EPFL

BioRob Lab – Bachelor's Project 2016

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Motivations

- Create a variable stiffness element

Reasons

- Soft elements – medical involvement, security, compliance, adaptation

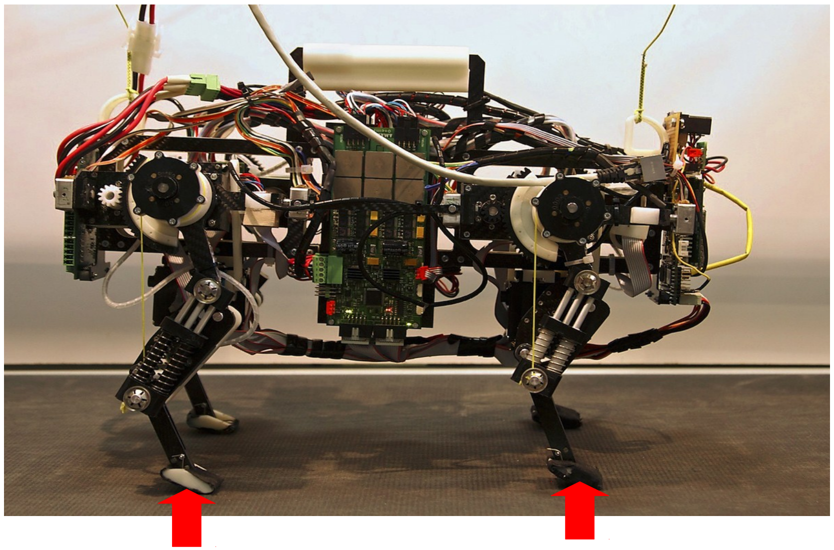
- VS stiff elements – precision, easier to simulate

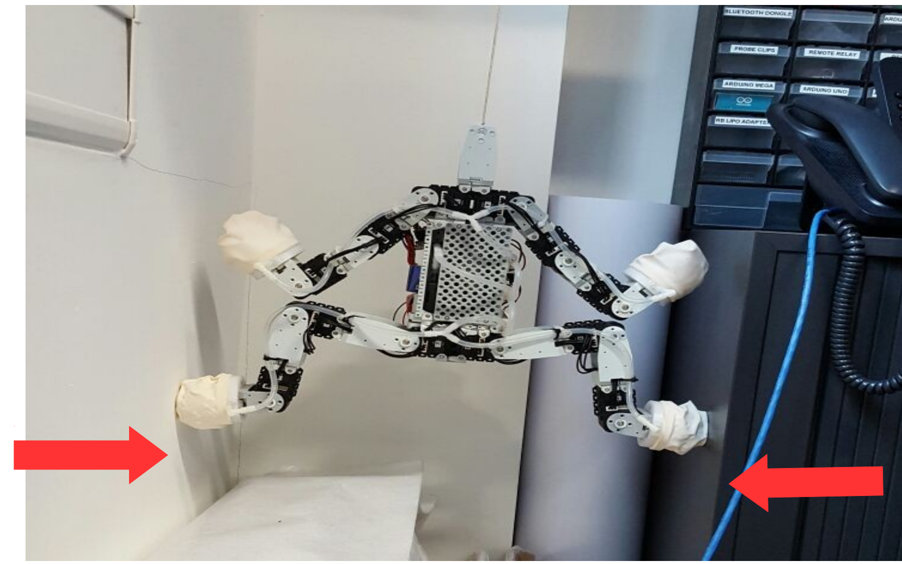
[**Design of a Variable Stiffness Flexible Manipulator with Composite Granular Jamming and Membrane Coupling**, Allen Jiang, Georgios Xynogalas, Prokar Dasgupta, Kaspar Althoefer, and Thrishantha Nanayakkara, *2012 IEEE/RSJ International Conference on Intelligent Robots and Systems October 7-12, 2012*]

Objectives

- 6 ECTS Bachelor's Project
- Design and creation of the element itself and the experiment process
- Characterisation of the element's Young's modulus' variation
- “Young's modulus variation of a variable stiffness element based on jamming of compliant granules”

Why a compliant medium?





Walking robot: slow gait = slow energy Xchange, rapid gait = quick energy Xchange

Climber: compliant cubes create a force on the walls => climbing!

Compliance in COMPRESSION!

What answer to what question?

How can we be sure that the element is capable of a linear range of compliance and how do we assess it ?

By measuring its Young's modulus throughout a range of pressure inside de VSE!

Experiment Design: Granules

Neukadur ProtoFlex:

- Elastomer
- Hardness Shore = 75A
- Tested in bending
- Best linear behaviour amongst every shape and dimensions tested

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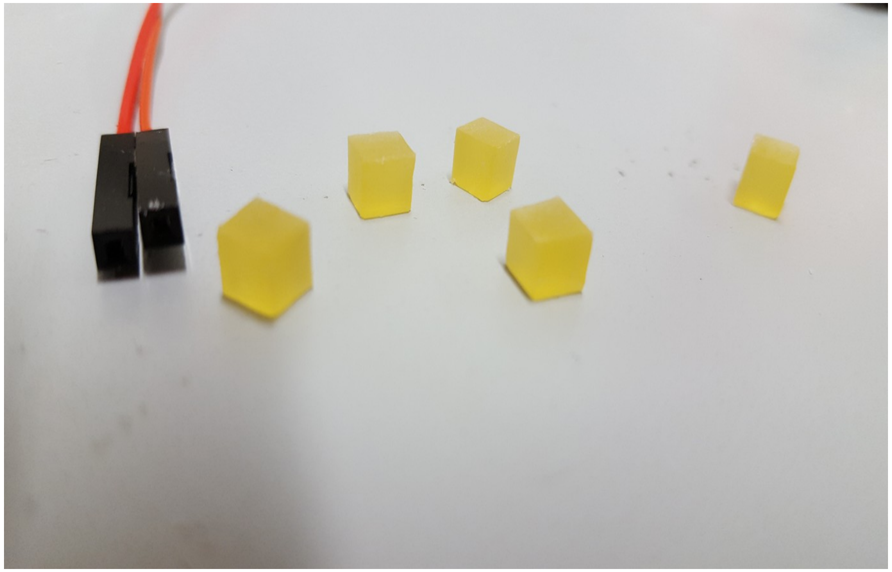
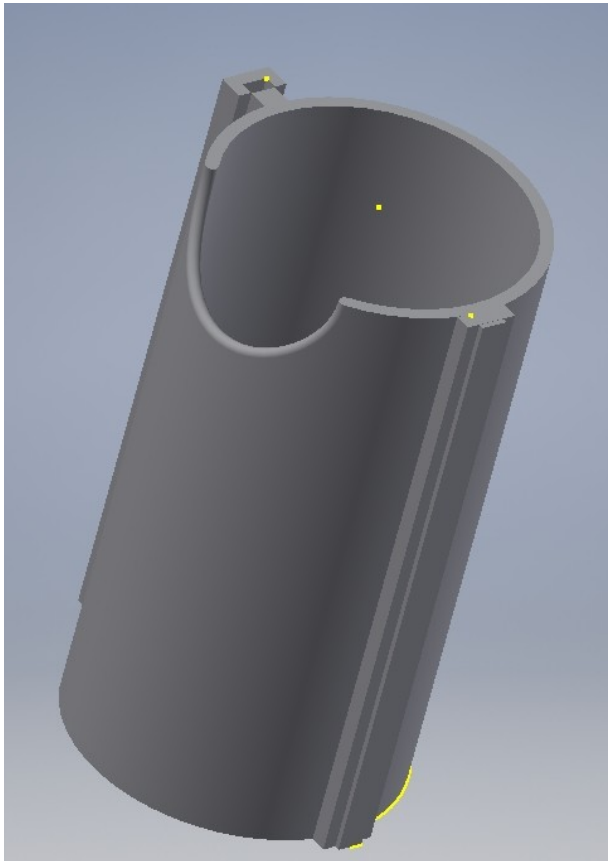
4x4x4 mm cubes used as granular medium

