Glider Yaw behaviour investigation with a Max 1400 transducer

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Abstract :
It is well known that the aerodynamic efficiency of a model is degraded by its yaw behaviour during the turning manoeuvres. This degradation grows with the high wings aspect ratio values of performance and competition gliders. The pilot tries to counter balance this effect with 3 axis piloting, having only, as a feed back of his efforts, the global result of the model eventually climbing or not in the thermal. The Mle 1401 yaw transducer continuously measures the angle of attack of the fuselage of the model and, connected to a Xerivision Xerus system, transmits to the ground on a HUD and/or on board records the current measured values for future data processing. The benefit is twofold: first, with the Lynx HUD the pilot has in real time the yaw angle of his model in sight during the spiral and can improve his judgment and his piloting skill keeping in sight his model using this short feed-back loop. Second, the off line study of the records give precious and appropriate information on the dynamic behaviour of the model and leads to a design improvement and/or an assessment of the various theories in this domain which are numerous because the measurements are scarce.

1. Introduction

To extract the best of a glider a pilot must use 3 axes piloting with a complex mix of ailerons and rudder orders. The mixing proportions are continuously evolving during the flight, especially during a spiral. The resulting hands movement of the pilot is appropriately called in French: making *mayonnaise*. Inside a full scale glider, the pilot has two important and highly precise instruments to control that: a wool braid on the canopy and his own butts.
For a modeller, the mean of perception of his efficiency are usually the deception to see his glider flying downward or at best the global indication of a variometer.

On ground, many specialists have tried to predict the behaviour of the model in the static and dynamic domain. Digital Wind tunnel computer programs such as XFLR5 have reached a highly sophisticated level and give a numerous precise curves describing static behaviour. The challenge now is to describe and to assess the dynamic one. Their precision and level of details exceed by far what we know for sure from the reality of flight of our models. To allow a rational judgement on the distance from these digitals models to the reality, a good precision measurement in flight of some aerodynamic parameters is necessary.
Among the model designers, some debates are ragging for example between pros and cons of V tails opposed to T or X tails topology. A trial and error approach is valuable but lengthy and resources consuming. Again, assessing a real judgement can be done more efficiently by confronting the theory to the reality through measurements. For all those reasons, we have developed a high precision aerodynamic angle transducer. Additionally, this angle transducer can be used to measure and/or transmit the angle of attack (in the vertical plane = incidence) which opens another field of study on profiles real efficiency and stall behaviour and limits.

2. The qualities of the angle transducer

A good angle transducer must have a good precision and a good resolution inside a limited range of angle: let us say +/20° around the zero is more than enough to be able to cover incidence measurement. If the greater resolution is the best and because it is easy to achieve an apparent resolution of a hundredth of degree, it should not hide the fact that a precision of .5° is desirable and not that easy to reach.
It must be resistant, and keep its qualities over a reasonable range of temperature.
It must be small, if possible tiny, easily fitted and unfitted in the model.
It must be easy to interface with common systems.

3. Error budget of the transducer

1 -The direction of the flow is given by a flap turning around an axis. The friction of the axis is a major parameter for the final result:

1. Mechanical resistance limits the minimum angle that the flap can detect from the flow.
2. Non linear friction phenomenon behaviour creates hysteresis. First tests with potentiometers (even very good ones) where disappointing although they demonstrated the interest of these kind of measurements.

2 - Once the flap is following faithfully the flow and the transducer is following the model, the conversion of the angle between the two in electrical signal is better done by a non contact mean. This technology contributes to point 1. The counterpart of contactless measurements is that the alignment of the transducer’s elements and its stability over the time is a key contributor to the final precision.
3 – The precision and the resolution of the conversion mean from the angle to an electrical signal is the last element that contributes greatly in the error budget of the whole.

4. Contactless technologies

There are several candidates for this noble task.

- Capacitive

- Magnetic
- Optical

Each one has its own advantages and inconveniences.
For the Mle 1401 we have chosen magnetic angle pickup.
That does not means that this is a definitive choice for all situations, but it currently addresses efficiently the requests of § 2.

The transducer has the shape of a potentiometer (but it is not) and the flap is easily removable

Fig 1 – The transducer Mle 1401 with its flap

It is calibrated on a test stand

Fig 2 – The transducer on its test bench

5. Test set up

The transducer is simply mounted on the canopy of the model, taking care that there is sufficient clearance from the nose so that the folding propeller does not damage the flap.

