MEHMET SITKI MERDİVENCİ

6th EMship cohort: October 2015 – February 2017

Design and Optimization of Composite Base Frames & Shaft of Wind Turbine for Catamaran

Supervisor: **Prof. Hervé Le Sourne, L'Institut Catholique d'Arts et Métiers**, Nantes, France

Reviewer: **Prof. Robert Bronsart , University of Rostock**, Rostock, Germany

EMShip Meeting ,Rostock, February 2017

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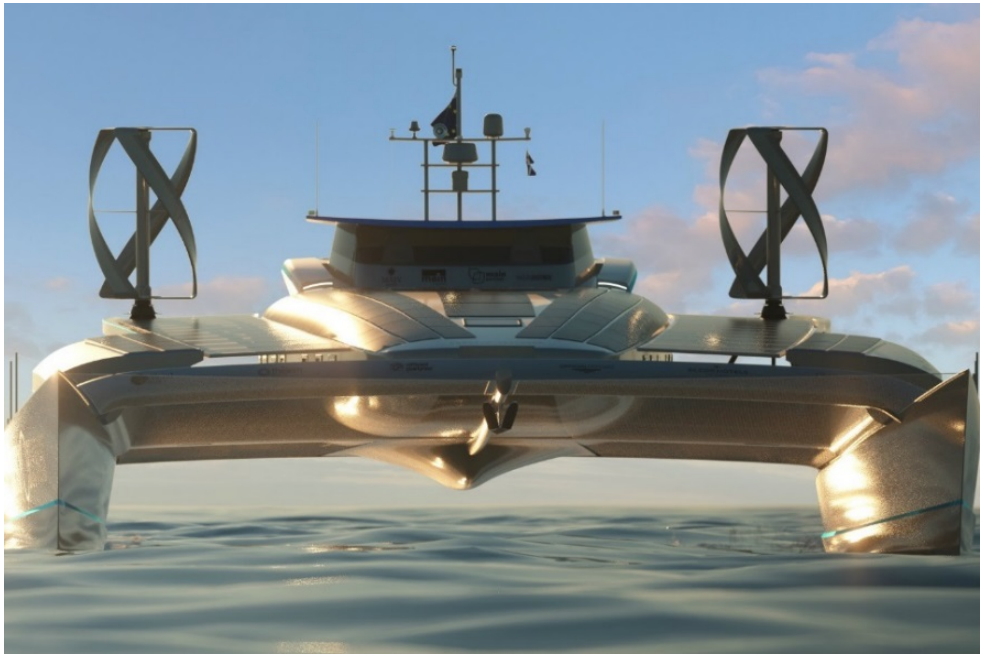
Introduction

Energy Observer



- **Absorbing the Energy**
  - Solar Panels
  - Wind Turbine
- **Stocking the Energy**
  - Hydrogen cells
- **Consuming the Energy**
  - Electrical Motors

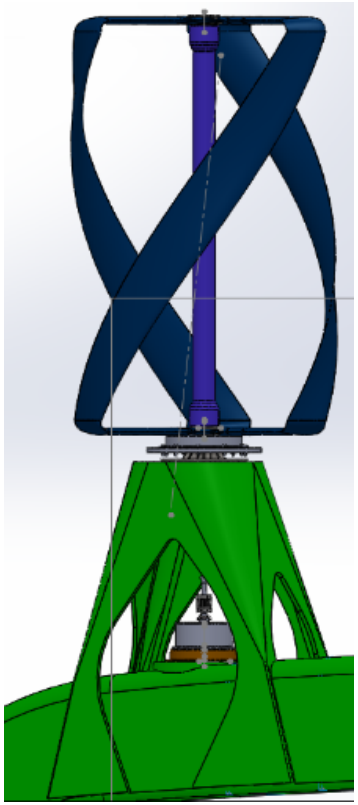
1. History of The Boat

Formule Tag (1983)

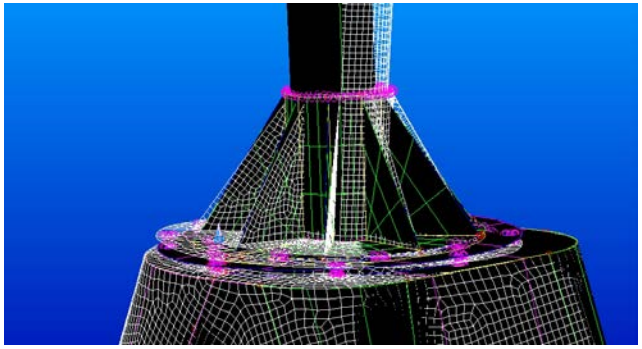
- *24 m long*
- *Jules Verne Trophy 75 days (1994)*

