Design and optimization of the wing with very high lift properties

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Who are we?

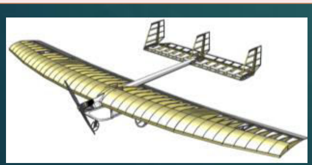
We are representants of SAE Students Club from Power and Aeronautical Faculty at Warsaw University of Technology. Since 1991, students of this club have taken part in SAE Aerodesign competition held annually in USA in which we are multiple champions.

Aerodesign competition…

…is organised by Society of Automotive Engineers. It's main goal is to design, build & fly the radio controlled planes that are to lift the highest payload possible having the lowest empty weight. All the designs have to comply with the **rules** set by the contest's organizers-volunteers from aeronautical industries.

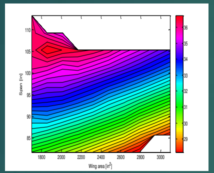
The rules for the Regular class 2014 plane

SUM OF LENGTH, HEIGTH, WIDTH	175 in
TAKE-OFF DISTANCE	200 ft
PROPULSION	electric engine, < 1000 W
BATTERY	Li-Po 4S1P; 4000 mAh, 25 C min
PAYLOAD BAY	4 x 4 x 10 in
FRP prohibited	



The Four steps:

1. Take off analysis

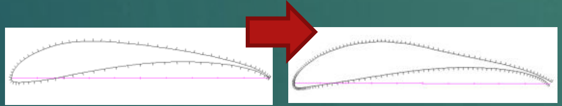


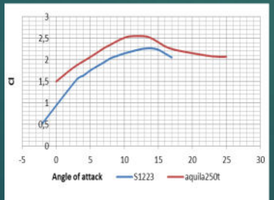
C++ code calculated the potential lift of a plane with a given wing area and span at certain take off distance with the formulas from Flight Mechanics including equasion of motion:

$$m\frac{d^2s}{dt^2} = T - D - \mu_r(m\,g - L)$$

2. Airfoils selection and design

The popular SELIG S1223 airfoil was taken as base of considerations. Knowing operating Reynolds number (Re=286000) and thanks to Mark Drela's program XFoil, it was possible to carry out the modification process, as result of which, the airfoil Aquila250t was developed.



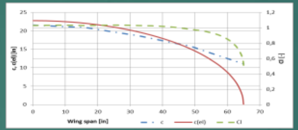


The new profile has much better characteristics than the old one in the operating range and also the separation region is quite smooth.

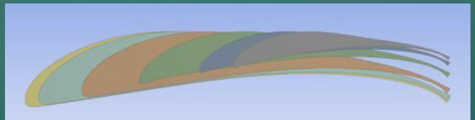
The trailing edge has a relatively big gap to achieve similar effect like this, given by Gurney flap.

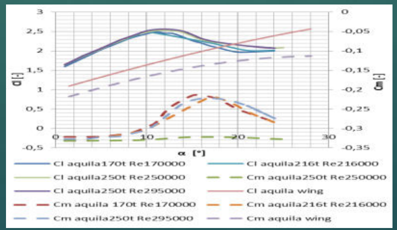
3. Wing geometry

Chord distribution was designed in that way, to prevent occurring of flow separation at the area of ailerons, to have them effective all the time. To control the area of flow separation, Schrenk distribution was used.



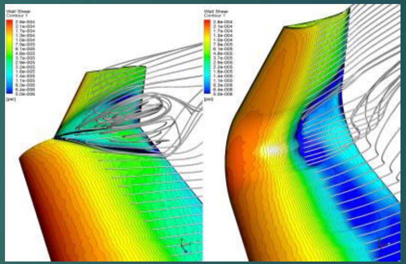
We divided the wing into 4 root sections available for twisting geometrically and aerodynamically. Because of different chords along wing span, there are different Reynolds numbers in each section. For that reason current airfoil had to be re-designed to meet requirements for smaller Reynolds numbers.

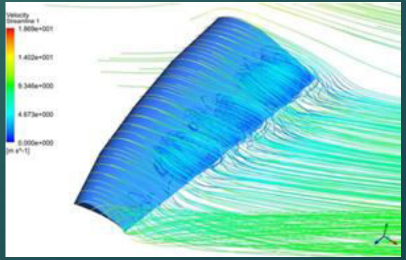




4. Winglets or …?

Large lift coefficients entails the induced drag part very big. What could reduce this effect? Winglets or tip plates. But: after performing various analyses, it turned out that winglets helping at small angles of attack, can make the flow worse at bigger angles by causing separation earlier. So yes, they reduce induced drag, but at the same time they decrease lift coefficient, for which we care the most.
Tip plates just couse the separation earlier.





Structure

Wing design is an awful lot of what makes the whole design successful, but it's certainly not the only thing. As the FRP are prohibited, we must rely on balsa, plywood, aluminium alloys and styrofoam. The great solutions here are all kind of sandwich structures. CAD/CAM/CAE softwares and CNC machines we use are also crucial to design planes capable of lifting

over 500% of their own weight.

So far ☺

PLACE	YEAR	PAYLOAD [lb]	WING AREA [ft²]
27	2011	41	16.14
4	2012	42	18.29
1	2013	43.5	18.29
1	2014	37	12.92

All of this is the sum of over 20 years experience, advanced technology, fresh approach and the passion of the members of SAE Students club.

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