The transducer is digital, but an analog output has been provided for ease of interfacing. It is connected to an analog input of the Xerus DMS (Data Management System) which provides a 3.3V power supply.

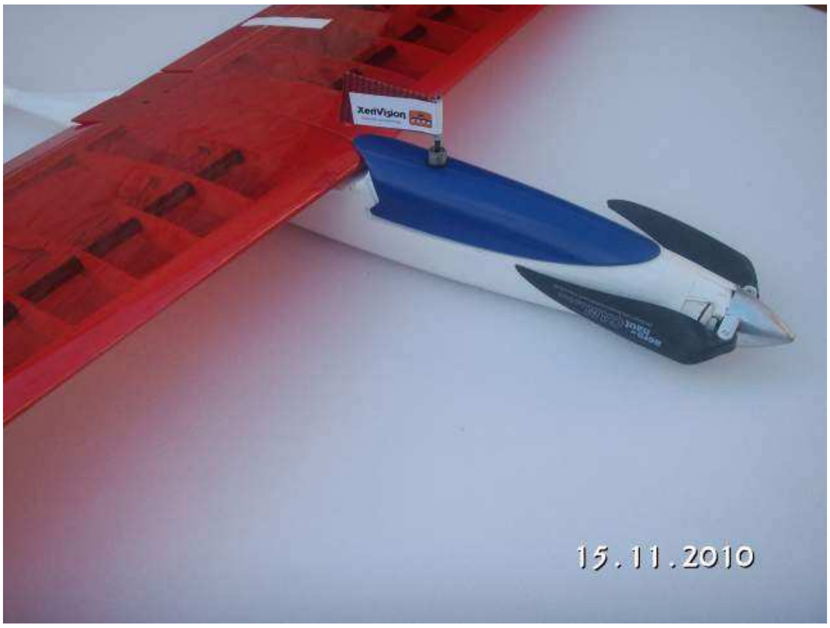

Fig 3 – The transducer fitted in a small electric glider

Others have fitted the transducer with some tape on the upper side of the wing.

Fig 4 – Another setup

6. Real time view in the HUD

Aboard the model, the angle is continuously measured with a Xerus expert module and the downlink is used to transmit the data to the pilot while the data are recorded if desired. The sample frequency, maintained through the RF link and the data processing chain, is 5 Hz to ensure a good reactivity.
The pilot operates his model as usual and with the HUD he can superpose the view of a horizontal bargraph with his model's view. The displayed horizontal needle has 15 positions and follows remotely the variation of the angle of the flap. He can in real time correct his orders to minimise the yaw value, producing aerodynamically perfect and efficient spirals.
The game consists in keeping the needle at the centre while spiralling.
A film is in preparation to demonstrate the result in flight.

