

Self-designed Model Airplane

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1 Introduction

First, my aim was to design a model airplane on my computer, because we started to work with Autodesk Inventor at school. The software was very interesting for me, therefore I wanted to try more than we had to. When I started to draw the first sketches and parts I have never thought that I will build this airplane one day. But after some time I recognized that it's possible to cut all of my parts with a machine, so I wanted to use this chance.

2 Basic Ideas

Of Course, everything starts in your head. After I had a lot of ideas, I made a hand-drawn sketch. Since I like the shape of a Mooney [1], I made the wings and the tail unit similar to it. Usually the side faces of model airplanes get closer at the tail, but I decided to make them parallel, because it saves a lot of work in Inventor – and it's something special.

However, there is always that point, where your imagination ends and you need a 3D view.

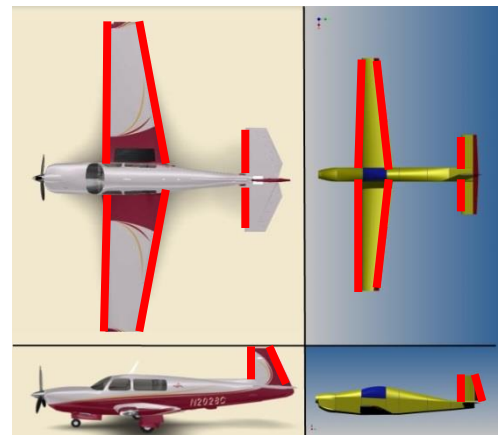


Figure 1: Similarities marked with red lines

3 Designing

The designing of the airplane took most of the working time. I started with the wings, therefore I needed a wing profile. I chose the NACA 2411 profile, which is a good profile for model airplanes. I used a website [2] which generates the points of this profile, so I could paste the coordinates of the points in Microsoft Excel and afterwards in Inventor.

3.1 Calculation of the frames

I wanted to draw each of the 15 different frames of the wing – even though it's not necessary for the cutting process. Therefore I had to calculate all of the coordinates for each frame. I multiplied the coordinates first with the factor $f_1=1.0594 (=1+0.01*a)$, then with $f_2=1.1188 (=1+0.01*2a)$, etc. .

$$\alpha = \tan^{-1} \frac{80}{700} = 6.52^\circ \quad a = 52 \times \tan(\alpha) = 5.94mm$$

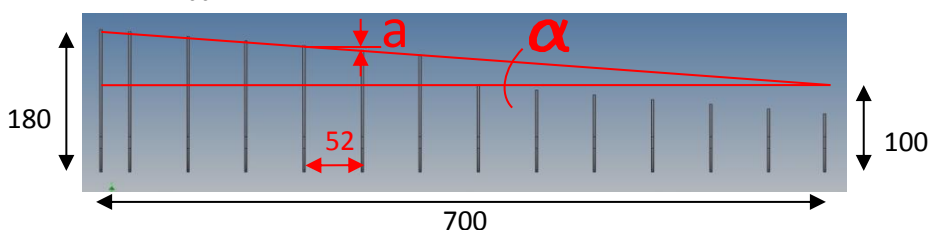


Figure 2: Calculation of a and α

The Drag&Drop function of Excel was very helpful, so it was not a big deal to calculate the coordinates of the 15 frames. Figure 3 shows an abstract of the calculation and some coordinates of frame 1 and 2 (in the Picture called “Spant 1” and “Spant 2”).