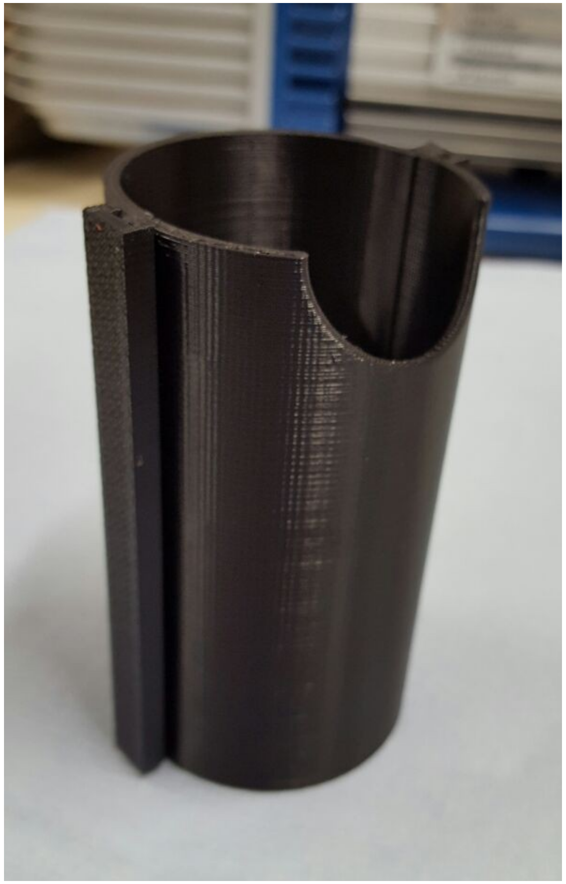


Experiment Design: Membrane

- Oblong;
- 4.5 cm in diameter;
- 9cm in height;
- 0.8 mm in thickness.

