Lower leg

Contents:

Fiber layup #1

This is the first mold, which we used to get some experience with the layup process, the fiber material and the characteristics of legs with a half circle shape.
This mold was too narrow - so we could only cook 2 legs at a time and was hard to seal on the sides.

8 layer circle leg - 700 N/m
9 layer circle leg - 1000 N/m

As you can see on the picture we had some problems with resin seeping into the breather ply and also into the vacuum pump nozzle.

Fiber layup #2

This mold was made out of an aluminum tube bought from Canadian Tire.
It's wide enough to get 8 legs out of one layup, but the aluminum was too soft and thin and it deformed in the oven. And so did the legs!
From this layup we made an entire set of legs to test on RHex. (they are the ones seen in the videos)

These circular legs are made out of 10 fiber layers and 2 additional layers on top - one covering 2/3 of the circumference the other one 1/3.

As you know, we tested these legs on RHex under various conditions and on the hikes.

We tested walking, turning, running, stair climbing, pronking and climbing over obstacles.

These are some of the outcomes:

- the legs are pretty rugged and we haven't managed to break one yet
- they are light - 35g for the fiber leg, 25g for the clamp and the key and at the moment we use a rubber layer and mountain bike tire on the outside which weight another 60g for a total weight of **120g**. I think we can easily reduce the weight to **80g** per leg

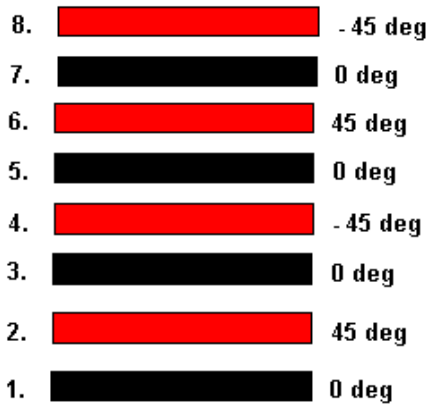
These are the main problems:

- the legs have a spring constant of **2300N/m** in the radial direction, which is too stiff, compared with the 1600N/m required for pronking.
  This can be fixed easily by changing the number of fiber layers.
- they are very soft in the lateral plane and even deform permanently
  In order to reduce the deflections in the lateral direction, in our next layup, we decided to place certain fiber layers at a 45 degree angle.
  As you can see below, after testing this new layup, we determined that this does indeed increase the lateral stiffness, as we wanted.

- the layup and manufacturing is rather simple

Fiber layup #3

This is an other layup with 8 legs with different numbers of layers and orientation of the layers. The goal was to find out, how layers at 45 degrees affect the flexibility in the different directions.

