I.T.T.S. Carlo Grassi

Aeronautical construction

School year 2014-2015

Class 5BCT

Barettina Hyper Lite 2 - Ghivarello

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Grassi

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1 - Introduction

Doing this project I wanted to show that with the force of will and a little of luck it is possible to realize what you believe in. I have therefore chosen to do a project which combines different subjects studied (aerotechnics, mechanics, English, logistics) and previously acquired knowledge which were later combined during the construction and subsequent relation. The choice has been directed towards the construction of a monosurface paraglider made of plastic and not of fabric for budget reasons. One of the main difficulties of creating a plastic paraglider has been to maintain a level of security for some tests of low flights. The reasons for which plastic instead of fabric (much more resistant) has been chosen were mainly the cost and the lack of competence in sewing, and also the lack of a sewing machine. Firstly, I decided to write to the designer of the wing for advice about the cost. He estimated a total cost with the fabric of about 800 €, too much for my finances. So I decided to proceed personally with some tests to check if there were any possibilities of success and luckily the tests showed that it was possible to try to build the wing having sufficient evidence to think that it would have worked within safe acceptable limits. However, the construction hasn't been easy at all, especially because the paraglider has been built during the school year. One of the major difficulties , in fact, was to combine schoolwork and the realization of the project in time. With a lot of effort, however, the wing has been built and tested in six months even though there have been times when it seemed nearly impossible to complete it. For example, after several hours of welding, a check on the lengths of the next extrados that should have been welded showed incongruence with the measurements given by the project. The problem was later solved by discovering that two extradoses were numbered differently with the same measures. An error like this could compromise the success of the work because it meant to rebuild more than half paraglider or try to repair it causing an unrecoverable delay in finishing the work. In conclusion, after working practically every day for 6 months, time has come to see if the work and calculations made corresponded to the reality. With great happiness all calculations made resulted correct and paragliding withstood the small flight (not more than 5-7 meters from the ground for safety reasons) and it has been shown also easy to fly and in the ground handling! A big thanks, finally, goes to my family. Without them I wouldn't certainly completed the construction of the paraglider.

2 - The project

The paraglider chosen is a single skin experimental paraglider, designed in Spain and later tested by a company of paragliders. I decided to build a single skin paraglider because it requires fewer hours of work respect to a conventional paraglider.

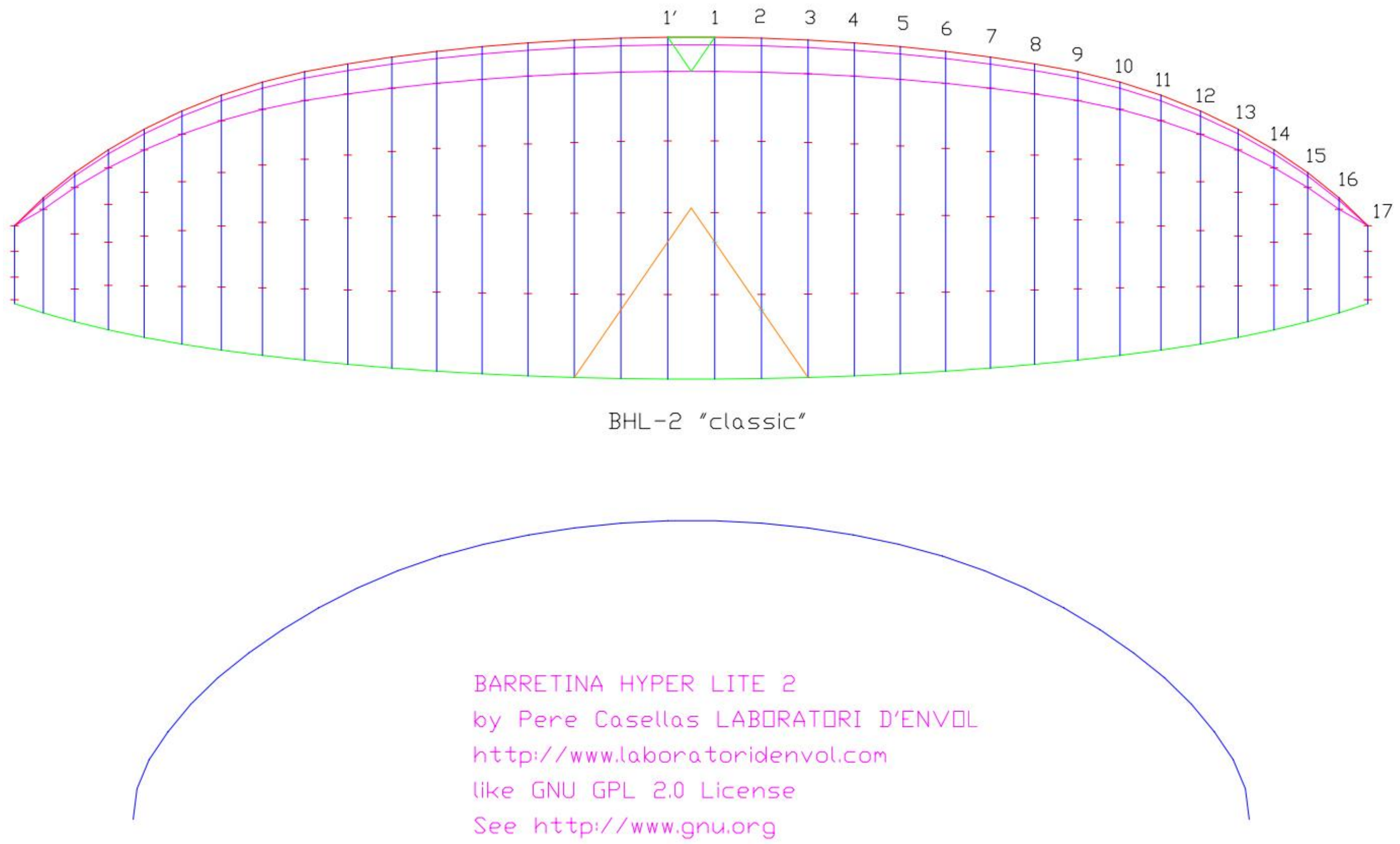


Fig. 1 – The wing and its characteristics

All the designs are free and can be found on the site http://www.laboratoridenvol.com/ , which includes several other projects.

LABORATORI D'ENVOL BARRETINA HYPER LITE 2
MODEL: BHL 2 "CLASSIC"
AREA: 23 m2
WEIGHT IN FLIGHT: 80-100 Kg (aprox)
SPAN: 10.69 m
ASPECT RATIO: 5.0
CELLS: 33
AIRFOILS: bhl2 four and tree points
GLIDE: 7+ (aprox)
SAIL: NYLON RIPSTOP SKYTEX 38 and 40 HF
LINES: SHEATED DYNEEMA
RODS: NYLON 2.8 mm
RISERS: POLYESTER (3 per side, 4 as option))
MAILLONS: INOX ø3.5 mm (6 units)
HOMOLOGATION: NO (EXPERIMENTAL)

3 - Pre project calculation

Before performing the tensile tests on the plastic the following calculations have been executed to get an idea about the magnitude of the loads that would have incurred the paraglidier in flight.

3.1 - Wing tension

The surface of the wing given by the project is 23 m^2 and the weight in flight is 80-100 kg (actually the weight in flight for the test has been 65 kg) but for the calculation of the tension we take 20 m^2 and 100 kg to create a higher wing load and so have higher resulting value in the tension of the plastic. The wing load so is:

$$\text{Wing load} = C = \frac{Q}{S} = \frac{100}{20} = 5\,\frac{\text{kg}}{\text{m}^2} = 50\,\frac{\text{g}}{\text{dm}^2}$$

3.2 - Points of attack tension

The Points of attack that have to keep the pilot are 5 for rib (A-B-C-D-F) but we consider only the first 4 points because the F point has to keep the load of the brake but not the weight of the pilot. The ribs are 16 for semi wing but the fifteenth and sixteenth have less points of attack so we consider only 14 ribs for semi wing. The weight of the pilot is considered 100 kg (actually it is 65 kg).Therefore, the loads for every point of attack are:

N=number of point of attack=
n°point of attack for ribs * n°ribs * 2 semi wings = 4 * 14 * 2 = 112 point of attack

Q=weight of the pilot=80 kg

$$\text{Load for one point of attack} = P = \frac{Q}{N} = \frac{100}{112} = 0.89\,\frac{\text{kg}}{\text{point}} \approx 890\,\frac{\text{g}}{\text{point}}$$

(the loads are approximately uniformly distributed for every point of attack A-B-C-D and even if there were accumulations of load they are irrelevant. For example only the A point would withstand the weight of the pilot)

3.3 - Lines tension

The lines have the maximum tension in correspondence of the braces because there are less cords. The lines , in correspondence of the braces are totally 20: 3 for the A, 4 for the B,3 for the C-D. So the loads for every cords are:

$$\text{Load for one line} = L = \frac{Q}{\text{n° lines}} = \frac{100}{20} = 5\,\frac{\text{kg}}{\text{line}}$$

4 - Material, tooling and cost

Build a paraglider with the conventional fabric (mylar, ripstop, nylon) would cost more than 800 euros. Because of the low budget, it has been chosen the plastic used to cover the greenhouses in agriculture that has a cost of about 0,45 Euros per square meter. The plastic has proved to be the best choice in relation to the cost, construction time and welding. The next difficulty, then, has been to choose how to merge together the various parts of the wing: sew them would be impossible because it would have caused a significant deterioration of the structural characteristics of the plastic and a large number of break points would be created; paste or attack it with the tape would be possible but would have greatly increased the cost and the total weight of the wing. The only solution then has been to weld the wing with an iron. Tests previously carried in the past (for the construction of a hot air balloon) had shown that in the points of welding the plastic didn't damage, but , on the contrary, it was more resistant. In order to weld straight, forms with stringers of aluminum have been built.

← old experimental type

Different measure of stringers →

Fig. 2 – The different irons

However also welding presented its problems. For example, the iron, heating also the edge, could dissolve the plastic if an unintended part has touched it. Another problem has been that the thermostat of the iron having to heat more (due to the stringer) and staying switched on for a long time burned, causing the breakup of 3 irons. The problem has been solved using an older type of iron with a thermostat that heated all the plate of it and turn on and turn off often the iron to avoid to going over temperature.

Total cost material:

Part	Where	Cost
1-N°5 plastic sheets 10x2m	Supermarket	44,5 €
2-100m polypropylene cords	Supermarket	5 €
3-300m dyneema cords	Web site	25 €
4-Nylon rod + american tape	Supermarket	10 €

Total cost	84,5 €

In addition to the total cost there are to add the costs of the electricity for the iron and the printer that is about 70 € but this is an operative cost and not a cost for the material.

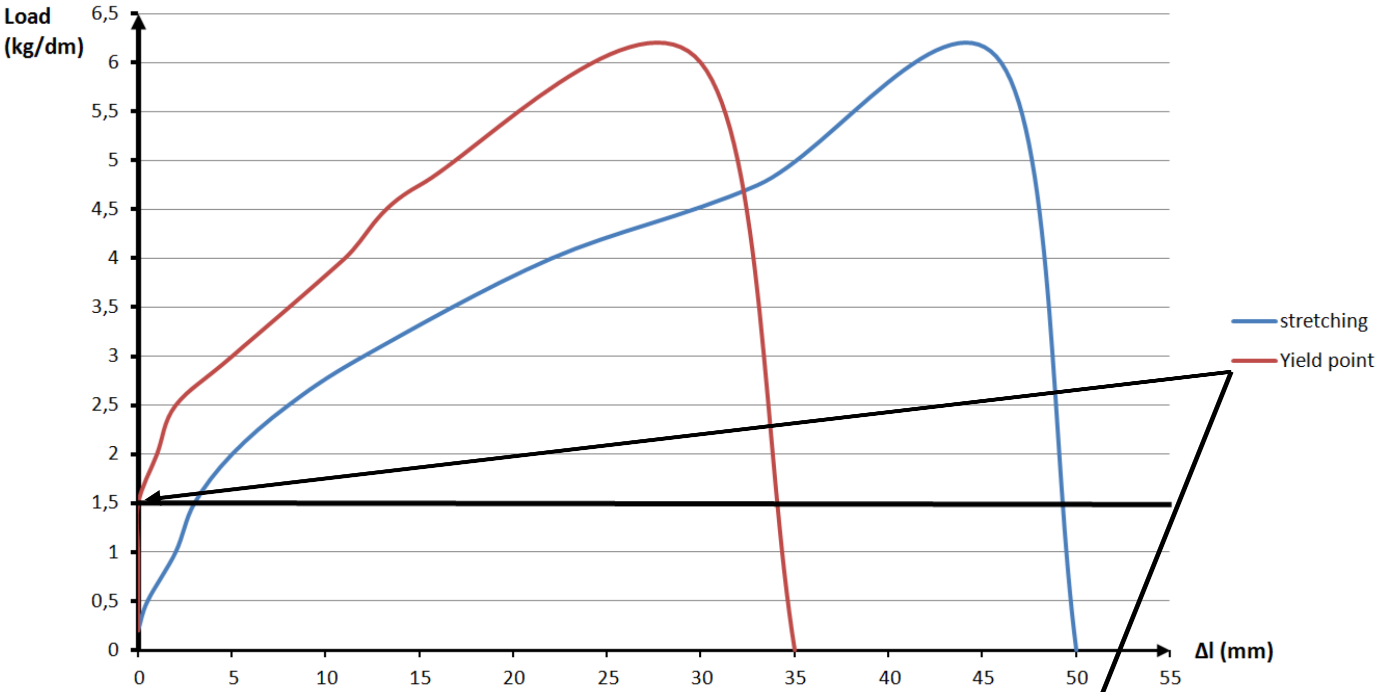
Fig. 3 – A special assistant!

5 - Pre project test

The requirements to be able to create the paraglider have been, therefore, a resistance of the material of 5 kg/m^2, a resistance for every point of attachment of 0,89 kg and a resistance for every cords of 5 kg. Tests have to show if the paraglider could withstand the loads of the flight.

5.1 - Wing tension test

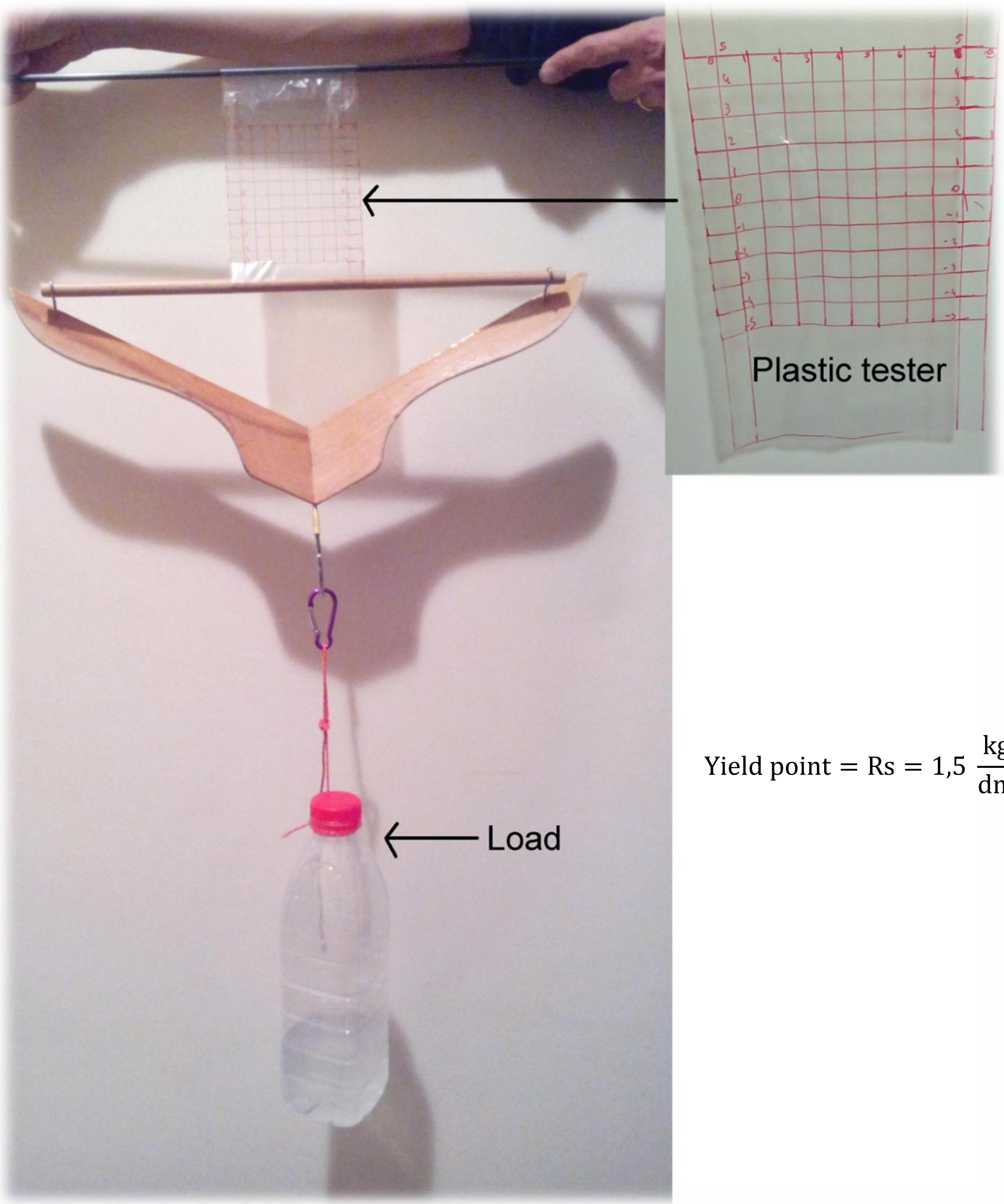
The load of 5 kg/m^2 is very low also for the plastic. The test has been directed from the resistance to the tension of the plastic also because the paraglider is principally subject to tensions. The test has been effected on a piece of plastic of 10x10cm increasing the loads, measuring the stretching of the plastic and, after have removed the load, checking if the plastic had passed the yield point. Following are reported the results:



Load(kg/dm)	Δl(mm)	yield point(mm)
0,2	0	0
0,5	0,5	0
1	2	0
1,5	**3**	**0**
2	5	1
2,5	8	2
3	12	5
4	22	11
4,75	33	15
6	46	30

Fig. 4 – Wing tension test graph and table

From the tests we understand that the yield point is at 1,5 kg. Beyond this point the plastic becomes longer and longer until the breaking point at about 6 kg.



$$\text{Yield point} = \text{Rs} = 1{,}5\ \frac{\text{kg}}{\text{dm}}$$

Fig. 5 – The tension test

5.2 - Points of attack tension test

Create points of attack sufficient safe has been the most difficult part in the structural test. Using the information got from the wing tension test, calculation has been done to understand how high could be the load that one point of attack must withstand for safely test of low flight. The yield point is at 1,5 kg, so, using a safety coefficient (k) of 1,5 (R.A.I part 223 cap. C, F.A.R.23 rules) the sigma admissible is:

$$\delta_{\mathbf{adm}} = \frac{\mathrm{Rs}}{\mathrm{k}} = \frac{1{,}5}{1{,}5} = 1\ \frac{\mathrm{kg}}{\mathrm{dm}}$$

The calculate load for one point of attack was 0,71 kg, so, imposing a minimum contingency coefficient (n) equal to 3 the load that each point of attack must support is:

$$\mathrm{P_c} = \mathrm{n_p} * \mathrm{Q} = 3 * 0{,}89 = 2{,}67\ \frac{\mathrm{kg}}{\mathrm{point}}$$

Knowing then, that each 10 cm of plastic can keep safety in 1 kg has been decided to overlay from the tip to the 30 cm of each point of attack another layer of plastic to make the rib (in theory every point of attack would hold easily 6 kg). The main difficulty, however, has been just in correspondence of the tip because the load couldn't be distributed over all the plastic but all in one point. Therefore, It has been chosen to create a plastic rectangle of 10x12mm to bend and then weld in correspondence of the tip.

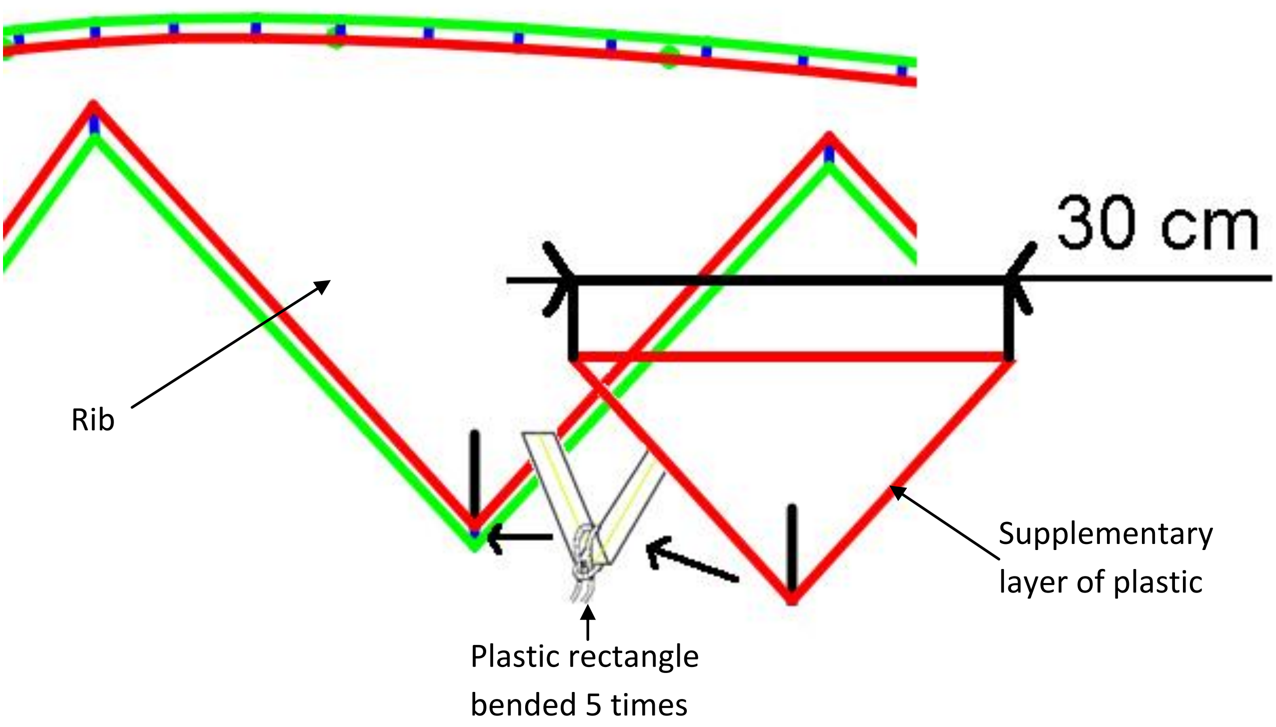
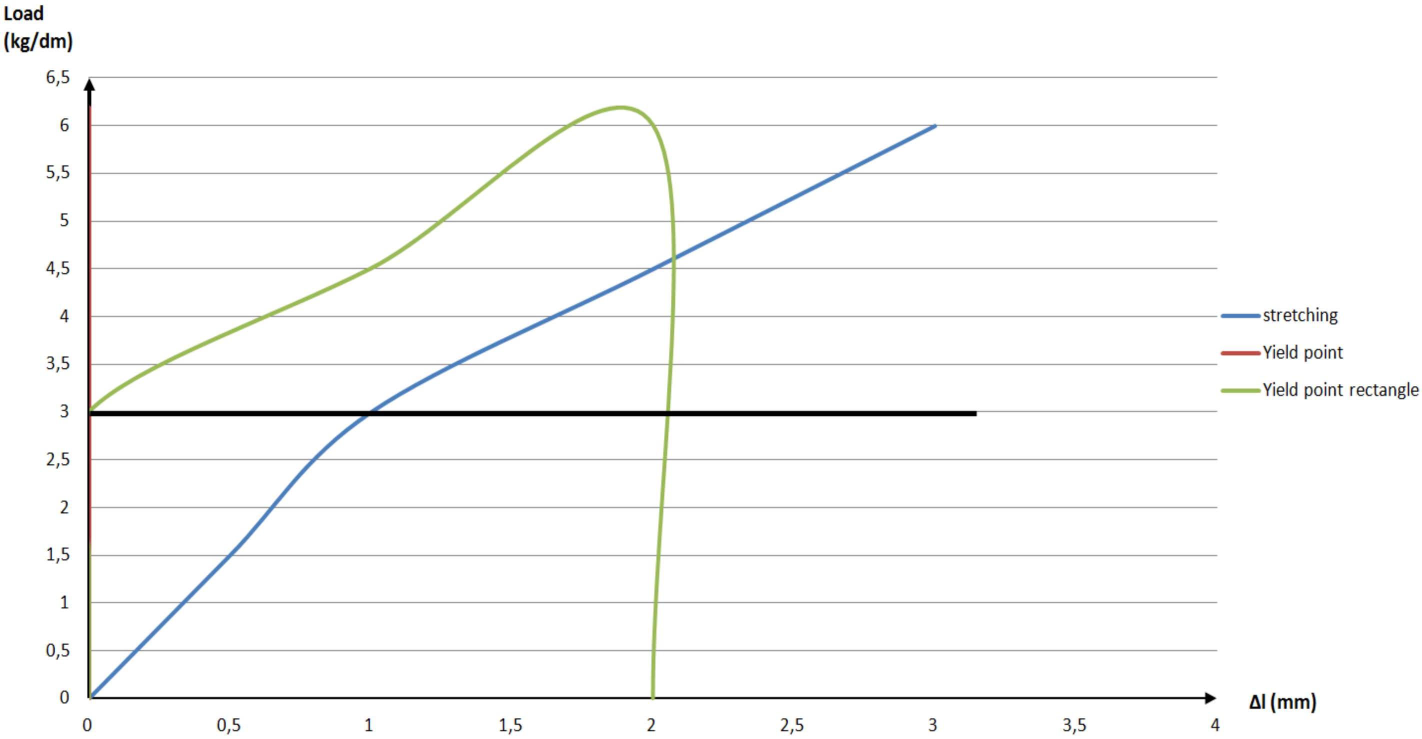


Fig. 6 – The reinforcement

The test has been performed on the 15th rib in the part corresponding to the minimum section to be sure which other withstand the loads. This because every rib has different sections.

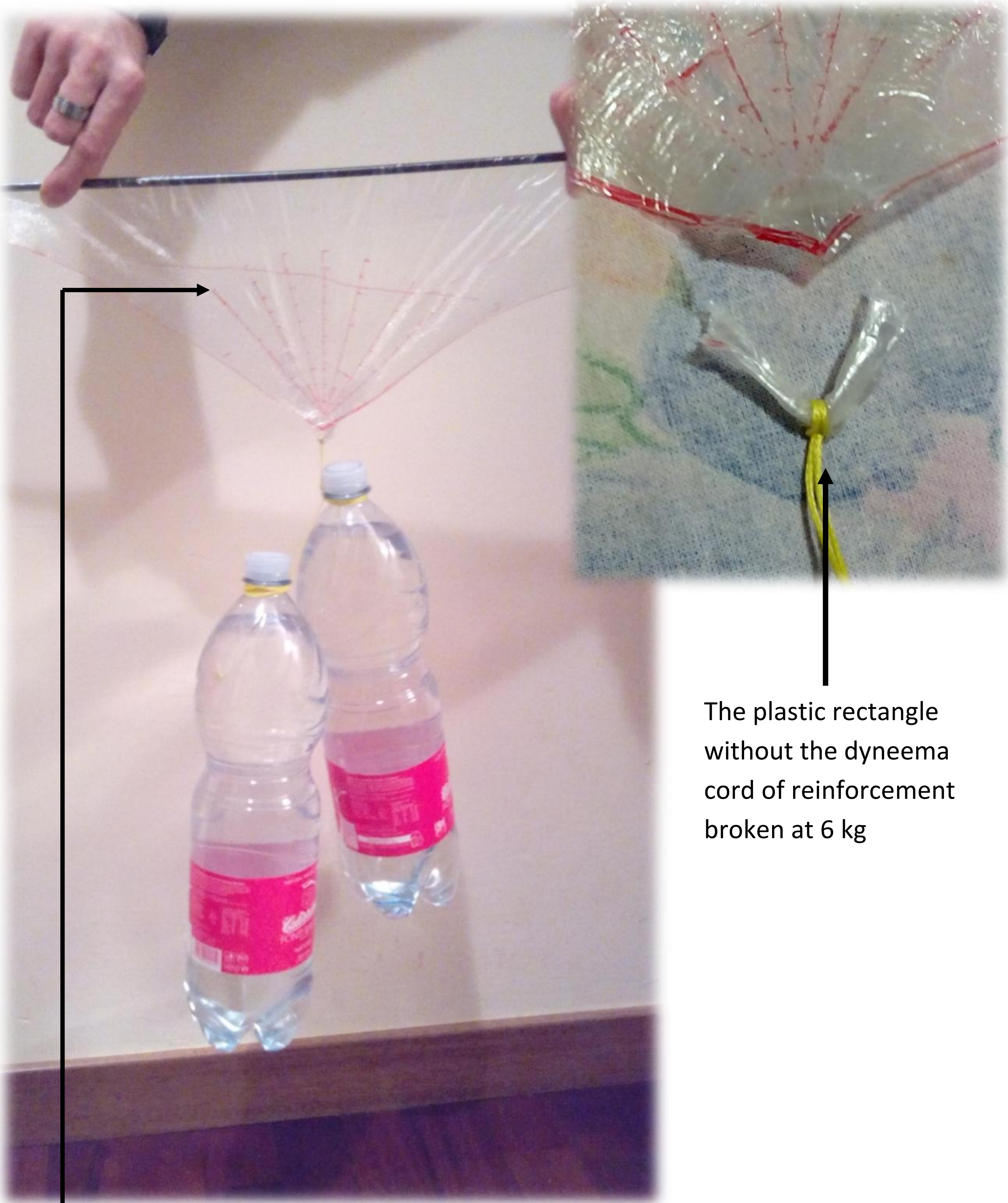


Load(kg/dm)	Δl(mm)	yield point(mm)	yield point(mm) rectangle
0	0	0	0
1,5	0,5	0	0
3	1	0	0
4,5	2	0	1
6	3	0	2

Fig. 7 – Points of attack tension test graph and table

Unfortunately, as we see from the graphic, the double layer of plastic holds the load without reaching the yield point but the plastic rectangle reach the yield point at about 4,5 kg and at 6 kg it breaks. This problem has required to redesign the rectangle plug in the plastic a dyneema cord of 0.75mm. This solution has completely solved the problem, greatly increasing the safety of the points of attack and , above all, eliminating the yield point of the rectangle.

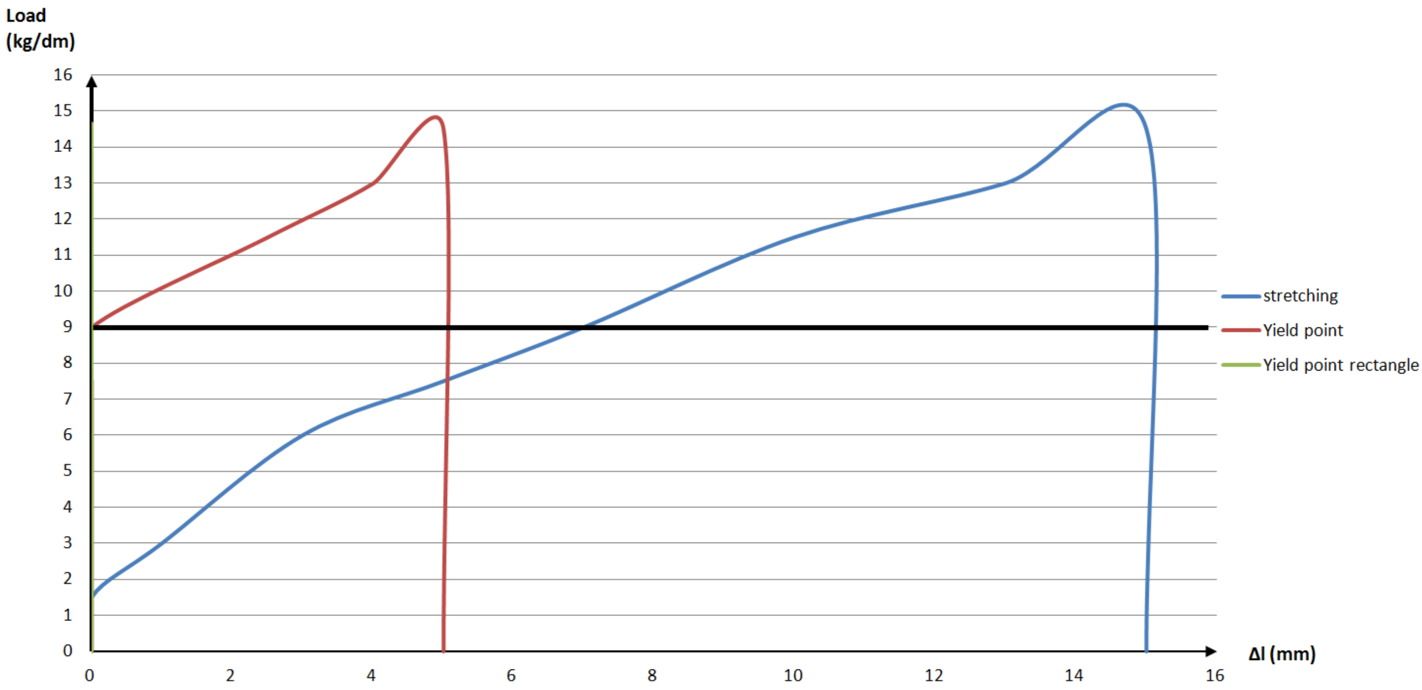
Fig. 8 – Points of attack tension test



The plastic rectangle without the dyneema cord of reinforcement broken at 6 kg

To comprise how was the lengthening the plastic has been marked with line having different angle to be sure that the load was uniformly spread

