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# Design of an Industrial Wooden Robot

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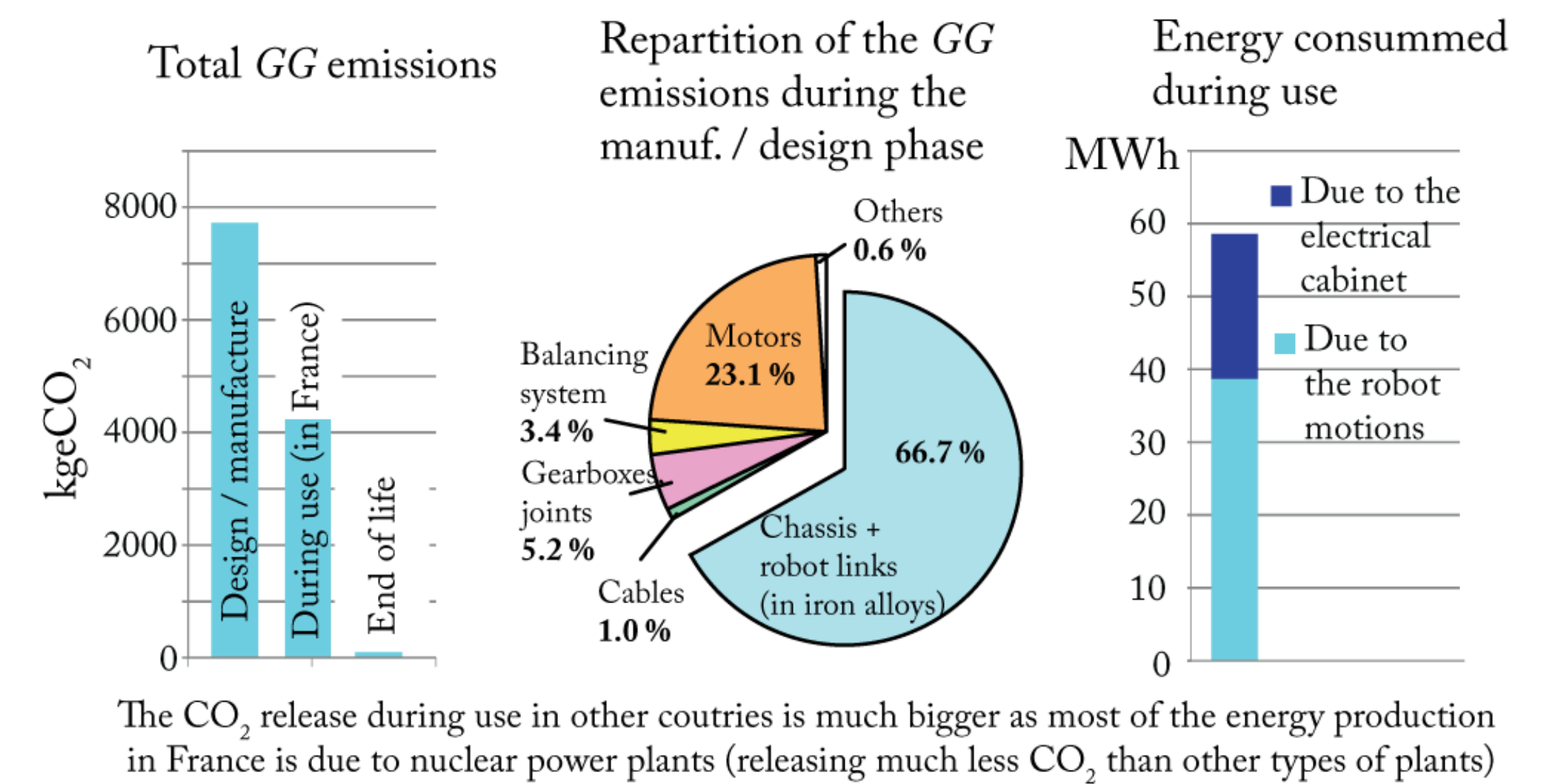
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## Why a project on the design of an industrial wooden robot?