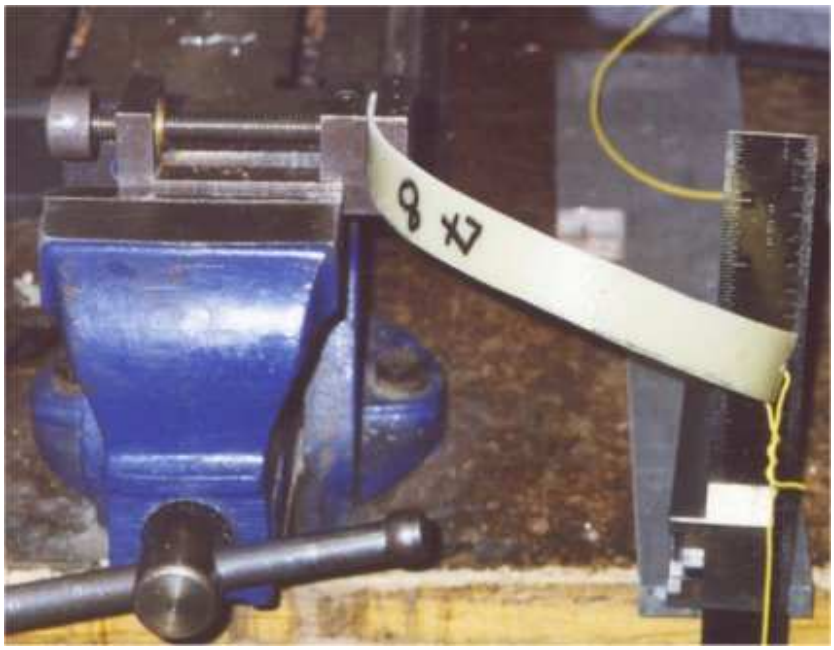


We did 5,6,7 and 8 fiber layers - one set with all layers orientated in the same direction, one set with every second layer at 45 degrees.

I measured the deflection of the legs under different loads and calculated the spring constants. Please note, that this is no precision measurement and it depends a lot on how you clamp and constrain the legs. (pictures of measurement setup)

Conclusion:

As you can see in the diagrams below the 45-degree-layers increase the lateral stiffness and decrease the permanent deflection (especially for the legs with higher numbers of layers).
I think we were able to fix the major problem - the permanent lateral deflection was reduced from 3cm (leg collides with the body and the other legs!) to about 0.5cm with this layup.
As it seems the top and bottom layers of the leg influence the characteristics a lot more than the inner layers.
That's why the next layup will have 45 degree layers on top and bottom in order to increase the lateral stiffness even more.



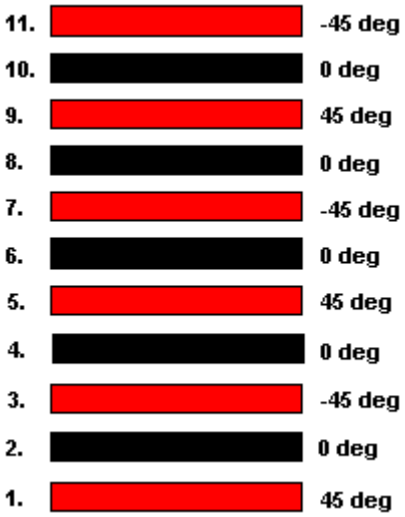
Fiber layup #4

This is a layup for a full set of new legs.

- 11 layers - every second at +/- 45 degrees
- 45 degree layers on the outsides to improve lateral stiffness
- weight: 35g per fiber leg
- spring constant (vertical) ca. 1260N/m
- lateral flexibility ca. 670N/m
- permanent deflection <3mm! (under max load 40N)

You'll find diagrams of the measurements below

Again problems with too much resin, resin going in the nozzle and the vacuum hose. This time we had to replace those parts, because they were stuck.
I'm happy the pump still works.



Comparison between different sets of legs

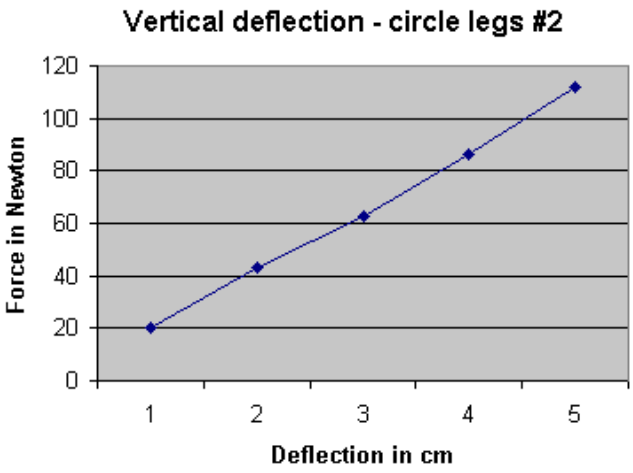
First set of legs (layup #2)

