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Design of an Industrial Wooden Robot

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Why a project on the design of an industrial wooden robot?

This idea comes from the actual contest of climate change. The **Climate Change Mitigation (CCM)** has become a priority in Europe. To deal with this huge challenge, the European Council adopted new environmental targets for EU in 2008, the so-called « 20-20-20 » targets, in which the first two targets are :

- To reduce emissions of Greenhouse Gases γ 20% by 2020, and
- To increase energy efficiency to save 20% energy consumption by 2020 (40% and 27% by 2030)

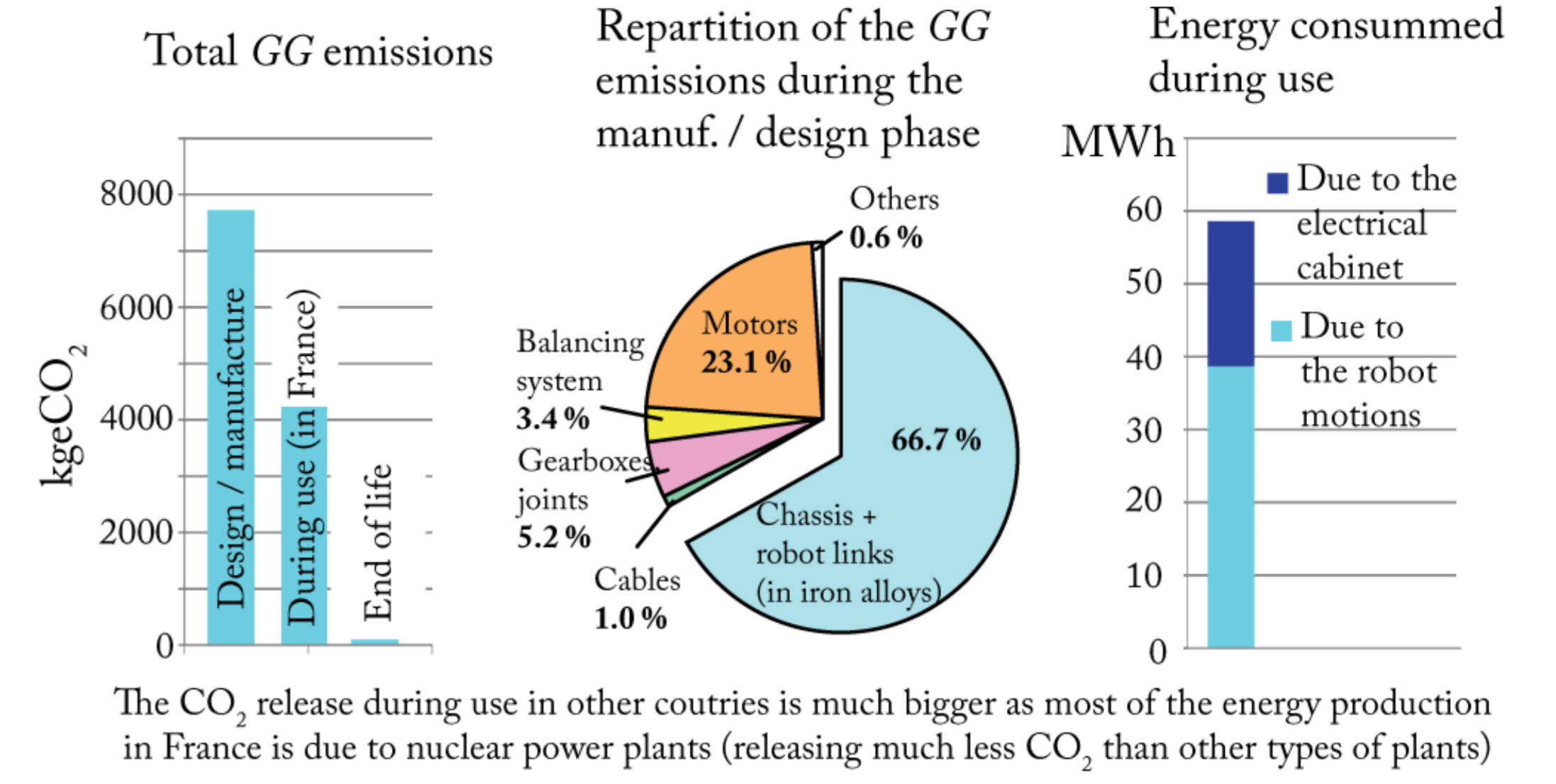
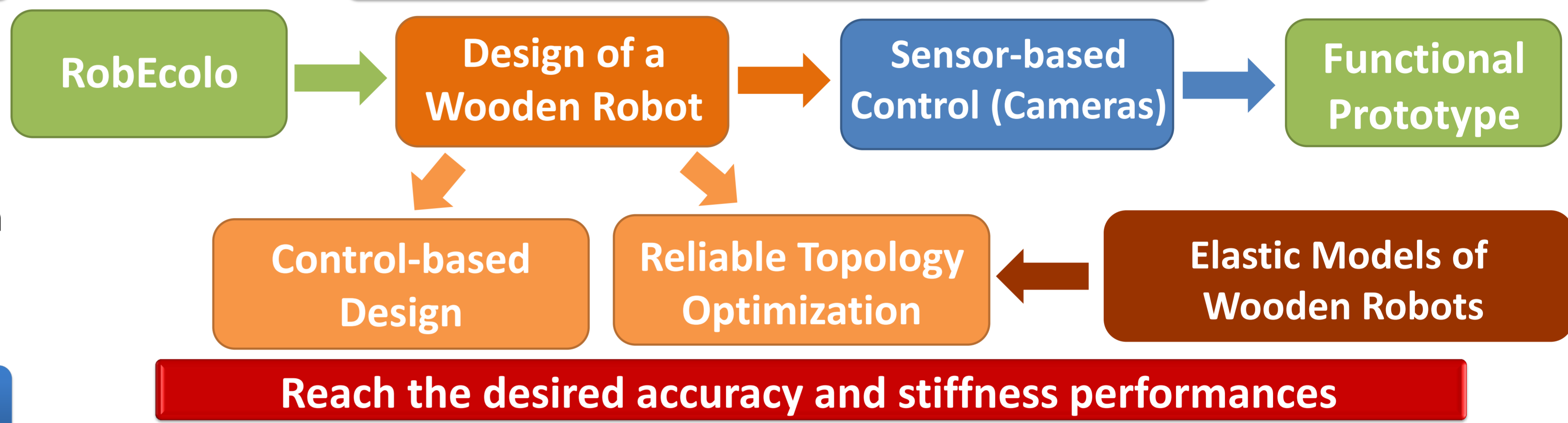