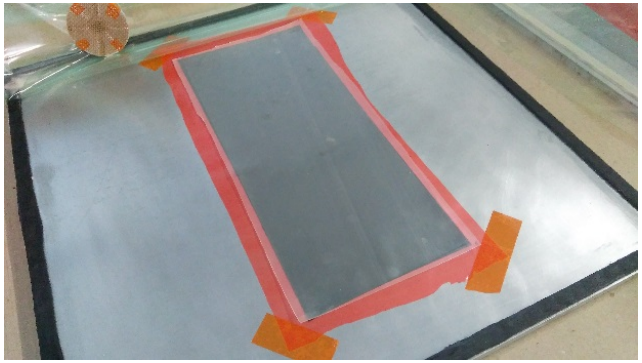
2. Main objectives of the study

- Design & Structural Analyzes of Vertical Axis Wind Turbine and Its Support



- Investigation of damping material selection



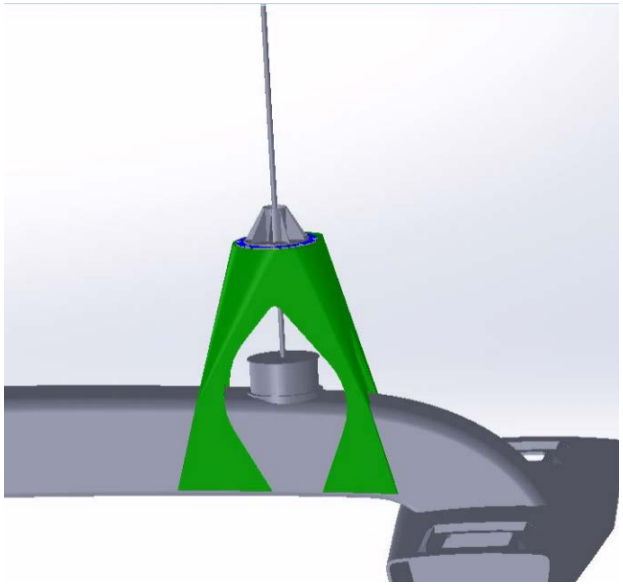


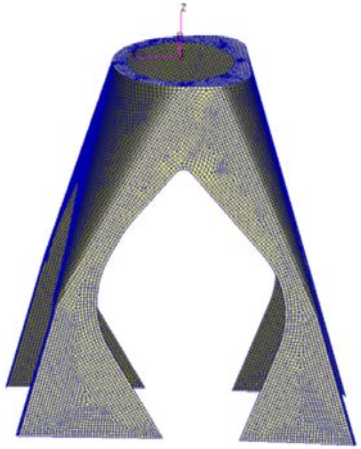
3. Presentation of Wind Turbine and Its Finite Element Model

Aerojoules

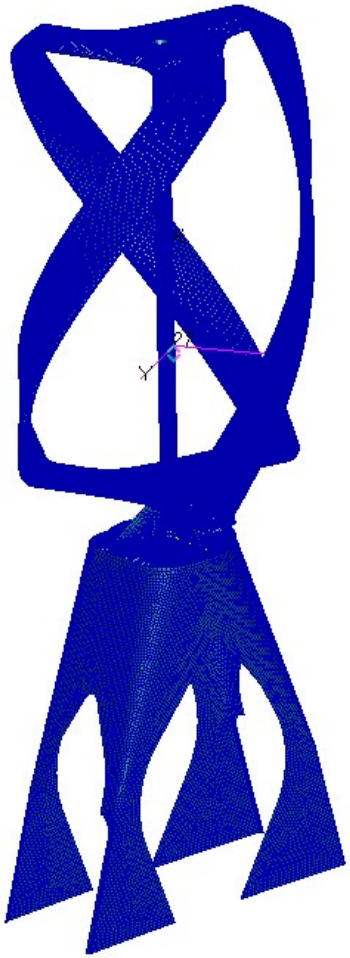
Adaptation of Aerojoules to Energy Observer

- Designing an Appropriate Support
- Using composite shaft





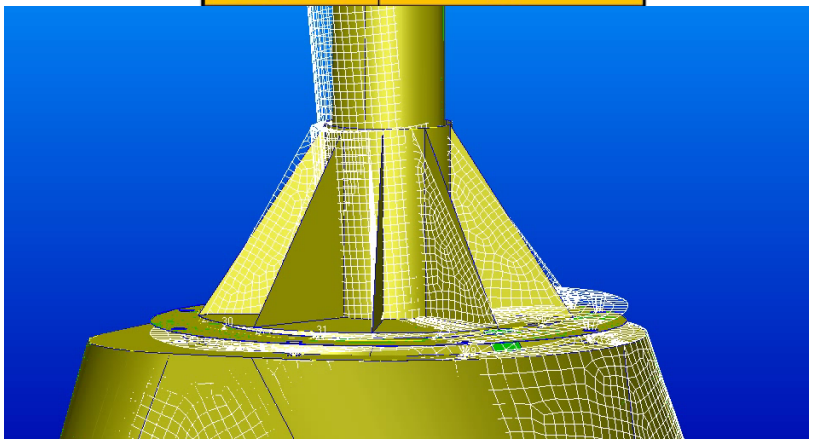
3. Presentation of Wind Turbine and Its Finite Element Model