Experiment Design: Hard Shell

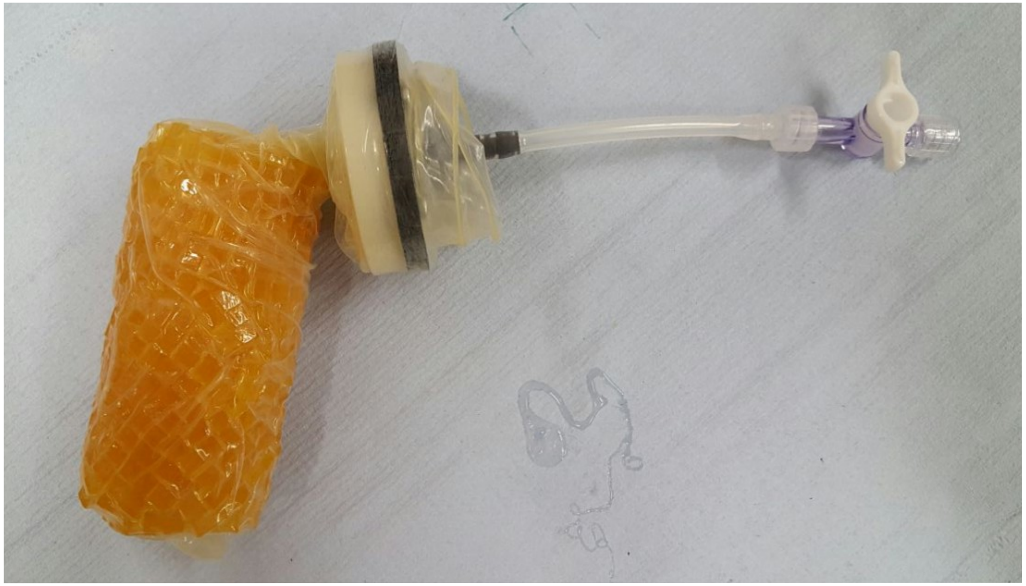


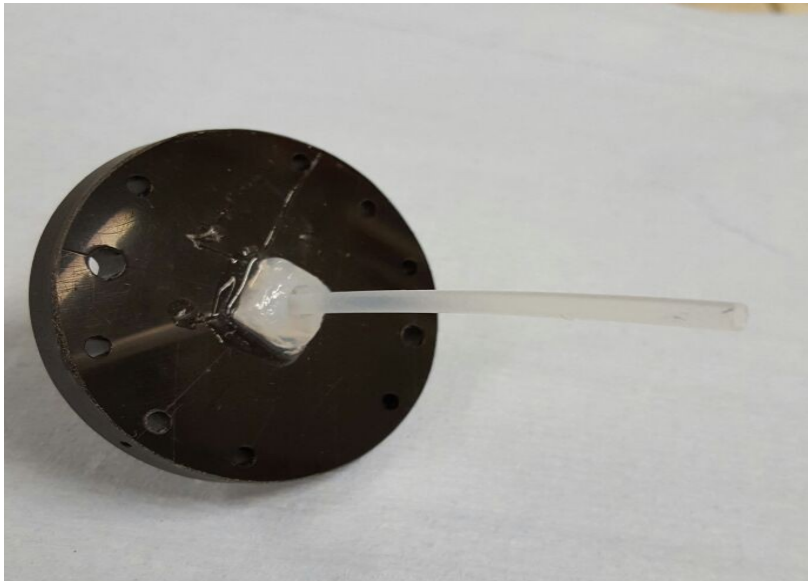


Diameter = 4.5 cm

Height = 9 cm

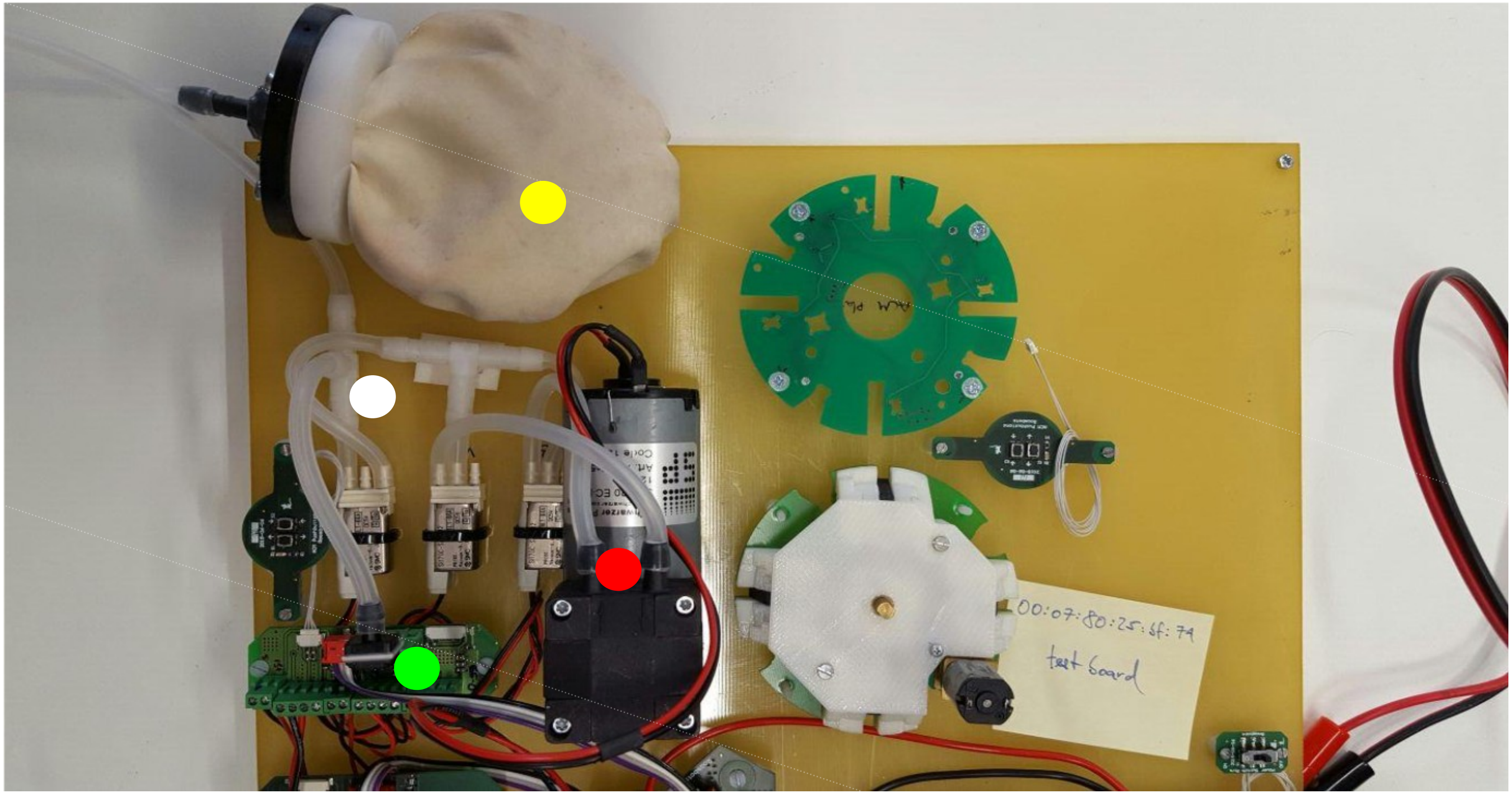
Experiment Design: Var. Stiff. Elmnt





Granules + Bases + Membrane + Airtight Switch

Experiment Design: Electronics

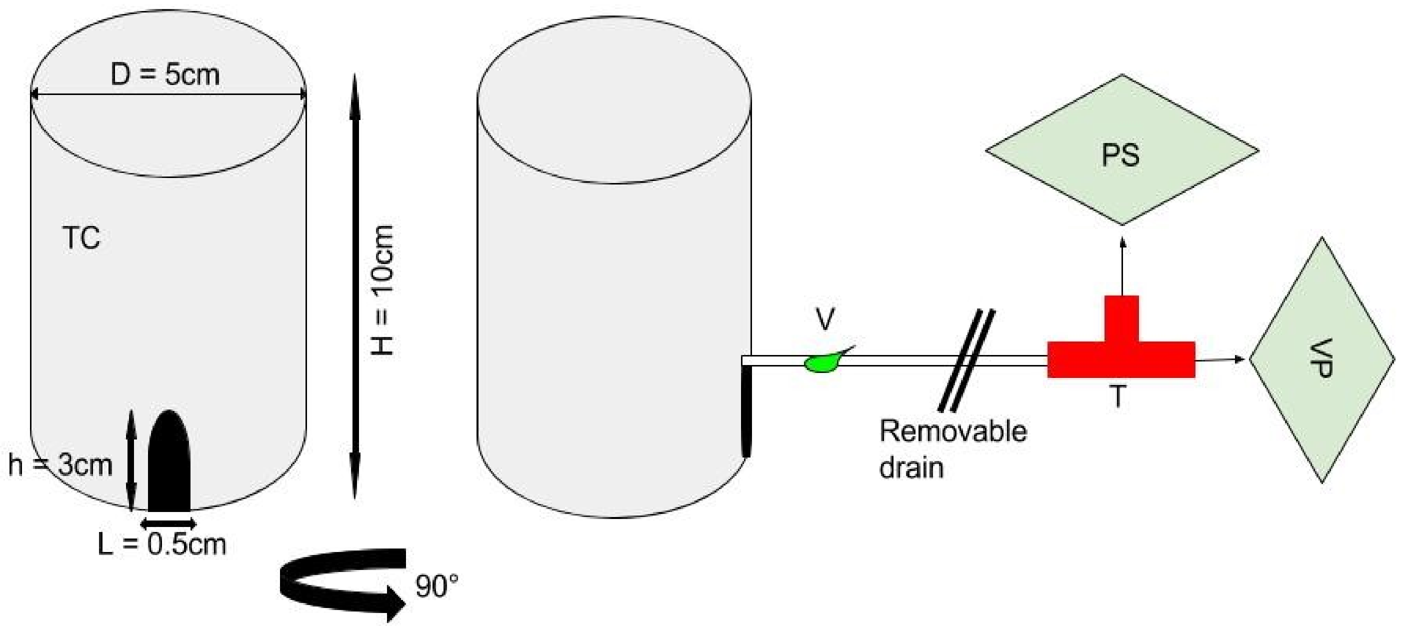


Vacuuming Test Setup

- Test element composed of a latex balloon filled with cubes, and a base;
- T-valve allowing the airflow going from the membrane to be sensed by the pressure sensor
- Vacuum Pump
- Pressure Sensor

Experimental Protocol: Shaping

NB: The shape as well as the Height = 2 x Diameter seem to be standards communicated to us by the Material Sciences department.