Here is reported the test with the reinforced rectangle:

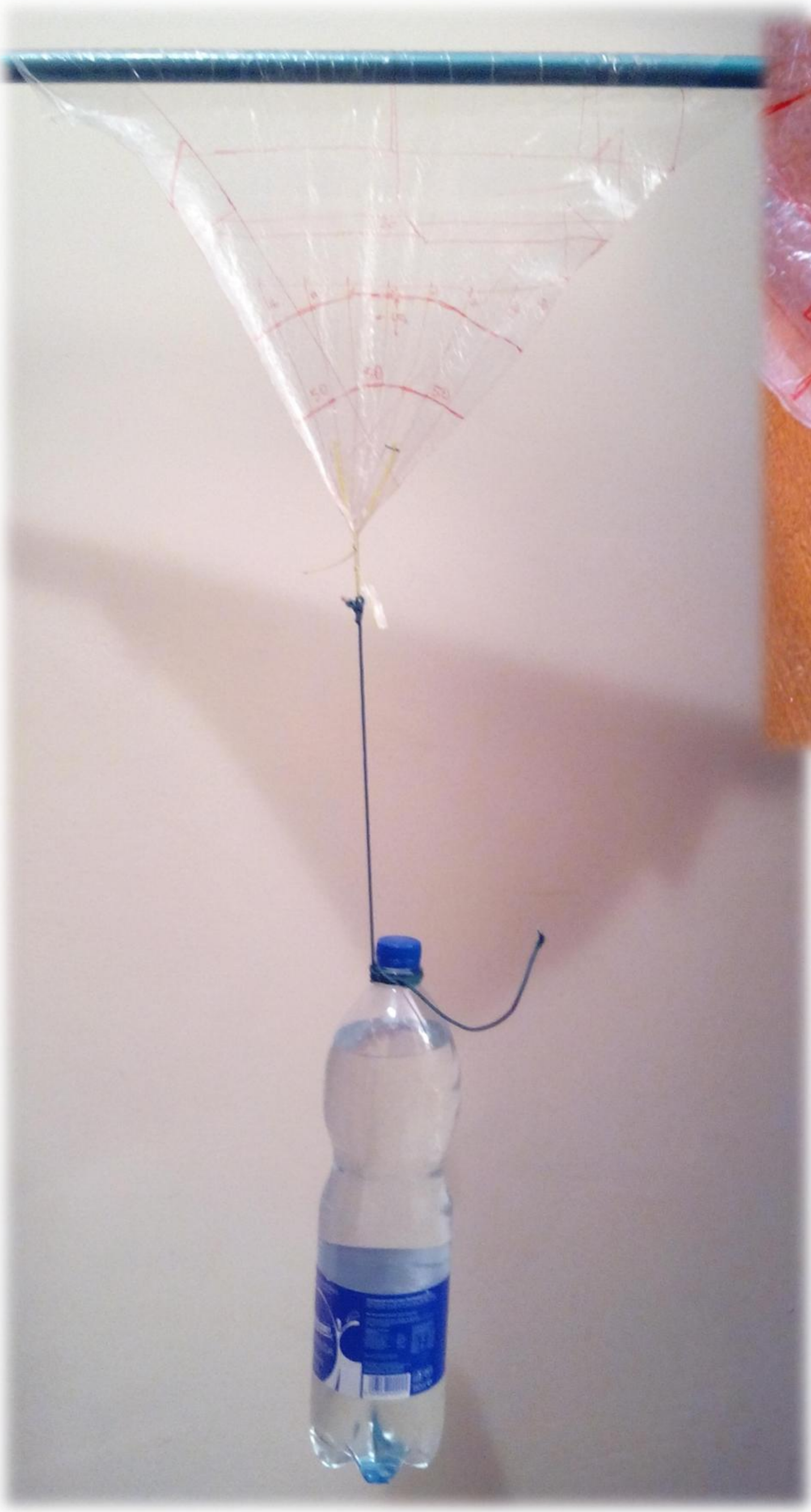


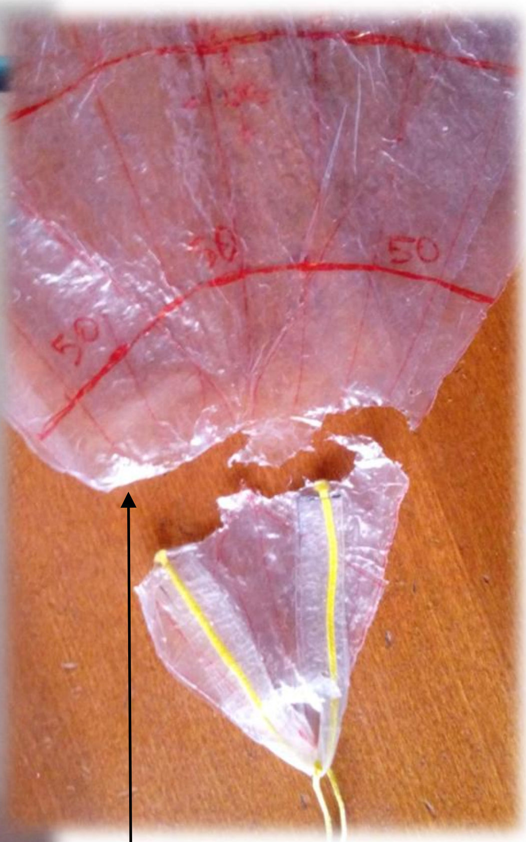
Load(kg/dm)	Δl(mm)	yield point(mm)	yield point(mm) rectangle
0	0	0	0
1,5	0	0	0
3	1	0	0
6	3	0	0
7,5	5	0	0
9	**7**	**0**	**0**
11,5	10	2,5	0
13	13	4	0
14,5	15	5	0

Fig. 9 – Points of attack whit the reinforced rectangle tension test graph and table

As can be seen from the graphs and the table using the rectangle reinforced the yield point occurs at 9 kg. Now introducing a coefficient of variability (k_c) of 1,5 (because doing many points of attack someone could be less resistant) the maximum load that each point can hold safely is 6 kg

$$\text{Maximun load for one point of attack} = P_m = \frac{Rs}{k_c} = \frac{9}{1,5} = 6\ \text{kg}$$





The plastic broken in the point expected.

The really contingency coefficient (n), so, is:

$$n_r = \frac{P_m}{P_c} = \frac{6}{0{,}89} \approx 6{,}7$$

The minimum contingency coefficient has been largely respected

$n_r \geq n_p \quad \rightarrow \quad 6{,}7 > 3$

Fig. 10 – Points of attack whit the reinforced rectangle tension test

5.3 - Lines tension test

For the lines two types have been chosen, different for convenience in the use of the paraglider (line of bigger diameter in correspondence of the braces to facilitate the recognition of the lines and avoid tangling).The lines have been divided in red polypropylene cords (of 2 mm) for the last ramifications of the line and the yellow dyneema cords (of 0,75 mm) for all the others.

-Yellow line test:

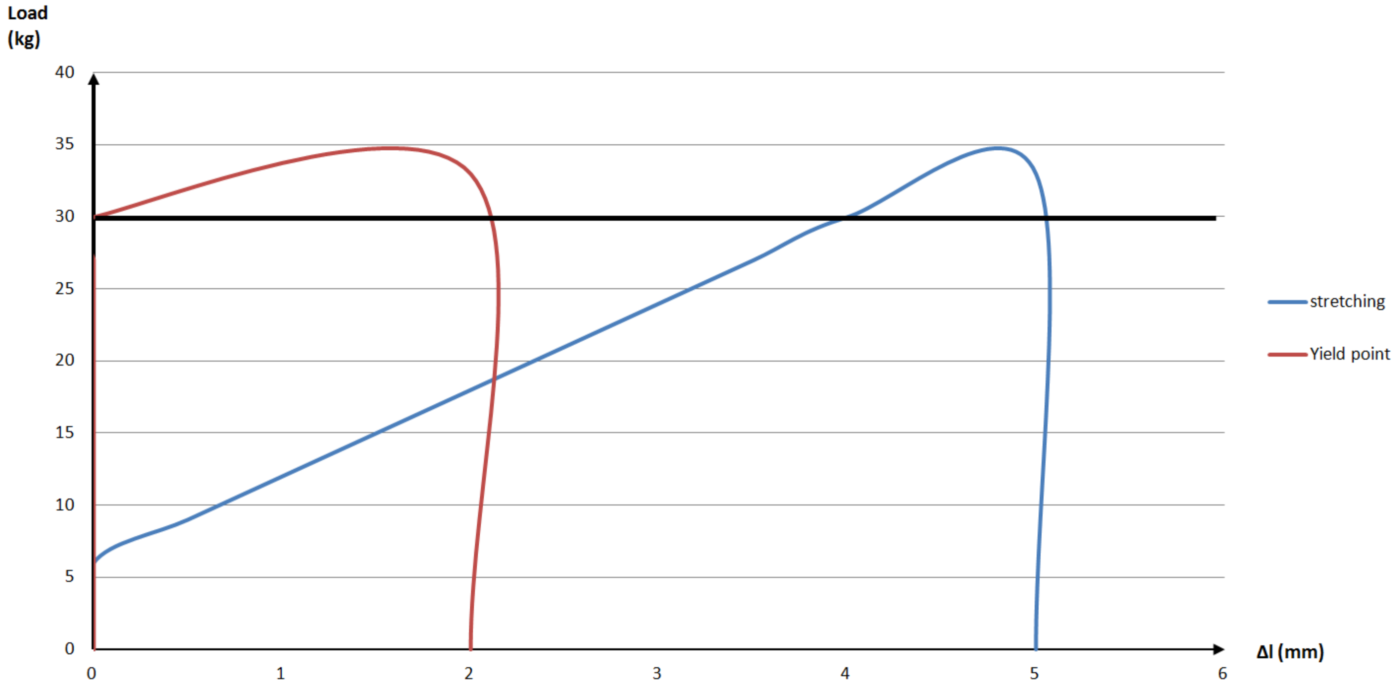
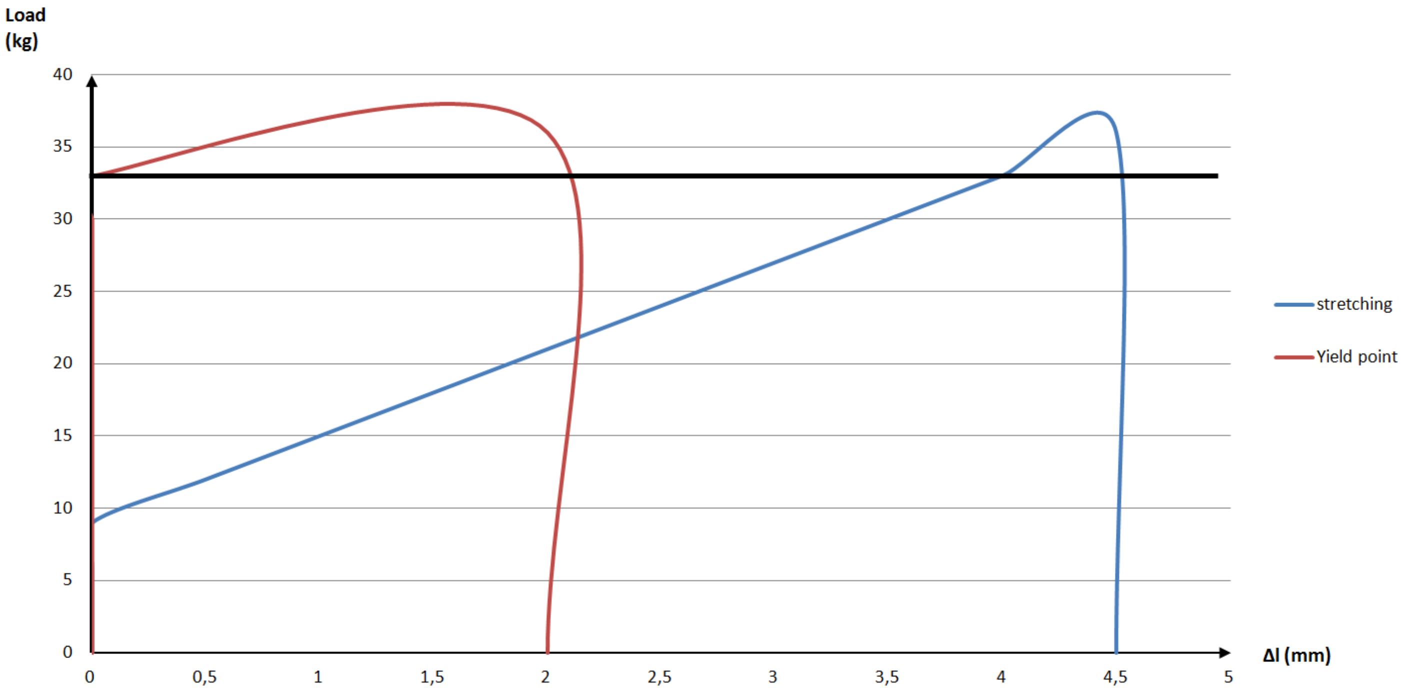


Fig. 11 – Yellow line tension test graph and table

Load(kg)	Δl(mm)	yield point(mm)
0	0	0
6	0	0
9	0,5	0
12	1	0
15	1,5	0
18	2	0
21	2,5	0
24	3	0
27	3,5	0
30	4	0
33	5	2

R_{my} = load max yellow cord = 30 kg

-Red line test:



Load(kg)	Δl(mm)	yield point(mm)
0	0	0
6	0	0
9	0	0
12	0,5	0
15	1	0
18	1,5	0
21	2	0
24	2,5	0
27	3	0
30	3,5	0
33	4	0
36	4,5	2

R_{mr} = load max red cord = 33 kg

Fig. 12 – Red line tension test graph and table

The calculate load for one line was 5 kg, so, imposing a minimum contingency coefficient (n) equal to 3 the load that each line must support is:

$$L_c = n_p * Q = 3 * 5 = 15 \frac{kg}{point}$$

Utilizing a safety coefficient (k) of 1,5 (R.A.I, F.A.R.23 rules) the load admissible is:

$$\text{Yellow cord} \rightarrow \text{ Maximun load for one line } = L_{my} = \frac{Rmy}{k} = \frac{30}{1,5} = 20 \text{ kg}$$

$$\text{Red cord} \rightarrow \text{ Maximun load for one line } = L_{mr} = \frac{Rmr}{k} = \frac{33}{1,5} = 22 \text{ kg}$$

The really contingency coefficient (n), so, is:

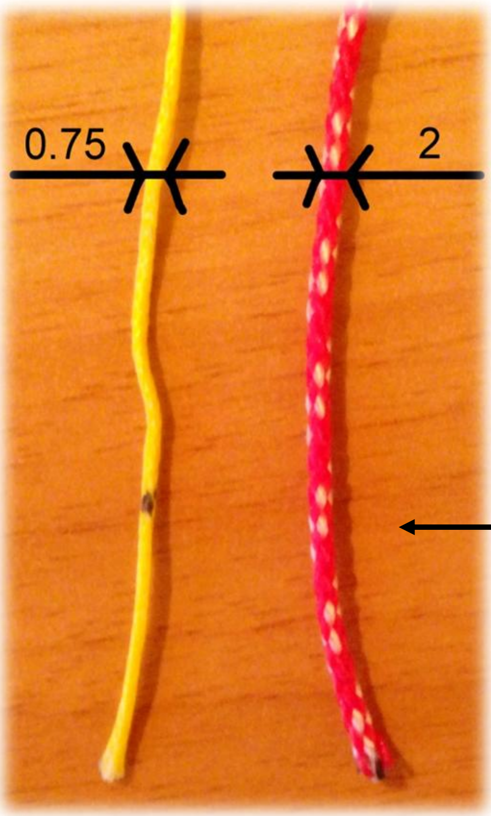
$$\text{Yellow cord} \rightarrow n_{ry} = \frac{L_m}{L} = \frac{20}{5} \approx 4$$

$$\text{Red cord} \rightarrow n_{rr} = \frac{L_m}{L} = \frac{22}{5} \approx 4,4$$

The minimum contingency coefficient has been respected

Yellow cord → $n_{ry} \geq n_p$ → 4 > 3

Red cord → $n_{rr} \geq n_p$ → 4,4> 3



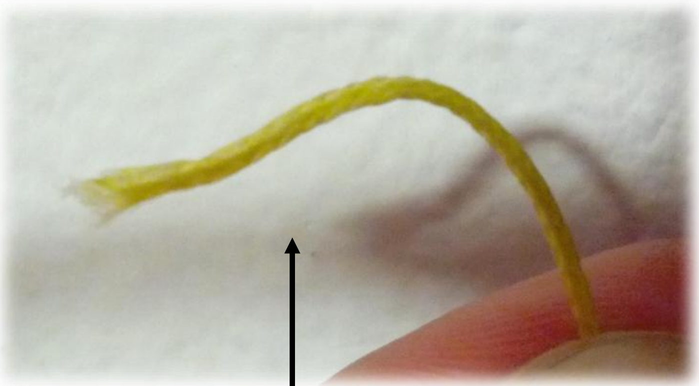


Fig. 13 – The lines and the dyneema cord broken

6 - Logistic and organization

Techniques of organization of the lean production, that is a systemic method for the elimination of waste within a manufacturing process, have been applied to build the paraglider. One of the main concepts is the identification of the 7 principal wastes that are:

- **Transport** (moving products that are not actually required to perform the processing): Keeping the wing on the balcony has minimized the moving from outside to inside. A total cancellation of the travel would have taken place if there were the possibility to keep the wing always open in a separate laboratory. The process has been divided in left wing and right wing that has been merged together avoiding to move all the wing every day for the welding.