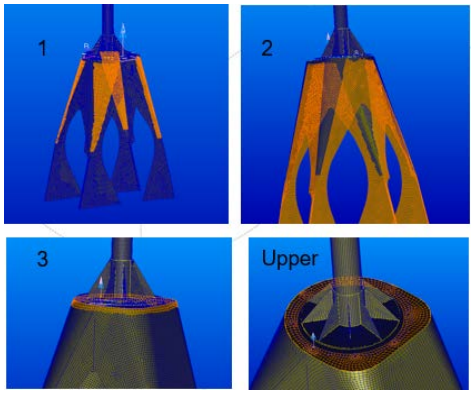
Expected Minimum Bending Natural Frequency

Maximum Rotation of Turbine : 300 RPM
Frequency = n(blades) x RPM / 60
3 x 300 RPM / 60 = 5 RPS
5 x 3 = 15 Hz

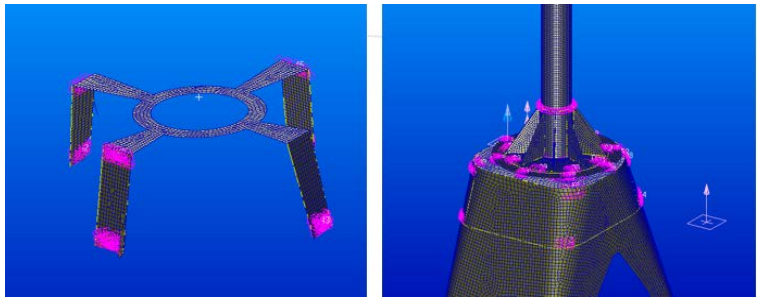
Modes	Frequency (Hz)
Mode 1	9.3
Mode 2	9.6



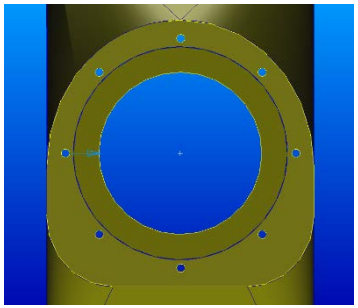
3. Presentation of Wind Turbine and Its Finite Element Model (Modifications)



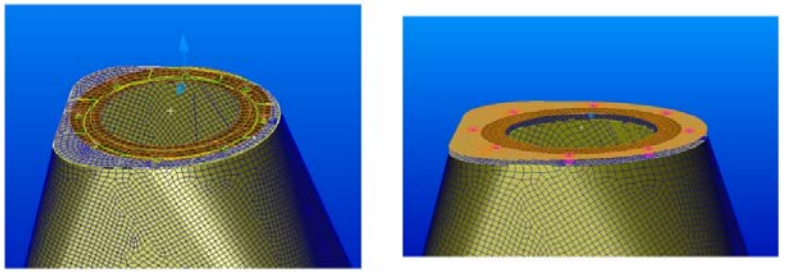
1st Bending Mode : 11,6 Hz
2nd Bending Mode : 11,7 Hz



1st Bending Mode : 11,9 Hz
2nd Bending Mode : 12,2 Hz



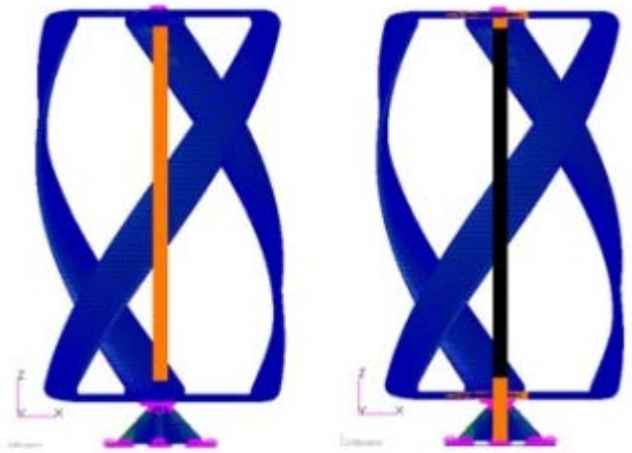
1st Bending Mode : 10,9 Hz
2nd Bending Mode : 11,3 Hz