1 a=	5.94285714	5.94285714	$\alpha= 6.51980175$	Spant 1 (100mm)		*1f	Spant 2 (105.9428mm)		*2f
2 a=	11.88571429	11.88571429		x	y		x	y	
3 a=	17.82857143	17.82857143	a= 5.94285714						
4 a=	23.77142857	23.77142857							
5 a=	29.71428571	29.71428571	f= 1.05942857	0.000	0.000		0.000	0.000	
6 a=	35.65714286	35.65714286		0.172	0.862		0.182	0.913	
7 a=	41.60000000	41.60000000		0.897	1.752		0.950	1.856	
8 a=	47.54285714	47.54285714		2.170	2.654		2.299	2.812	
9 a=	53.48571429	53.48571429		3.985	3.553		4.222	3.764	
10 a=	59.42857143	59.42857143		6.317	4.427		6.692	4.690	
11 a=	65.37142857	65.37142857		9.148	5.253		9.692	5.565	
12 a=	71.31428571	71.31428571		12.448	6.006		13.188	6.363	
13 a=	77.25714286	77.25714286		16.175	6.659		17.136	7.055	
14 a=	80.00000000	80.00000000		20.292	7.193		21.498	7.620	
				24.745	7.588		26.216	8.039	
				29.485	7.831		31.237	8.296	
1 f=	1.059428571	1.059428571	Spant 2	34.455	7.912		36.503	8.382	
2 f=	1.118857143	1.118857143	Spant 3	39.597	7.830		41.950	8.295	
3 f=	1.178285714	1.178285714	Spant 4	44.807	7.606		47.470	8.058	
4 f=	1.237714286	1.237714286	Spant 5	50.067	7.276		53.042	7.708	
5 f=	1.297142857	1.297142857	Spant 6	55.322	6.852		58.610	7.259	
6 f=	1.356571429	1.356571429	Spant 7	60.513	6.347		64.109	6.724	
7 f=	1.416000000	1.416000000	Spant 8	65.583	5.777		69.481	6.120	
8 f=	1.475428571	1.475428571	Spant 9	70.475	5.158		74.663	5.465	
9 f=	1.534857143	1.534857143	Spant 10	75.138	4.506		79.603	4.774	
10 f=	1.594285714	1.594285714	Spant 11	79.520	3.839		84.246	4.067	
11 f=	1.653714286	1.653714286	Spant 12	83.577	3.175		88.544	3.364	
12 f=	1.713142857	1.713142857	Spant 13	87.260	2.532		92.446	2.682	
13 f=	1.772571429	1.772571429	Spant 14	90.535	1.927		95.915	2.042	
14 f=	1.800000000	1.800000000	Spant 15	93.365	1.380		98.914	1.462	
				95.720	0.906		101.409	0.960	
				97.570	0.520		102.277	0.551	

Figure 3: abstract of the calculation

3.2 Structure of the airplane

The frames are connected by two pinewood bars. I mounted CFK-rods to connect the wings with the body. A pipe with a inner diameter of 4mm is attached to the wing. As a result of this, I can use a stick with a diameter of 4mm to connect both of the wings together with the body. This generates only a connection between the wings and the body, it hasn't been fixed yet! At the same time, these CFK-sticks create a V-form of 3°, which is necessary for good flying properties.

I added a plate, where I can fix the electronic equipment. It's very long, so I can fix the batteries wherever I want to. This is very helpful to change the center of gravity.

The side faces have holes to reduce the weight of the whole airplane.