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 y 20% by 2020, and
- To increase energy efficiency to save 20% energy consumption by 2020 (40% and 27% by 2030)

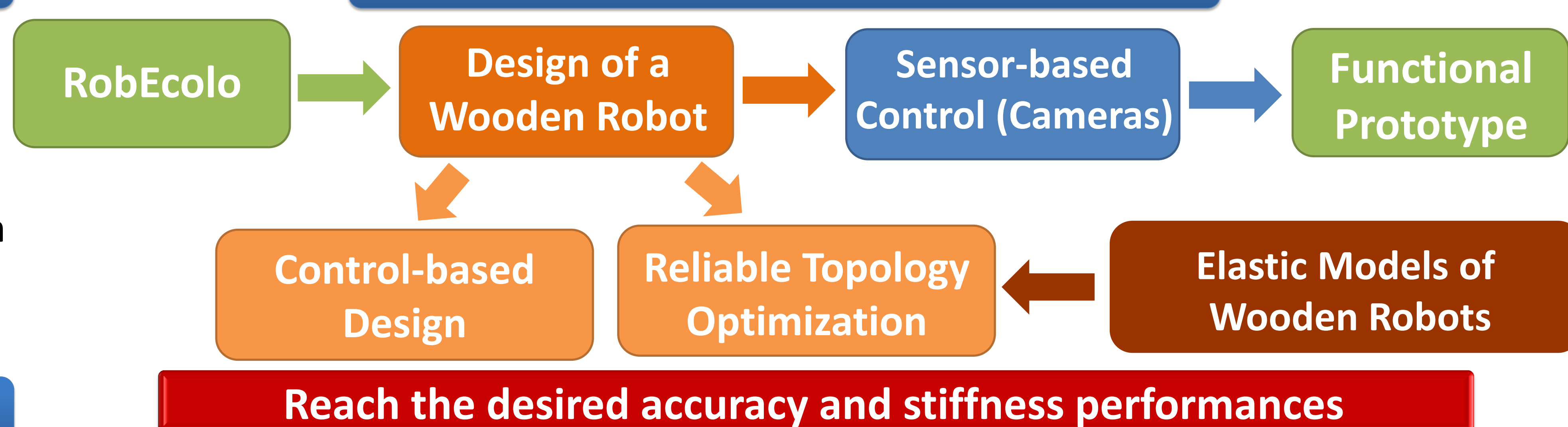


**Fig. 1** Environmental impact of a Kuka KR 270 robot during its total life cycle (manufacturing + use during 12 years)/ Energy consumed during the use phase data from [1]