1st Bending Mode : 12,1 Hz
2nd Bending Mode : 12,4 Hz

4. Parametric Study of Composite Fixed Shaft

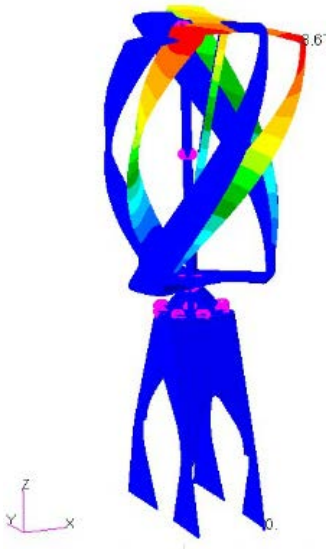
- Carbon epoxy composite material
- 80 mm of external diameter
- Same behavior as Aerojoules



Thickness (mm)	1st Mode Frequency (Hz)	2nd Mode Frequency (Hz)	3rd Mode Frequency(Hz)	Stacking Sequence
16	9 (180 rpm)	9,2 (184 rpm)	16 (320 rpm)	$([-30,0,30,0]_4,[45,0\text{-}45,0])_s$
16	9,1 (182 rpm)	9,3 (186 rpm)	16 (320 rpm)	$([-30,0,30,0]_5)_s$
24	9,6 (192 rpm)	10 (200 rpm)	16,5 (330 rpm)	$([-30,0,30,0]_6, -30,0,[45,0\text{-}45,0])_s$
24	9,7 (194 rpm)	10 (200 rpm)	16,5 (330 rpm)	$([-30,0,30,0]_7, -30,0)_s$

5. Static and Dynamic Analysis of Entire Optimized Model

Bending Modes



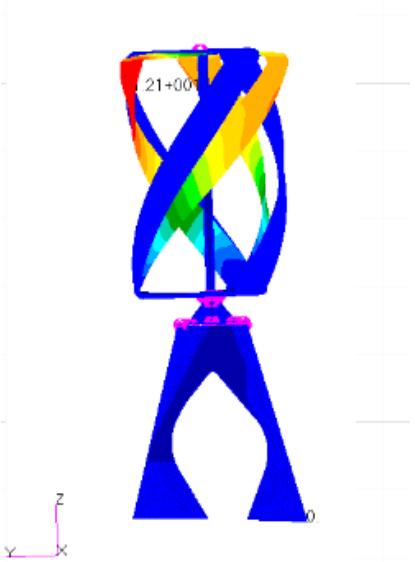
9.1 Hz

(182 RPM)

9.3 Hz

(186 RPM)

Flexion Modes

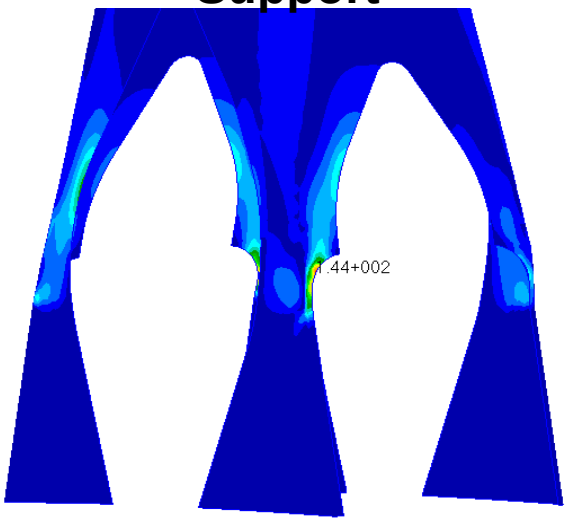


9 Hz

(180 RPM)