- **Inventory** (all components, work in process, and finished product not being processed): It has been reduced to the minimum: extra stocks consist only in 10 m^2 of plastic and 20m of cords to recover possible errors.

- **Motion** (people or equipment moving more than is required to perform the processing): To maintain a more ergonomic position and avoid burning plastic has been used the floor of the kitchen, very close to the table, to lay the iron. This has increased the speed of production and avoid strenuous movements. Having to work 6 days out of 7 for at least one hour and half a day, this has been very important for the success of the project. However, it was not possible to restrict the movement of disconnecting and inserting the plug of the iron into the socket, because if I had not done it, after a short time the thermostat would have burned and furthermore the iron was heavy (about 2kg).

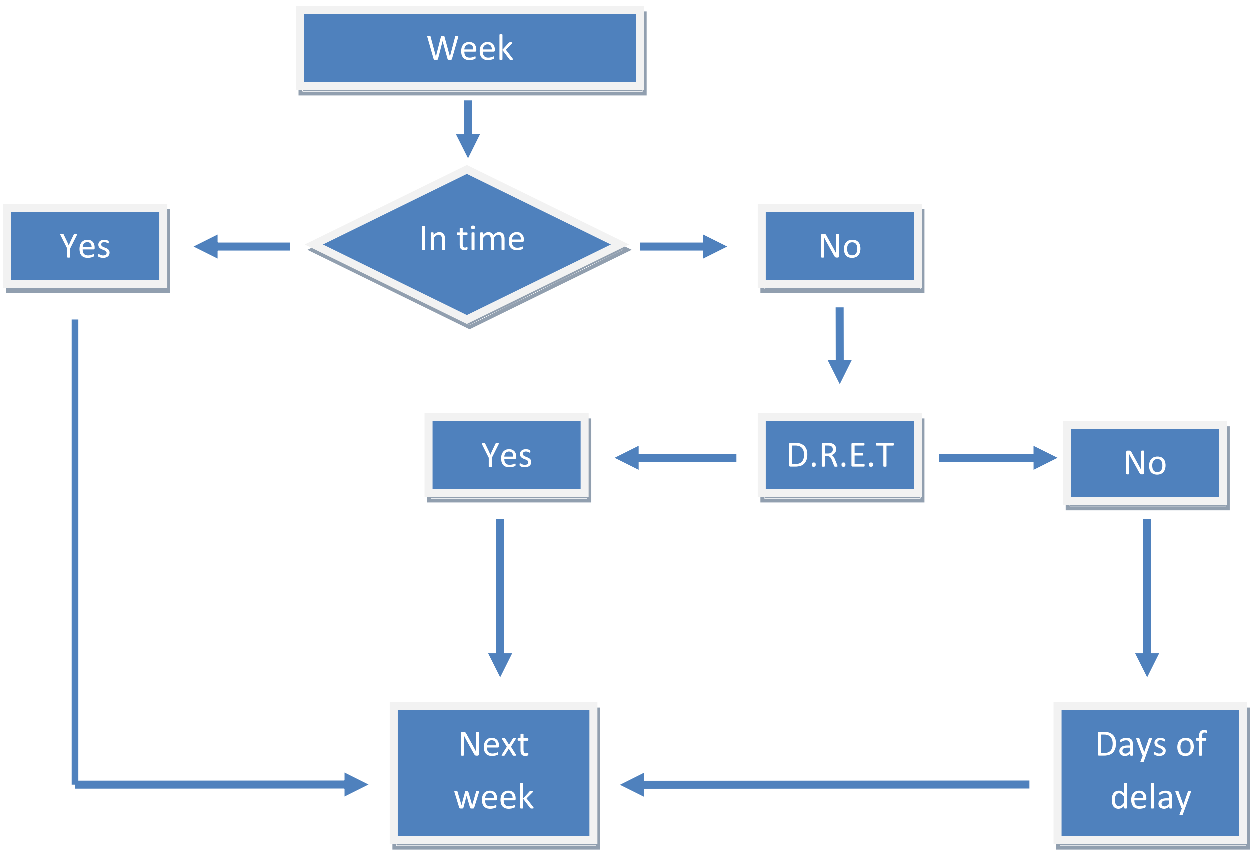
-**Waiting** (waiting for the next production step or for equipment working): To minimize waiting times each working day has been turned on iron as the first point and, then, the material has been prepared for the following welding .This has helped to save about 10 minutes of work every day. Furthermore, being impossible to use the iron with the washing machine or the oven on (it would have caused a black out) I had to arrange for schedules times of welding with my mom.

-**Overproduction** (production ahead of demand):
All the ribs have been numbered and only one case of overproduction has been found with 2 extra series of extradoses products for an error of processing.

-**Over Processing** (use of more expensive resources necessary to reach the same goal): The project is based mainly on this point. In fact, knowing what was the ultimate goal has been decisive to work at the minimum of the essential resources. For example, if the choice of the material had been the fabric I would have to pay a person qualified in sewing in addition to the price of the material to arrive at the same end result, namely the use of the wing for short and low altitude flights. As the specifications of the project, the first question, so, has been: "How to build a paraglider in a short time and with limited resources available?" Around this point was therefore born the entire project.

-**Defects** (produce waste and the effort involved in inspecting for this): Another crucial point of the project has been the limitation of defects, trying to tend to the 'zero-defect'. In fact having about 8 months of work available (few in relation to the work hours) errors that I could do in welding ribs with extradoses were practically zero as they would have required to re-do all the work done up to that moment or try to repair the wrong part losing many weeks respect to the scheduled time. However, errors were anyway committed in printing the paper but they have been recovered with some effort.

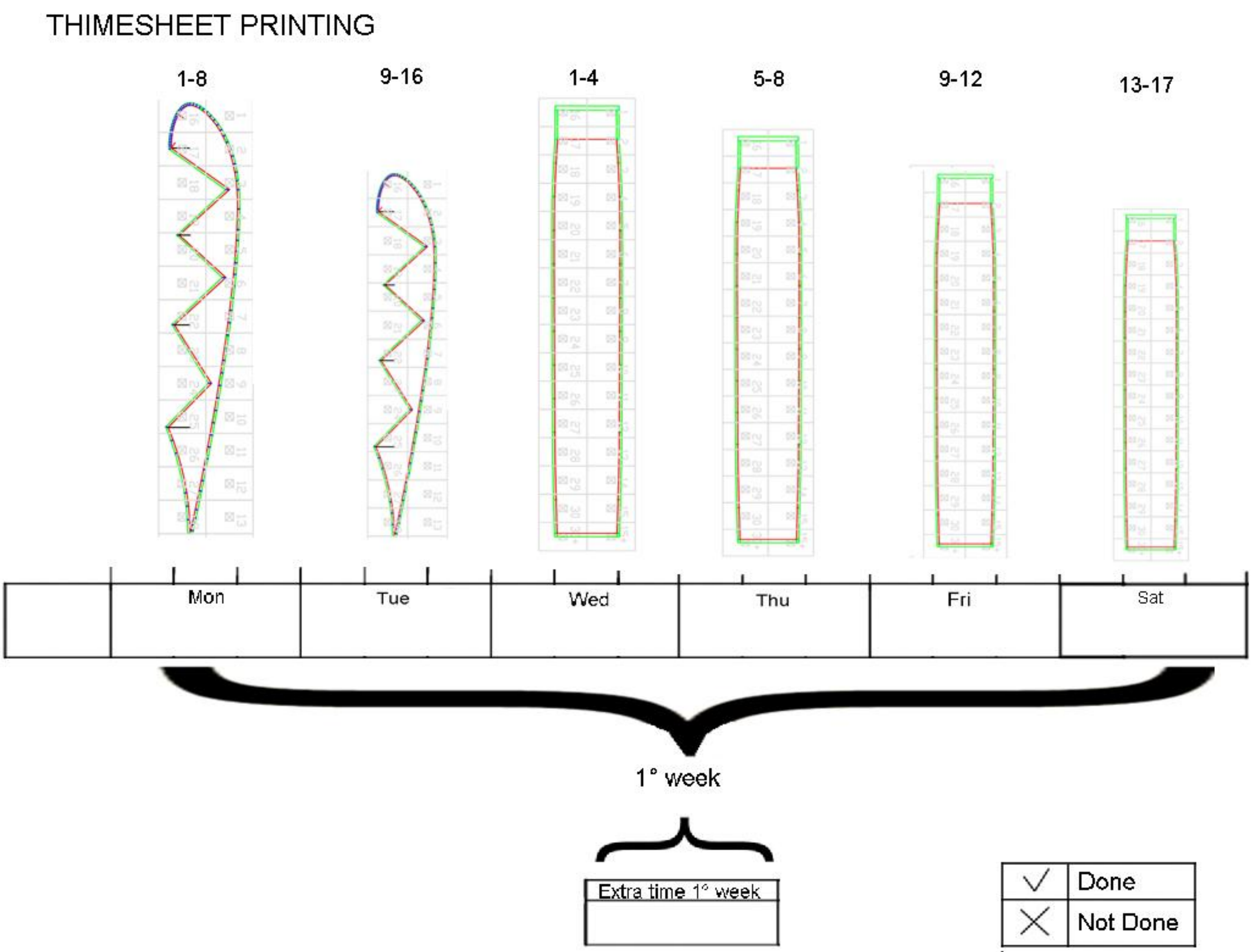
To be able to apply the techniques of lean production and having a relatively limited time in the scholastic year to finish the project I had to create a timesheet of 6 working days out of 7 and also the 7th day to recover possible delays caused by no-working days. The timesheets are divided in work order and every day of work is marked with V (Done) or X (Not done) and every week of work is filled in the correspondent table (ex: "timesheet welding wing") to maintain the work rate fast and the time respected. The block diagram of the structuring of the tables appears in this way:



7 - Timelines and organization printing

A work apparently as easy as printing has however presented several difficulties especially due to the size of the ribs (over 2,5 meter of chord).Not having the plotter I had to print on A3 sheets and then merge them also having to put more ribs on the same sheet as not to waste too many sheets. The printing of the sheets has, in addition, presented problems as regarding the nomenclature of the ribs and extrados because misunderstandings have been created between who gave the print order and who had to print.

Hours of work ≈ 18 h



Timesheet printing wing

Week	In time	D.R.E.T	Days of delay	
Example	Yes/no	Yes/no	Number of days if not	
Printing				
1				
Merging				
1°				

Week : Represents the work week

In time : Yes → The timesheet was respected

No → The timesheet wasn't respected

D.R.E.T. (Delay recovered in extra time) : Yes→The delay was recovered in the extra time

No→The delay wasn't recovered in the extra time

Days of delay : Represents the days of delay

: In time D.R.E.T Delay

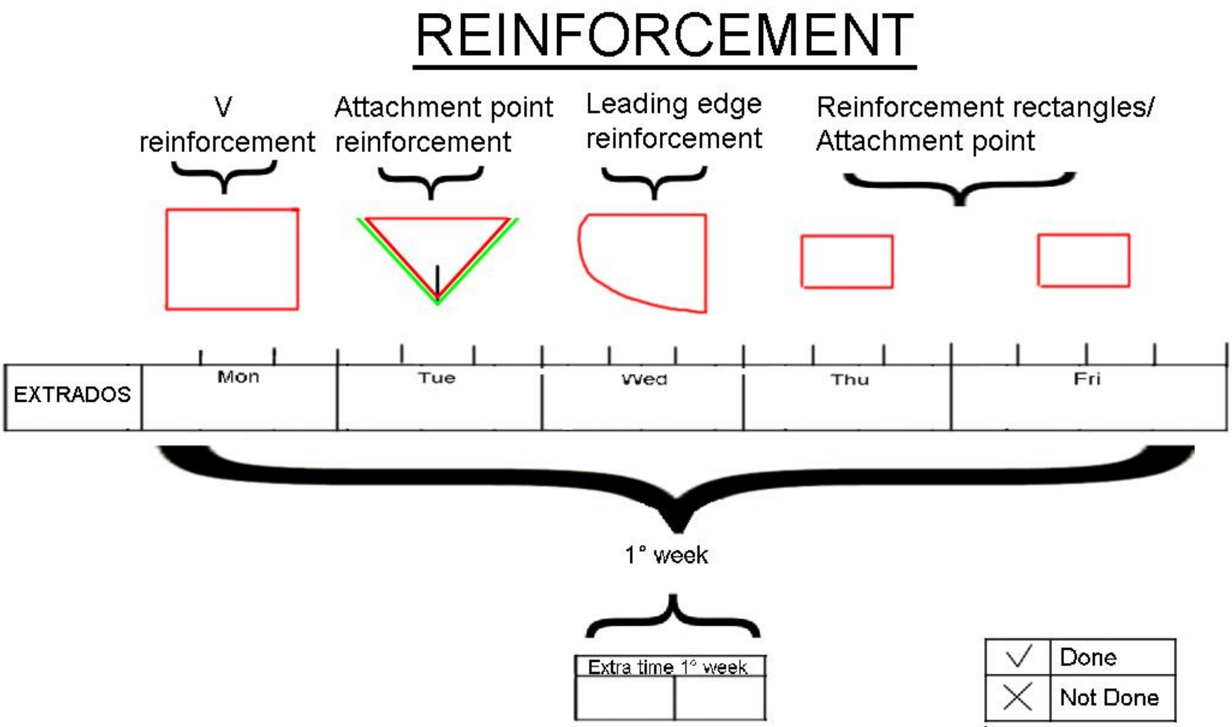
Fig. 14 – The drawing of the ribs

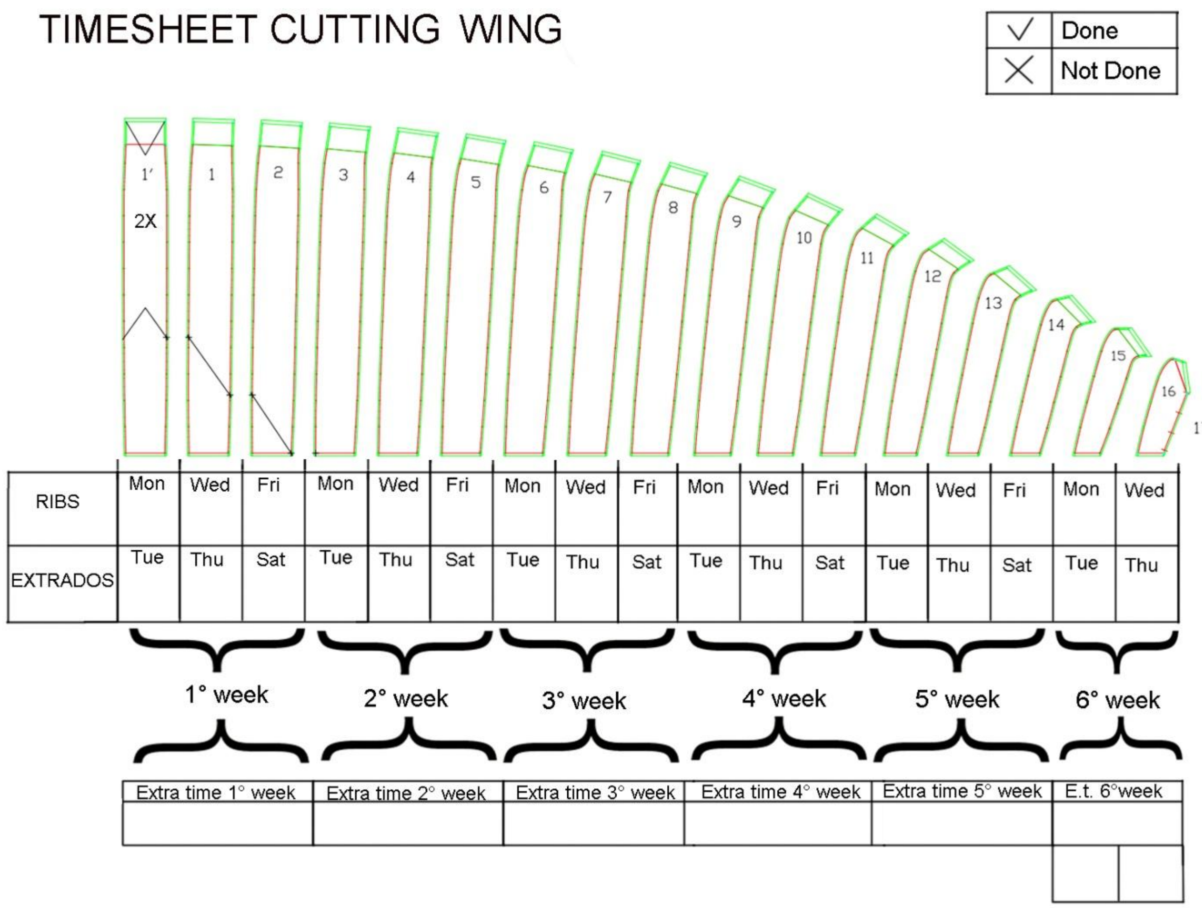
8 - Timelines and organization cutting

Thanks to the help of my grandmother, that has cut all the ribs, extrados and reinforcements , I had proceeded to the assembly of the wing . Even so, these operations have required many hours of work and a constant timesheet check for all the phase of cutting. Furthermore I had to arrange with her to avoid running out of material, or have it in excess. Following are reported the timesheet(each tracking and cutting of ribs and extrados include both the left and right part)