## Objectives of RobEcolo

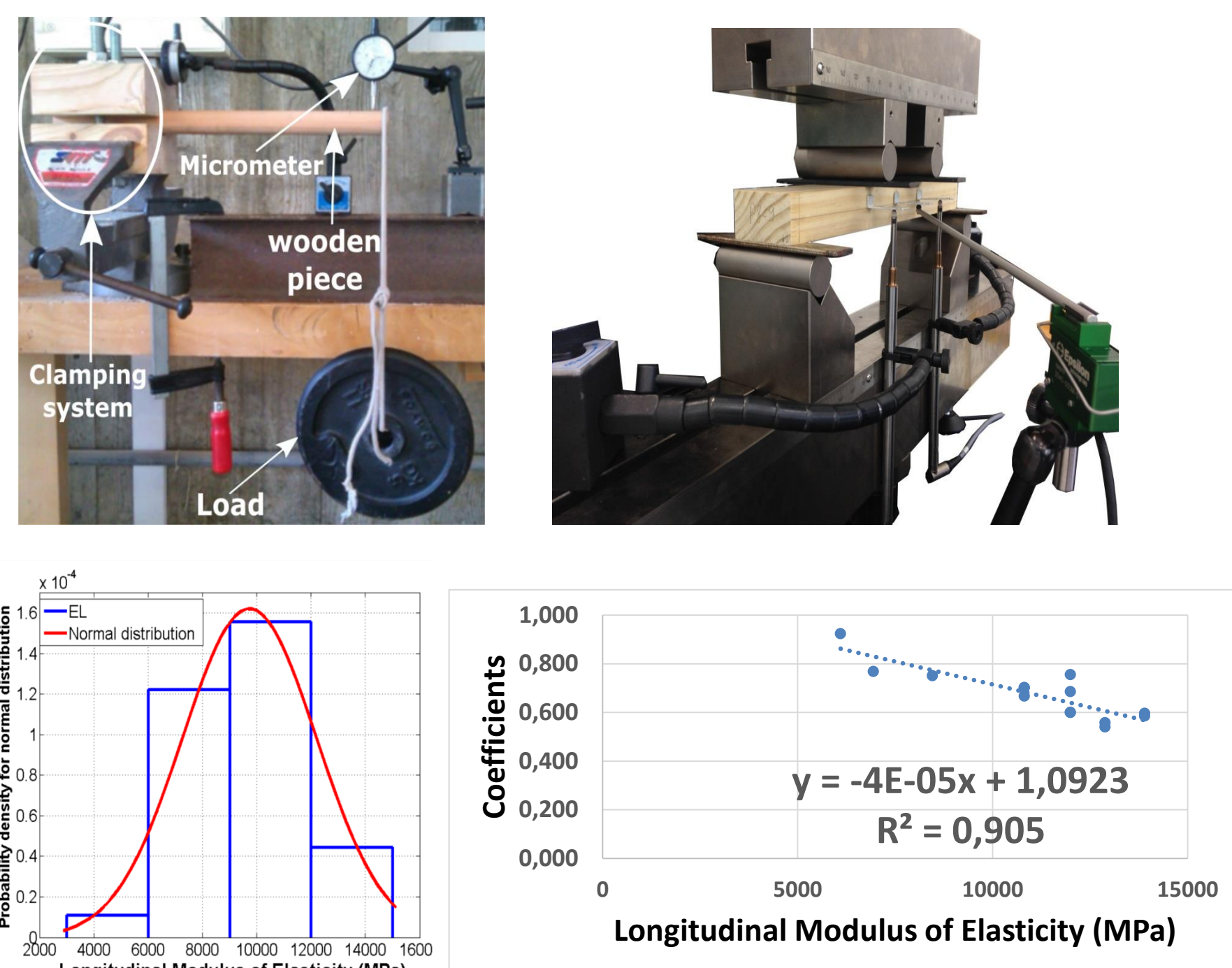
- Design and control of **2 degrees-of-freedom** wooden parallel robot (Five-bar Mechanism)
- **Repeatability** < 0.5 mm
- **Deformation** (under a load of 1 kg) < 0.5 mm
- **Workspace dimensions**: 800 mm x 200 mm