5. Static and Dynamic Analysis of Entire Optimized Model

Stresses on Composite Support

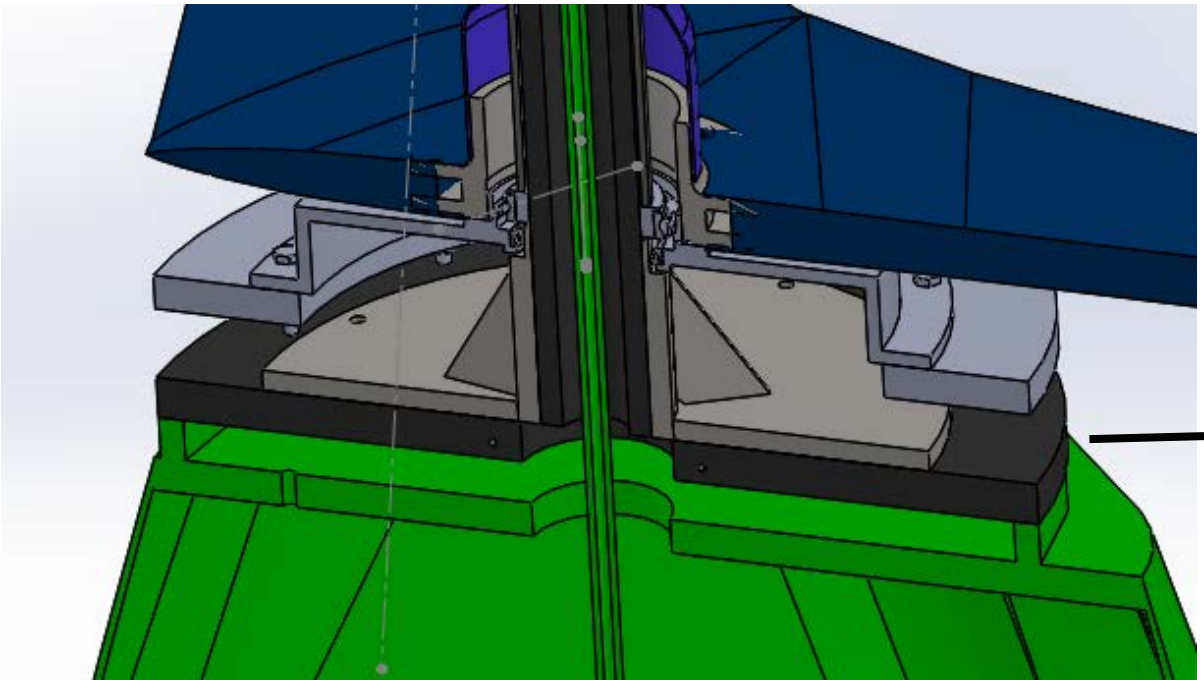


144 MPa
1st Layer

121 MPa
3rd layer

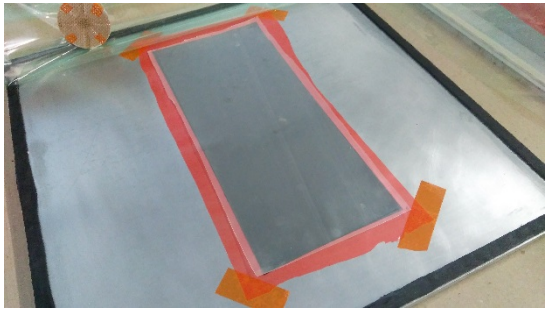
- Elastic limit of composite material: 603 MPa
- Less than 25 % of Elastic limit

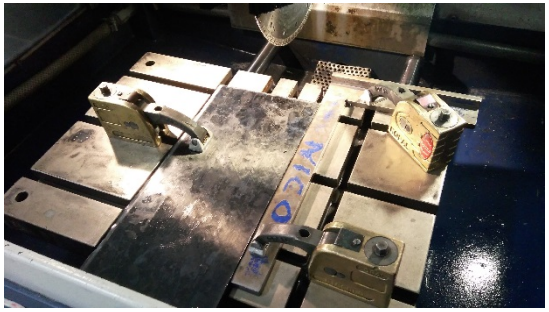
6. Investigation of a Damping Material Selection

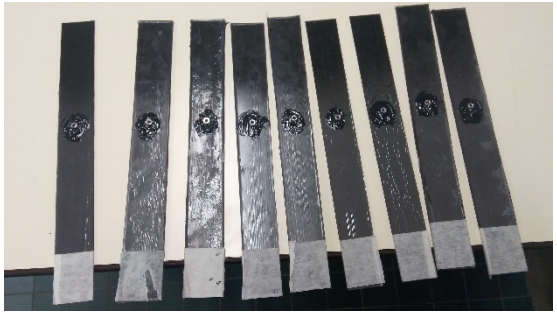


Carbon composite with viscoelastic material

6. Investigation of a Damping Material Selection





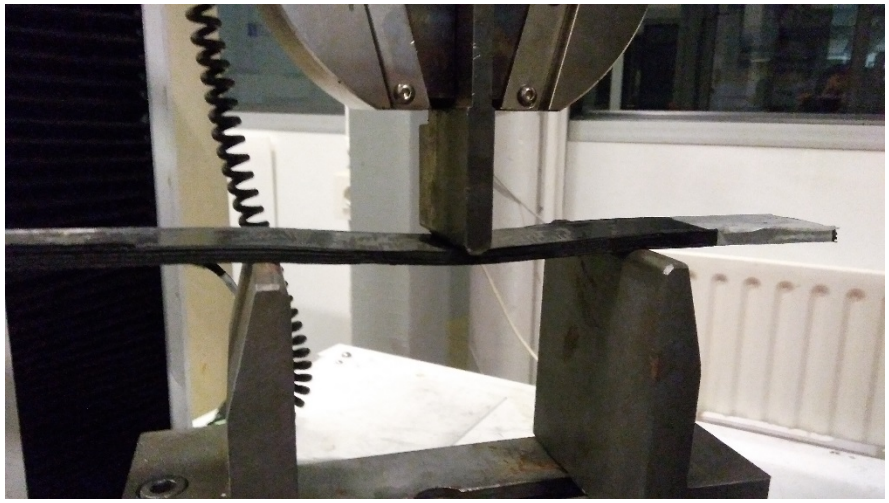


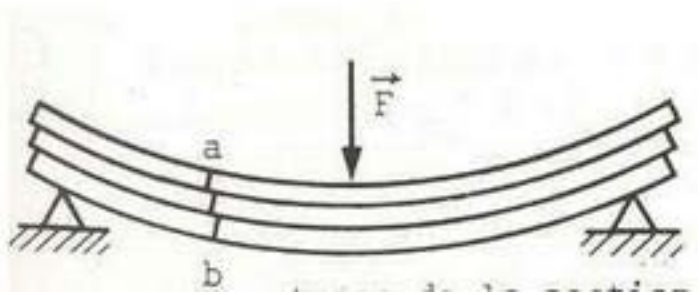
3 different type of samples:

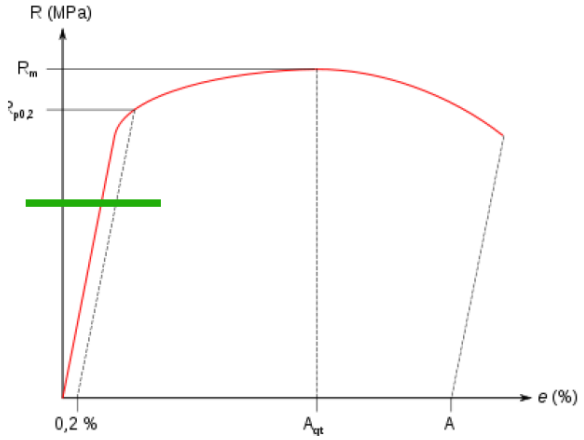
- 0 layer of DYAD
- 2 layers ofDYAD
- 4 layers of DYAD

6. Investigation of a Damping Material Selection

Flexion 3 points





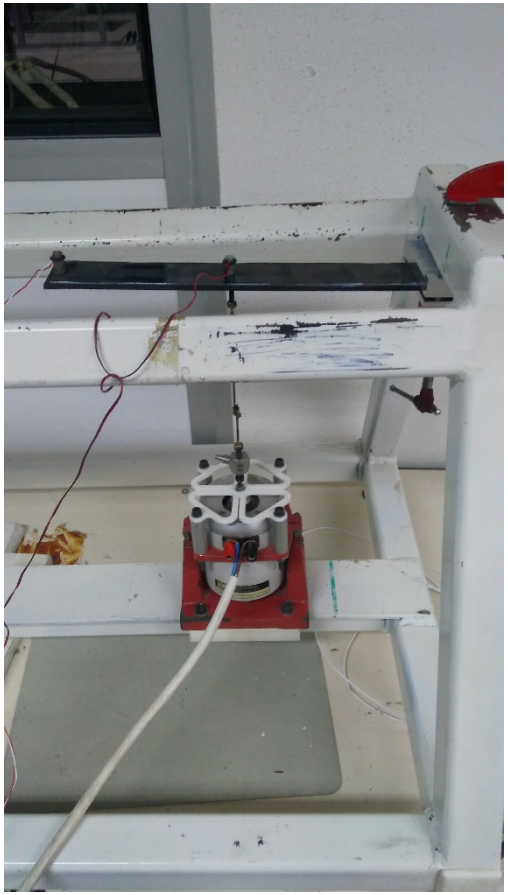


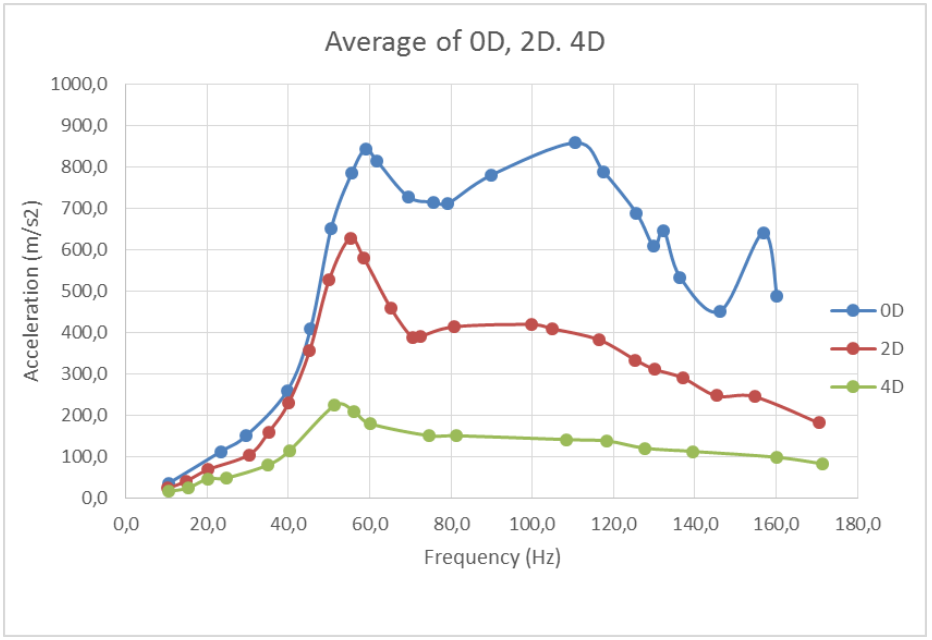
E_{0D} = 72 GPa
E_{2D} = 1,3 GPa
E_{4D} = 0,33 GPa