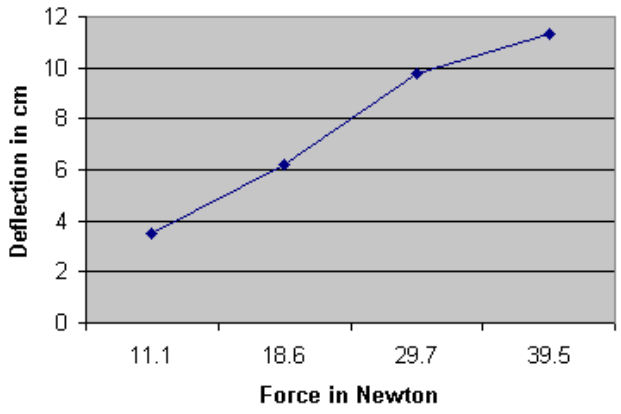
- 12 fiber layers
- all layers at 0 degrees
- spring constant (vertical) **ca. 2300N/m**
- lateral stiffness **ca. 360N/m**
- max. permanent deflection (40N) **ca. 3cm!**

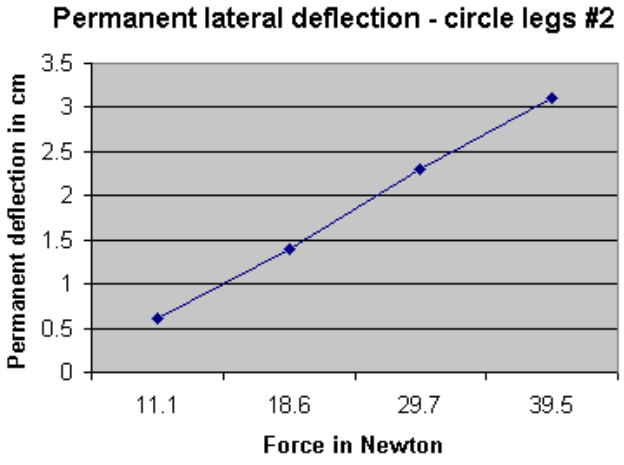
Improved set of legs (layup #4)

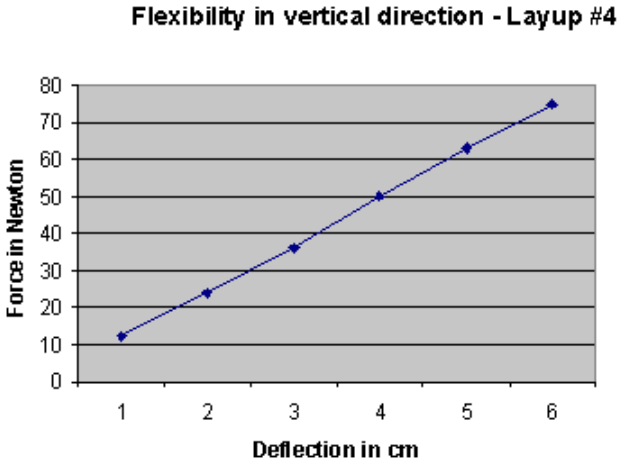
- 11 fiber layers
- every second layer at +/-45 degrees
- spring constant (vertical) **ca. 1260N/m**
- lateral stiffness **ca. 670N/m**
- max. permanent deflection (40N) **<3mm!**

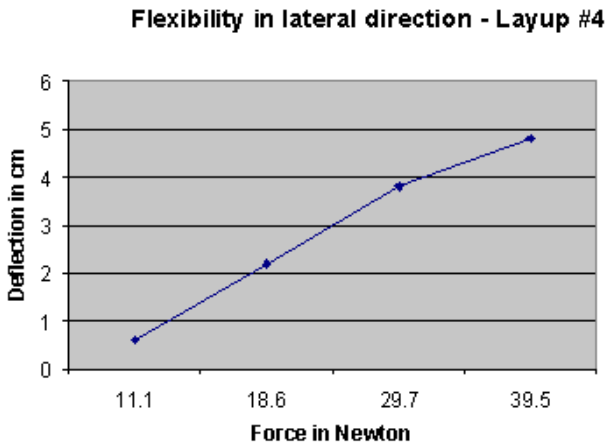
- Reduced spring constant from 2300 to 1260N/m - goal was ca 1600N/m
- Increased lateral stiffness by factor 2
- Reduced permanent deflection by factor 10!