## Methodology



## Elastic Models of Wooden Robots

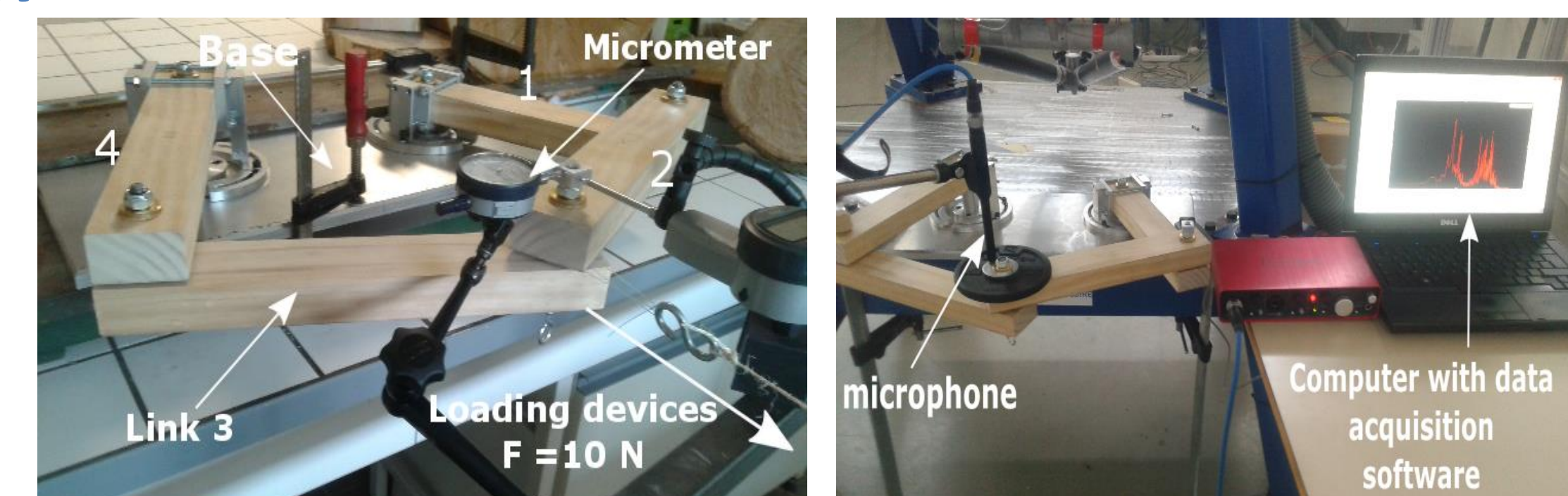
### Mechanical Properties of Wood



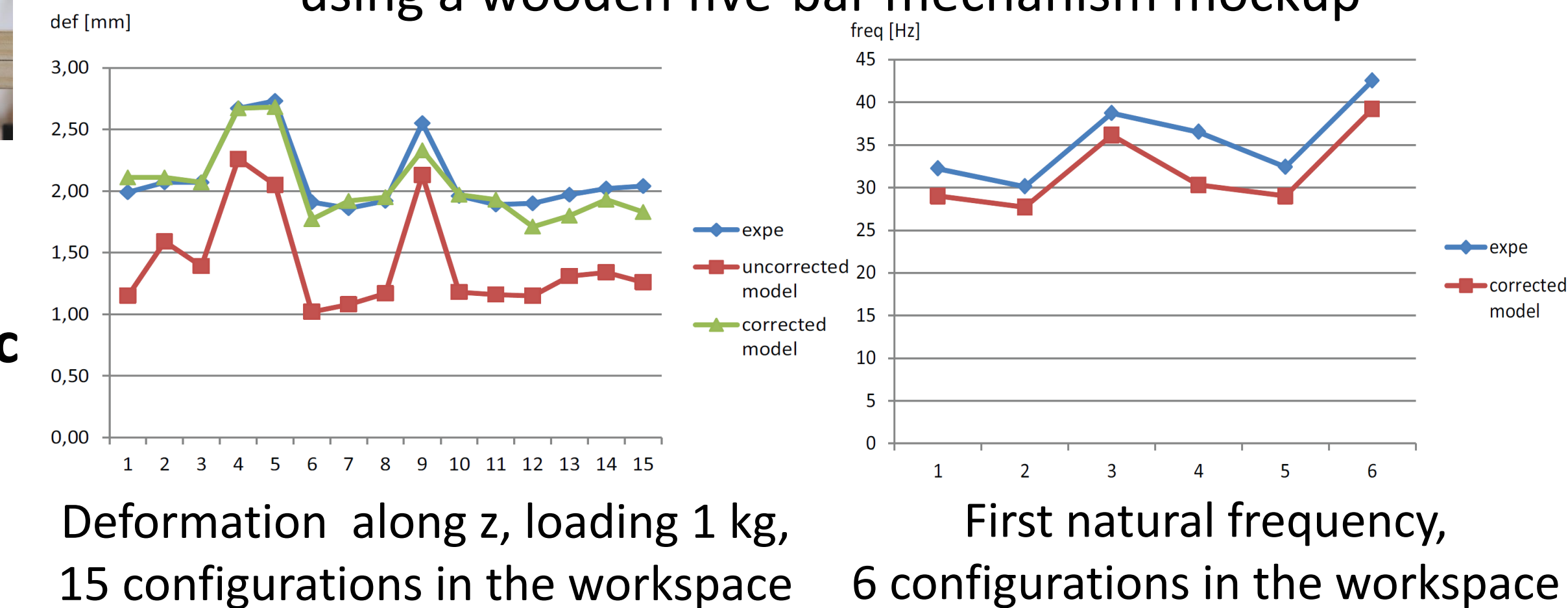
**Fig. 3** Bending tests to define the mechanical properties of acetylated wood [3]