Shear Modulus of DYAD:
τ = 0,33 Mpa
(Steel = 70000 MPa)

6. Investigation of a Damping Material Selection

Frequency Response Analyses Experiment

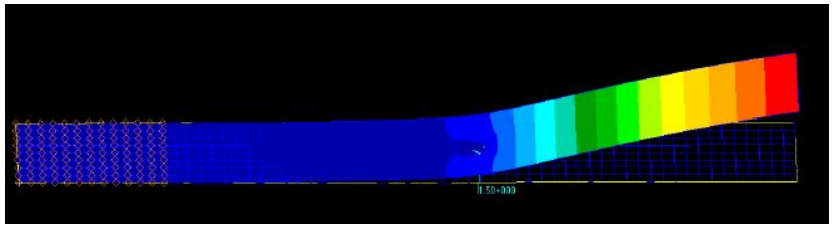




Samples	1st Natural Frequencıes
0D	58.9 Hz
2D	55.1 Hz
4D	52 Hz

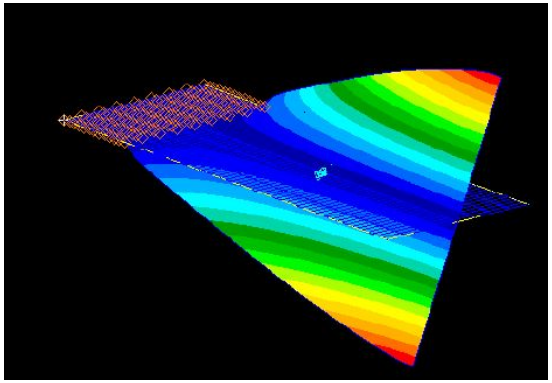
7. Comparison between Experimental and Numerical Results 2D Sample