To the measuring machine

Caption:

TC: Tin Can (or cardboard can), which serves as hard shell for shaping the membrane
PS: Pressure Sensor
VP: Vacuum Pump
V: Closing valve to ensure the vacuum once we have removed the drain to go to the measuring tool
T: T-valve allowing both vacuum pumping as well as pressure sensing from the same pipe

Experimental Protocol: E-Modulus

INSTRON AVE 2 Non-Contacting Video Extensometer

Static Compressive Test, const. ΔL = 3mm

1) Compression loading @ 20mm/min

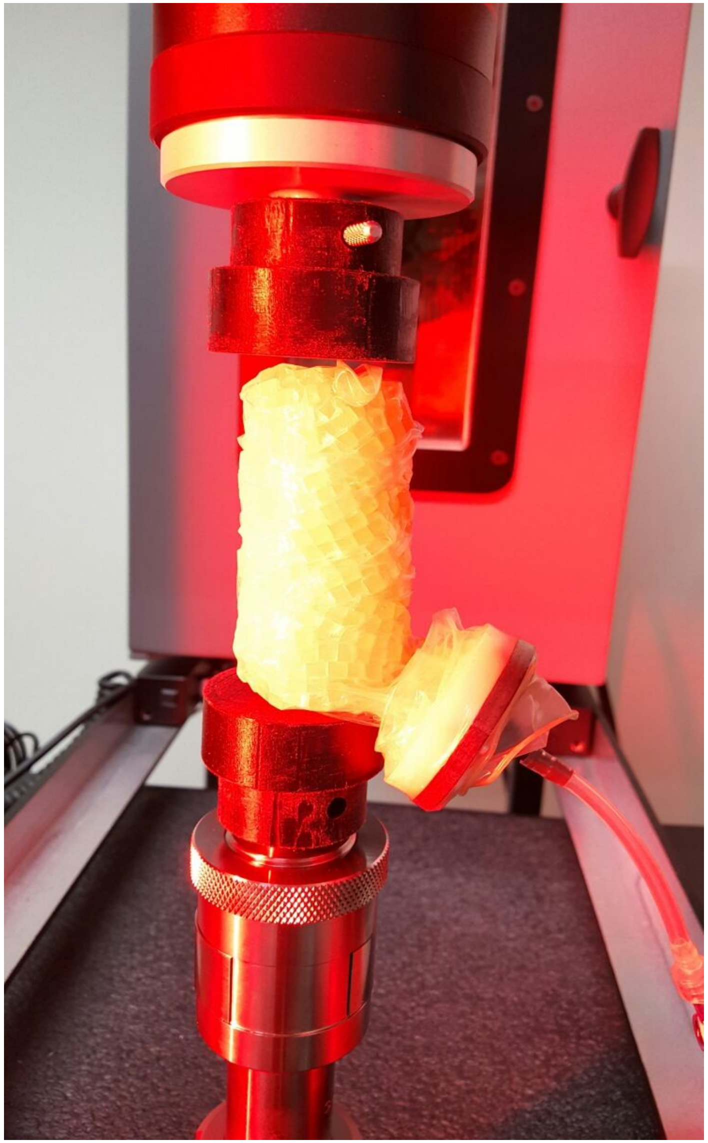
2) Loading stops at 3 mm

3) Sample free expansion

4) Raw Data (time, load, ΔL)