### 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**



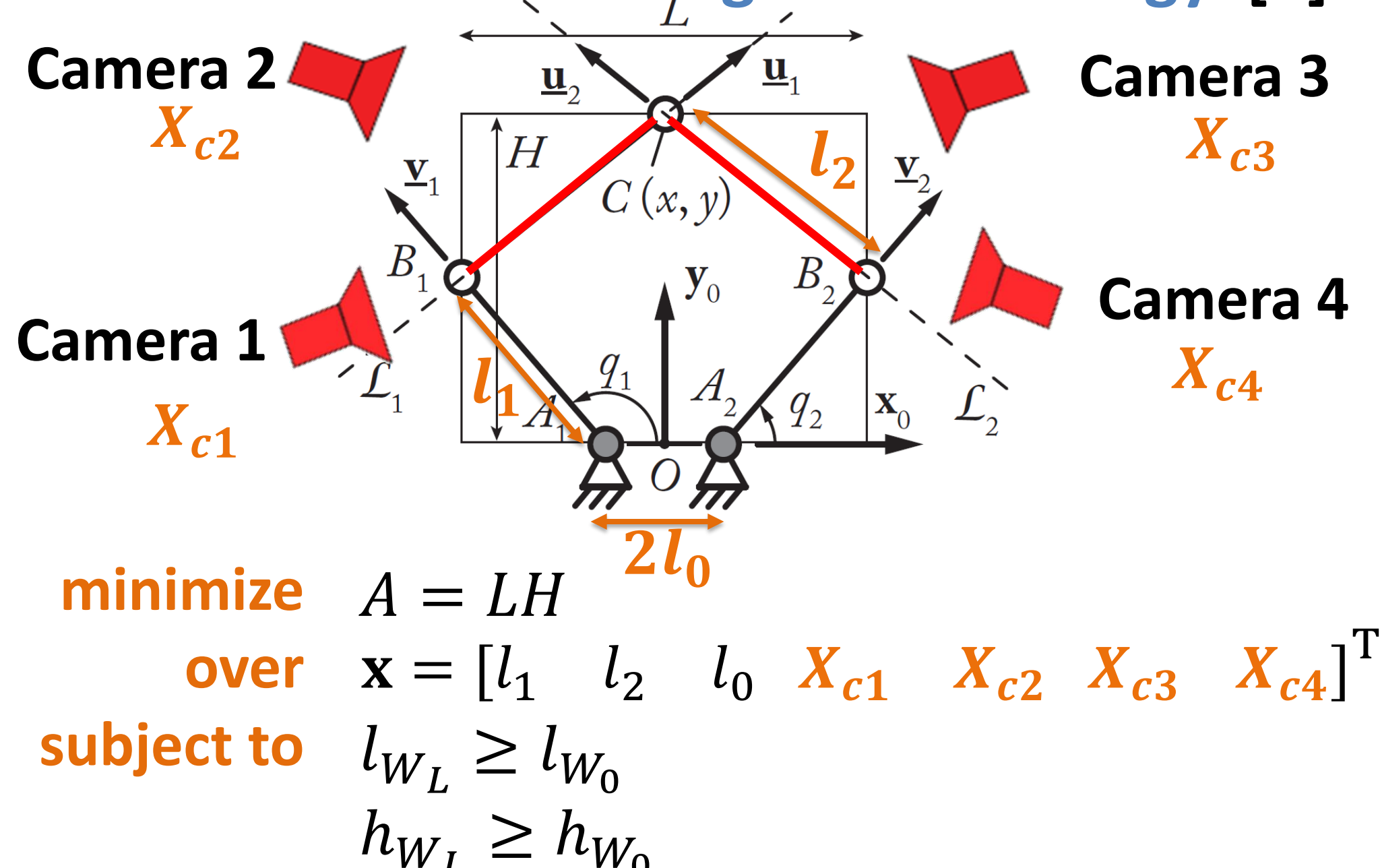
**Fig. 4** Experimental setups to validate the theoretical models using a wooden five-bar mechanism mockup