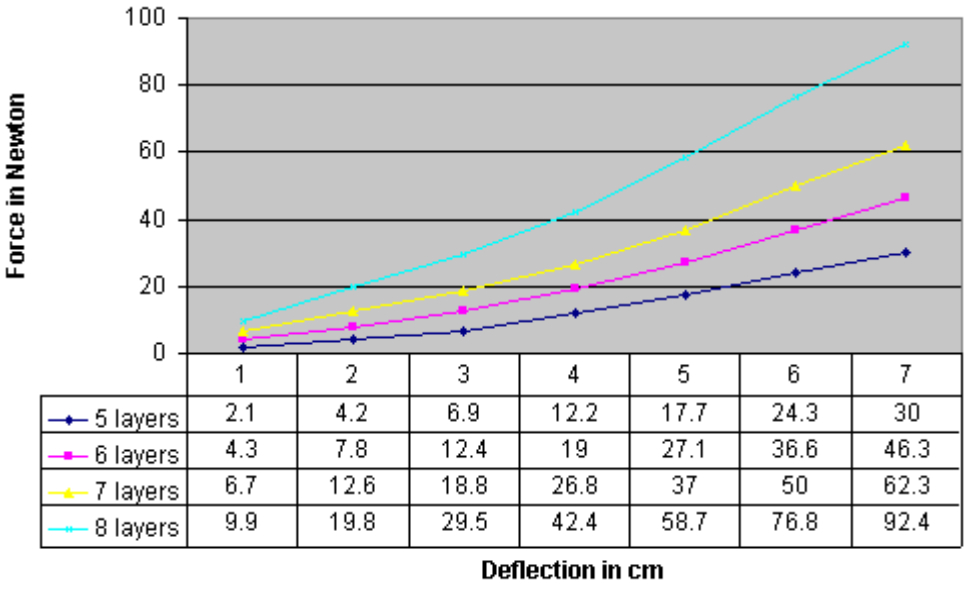


I didn't include a diagram of the permanent deflections because they were too small to measure for 1 and 2 kg loads - and for 3 and 4 kg we measured ca. 2mm.

Measurement fiber layup #3 - 5.11.2001

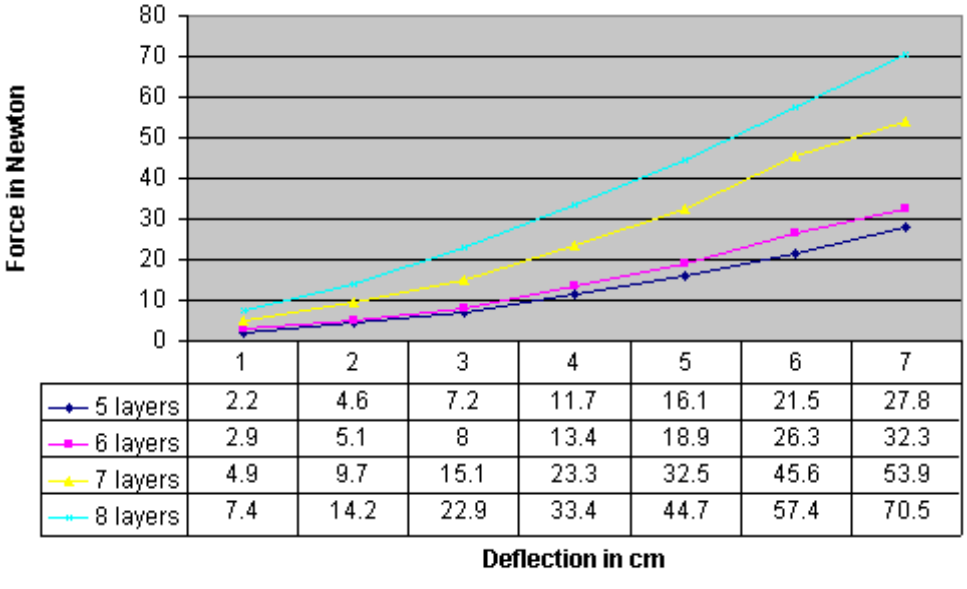
This is the data from the test layup with different numbers and arrangements of layers.