Repeat 5 times @ each pressure

Experimental Protocol: Creep



Static Compressive Test, const. ΔL = 3mm

1) Compression loading @ 20mm/min

2) Loading stops at 3 mm

3) Hold 60 sec

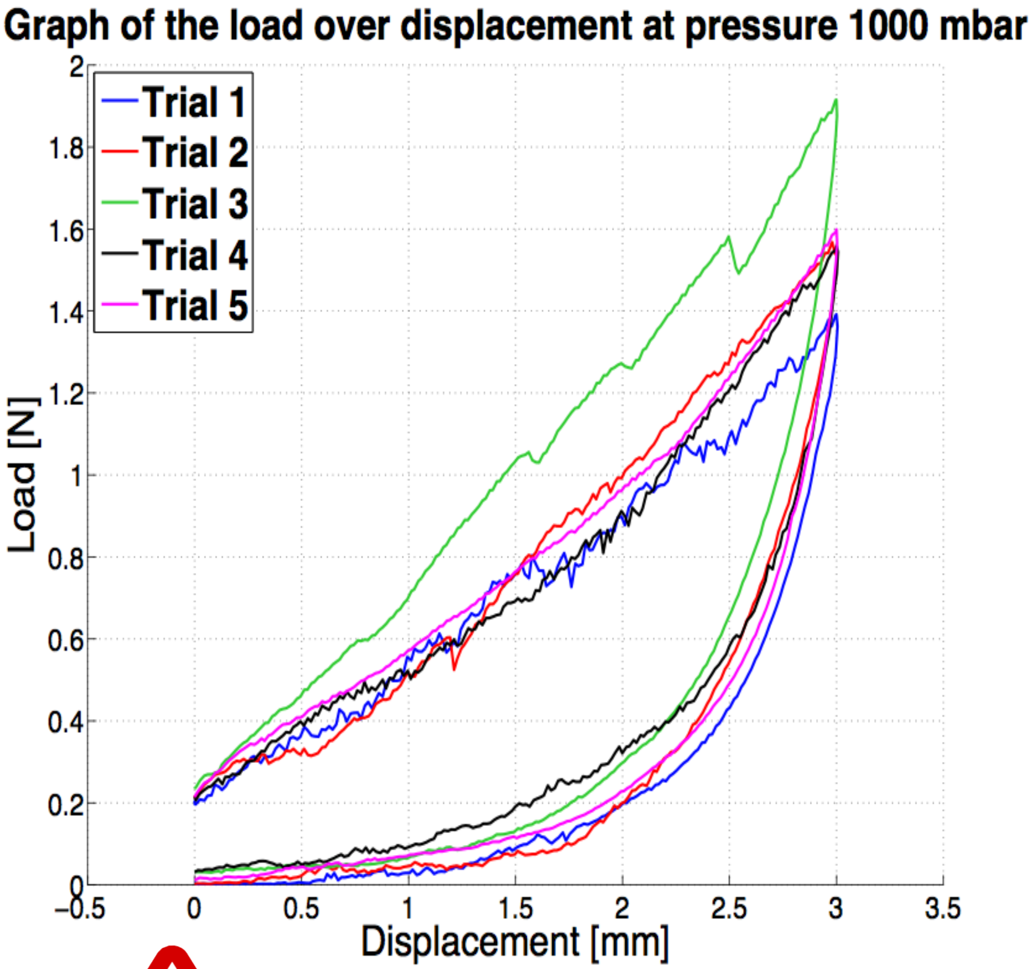
4) Sample free expansion

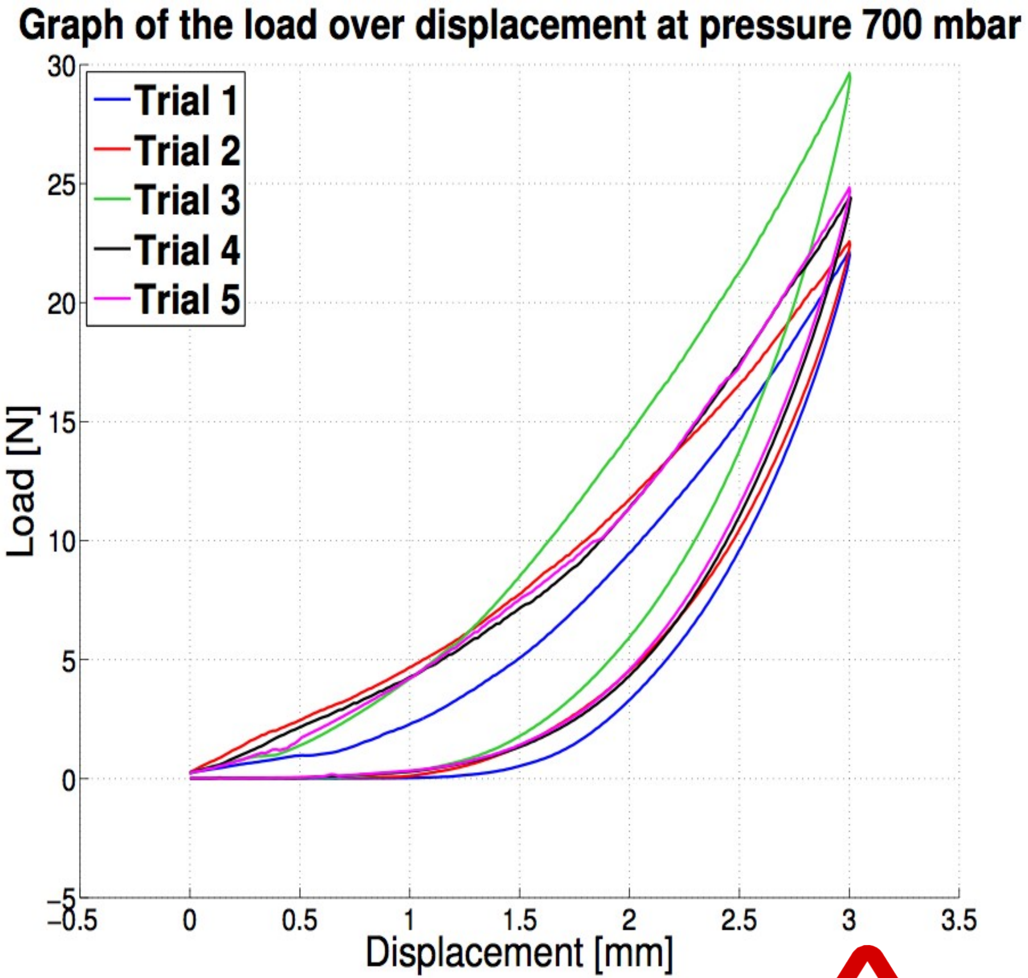
5) Raw Data (time, load, ΔL)