Fig. 1 Environmental impact of a Kuka KR 270 robot during its total life cycle (manufacturing + use during 12 years)/ Energy consumed during the use phase data form [1]

Objectives of RobEcolo

- Design and control of **2 degrees-of-freedom** wooden parallel robot (Five-bar Mechanism)
- **Repeatability** < 0.5 mm
- **Deformation** (under a load of 1 kg) < 0.5 mm
- **Workspace dimensions:** 800 mm x 200 mm

Methodology



Elastic Models of Wooden Robots

Mechanical Properties of Wood

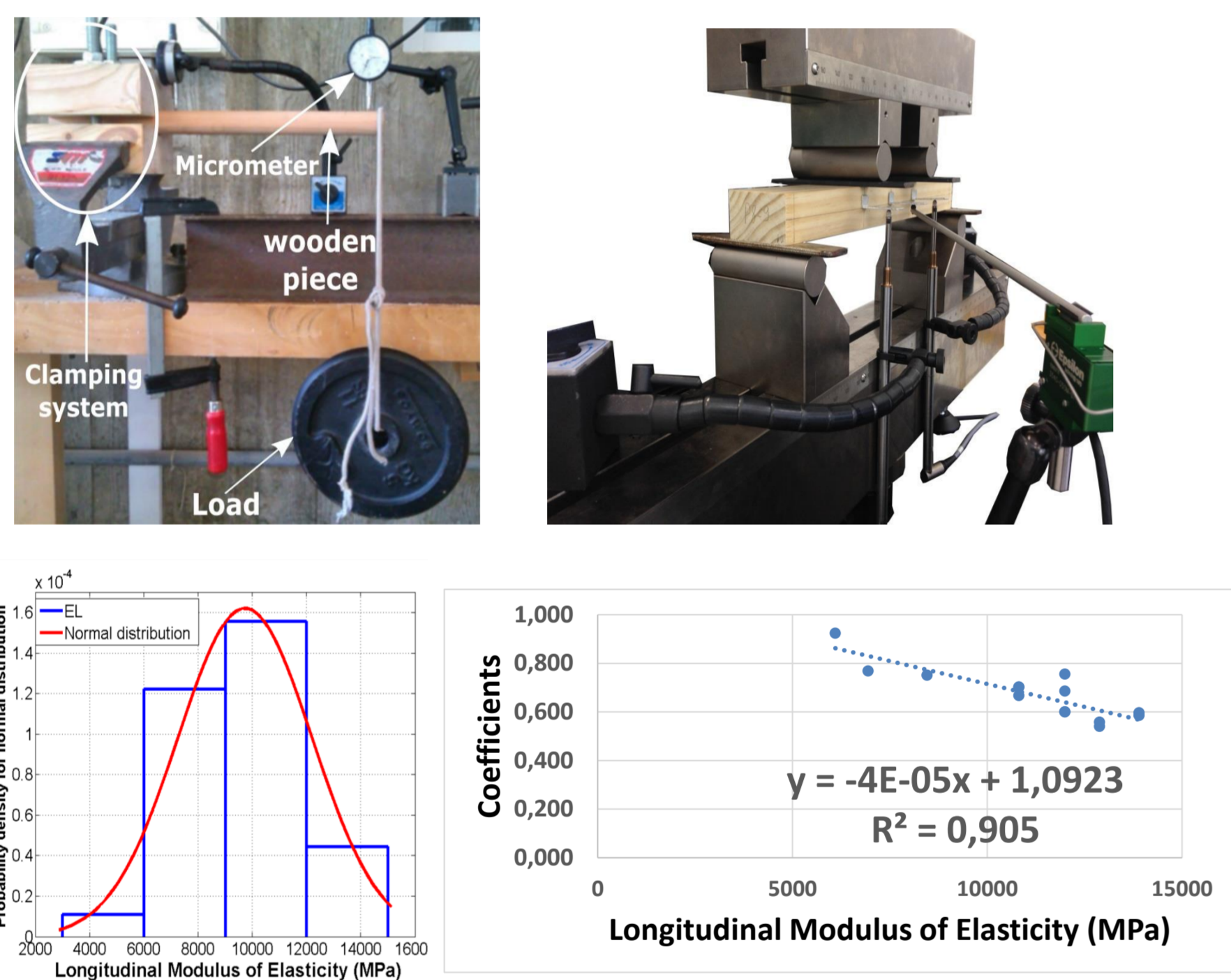


Fig. 3 Bending tests to define the mechanical properties of acetylated wood [3]

Elastic Modelling Methodology of a Wooden Robot

1. Euler-Bernoulli Model => **Beam Theory**
Shear, bending & torsion
2. Identification of laws defining coefficients to take into account the joints behavior
3. **Deterministic Elastostatic and Elastodynamic Models of a Five-bar Mechanism**
4. **Sensitivity Analysis [3] => Monte-Carlo Method**