Flexibility in vertical direction - 0 degree layup #3

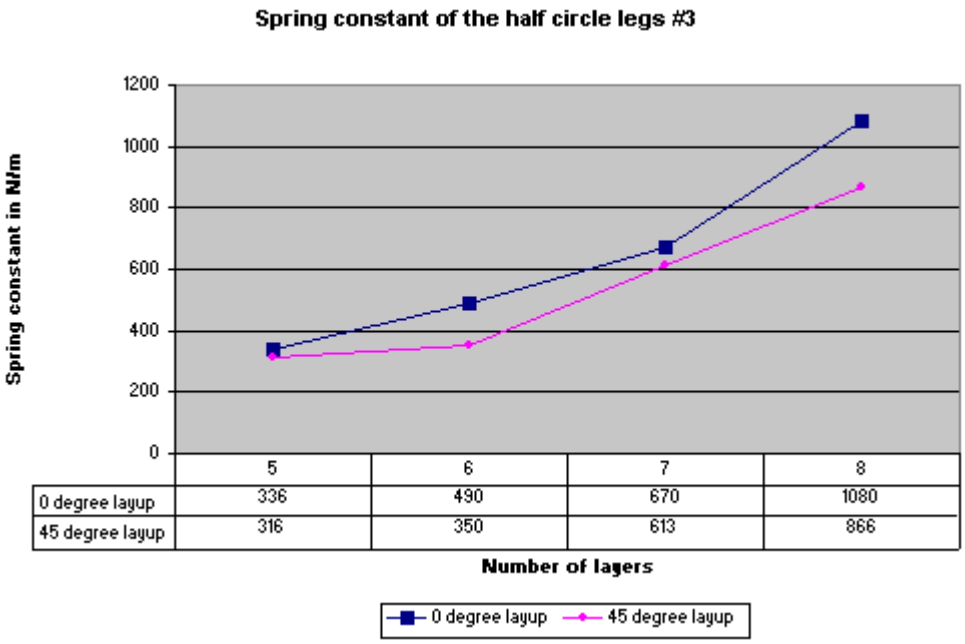


	1	2	3	4	5	6	7
5 layers	2.1	4.2	6.9	12.2	17.7	24.3	30
6 layers	4.3	7.8	12.4	19	27.1	36.6	46.3
7 layers	6.7	12.6	18.8	26.8	37	50	62.3
8 layers	9.9	19.8	29.5	42.4	58.7	76.8	92.4

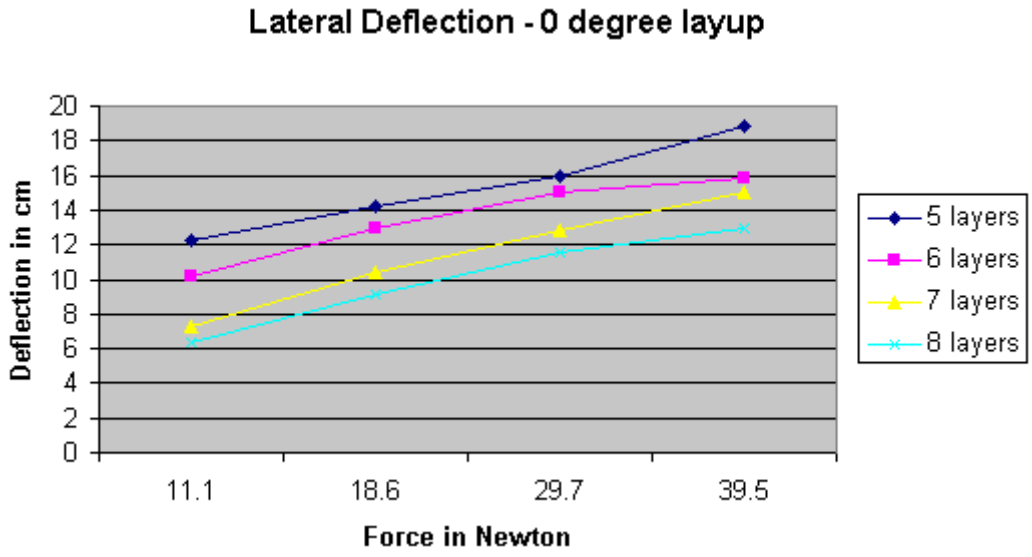
Flexibility in vertical direction - 45 degree layup #3