Hours of work ≈ 37 h

Fig. 15 – The first rib





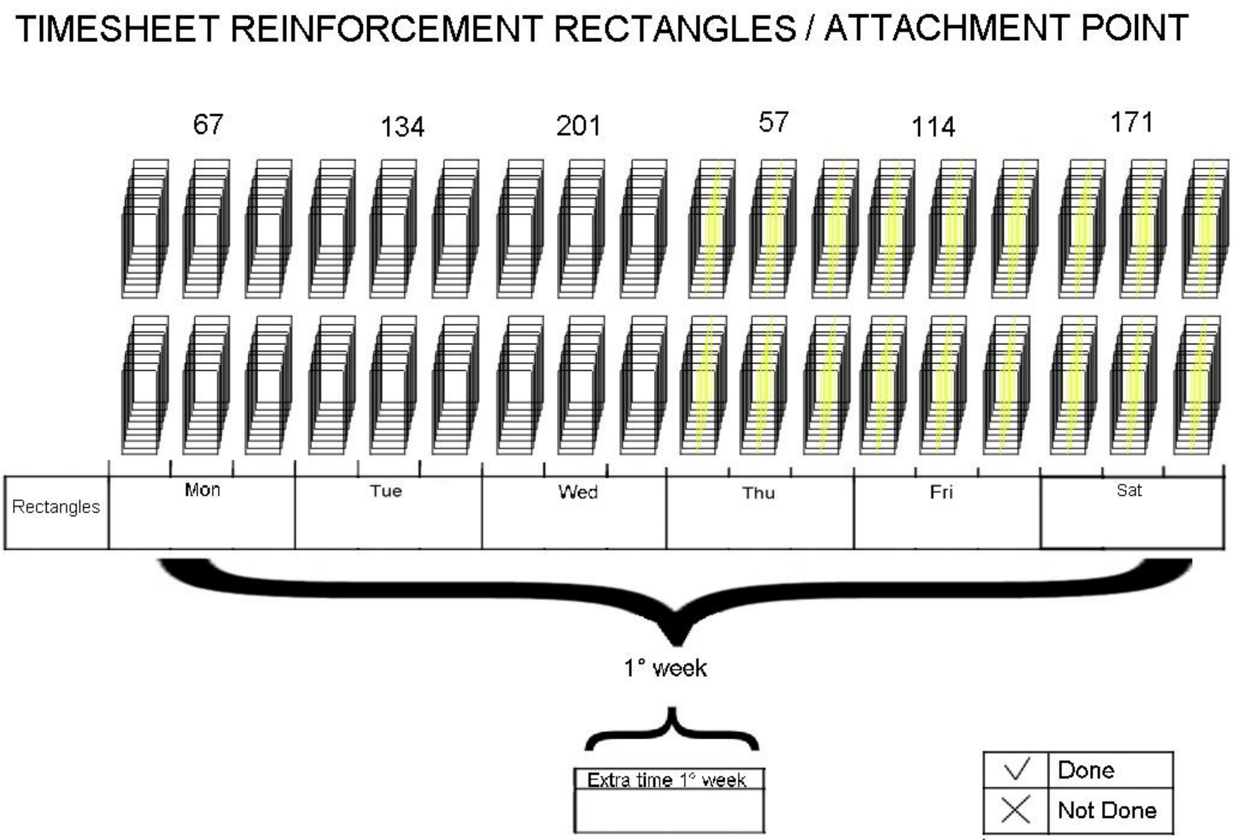
Timesheet cutting wing

Week	In time	D.R.E.T	Days of delay	
Example	Yes/no	Yes/no	Number of days if not	
Reinforcement				
1				
Cutting wing				
1°				
2°				

3°				
4°				
5°				
6°				

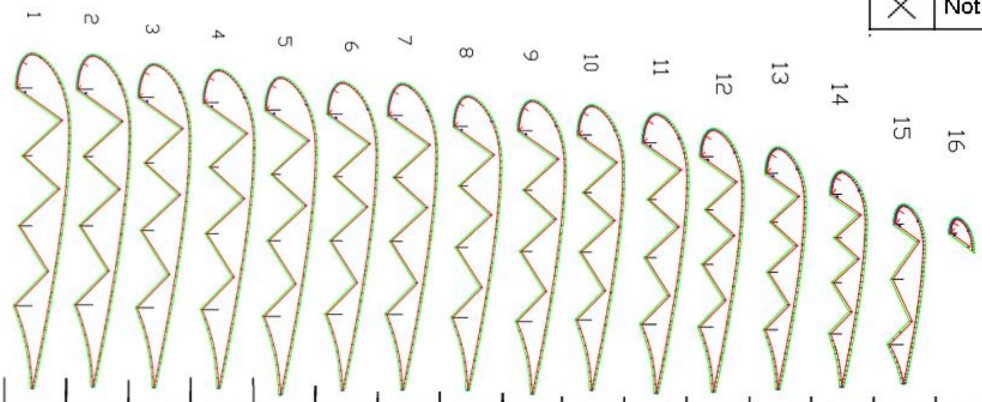
9 -Timelines and organization assembly

The assembly has been the longest and most difficult part of the job. The timesheets that are divided, in work order, in “Timesheet reinforcement rectangles”, “timesheet reinforcement ribs”, “timesheet attachment point ribs”, “Timesheet welding right wing”, “Timesheet welding left wing” are reported below.



TIMESHEET REINFORCEMENTS RIBS

√	Done
X	Not Done



RIBS	Mon	Tue	Wed	Thu	Fri	Sat	Mon	Tue	Wed	Thu	Fri	Sat	Mon	Tue	Wed	Thu

1° week

2° week

3° week

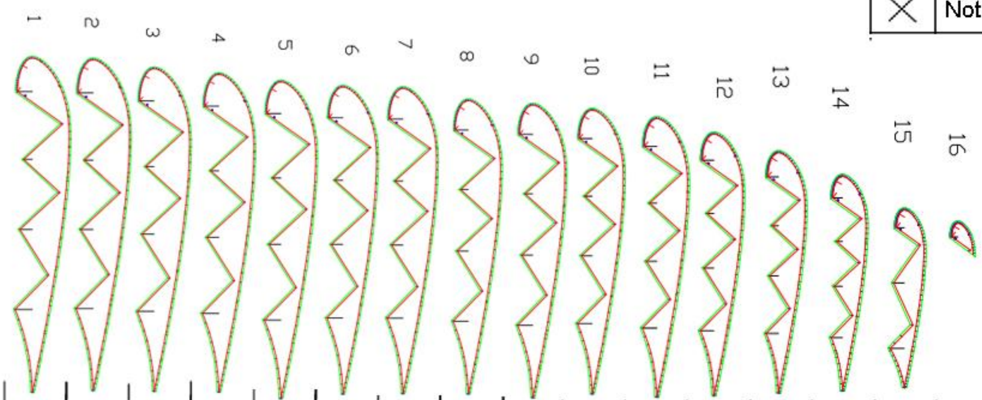
Extra time 1° week

Extra time 2° week

Extra time 3° week	

TIMESHEET ATTACHMENT POINTS RIBS

√	Done
X	Not Done

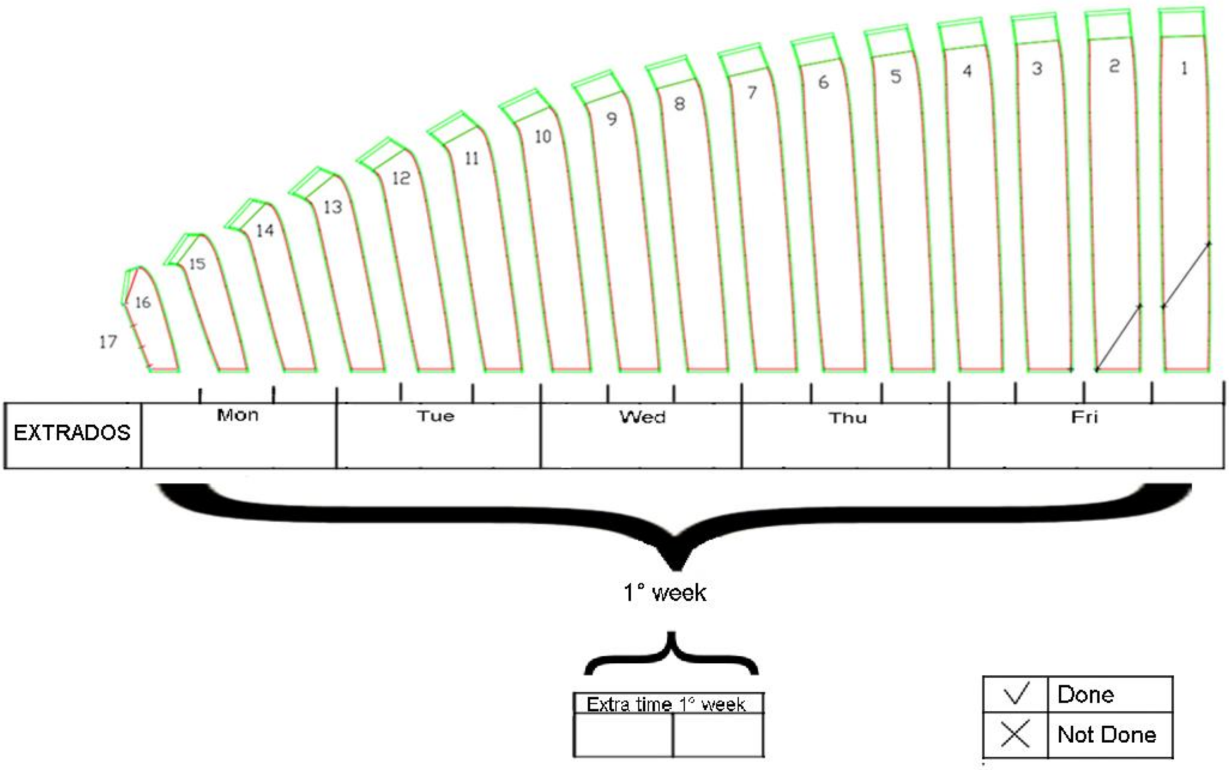


RIBS	Mon	Tue	Wed	Thu	Fri

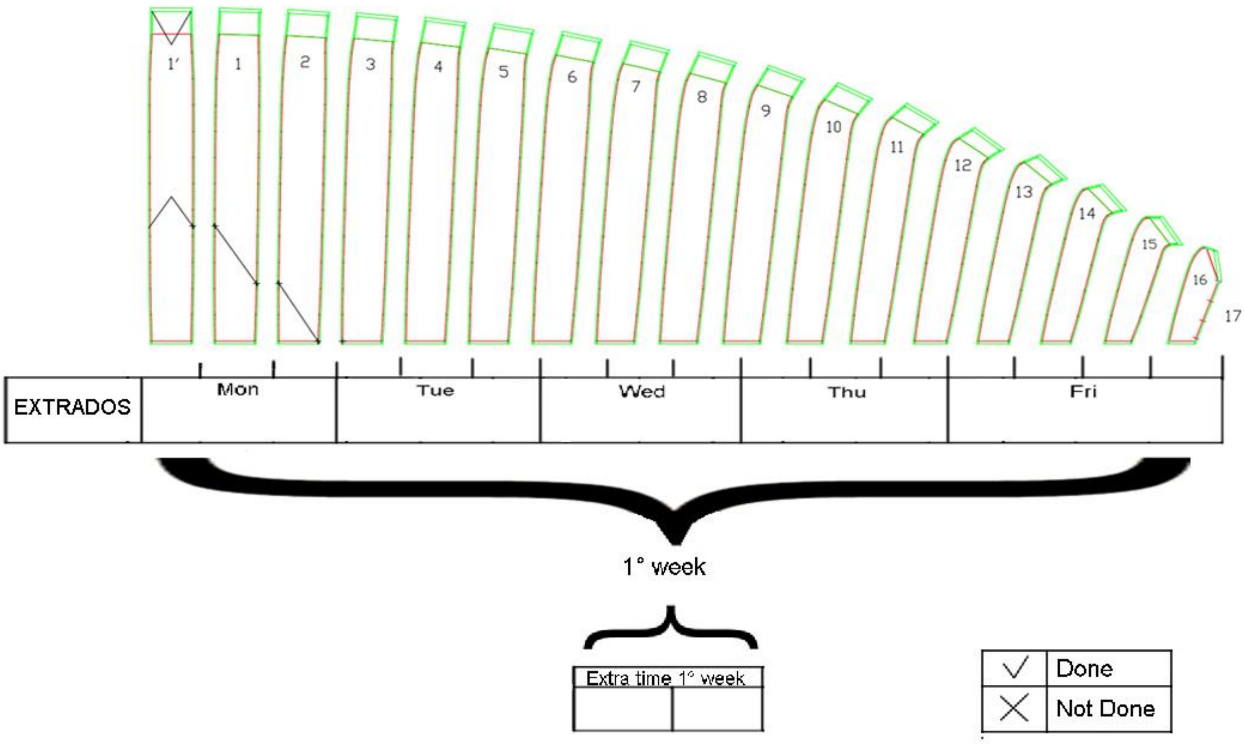
1° week

Extra time 1° week

EDGES-MARKING

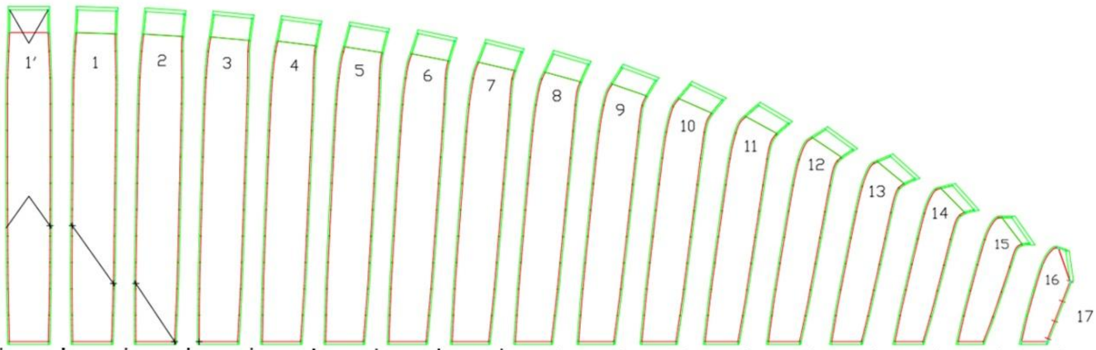


EDGES-MARKING



TIMESHEET WELDING RIGHT WING

√	Done
X	Not Done



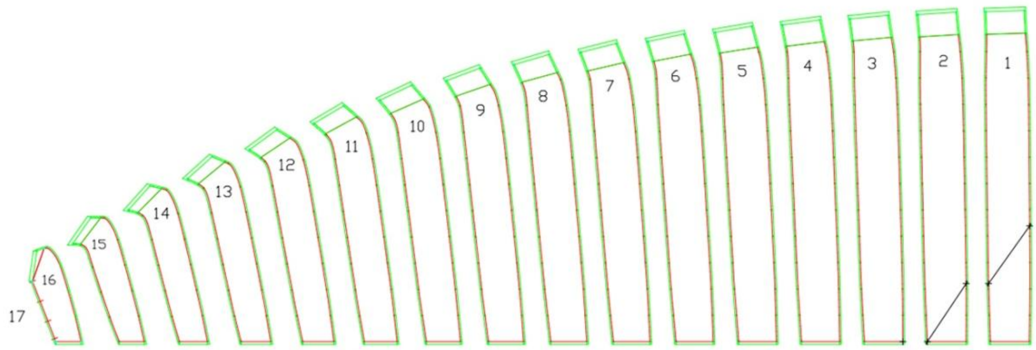
RIBS	Mon	Wed	Fri	Mon	Wed	Fri	Mon	Wed	Fri	Mon	Wed	Fri	Mon	Wed	Fri	Mon	Wed
EXTRADOS	Tue	Thu	Sat	Tue	Thu	Sat	Tue	Thu	Sat	Tue	Thu	Sat	Tue	Thu	Sat	Tue	Thu