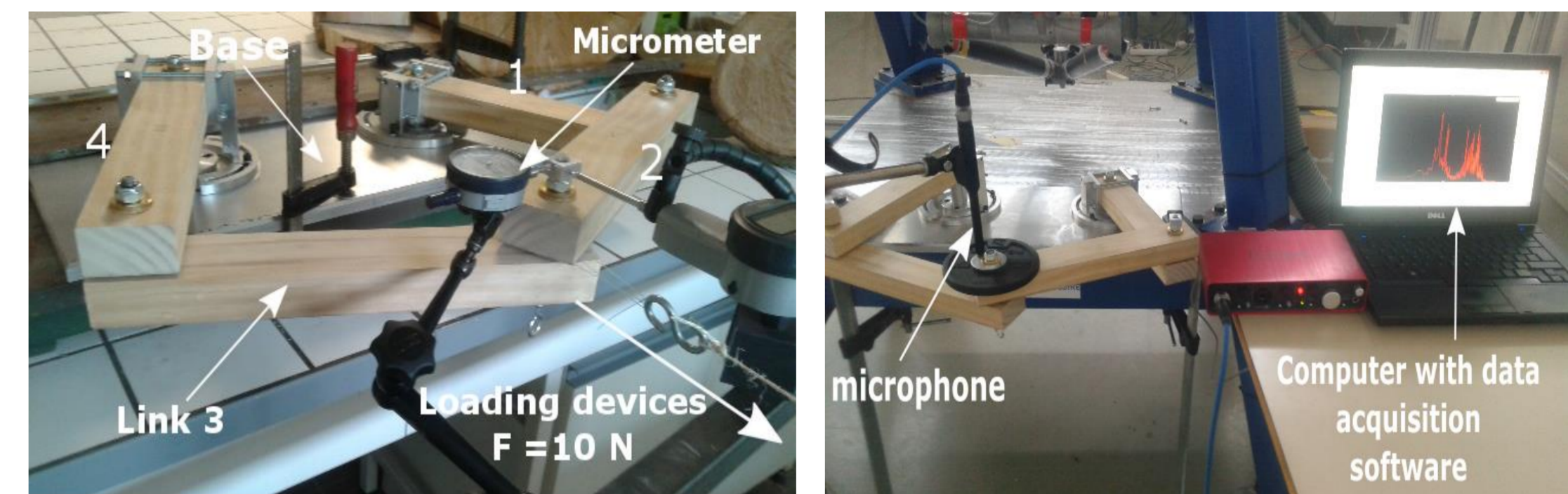
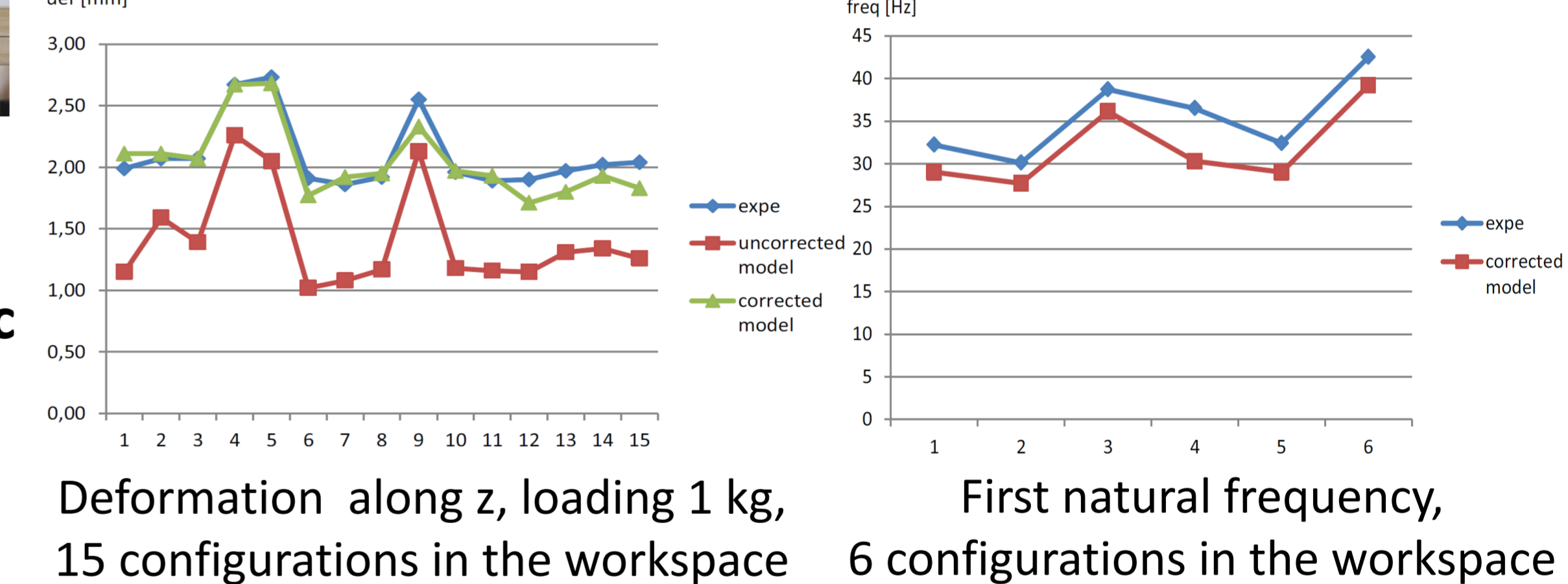