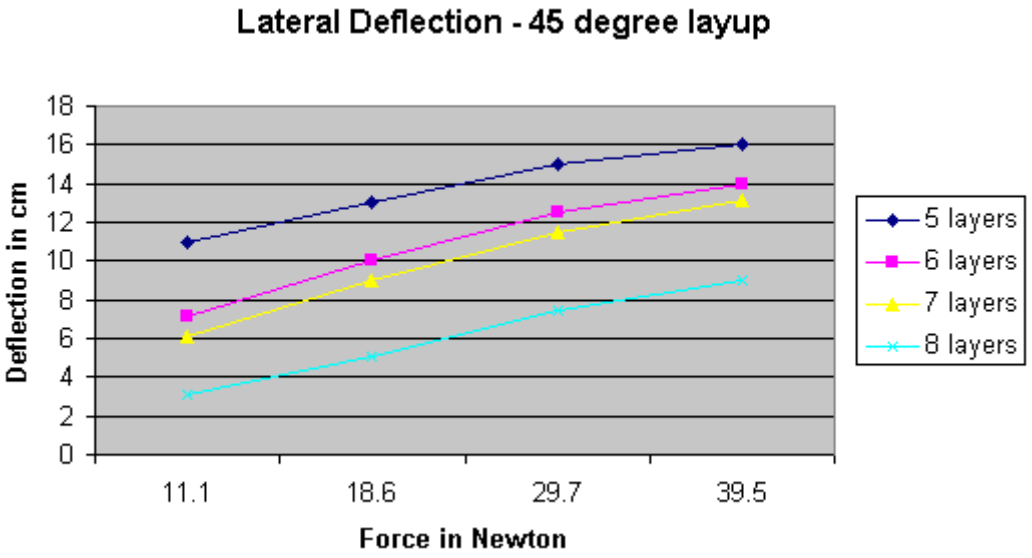


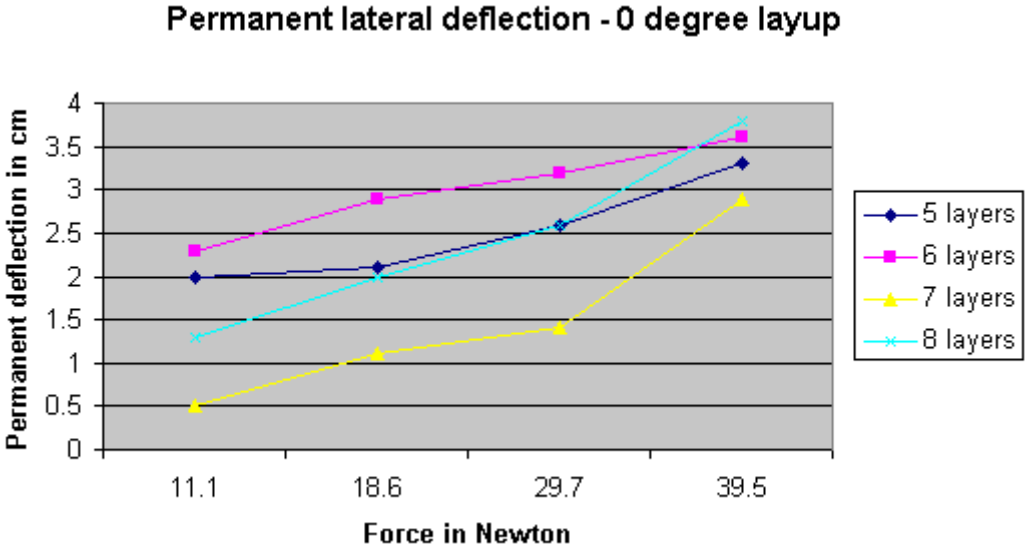
	1	2	3	4	5	6	7
5 layers	2.2	4.6	7.2	11.7	16.1	21.5	27.8
6 layers	2.9	5.1	8	13.4	18.9	26.3	32.3
7 layers	4.9	9.7	15.1	23.3	32.5	45.6	53.9
8 layers	7.4	14.2	22.9	33.4	44.7	57.4	70.5

