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Custer CCW-5 Channel Wing 1/4 scale model

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1 Introduction

The Custer Channel wings are an original way to achieve STOL capabilities for an airplane. After reading about the story of Willard Custer and his designs, I decided to make a replica of his late design, the Custer CCW-5. The goal was to investigate the channel wing capabilities by real flight testing and to build my first large composite rc plane.

2 Preliminary design

At first I had to choose the scale of the model. The constraints were to build a model large enough so the aerodynamic effects could be compared to those on the real airplane. Then in France rc models with a mass of more than 24kg must have special authorizations to operate. The Choice of a 1/4 scale was a compromise between theses constraints and also to have an airplane that can fit inside a car for transportation and that is not too expensive to build.

Then finding documents about the CCW-5 is not an easy task. An accurate 3 view drawing was almost impossible to find. The solution was to use several photos from the CCW-5, to correct the perspective effects on each picture and to use reference points and projections to rebuild an accurate numerical 3d model.

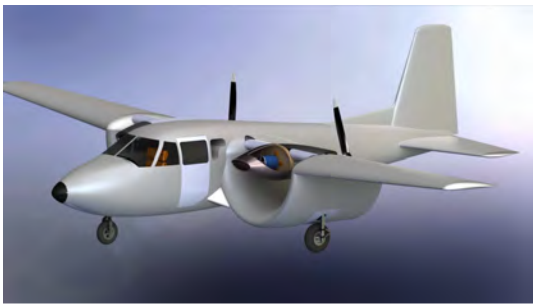

Fig. 1 . Numerical model on Solidworks, 2013

3 Detailed design

The real CCW-5 uses a naca 4418 on the channel and a 4412 on the wing tip. Theses 2 airfoils have good properties for model airplanes and the 4418 is very thick. It creates a lot of drag but it makes the structure easier to build so they were taken for the model.

Taking the fuselage as a reference the "Channel" have an incidence of 3 degrees and the wing tip are at 0 to make stall less brutal.

To estimate the loads on the wings the following method was used. A maximum speed is roughly determined as if the plane was making a vertical dive (weight and drag compensates each other) then you recover as quickly as possible so you are at maximum speed and maximum Lift coefficient so you are at the maximum load on your structure. For this plane the conclusion was that it has to resist to a 6g acceleration. The channel were not easy to design and so large safety coefficients were taken, the main target was to be below the 24kg category at the end.

At first, the model was designed to fly with 2 gaz engines. Engine nacelles were large enough so two 40cc flat twin engines can fit in. But this solution was expensive and I had not at this time the experience of dealing with the vibrations coming from such engines. So I choose two 3kW brushless motor to have a maximum power to weight ratio of 300W/kg.

I had also to deal with the landing gear design and that everything could fit in the airplane. At the end the internal structure looks like the one on the figure2. Most of it was made of a sandwich of wood and glass fiber. A large part of the structure strength is coming from the skin with the use of some carbon-epoxy composite.

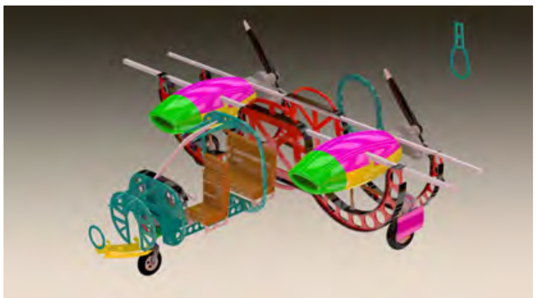

Fig. 2 . Fuselage and center section structure (gaz powered version), 2013

4 construction

The fuselage nose, the channels and the engines nacelles are made of glass-epoxy composite with carbon reinforcement where needed. The numerical model was discretized into sections and each section was then cut in high density foam. The final shape is covered with glass fiber, mastic, paint.. in order to reach a good surface finish. Then some scale effects are added. In figure 3, the result for the nose section of the fuselage. We are now ready to make the molds out of our model. Not less than 20 molds made of Glass-polyester were needed for the entire airplane and it represents a lot of time and energy in the building process.