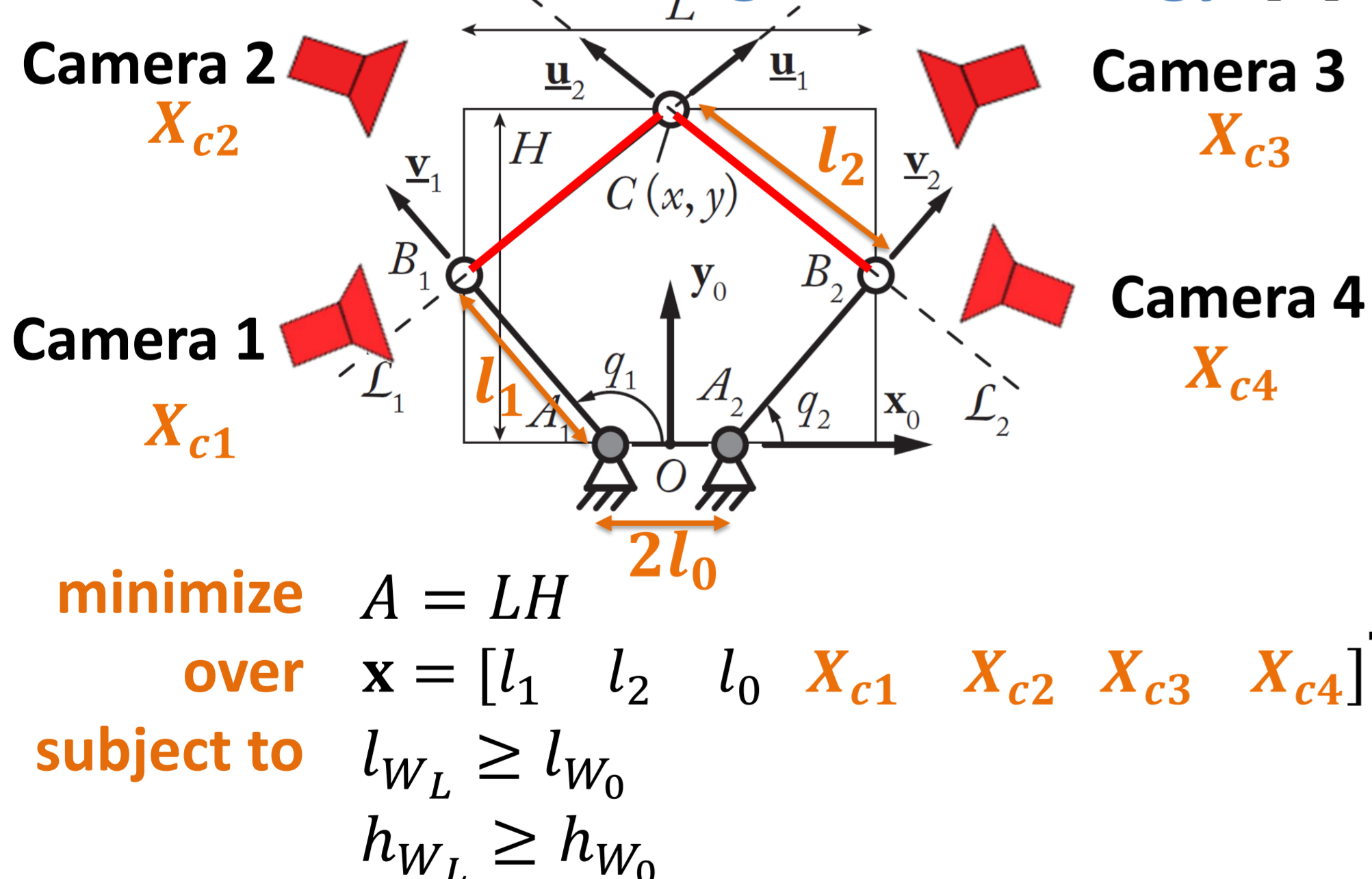
Fig. 4 Experimental setups to validate the theoretical models using a wooden five-bar mechanism mockup



Design Process and Final Prototype

Good Correlation between models and experiments => **Error < 10%**

Control-based Design Methodology [2]



minimize $A = LH$
 over $\mathbf{x} = [l_1 \ l_2 \ l_0 \ X_{c1} \ X_{c2} \ X_{c3} \ X_{c4}]^T$
 subject to $l_{WL} \geq l_{W0}$
 $h_{WL} \geq h_{W0}$