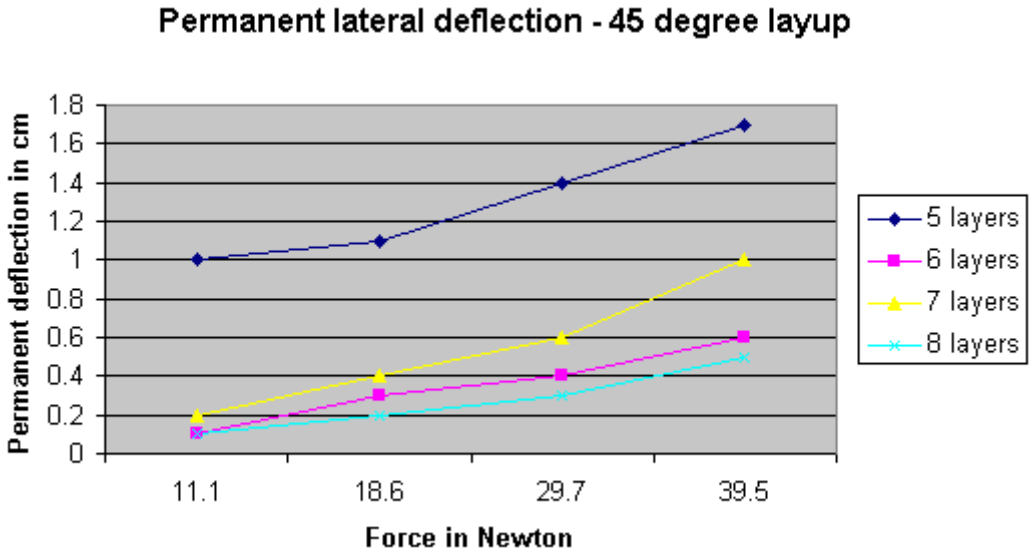


Measurement fiber layup #3 - Lateral direction


Lateral Deflection - 0 degree layup
Deflection in cm
20
18
16
14
12
10
8
6
4
2
0
11.1
18.6
29.7
39.5
Force in Newton
5 layers
6 layers
7 layers
8 layers


Lateral Deflection - 45 degree layup
Deflection in cm
18
16
14
12
10
8
6
4
2
0
11.1
18.6
29.7
39.5
Force in Newton
5 layers
6 layers
7 layers
8 layers


Permanent lateral deflection - 0 degree layup
Permanent deflection in cm
4
3.5
3
2.5
2
1.5
1
0.5
0
11.1
18.6
29.7
39.5
Force in Newton
5 layers
6 layers
7 layers
8 layers


Permanent lateral deflection - 45 degree layup
Permanent deflection in cm
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
11.1
18.6
29.7
39.5
Force in Newton
5 layers
6 layers
7 layers
8 layers