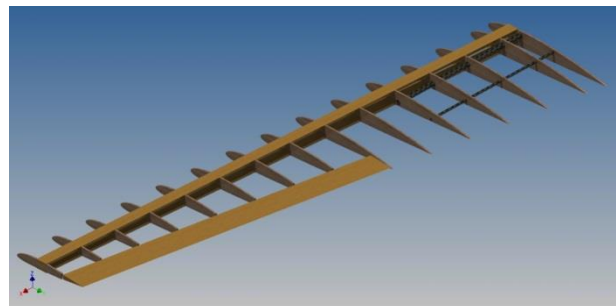


Figure 4: Structure of the wing

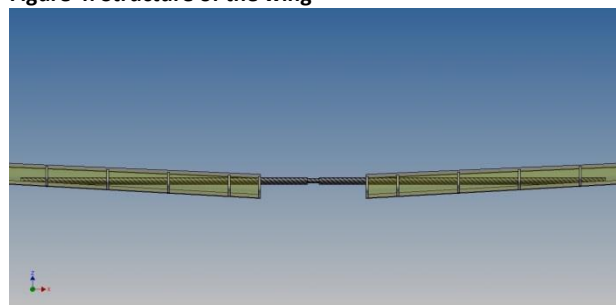


Figure 5: V-form and connection of the sticks

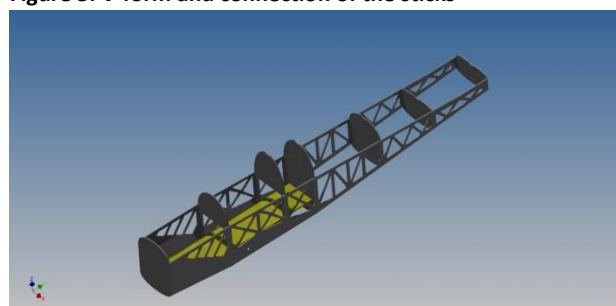


Figure 6: Plate for electric equipment

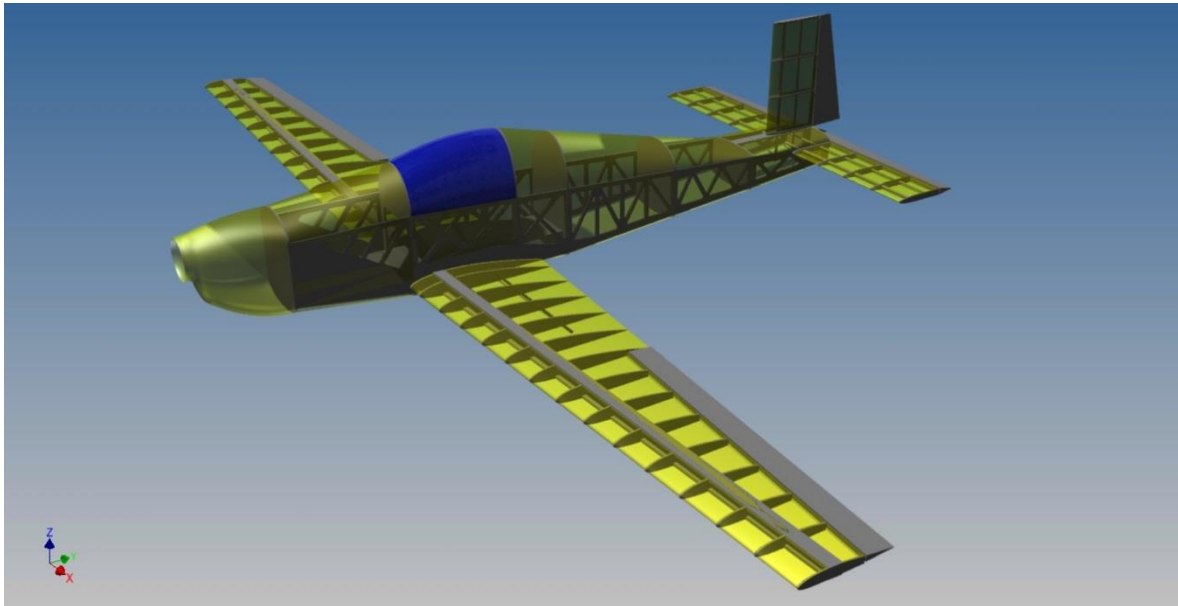


Figure 7: Whole airplane in Inventor

4 Manufacturing

After I had realized that I have good possibilities to cut all of the parts, I immediately wanted to build this airplane. First I thought the best solution is a milling machine, but then I heard of a laser cutting machine in the workshop of the TGM. The laser cutting machine is way faster than the milling machine I've planned to work with. Another advantage is that laser cutting belongs to chipless manufacturing. As a result of this I didn't have to grind the edges of the parts. This leads to less working time after the cutting process. Figure 8 shows the difference of milling and laser cutting.



Figure 8: Comparison of milling (top) and laser cutting (bottom). Milled frame had to be grinded after milling. Laser cut frame has burned but sharp edges.

4.1 Laser Cutting

The wings, the tail unit and the side faces are made of balsa wood with a thickness of 2mm. I used 2mm thick plywood for the body frames, because they will probably be more stressed than the other parts. Because of the small thickness and the lightweight material the cutting process was done within 10 minutes.

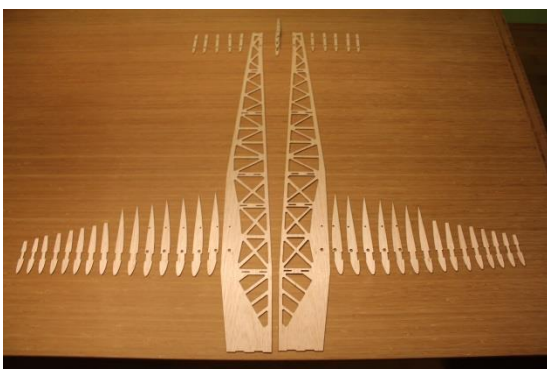


Figure 9: parts made of balsa wood (2mm)

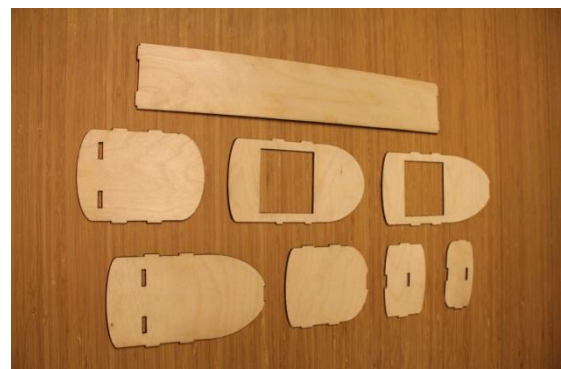


Figure 10: parts made of plywood (2mm)

4.2 Assembling

The assembling (gluing) process was way more time consuming than the cutting process. I used a two-component epoxy glue, which dries within 5 minutes and hardens after 1 hour. It's total hardness is reached after 72 hours. However, after 30 minutes I was already able to grind the areas I wanted to.