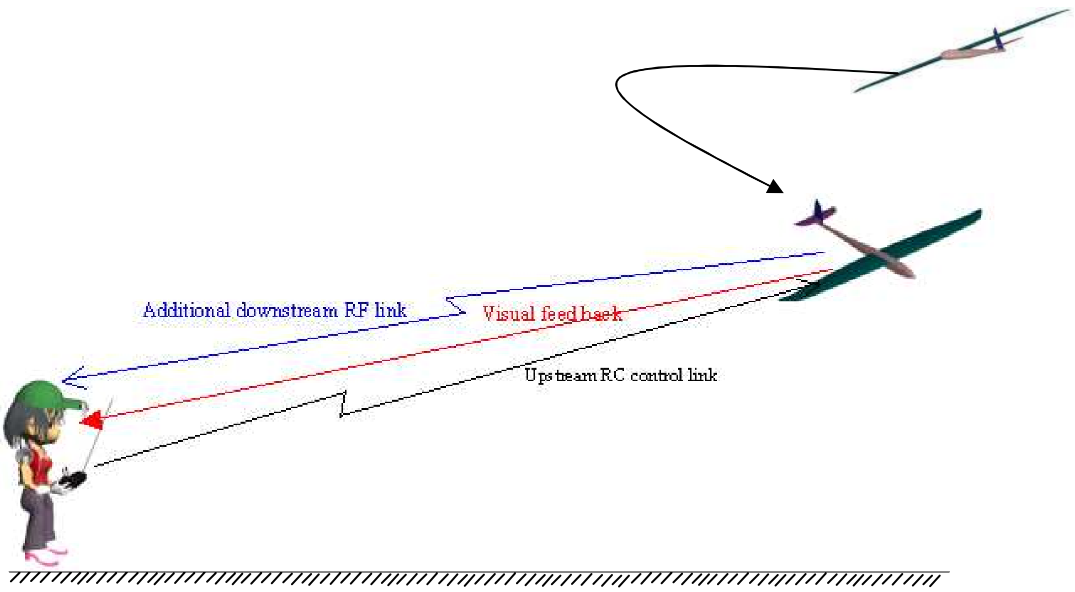

Fig 5 – In flight set-up with HUD

7. Off line results

The 1st chart is a flight made with a potentiometer on a small glider connected to a Xerus expert system. The data are plotted with Flight Test Studio. Please note that the angle variations are very brutal and that the form of the signal is close to staircases. To produce changes of angular measurement, it was necessary to make violent rudder manouvers. The root cause was that the friction forces were too high and that the model could fly with an angled flap without being tracked by the transducer.

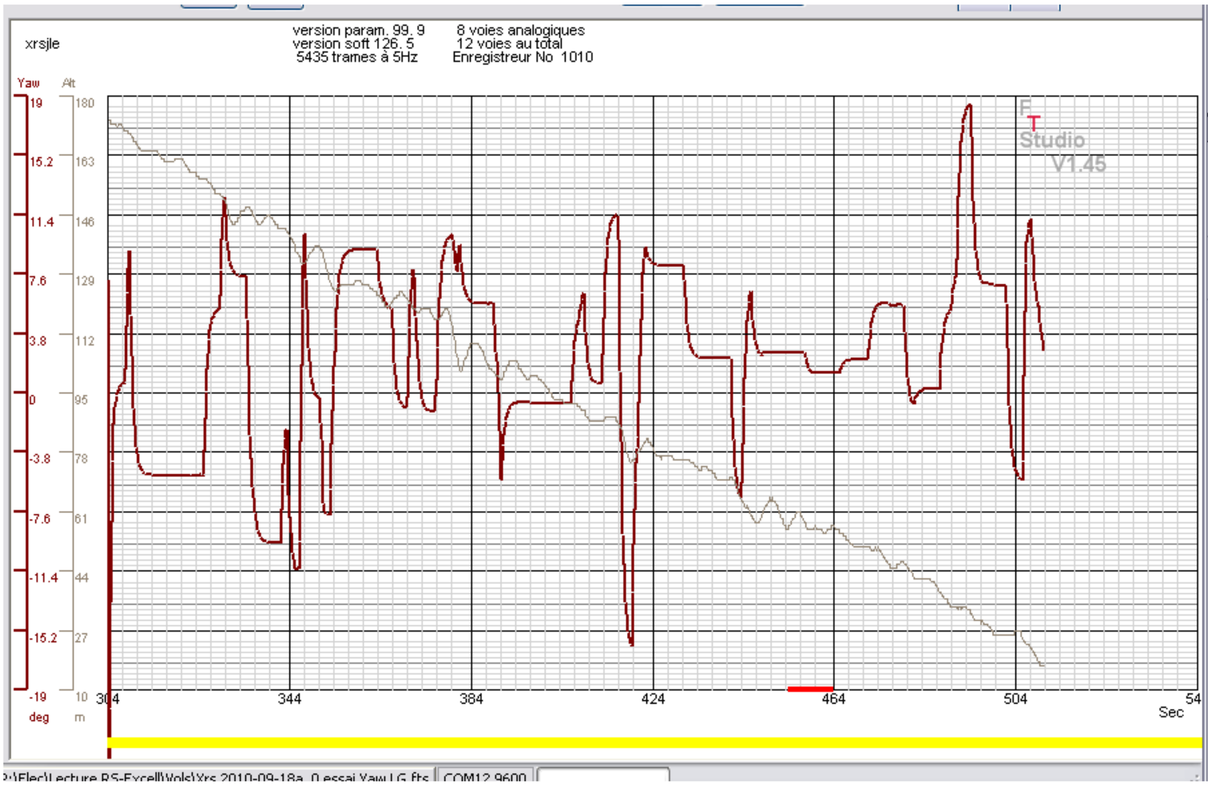

Fig 6 – Potentiometer record

The second plot, with the same scale but on a larger airplane, is made with a Mle 1401 transducer with low friction forces. The shape of the signal gives sufficient confidence that the aerodynamic flow angle is closely followed as already confirmed by wind tunnel tests. More theoretical development and measurement exploitation can be found in Marc Pujol's paper of ref [1]