## Design Process and Final Prototype

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

### Control-based Design Methodology [2]



### 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 <sup>2</sup> ]	<b>0.1372</b>	rot [rad]	0	0
		$\theta$ [rad]	$\pi$	$\pi$
		$\psi$ [rad]	0	0

### Reliable Topology Optimization

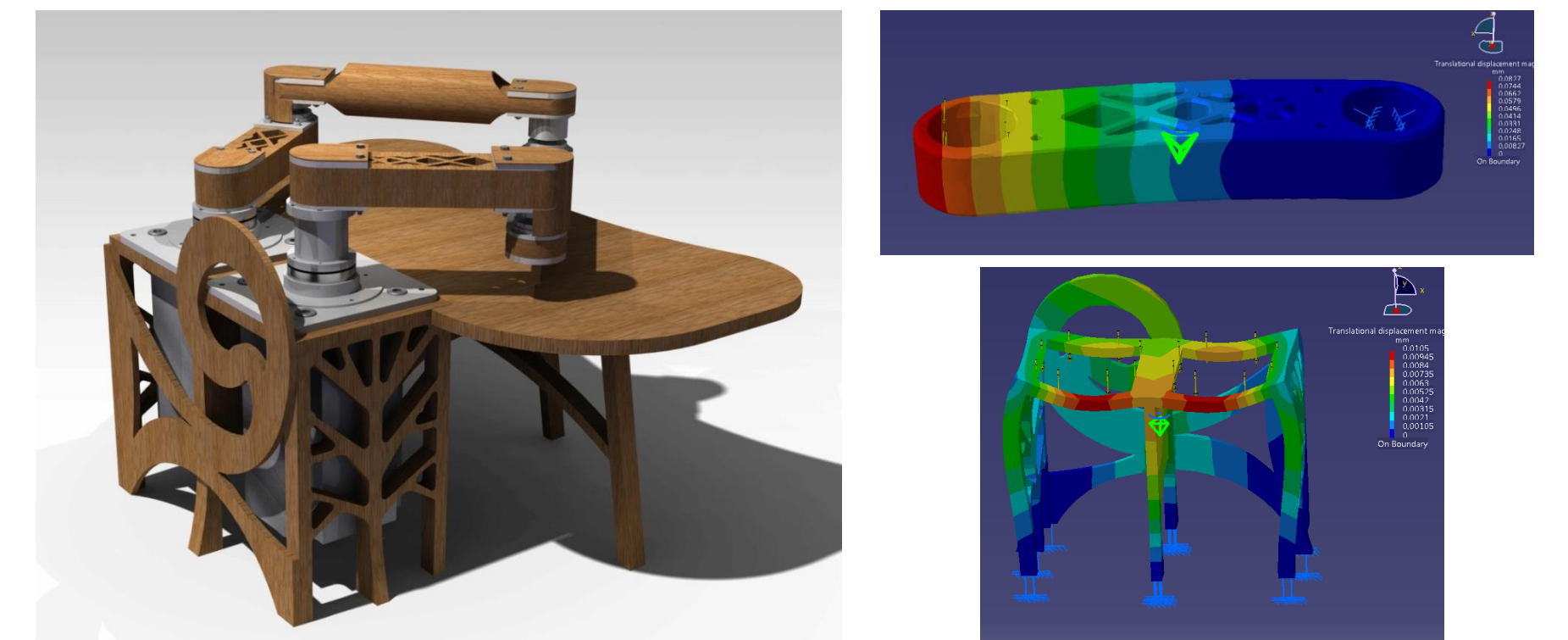
$$E(\|\mathbf{u}_e\|) + k \sigma(\|\mathbf{u}_e\|) \leq u_{\max}$$

- $E(\cdot)$ : 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.