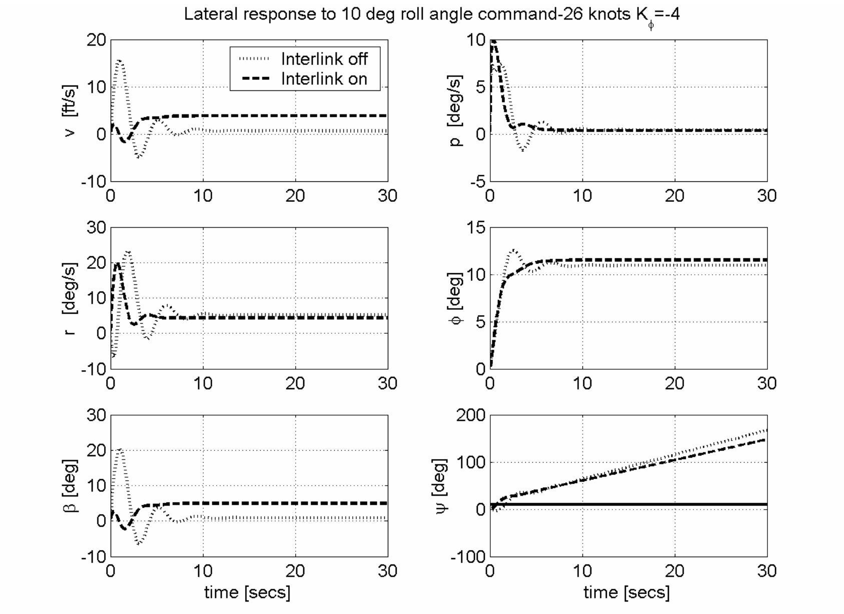

Figure 6. Time Response, 1903 Flyer (4 deg canard/deg roll error)

Figure 6 demonstrates the effect of warp to roll attitude closed look control with and without the interlink system enabled on the 1903 Flyer. The rudder-to-warp interlink has only a minor effect on closed loop stability, but does significantly improve the turn entry characteristics when using the simple warp-to-roll pilot model. The Wrights discovered that the best turn performance was achieved when the nose was lowered to maintain airspeed with the independent 3-axis control and dihedral configuration.

4. **Piloted Handling qualities Tests**

Finally, the paper will present results from piloted simulation tests conducted on the Liverpool Flight Simulator, featuring six motion axes and six visual channels (Padfield and White, 2001). The trials exercise the 1905 Flyer in a number of specified test manoeuvres and make a subjective and objective assessment of the flying qualities of an aircraft that lead Wilbur Wright to make the judgement *"…We felt we were ready to place flying machines on the market."*

References

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