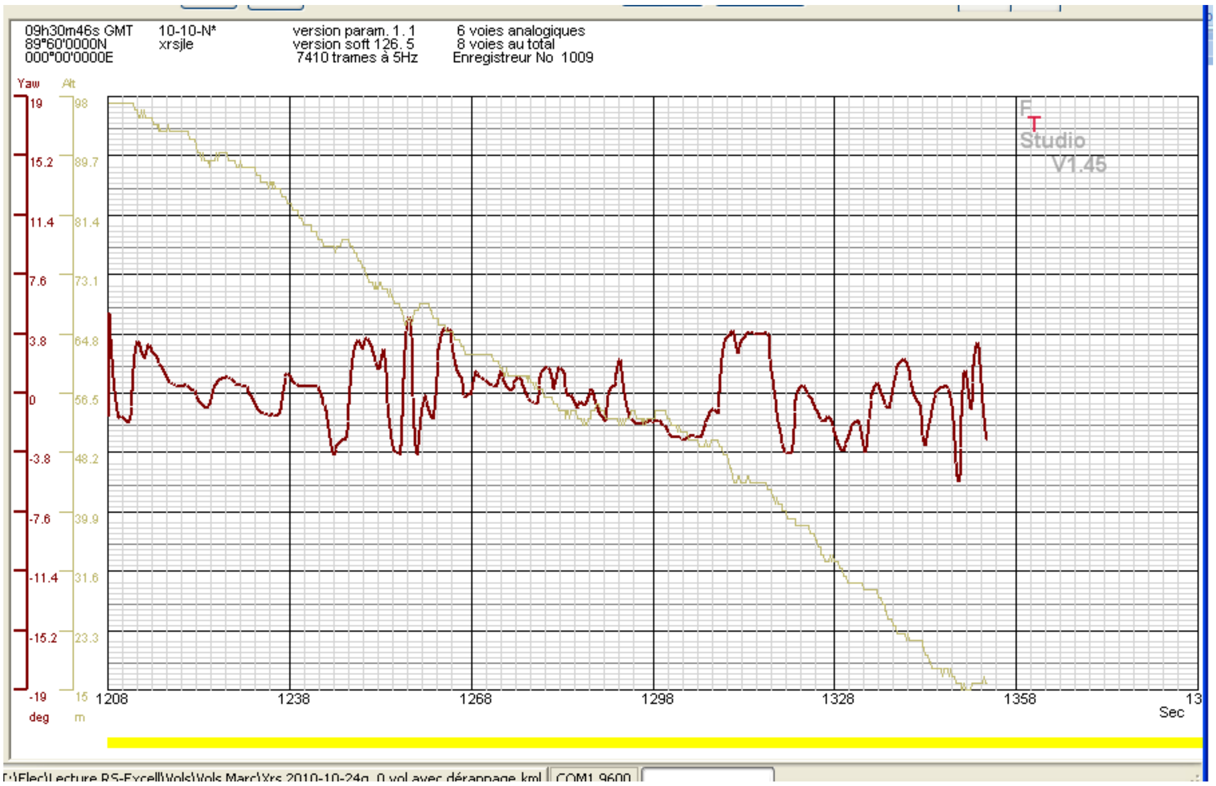

Fig 7 – Mle 1401 transducer record

With the corresponding flight path recorded by the attached GPS module

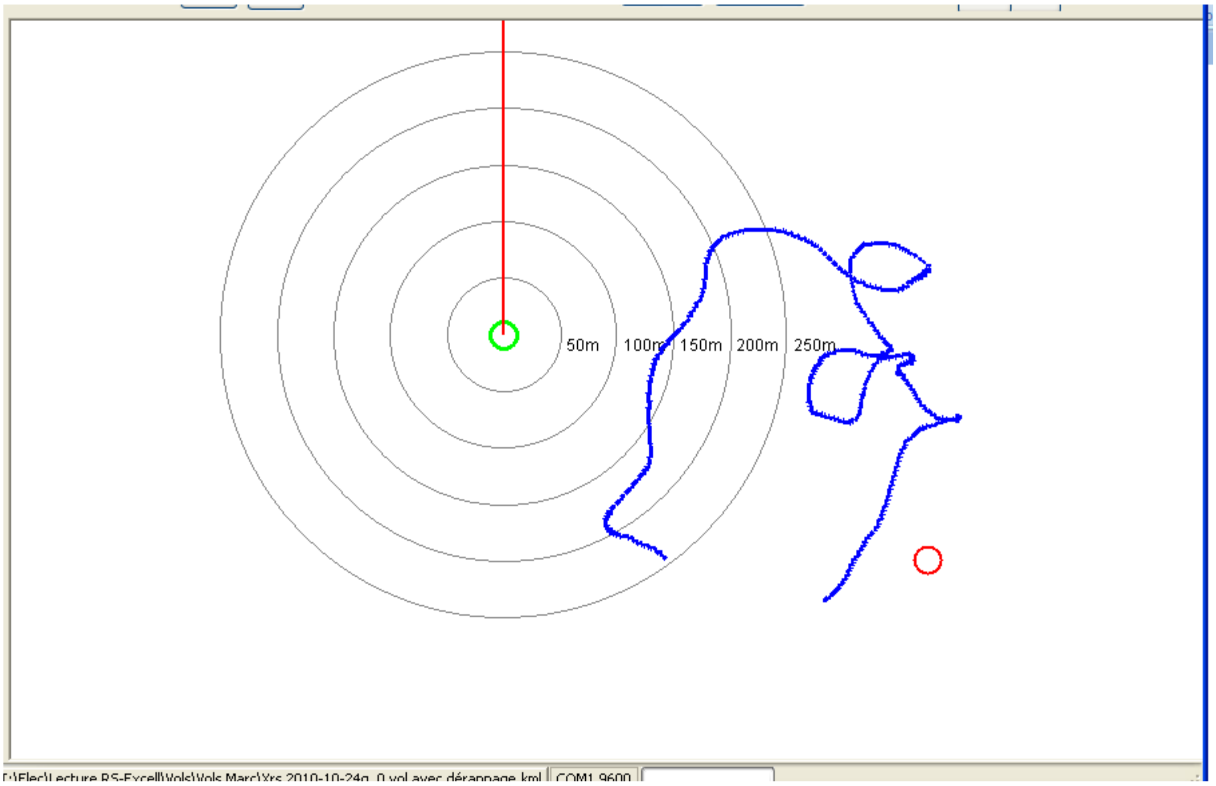

Fig 8 – Flight path corresponding to the above flight slice

8. Way forward

The ways forward in different domain are clear enough:

- Making smaller, less intrusive transducers allowing an even easier integration in the models.
- Making a balanced flap to explore the interest, which must be great, to make incidence angle of attack measurement. The interest might be either for calculation models assessment or pilot control and/or warning through real time link or accurate flight testing and comparison.
- Installing a closer loop aboard the model with an intelligent automatic feedback algorithm that could pilot the rudder and gives accurate yaw control.

9. Conclusion

After considering the benefits of measuring aerodynamic angles on the models a set of specifications has been established.
These specification where sufficiently tightly met to set-up an appropriate transducer.
The first results in flight gave results beyond the expectation both for real time fed-back and for differed time analysis.

This transducer did hit several targets so far:

- In flight, with the Xerivision HUD, it provides a positive feedback loop between the pilot and the model and help improving piloting skills as well as understanding the subtle behaviour of the model in flight. No doubt it will offer to the pilot a competitive advantage.

- In differed time, it is already seriously considered to confirm several prediction algorithms in Wind tunnel programs.
- A paper, fed with experimental results from this transducer, will be released soon on the comparison of V-tail vs. X-tail gliders.

Some other targets exist for this transducer, or a companion one, measuring airplane's incidence for stall survey or warning, in-flight profiles efficiency comparison etc...
A new field of investigation is opened.

References

1 – Marc Pujol – Stabilité latérale (Lateral stability) - 2010