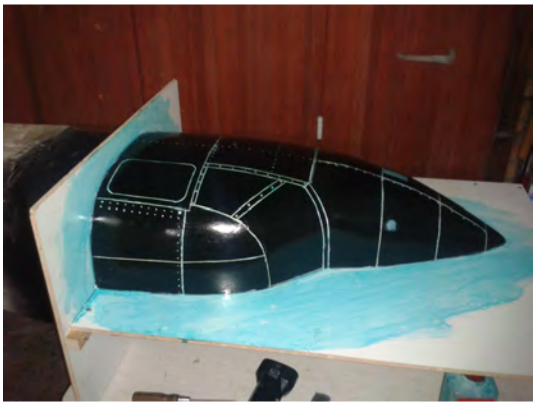

Fig. 3 . Nose section master ready for the mold manufacturing, December 2013

The airplane standard skin layup is made of light gelcoat, a 50gr/m^2 and two or three 200gr/m^2 glass fabrics. Carbon Unidirectional fabric is added for spars and bidiagonal in the channels leading edges and near every area submitted to mechanical constraints. To save weight and time, the wings and tail are directly vacuum molded on a foam core. The outer surface is made on wood with carbon reinforcement between the wood and the foam.

At the end, the model has the following characteristics :
- Take Off weight : 18kg
- Wingspan : 3.20m
- length : 2.5m
- fuselage section size : 0.35*0.4m
- Engines : (2) 3kw 192kv outrunner brushless motor
- propellers : (2) 19*10 APC electric
(diameter of the channel wings)
- speed controllers : (2) max 120Amp (140 burst)
- Batteries for propulsion : Lipo 12s 6600mAh
- Batteries for radio electronics : 2s 2200mAh Lifepo4

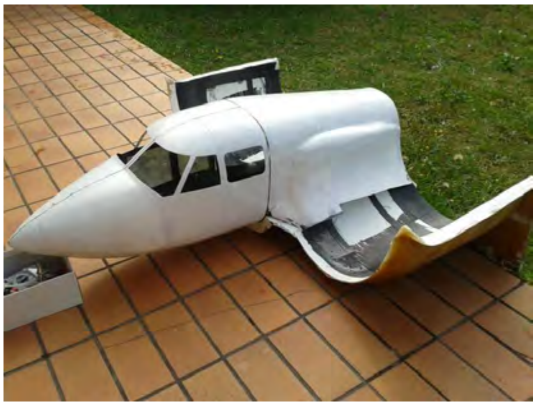

Fig. 4 . composite parts. Carbon reinforcement for the "channel" spar, leading and trailing edge and in the fuselage nose to transmit the forces from the nose gear , 2014

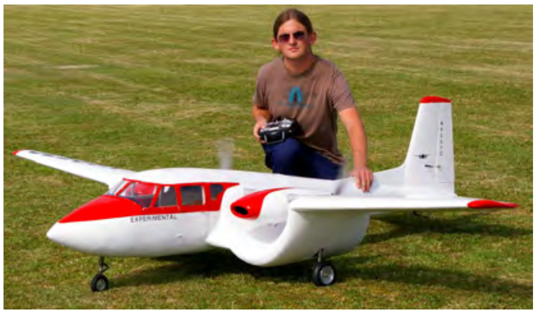

Fig. 5 . Scale CCW-5 ready for takeoff , 2015

5 Flying a channel wing airplane

5.1 Takeoff

To take off, wait until you have some speed on the runway. That can be very short (this is still a short take off airplane) but if you put full power to early, the channels creates enough lift but you don't have enough airspeed for the moving surfaces to operate effectively. When you have enough horizontal speed you can put more power. Take off is inevitable. Be prepared to push the elevator stick. When the airplane is no more on ground effect, a huge nose up pitch moment is coming from the channel effect and remember that you still don't have a lot of speed. The airplane can climb with a very high slope angle that can reach up to 60 degrees .