1° week | 2° week | 3° week | 4° week | 5° week | 6° week

Extra time 1° week	Extra time 2° week	Extra time 3° week	Extra time 4° week	Extra time 5° week	E.t. 6°week

TIMESHEET WELDING LEFT WING

√	Done
X	Not Done



RIBS	Mon	Wed	Fri	Mon	Wed	Fri	Mon	Wed	Fri	Mon	Wed	Fri	Mon	Wed	Fri	Mon
EXTRADOS	Tue	Thu	Sat	Tue	Thu	Sat	Tue	Thu	Sat	Tue	Thu	Sat	Tue	Thu	Sat	Tue

1° week | 2° week | 3° week | 4° week | 5° week | 6° week

Extra time 1° week	Extra time 2° week	Extra time 3° week	Extra time 4° week	Extra time 5° week	E.t. 6°week

Timesheet welding wing

Week	In time	D.R.E.T	Days of delay	
Example	Yes/no	Yes/no	Number of days if not	
Reinforcement Rectangles/ Attachment points				
1°				
Reinforcements ribs right wing				
1°				
2°				
3°				
Reinforcements ribs left wing				
1°				
2°				
3°				
Attachment points right ribs				
1°				
Attachment points left ribs				
1°				
Edges - marking right wing				
1°				
Edges - marking left wing				
1°				

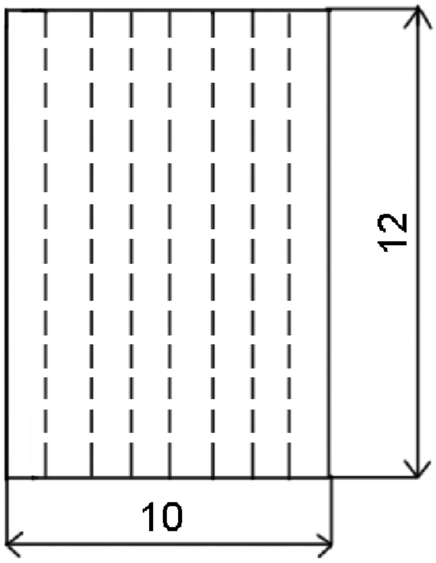
Welding right wing				
1°				
2°				
3°				
4°				
5°				
6°				
Welding left wing				
1°				
2°				
3°				
4°				
5°				
6°				

Total weeks = 23 ≈ 6 months

Fig. 16 – The work table

9.1 - Processing cycles welding

9.1.1 - Reinforcement rectangles/ Attachment point



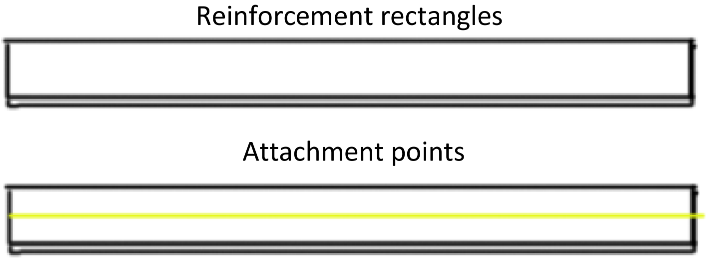
1-Cut n° 400 plastic rectangle (dimension 10x12mm)

2-Turn n° 201 plastic rectangle along the dashed lines and weld them

3-Turn n° 171 plastic rectangle along the dashed lines and weld them putting inside a reinforcement core (dyneema rope 0,75mm)

Hours of work ≈ (1rectangle/1 minute) x 400 ≈

≈ 6 h 40 minutes



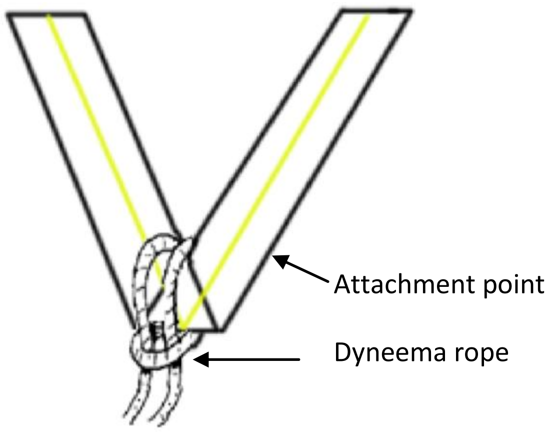


Fig. 17 – Attachment points

9.1.2 - Reinforcements ribs wing

1-Weld the reinforcement rectangle on the rib in correspondence to the "v" of the rib

2-Rotate the reinforced edges (35 mm) around the red line and weld it

3- Weld "V reinforcement" (160x135 mm) over the reinforcement rectangle (then cut the excess plastic along the v of the rib

Hours of work ≈ (1 reinforcement /1 h) x 30 ribs ≈ 30 h

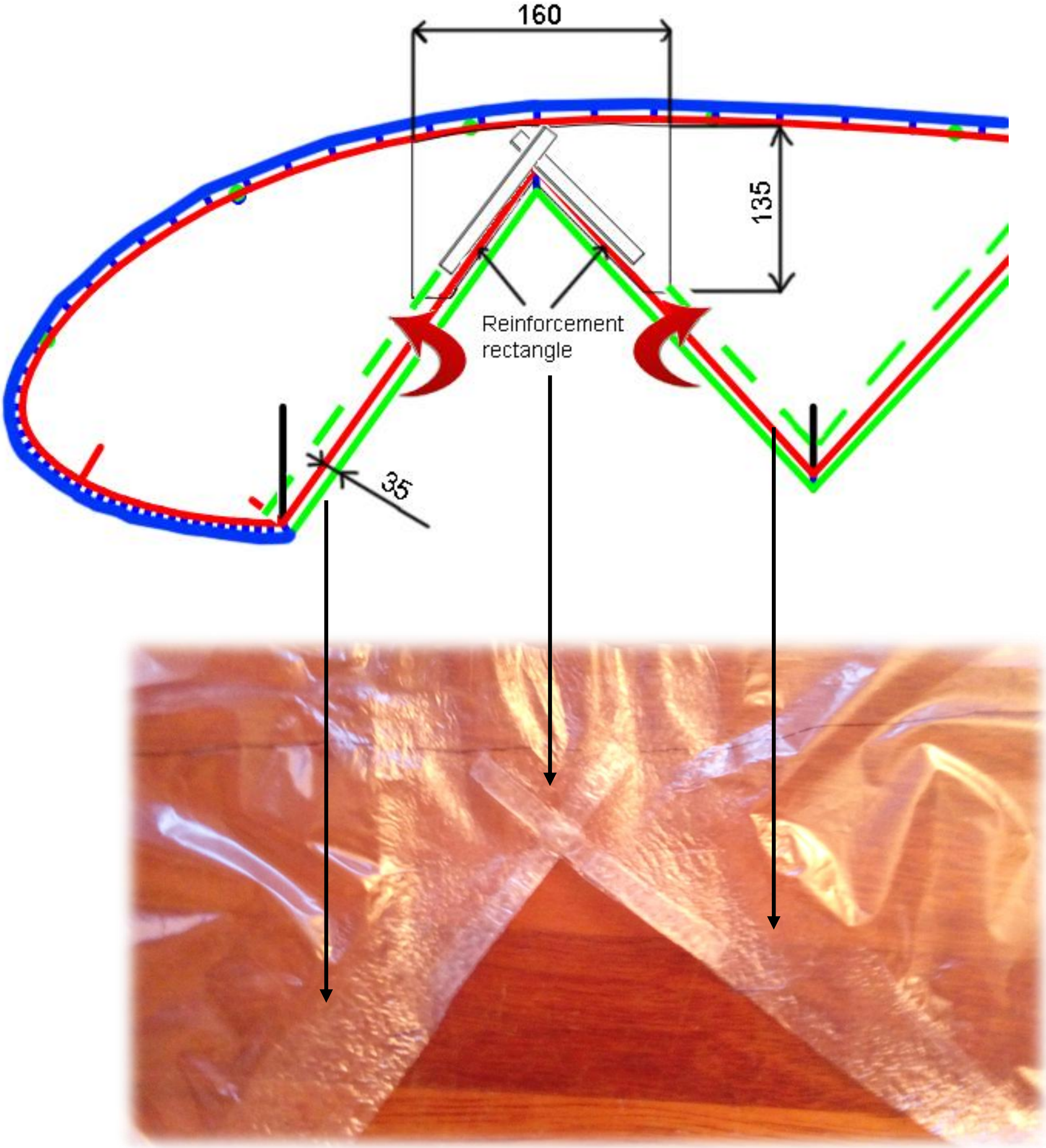
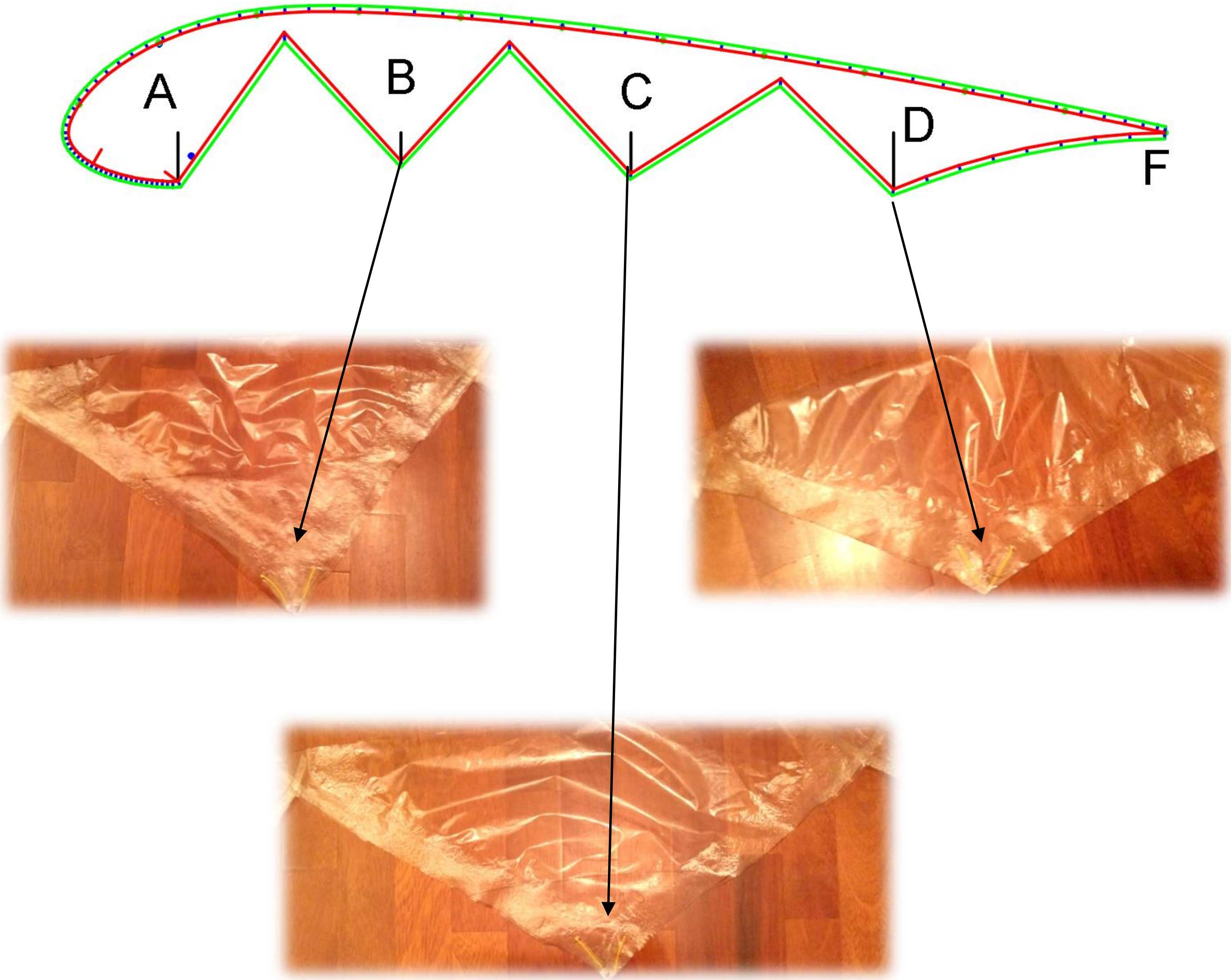


Fig. 18 – An example of reinforcement

9.1.3 - Attachment points ribs

1 – Weld the attachment point in correspondence of the B-C-D point (A-B next)

2 –Weld, now, the attachment point reinforcement over the attachment point



Hours of work ≈ (0,5 h/1 attachment point) x 30 ribs ≈ 15 h

Fig. 19 – An example of rib finished

9.1.4 - Edges marking

1– Using a string, take 5 or 6 points on the leading edge and bring them back on the extrados

2-Bending the plastic along the line with the * and welding it

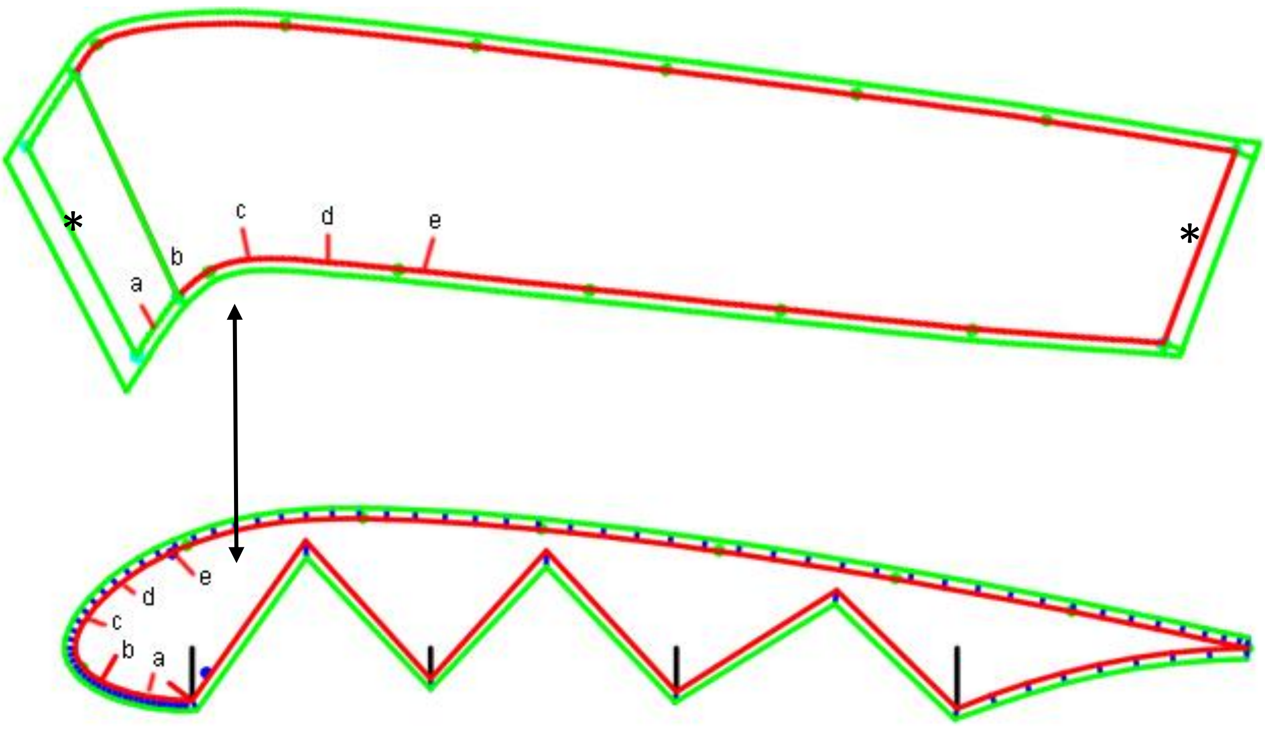


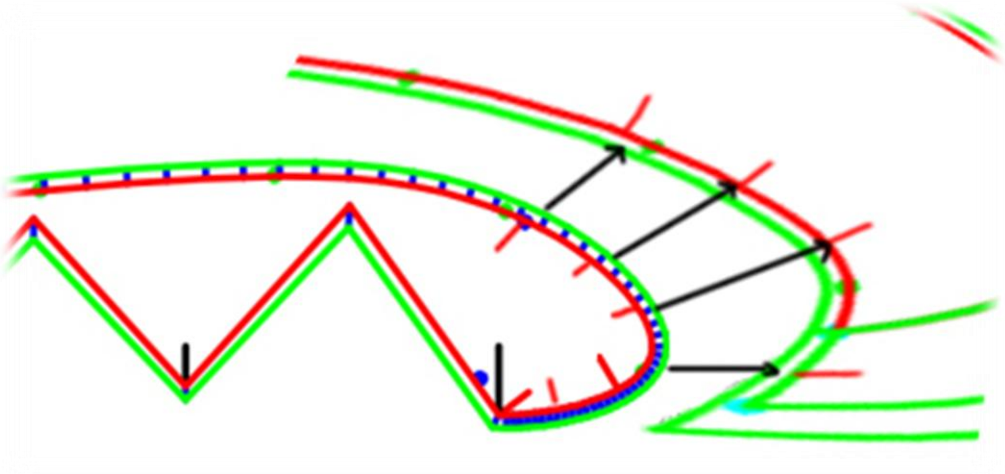
Fig. 20 – The marking of the edge

9.1.5 - Welding wing

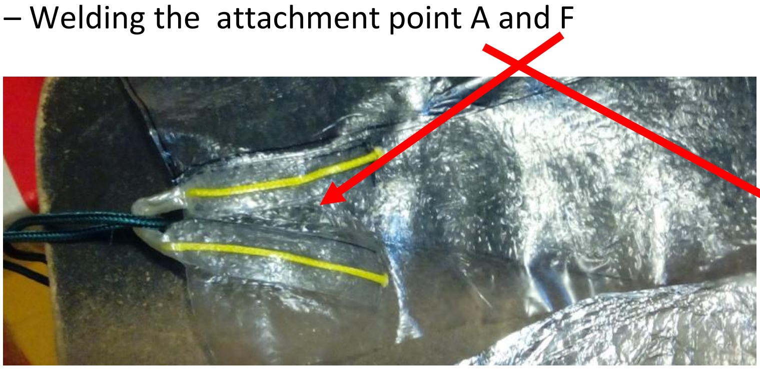
1 – After creating a reference template (with the size of the leading edge of the first rib) pointing the extrados over it