Repeat 1 times @ each pressure

→ MATLAB

Results: Hysteresis Curves

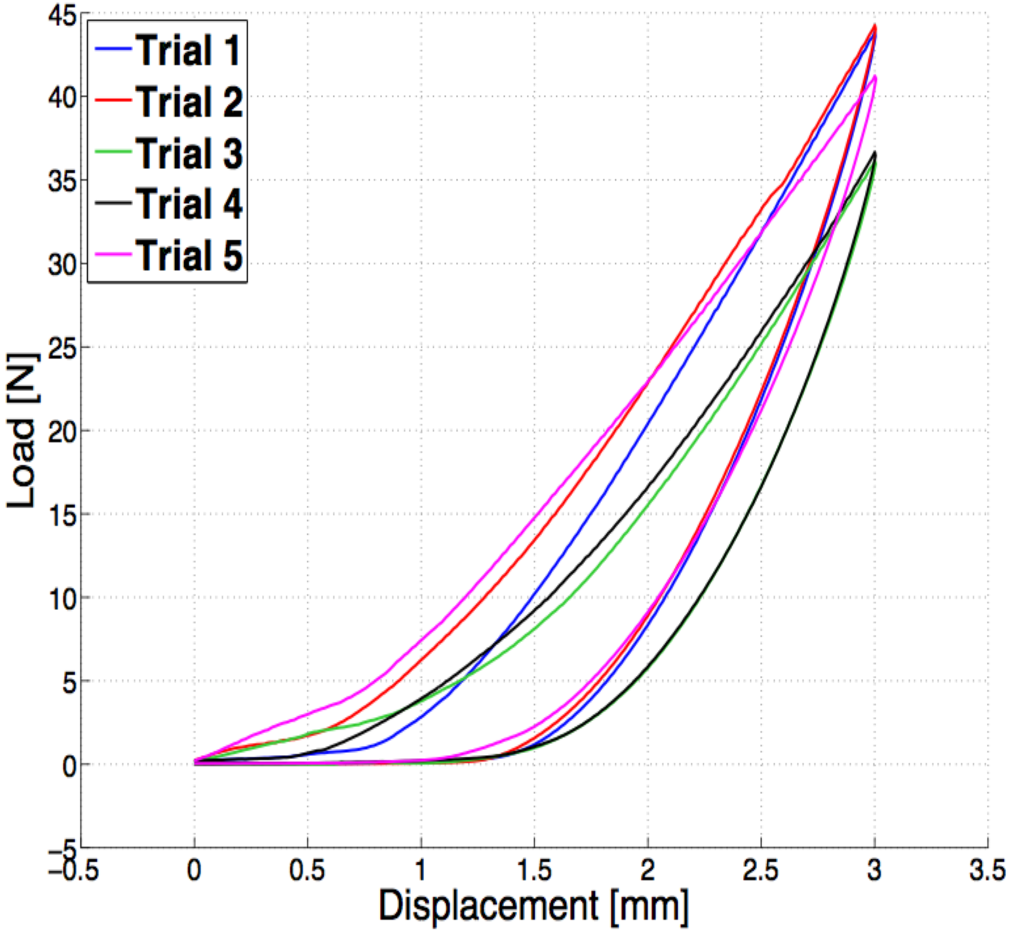




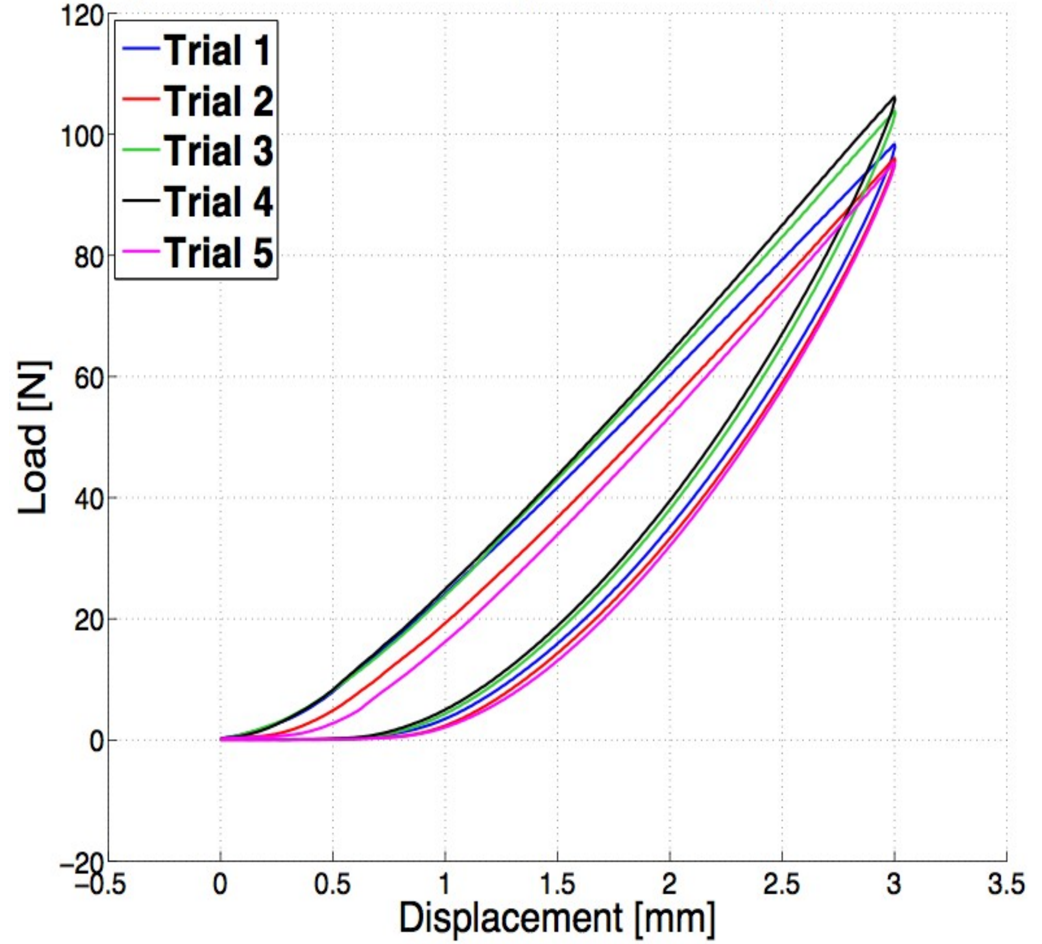
⚠ Scales are different ⚠

Results: Hysteresis Curves

Graph of the load over displacement at pressure 400 mbar

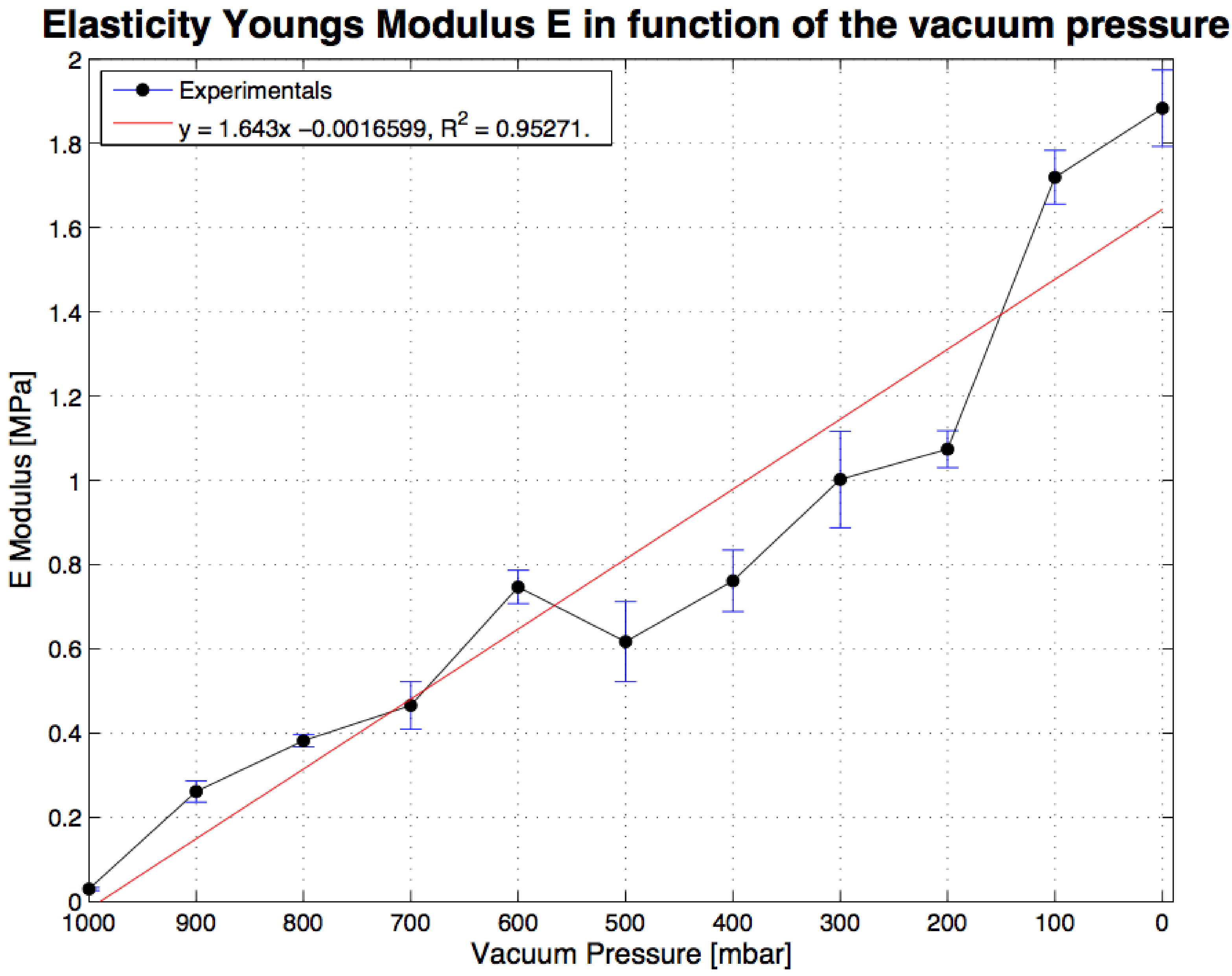