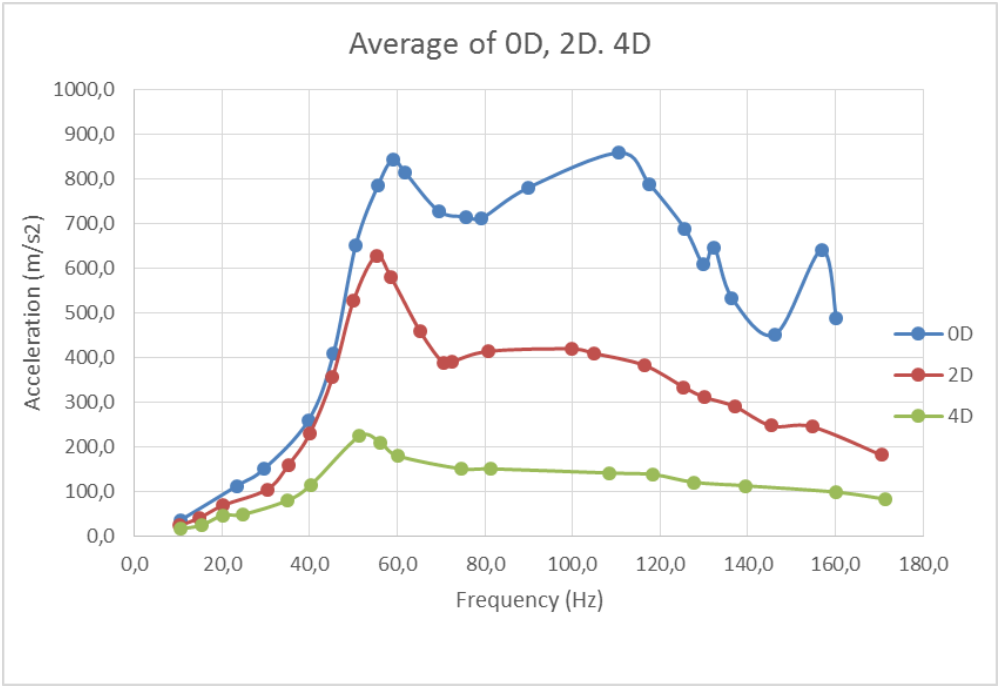
First Bending Mode at 53.5 Hz



Samples	1st Natural Frequencies
0D	58.9 Hz
2D	55.1 Hz
4D	52 Hz

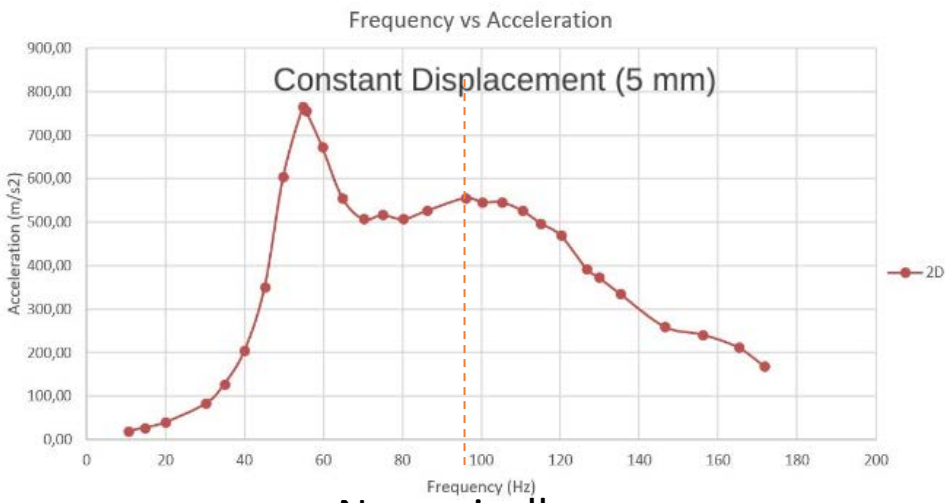
Torsion Mode at 86.3 Hz



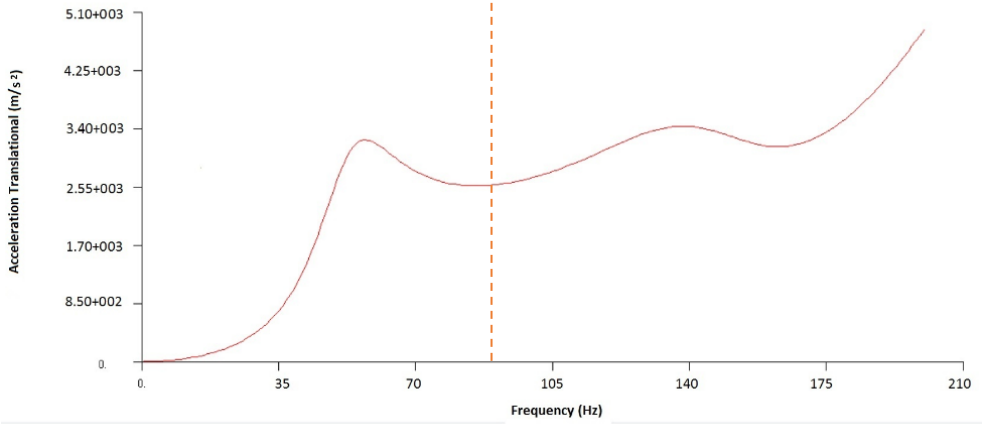


7. Comparison between Experimental and Numerical Results

Experimentally



Numerically



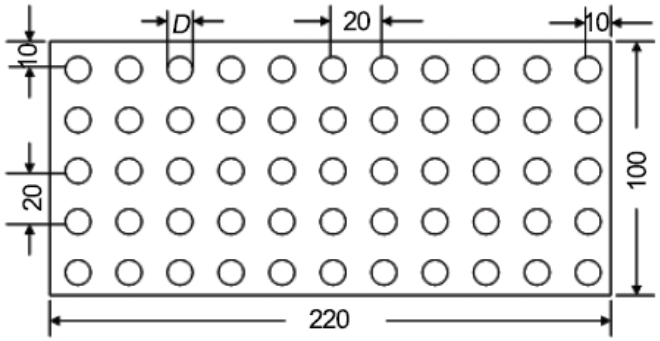
8. Conclusions

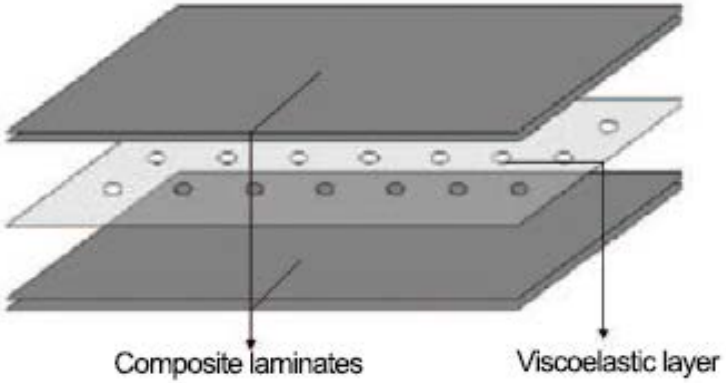
- Using more composite layers or having an interior structure of a composite support does not increase sufficiently the stifness of entire system and consequently the first natural frequency.

- Implemented viscoelastic material increases the damping characteristics of carbon epoxy composites, however it causes a significant decrement on Young's modulus.

9. Future Work

Perforation of small holes on DYAD 601 (Pan & Zhang 2009)





Thank you.