Fig. 21 – The welding of the leading and trailing edges

2 – Putting the ribs over the extrados and weld it



3 – Welding the attachment point A and F



4 – Weld, now, the leading edge reinforcement over the A point of attach

5 – Turn the ribs and revise the welding in correspondence of the ‘V’ reinforcement

6 – Repeat the process for the other welding

Fig. 22 – Two cells done

Fig. 23 – The wing becomes larger…

Fig. 24 – …and larger

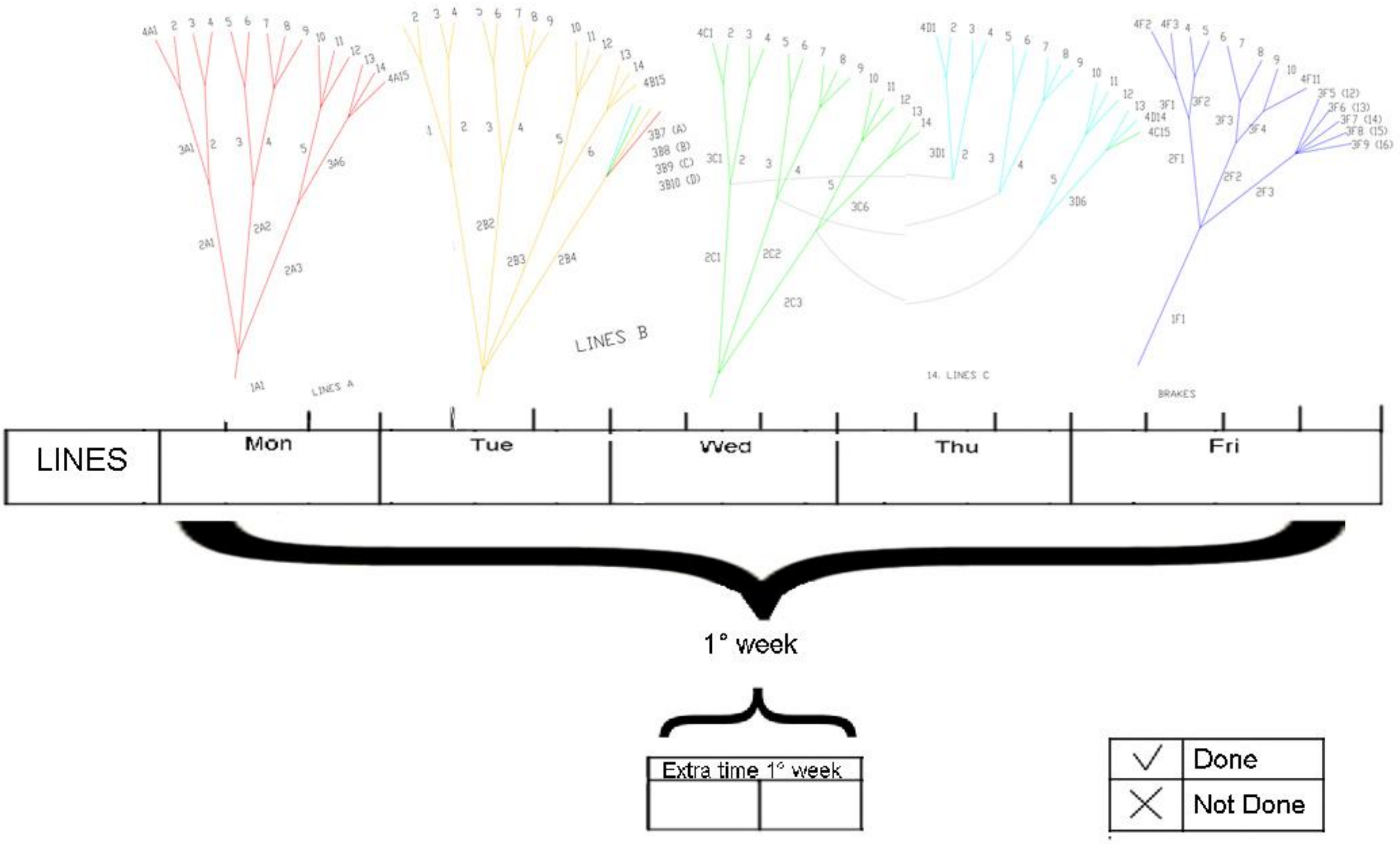
Hours of work ≈ (1,5 h/1 welding) x 64 welds ≈ 96 h

10 - Timelines and organization lines

The cutting and assembly of the lines have required, a little time respect to the cutting and the welding. However it hasn't been easy to work on the floor (not good ergonomic position), because of the number of the cables and the small space in the house to spread the wing. Below is reported the timesheet for both the cutting and the assembly that at the end have needed one month of work.

Hours of work ≈ (2 h/1 cutting-assembly) x 20 ≈ 40 h

TIMESHEET LINES



Timesheet lines

Week	In time	D.R.E.T	Days of delay	
Example	Yes/no	Yes/no	Number of days if not	
Cutting lines				
1°				
2°				
Assembly lines				
3°				
4°				

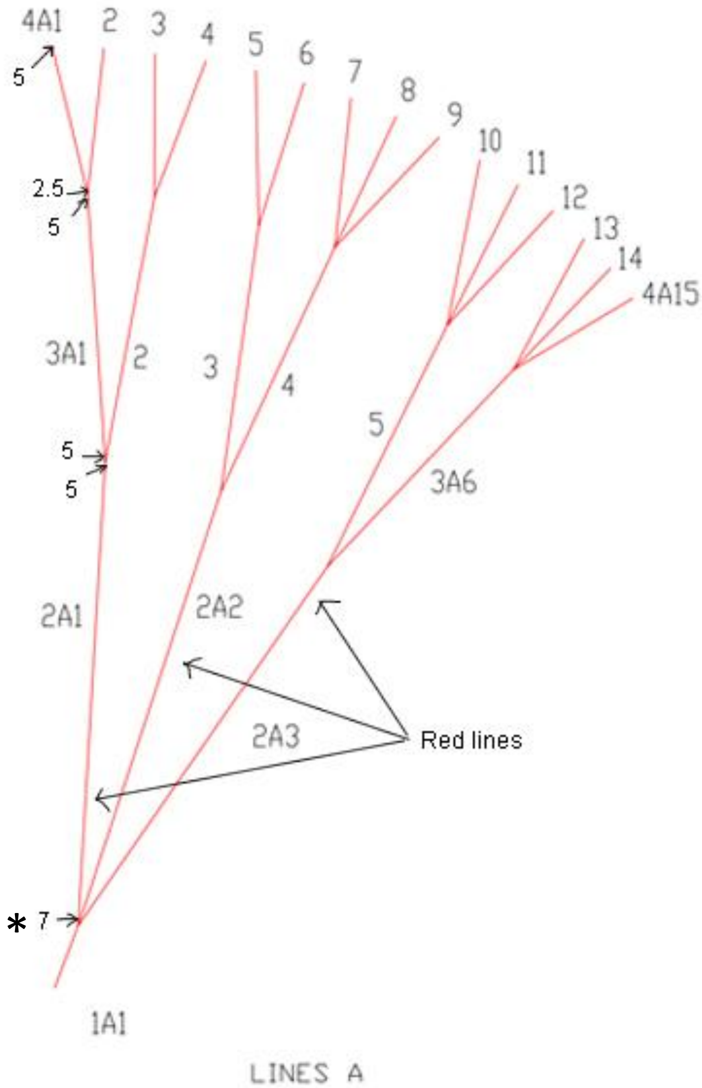
10.1 - Processing cycles lines

10.1.1 - Cutting lines

1 – Using a ruler take the measures keeping in mind the space for nodes* and then cut all the lines.

2 – Put a piece of paper tape writing over the name of the line and pick up neatly the lines divided in A-B-C-D-F

Fig. 25 – One of the long day of work



Plan	A	cm
1	1A1	47
2	2A1	348,4
3	2A2	340,5
4	2A3	328,3
5	3A1	190,5
6	3A2	190,5
7	3A3	190,5
8	3A4	190,5
9	3A5	190,5
10	3A6	190,5
11	4A1	107,8
12	4A2	103,6
13	4A3	102
14	4A4	103
15	4A5	111
16	4A6	106,5
17	4A7	106,2
18	4A8	101,3
19	4A9	105,6
20	4A10	117,4
21	4A11	110,29
22	4A12	110,1
23	4A13	108,1
24	4A14	106,7
25	4A15	111,3

*Space in plus indicated in mm

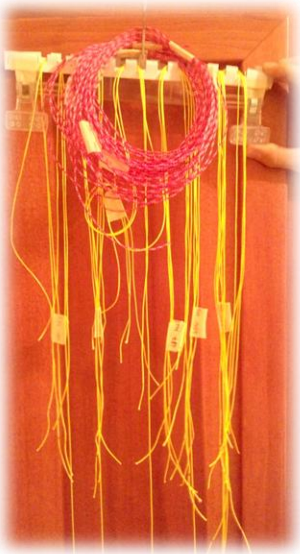
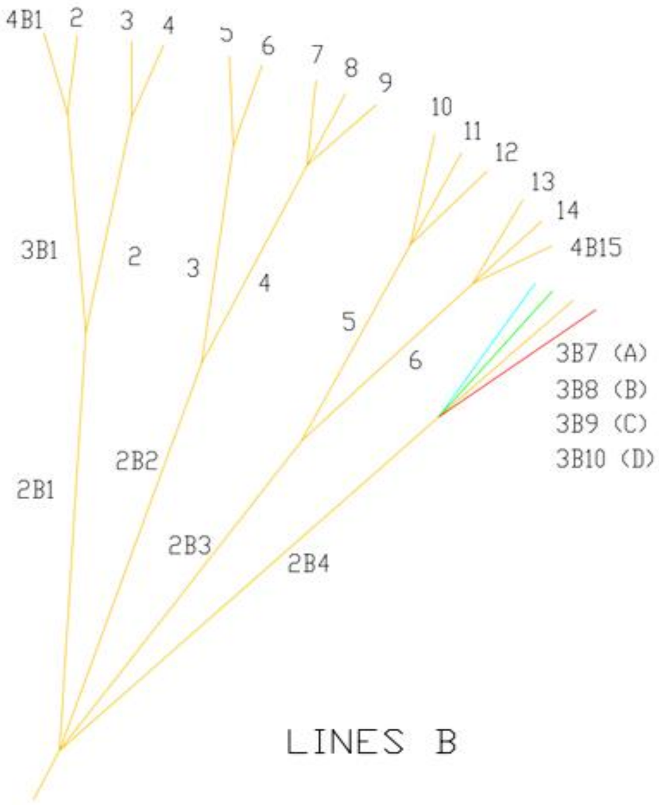
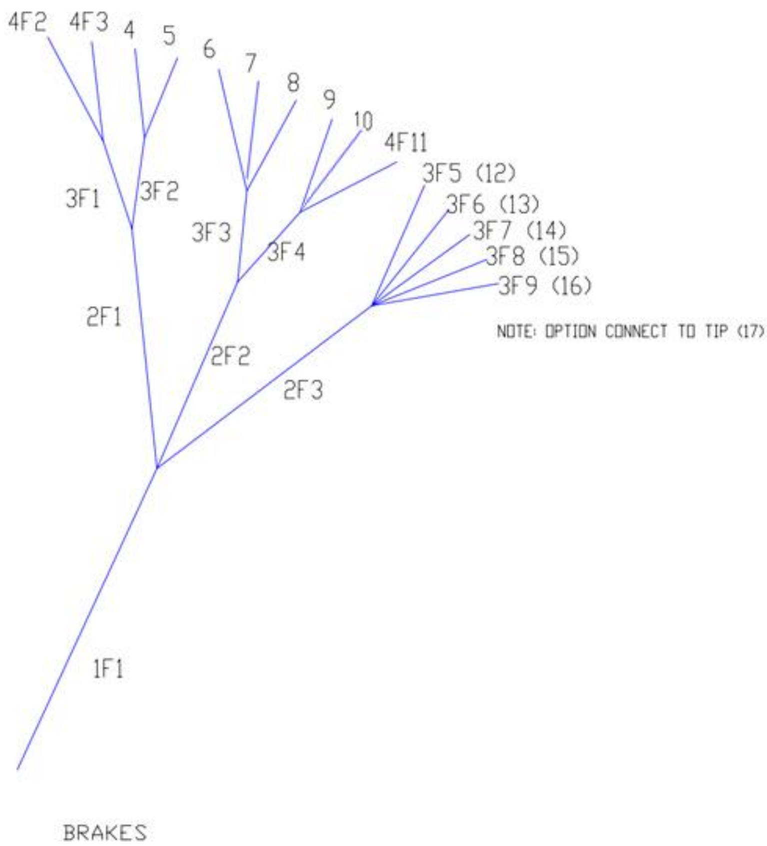


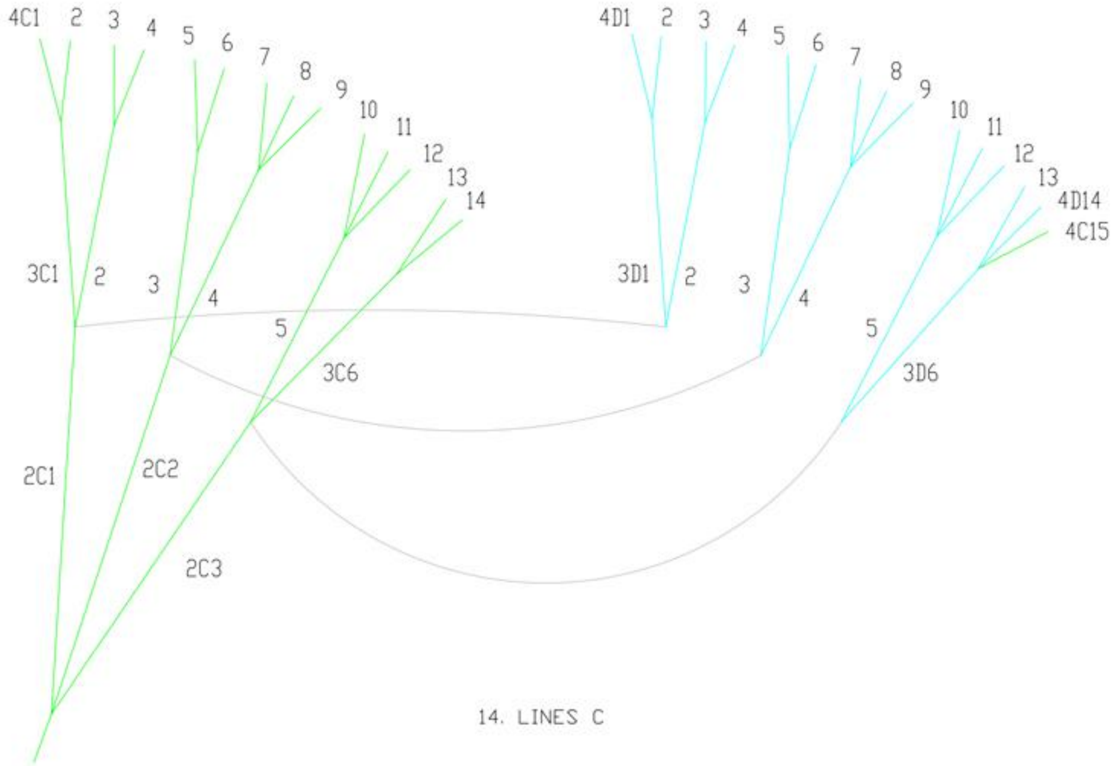
Fig. 26 – The lines



Plan	B	
26	1B1	47
27	2B1	385,5
28	2B2	374,2
29	2B3	348,1
30	2B4	430
31	3B1	190,5
32	3B2	190,5
33	3B3	190,5
34	3B4	190,5
35	3B5	190,5
36	3B6	190,5
37	3A17	163,7
38	3B17	155,7
39	3C17	150,3
40	3D17	147,8
41	4B1	72,9
42	4B2	68,2
43	4B3	66,4
44	4B4	67,8
45	4B5	79,5
46	4B6	74,3
47	4B7	74,2
48	4B8	69,1
49	4B9	74,5
50	4B10	97,7
51	4B11	89,6
52	4B12	87,4
53	4B13	82,4
54	4B14	75,2
55	4B15	74