Graph of the load over displacement at pressure 0 mbar

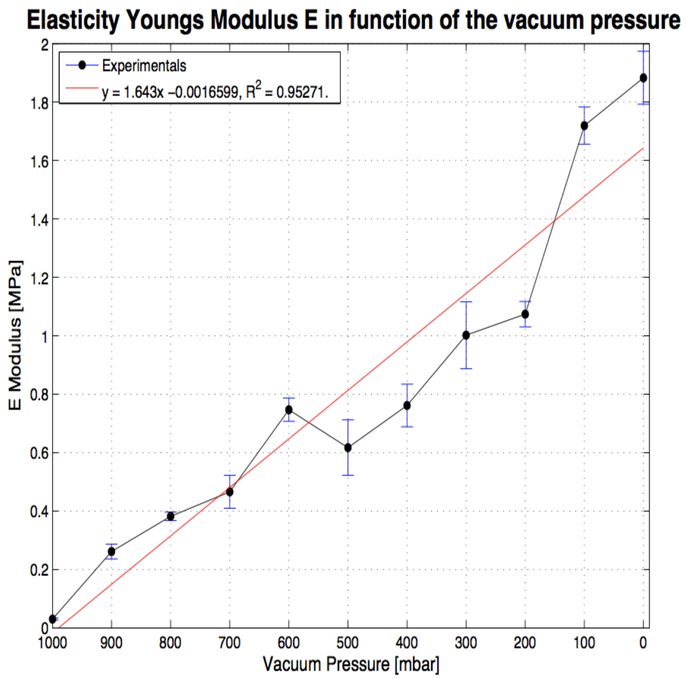


$$E = \frac{\sigma}{\epsilon} = \frac{F/A_o}{\Delta L/L_o} = \frac{F L_o}{\Delta L A_o}$$

Results: E-Modulus as f(pressure)



Results: E-Modulus as f(pressure)



- Corr. Coeff = 0.95271
  => LINEAR!