Figure 11: framework side-view



Figure 12: framework rear-view

Current dimensions:

- Span: 1490mm
- Length: 800mm
- Height: 240mm
- Body-width: 90mm
- Weight: **200g**



Figure 13: body-wing connection

4.3 Comparison of Design and Construction

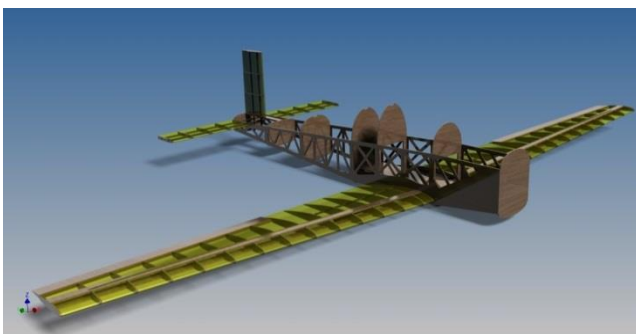


Figure 14: Design



Figure 15: Construction

5 Future Plans

Everybody knows, that real airplanes can be controlled by an autopilot. The autopilot even lands when the weather conditions are very bad. So it's worth a try to add a kind of autopilot to a model airplane. A robot-controlled traffic pattern (Figure 16) should be possible.

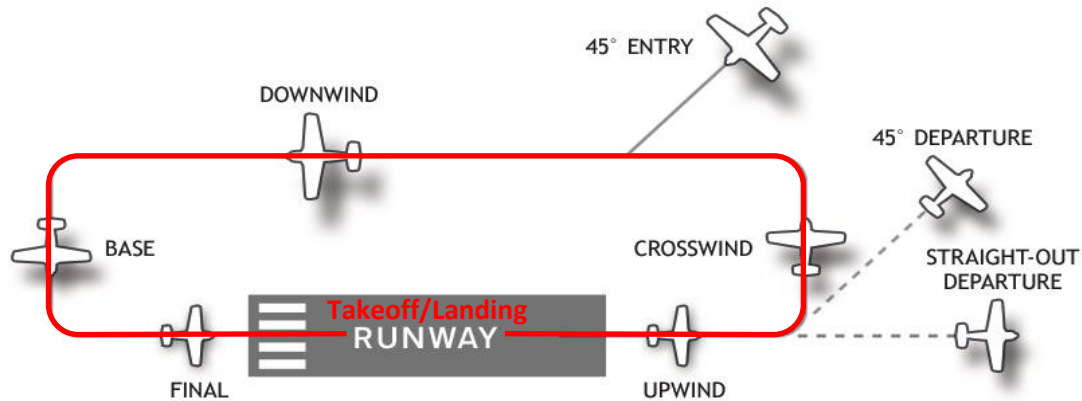


Figure 16: Traffic Pattern [3]

5.1 Problems

1) Wind:

It's probably the major problem for a robot-controlled traffic pattern. One characteristic of winds is that they don't follow certain rules concerning the wind direction. In fact, they can hit the airplane from every direction – even from above or below.

2) Uneven Runway:

Airfields for model airplanes mostly have grass runways. This is no problem for manual flying, but the uneven ground will cause some problems for a robot-controlled airplane.

5.2 Useful Sensors

The wind can change the course of the airplane by influencing the bank, the pitch, the speed and the altitude. Therefore a lot of sensors are required for a robot-controlled traffic pattern.

For example:

- Altimeter
- Accelerometer
- Speed-Indicator
- GPS (electronic compass)

A sensor-based program is definitely required for robot-controlled flying. Otherwise the airplane probably couldn't even keep in the air for a single blink.

6 Acknowledgements

First of all, I'm very thankful for the great support by Prof. Peter Herzog, who has helped me a lot with his know-how of airplanes.

Special thanks to technical instructor Uwe Dröszler, who handled the laser cutting machine.

I'm sure I will receive a lot of help at the robotics part by Prof. Gottfried Koppensteiner, therefore I'm already thankful for this and the positive motivation in all cases.

Moreover, I want to thank Autodesk for providing Autodesk Inventor and all the other software I can download with my student account.

References

- [1] Customize your Mooney: <http://www.mooney.com/customize/Ovation2GX.html>
- [2] NACA 4 Digits Series Profile Generator: <http://www.ppart.de/aerodynamics/profiles/NACA4.html>
- [3] Figure 12: http://en.wikipedia.org/wiki/File:Airport_traffic_pattern.jpg