5.2 Cruise flight

Flying the CCW-5 is not flying an airplane. A large part of the lift is coming from the Channel-engine association. The only aircraft that is close to that is for me the autogyro. The elevator stick is here mainly to control the airplane attitude and then if you want to

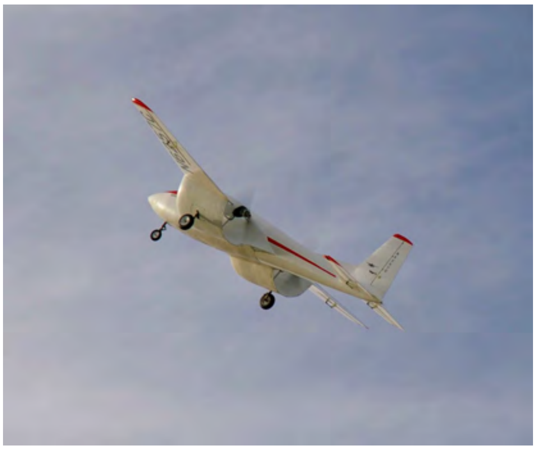

Fig. 6 . The CCW-5 model during a high angle climb.

dive or to climb, use the throttle. The throttle stick is mainly a "Lift" stick. The horizontal speed range is not large. If you try to fly fast, you must adopt a negative incidence attitude to counter the Channel effect.

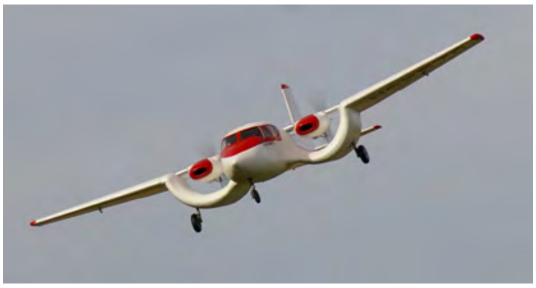

Fig. 7 . Just after a turn, the airplane unusual wings are clearly visible, 2015

5.3 maneuvering capability

The model can fly at high angles of attack. It is almost impossible to stall as long as your propellers rotate. But control in this configuration is not easy. There is still pitch and yaw control because the tail is blown by the propellers but it is not the case for the ailerons. Turning radius can be reduce to almost a point! You have the feeling that the airplane is just turning around the inner channel. But pay attention to anticipate the inertia and a large coupling between the 3 axis.

5.4 Landing

Short landing is theoretically possible. But in practice it is not easy to made. Compared to the cruise speed, the approach speed is not as slow as we can expect. The main reason is that you are in a high lift configuration when you land which also means that you need to have engine thrust. You can increase your angle of attack on final approach and reduce the power gently when you are on ground effect. The Airplane will stop rapidly.

Finally Never cut off the engine at any moment during flight! You will loose all your lift and you are near a "normal" stall speed. The only solution if you have an engine failure is to cut of the other propeller and dive vertically to recover when your airspeed is sufficient. Then you have a glider with a very very poor glide ratio and a tremendous amount of drag so don't hesitates too much to find a landing field.

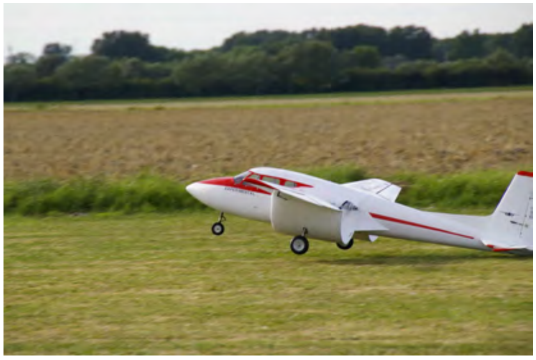

Fig. 8 . Landing at high angle of attack

6 Conclusion

Designing and Flying this Custer Channel Wing airplane is not easy. It took me more than 2 years, hundreds of hours and requires all attention during flight. But it was a great challenge to build my first composite "large" model airplane and I learned a lot. It improved my mechanical, designing, composite manufacturing and aerodynamics skills. For the Channel Wing itself. Of course they are drawbacks but many of them can be reduced or avoided. There is, in my opinion, still a large potential for such type of powered lift systems.

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