- @ 100% Vacuum, E = 1.9 Mpa

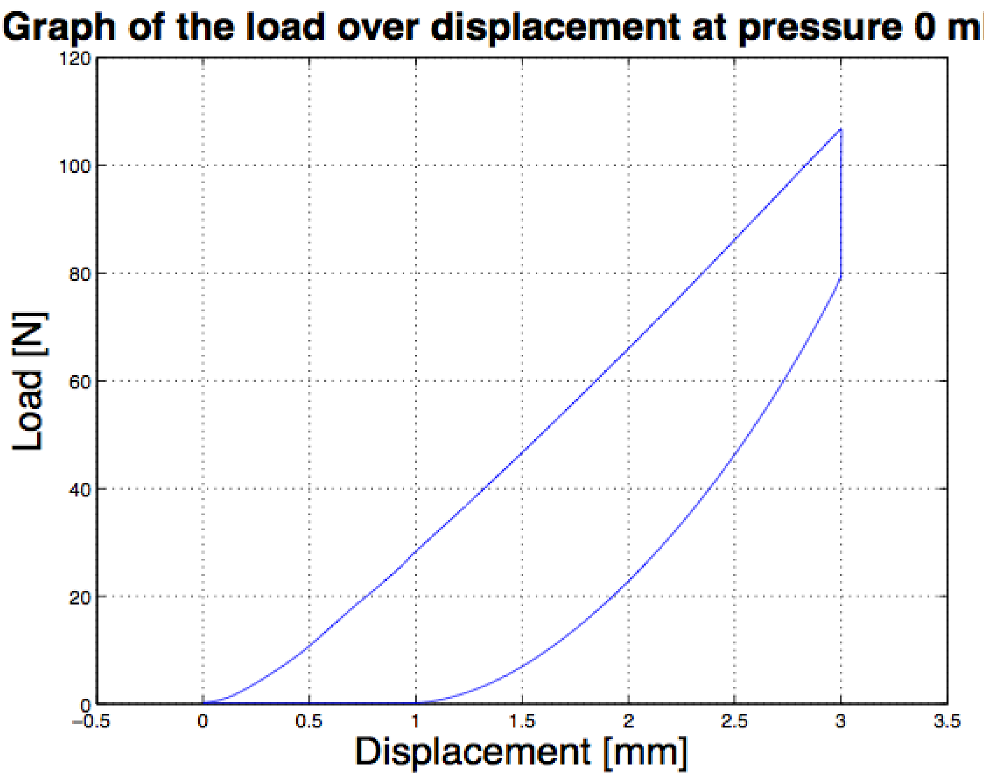
-E for full material = 6.5 Mpa

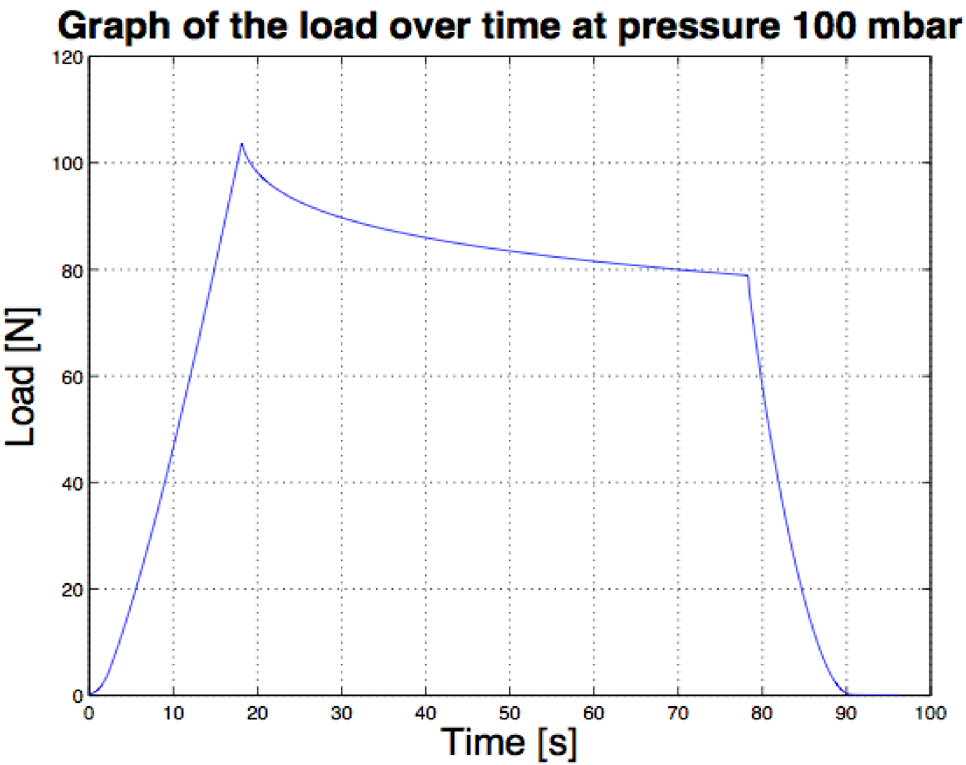
ΔE due to stochastic arrangement of the cubes:

- Spring stiffness not the same for length or diagonal

- Lateral expansion (membrane)

Results: Creep





Lowest pressure = best stabilisation of creep

Flexible membrane = enhancement of creep

Lesser grip after some time...

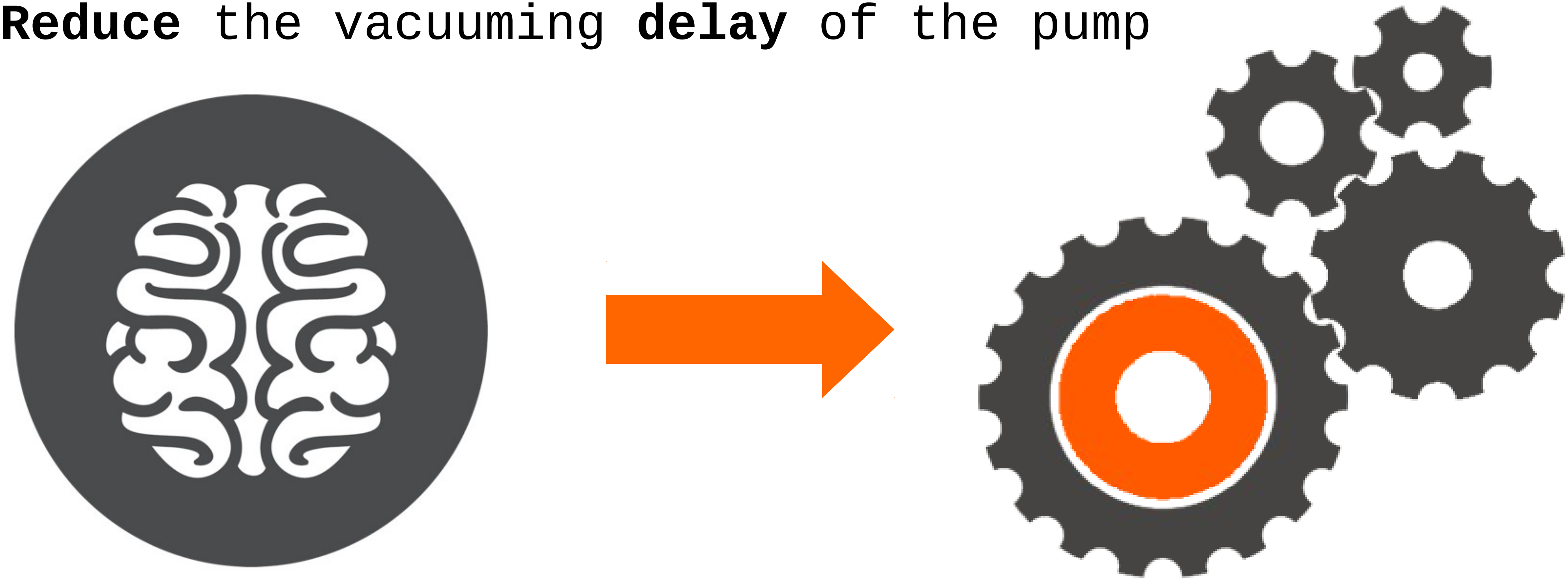
Future Work

Modeling the E modulus as f(pressure, stoch. Arr.)

Dependance between pressure and arrangement

Creep: time before grip not sufficient enough

Reduce the vacuuming **delay** of the pump



THANKS FOR YOUR ATTENTION

- Questions :) ?