Optimal Design Parameters

Geometric parameters		Position/ Orientation	Camera 3	Camera 4
l_0 [m]	0.125	x_c [m]	0.01	0.02
l_1 [m]	0.280	y_c [m]	0.5	0.5
l_2 [m]	0.400	z_c [m]	0.75	0.75
A [m ²]	0.1372	rot [rad]	0	0
		θ [rad]	π	π
		ψ [rad]	0	0

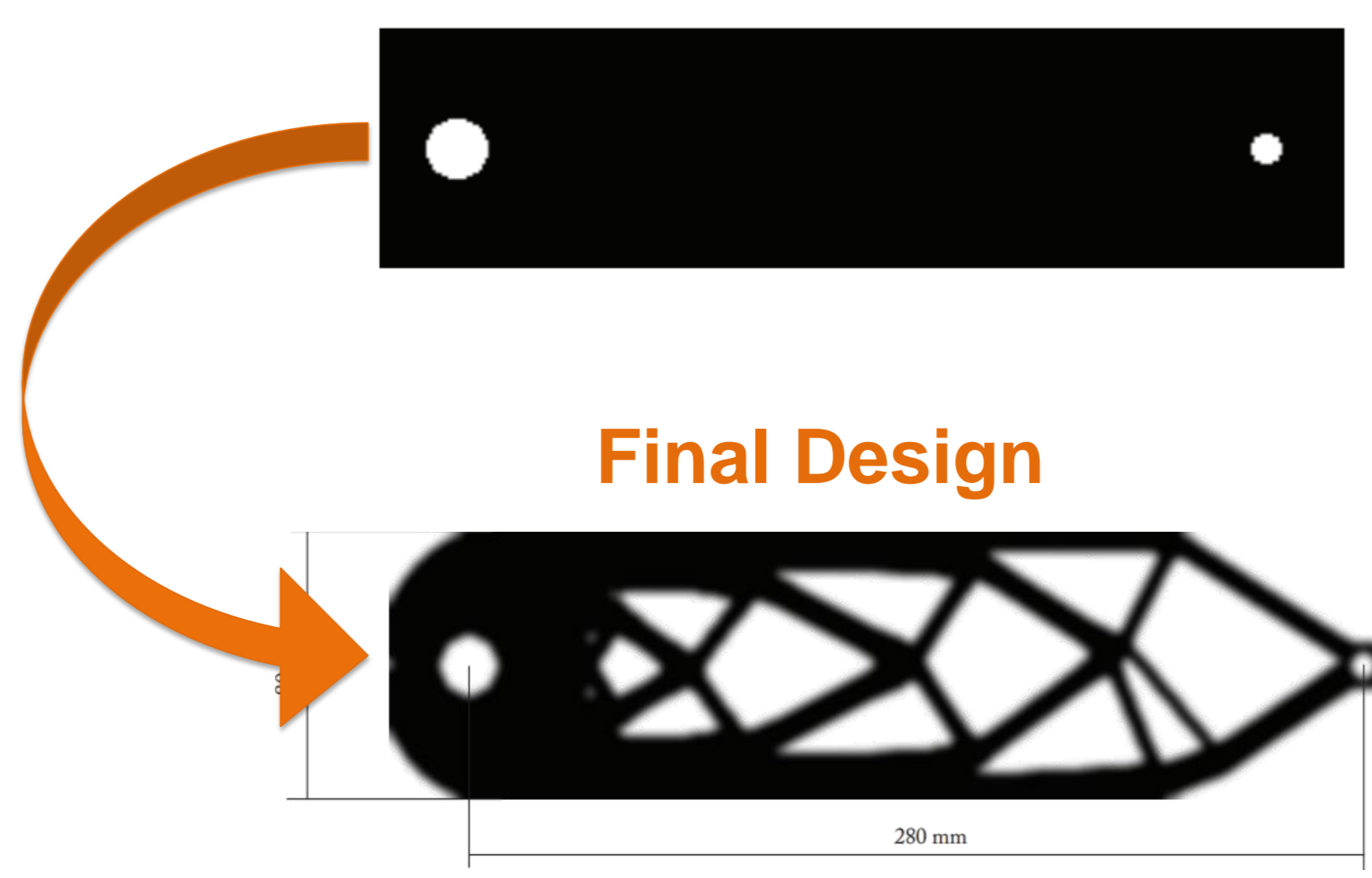
Reliable Topology Optimization

$$E(\|\mathbf{u}_e\|) + k \sigma(\|\mathbf{u}_e\|) \leq u_{\max}$$

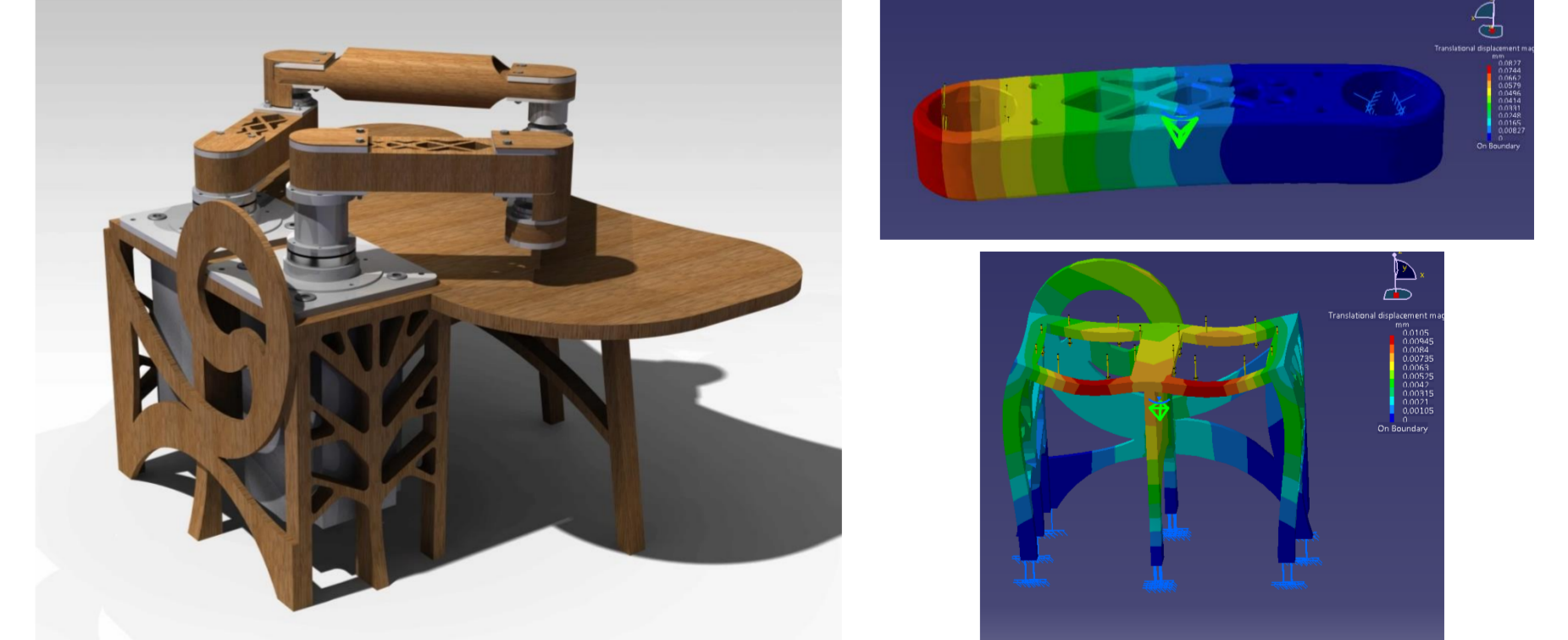
- $E(\cdot)$: expectation operator
- $\sigma(\cdot)$: Standard deviation operator
- k : a positive real
- \mathbf{u}_e : deformation vector at given nodes, for a fixed nodal loading \mathbf{f}

Initial Design

Final Design



CAD Model of a Wooden Parallel Robot



Final Prototype



[1] Fizians Environnement "Eco-design of two types of robots: KUKA 270 and IRSbot-2", 2014

[2] L. Kaci et al. "Control-based Design of a Five-bar Mechanism". (EuCoMeS2016), September 2016 Nantes, France.

[3] L. Kaci et al. "Elastostatic Modelling of a Wooden Parallel Robot," (CK2017), May 22-24, 2017 Futuroscope-Poitiers, France.