Brake	lines	
101	1F1	288,9
102	2F1	231,5
103	2F2	198,4
104	2F3	241,6
105	3F1	80,2
106	3F2	80,2
107	3F3	80,2
108	3F4	80,2
109	3F12	117,7
110	3F13	107,7
111	3F14	102,8
112	3F15	103,1
113	3F16	104,3
114	4F2	101,4
115	4F3	87,3
116	4F4	78,8
117	4F5	76,3
118	4F6	109,6
119	4F7	95,1
120	4F8	90,1
121	4F9	86,3
122	4F10	82,6
123	4F11	89

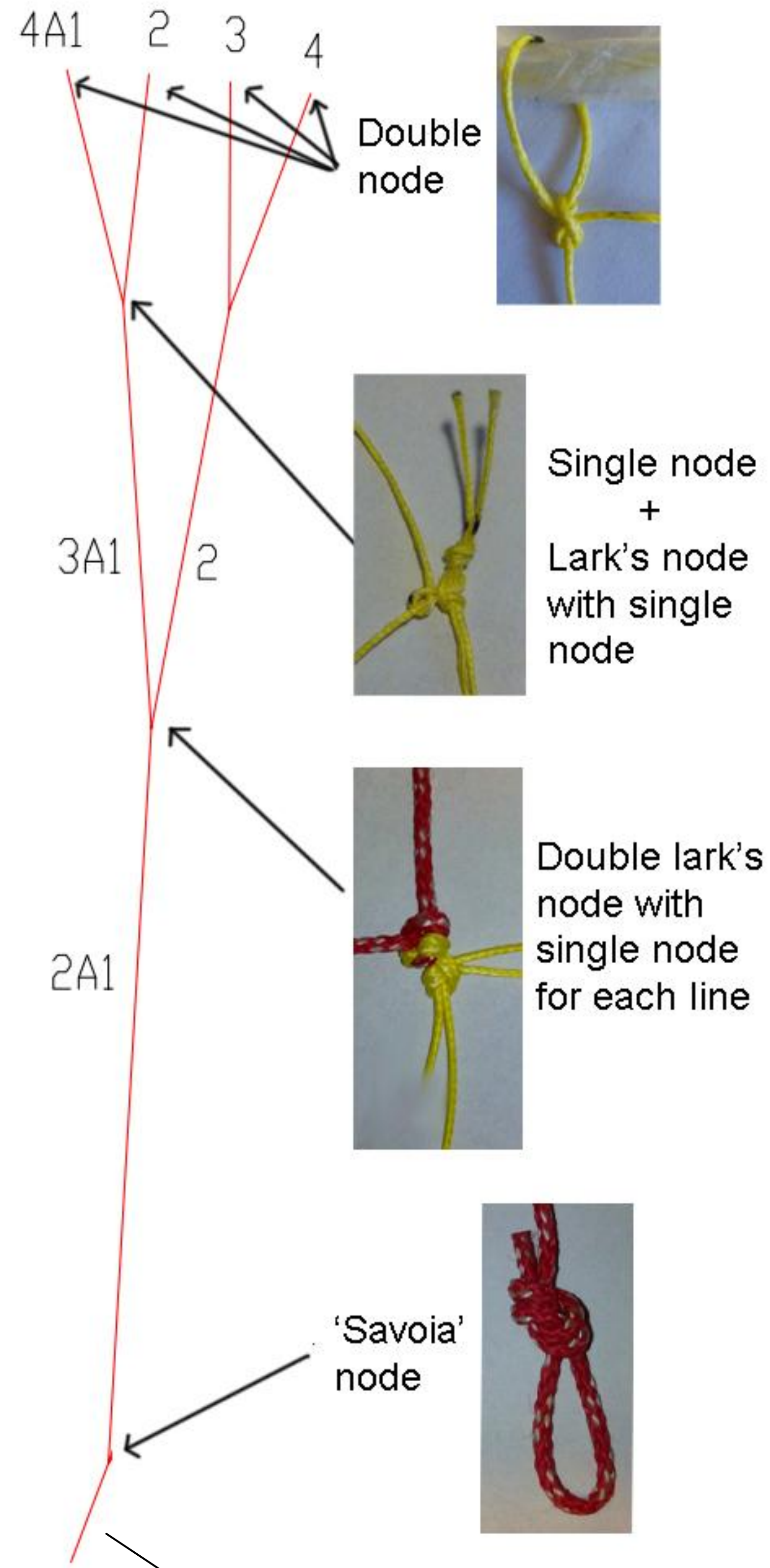


14. LINES C

Plan	C	
56	1C1	47
57	2C1	375,2
58	2C2	366,1
59	2C3	341,3
60	3C1	190,5
61	3C2	190,5
62	3D3	190,5
63	3D4	190,5
64	3C5	190,5
65	3C6	190,5
66	3D7	190,5
67	3D8	190,5
68	3C9	190,5
69	3C10	190,5
70	3D11	190,5
71	3D12	190,5
72	4C1	79,3
73	4C2	75
74	4C3	73,5
75	4C4	75
76	4D1	83,6
77	4D2	79,4
78	4D3	78
79	4D4	79,1
80	4C5	84,7
81	4C6	80,1
82	4C7	80,3
83	4C8	75,7
84	4C9	80,6
85	4D5	88,7
86	4D6	84
87	4D7	84,1
88	4D8	79,2
89	4D9	83,3
90	4C10	100,5
91	4C11	91,5
92	4C12	89,6
93	4C13	82,9
94	4C14	79,2
95	4D10	102,2
96	4D11	92,4
97	4D12	89,6
98	4D13	84,7
99	4D14	77,9
100	4C15	74,6

10.1.2 - Assembly lines

1 – Tie the lines on the point of attach of the ribs using different type of nodes for all the lines



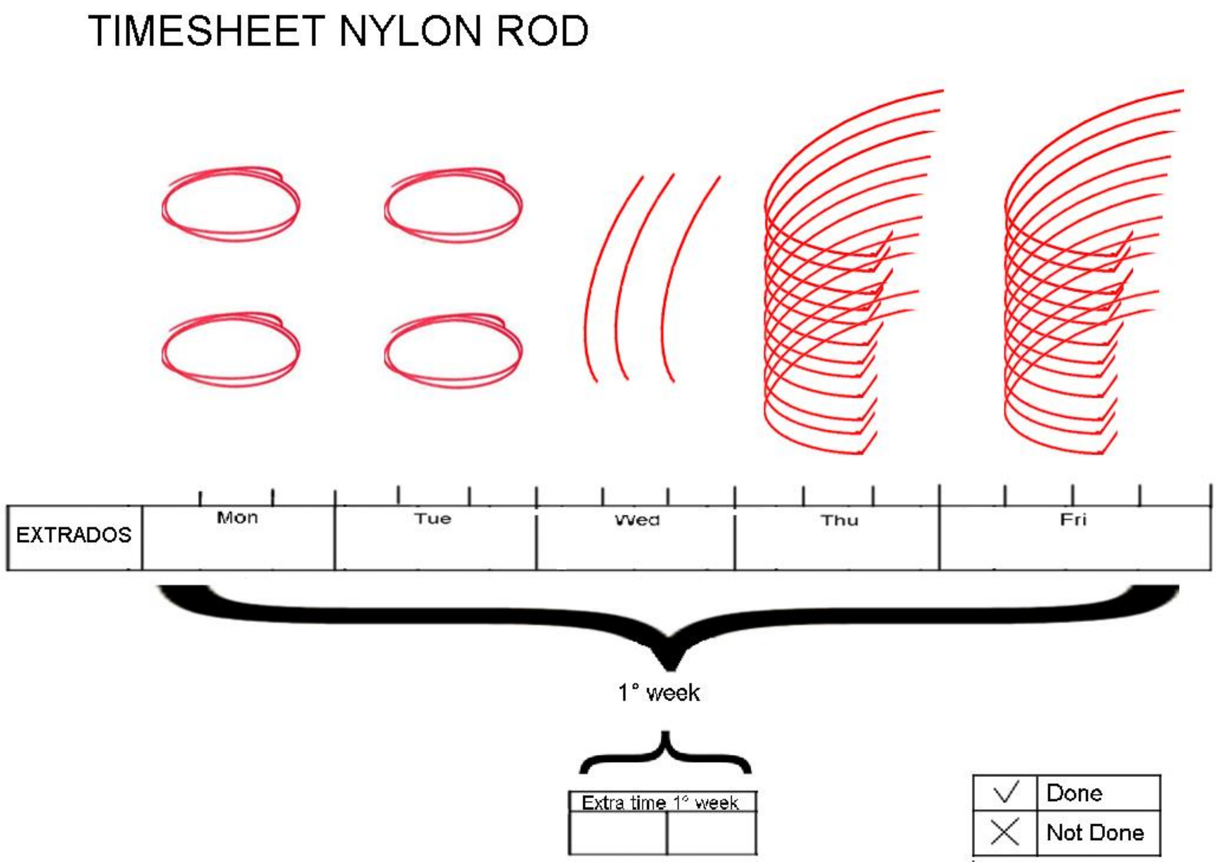
2- Put the lines in the carabiners at the end of the braces (in order A-B-C-F)[The braces in the photo have a string in more]

Fig. 27 – The braces

11 - Timelines and organization nylon rods

To keep more fit the wing the project expected the 2,8 mm nylon rods reinforcement (using the wire coil of the mower) from 8,3% in extrados to 11,2% in the intrados. To straighten the nylon rods, it has been heated on the fire while he was in tension (the nylon rod has to have the shape of the leading edge when it is mounted)

Hours of work ≈ (1,5 h/1 cutting-assembly) x 5 ≈ 7,5 h



Timesheet nylon rods

Week	In time	D.R.E.T	Days of delay	
Example	Yes/no	Yes/no	Number of days if not	
Nylon rods				
1°				

11.1 - Processing cycles nylons rod

11.1.1 - Cutting nylon rods

1 –Cut the nylon rod with the measure of the following table:

Number of the rib	Length
1	704
2	695
3	687
4	680
5	670
6	656
7	640
8	620
9	595
10	565
11	528
12	481
13	430
14	364
15	297
16	230

2 – Heat on the fire the nylon rod while they are under tension for straighten them

Fig. 28 – The rods

3 – Mount the nylon rod on the wing using the scotch tape

4 –To give more structural resistance to the wing, rectangular American tape reinforcements have been put in correspondence of each rib (leading and trailing edge) and transparent scotch reinforcements on the whole edge of the wing.

One of the American tape reinforcement (Total weight of the wing ≈ 3,1 kg)

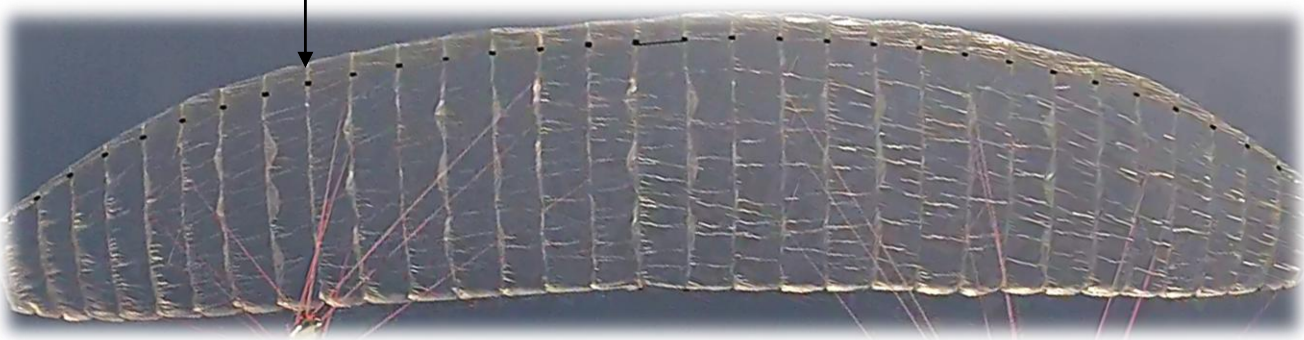


Fig. 29 – The wing in fly

12 – Flight test

After working for six months it was time to try the paraglider. It was, so, created the following checklist to avoid making mistakes and check if the paraglider had been damaged after the flights (ex. yield point exceeded).

NORMAL CHECKLIST

BARRETTINA
HYPER
LITE
2

PREFLIGHT	
Towel (with dry grass and brambles)	Put
Paraglider	ok(not cuts)
* Control point	<1mm
Lines	ok(linked,not cut)
Pin emergency	ok(not distorted,in)
Point of attack	ok(not unsoldered)
Lines	ok (not twisted)
Pilot weight	checked
Nylon rods	checked

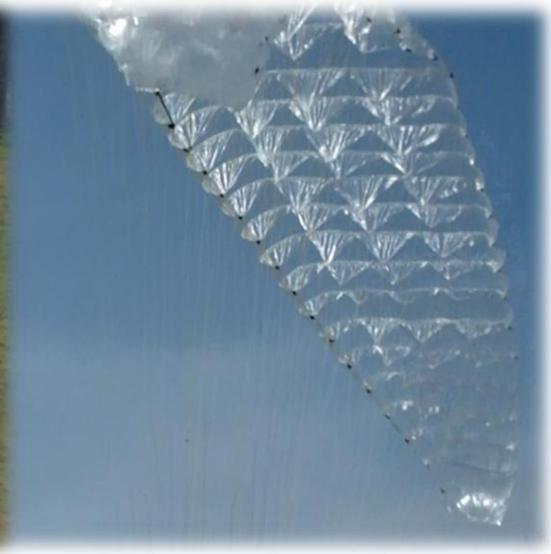
BEFORE TAKEOFF	
Leg straps	closed
Ventral strap	closed
Carabiners	closed and locked
Boots	laced
Flight recorder	on
Camera 1	on
Camera 2	on
A lines	free
Brakes	free
Helmet	laced
Emergency	strap laced
Wind	ok
Leg straps	closed

LIMITATIONS	
Pilot weight	80-100kg
Wind	<5 m/s
Flight altitude	<10m

*Control point= Perpendicular lines long 20 cm in correspondence of the central extrados to determine eventually yielding of the material.

The first flight

Fig. 30 – The wing in fly for the first time



Following are the flight data of the flight recorder:

»altitudine	238 m	»terreno	238 m	»AGL	0 m	»vario	0.0 m/s	»veloc.	0 km/h	»ora	13:43:10 UTC
»altitudine	237 m	»terreno	230 m	»AGL	7 m	»vario	+1.7 m/s	»veloc.	16 km/h	»ora	13:43:13 UTC
»altitudine	235 m	»terreno	230 m	»AGL	5 m	»vario	0.0 m/s	»veloc.	17 km/h	»ora	13:43:14 UTC
»altitudine	237 m	»terreno	230 m	»AGL	7 m	»vario	-1.0 m/s	»veloc.	16 km/h	»ora	13:43:15 UTC
»altitudine	230 m	»terreno	227 m	»AGL	3 m	»vario	-2.0 m/s	»veloc.	20 km/h	»ora	13:43:18 UTC
»altitudine	228 m	»terreno	225 m	»AGL	3 m	»vario	-1.5 m/s	»veloc.	16 km/h	»ora	13:43:19 UTC
»altitudine	225 m	»terreno	225 m	»AGL	0 m	»vario	0.0 m/s	»veloc.	0 km/h	»ora	13:43:21UTC

The data are only indicative because on such a short flight the GPS takes a few steps and staggered in relation to the distance of the flight. Moreover, the presence of moderate headwinds, not constant velocity of flight due to the close take off and landing and a flight close to the ground that cause ground effect helped to change the values. Anyway , the wing has flown at a speed trim of about 18 km/h (25-30 km/h without wind) for 60 meters with a height difference from the takeoff to the landing point of 13 m. This means that the real efficiency (in normal flight condition with frontal wind) is about 5; not bad for a plastic paraglider!

13 – Sitography

- http://www.laboratoridenvol.com/projects/bhl2/bhl2.html

- http://en.wikipedia.org/wiki/Lean_manufacturing

14 – Software used

- Portable DSS CATIA P2 V5R20 Multilanguage (print drawings)

- Adobe Photoshop CS4 (timesheet)

-Microsoft Office 2007: - Word (relation)

- Excel (tension test)

- PowerPoint (presentation of the work)

-GoPro studio and Windows Movie Maker (movie editing)