Design of High Performance Flexural Joints for Additive Manufacturing

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Assembling, friction and lubrifaction are the main issues when designing traditional rigid mechanisms. **Flexure-based compliant mechanisms** overcome this problem because they are monolithic and gain their mobility thanks to a proper design and a material deflection. However, the accurate and convenient design and the **production of such mechanisms remain critical**. Thanks to its capabilities, **ADDITIVE MANUFACTURING** approach could attack this challenge and opens a **NEW UNEXPLOITED FIELD.**

PERFORMANCE IMPROVEMENT

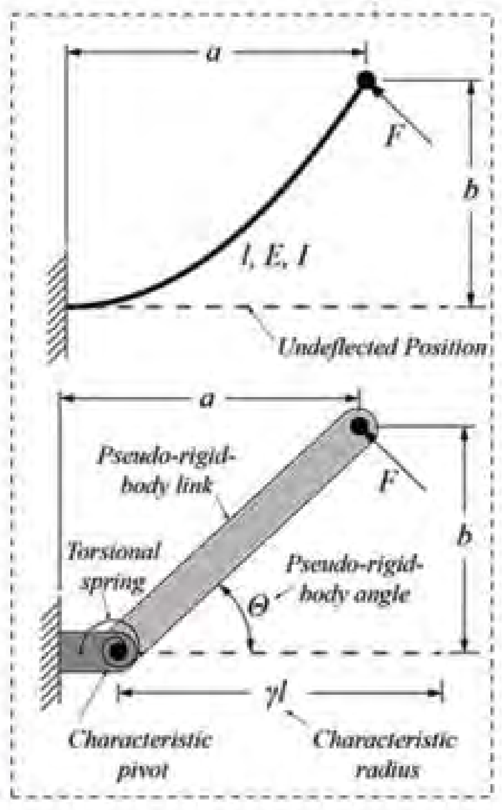
- REDUCTION OF WEAR AND PLAY
  - HIGH PRECISION
  - HIGH REPEATABILITY
  - NO LUBRICATION REQUIRED
- LOW WEIGHT
- REDUCED NUMBER OF PARTS
- INTEGRATION OF MORE FUNCTIONS
- COST REDUCTION

ONLY A COMPLETE RETHINKING OF THE COMPONENT CAN ALLOW A REALLY GREAT IMPROVEMENT OF THE MECHANICAL PERFORMANCE

COMPLEX DESIGN ← DESIGN METHODS

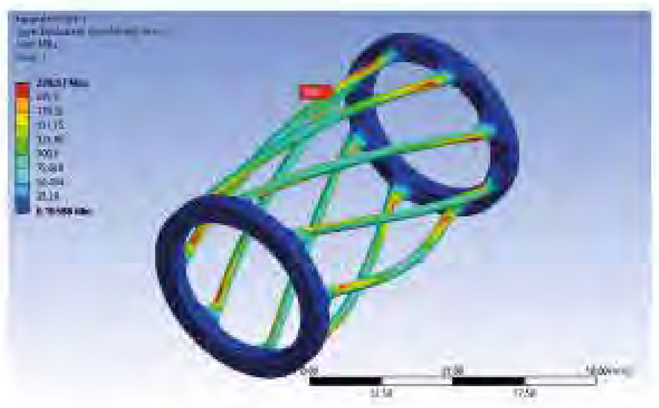
DESIGN METHODS: DESIGN FREEDOM; ERRORS; FLEXIBILITY; STRESSES AND DEFORMATIONS

COMPLEX DESIGN → DESIGN FOR ADDITIVE MANUFACTURING



AIMS: Improve the mechanical performance of the original component by exploiting the design freedom of additive manufacturing processes and prove the effectiveness of these processes and contribute in the building of a critical grounding in the field of flexural joint design

CHALLENGES: balance the mechanical reply of the new mechanism with the manufacturing constraints (needs of supports and finishing operations)



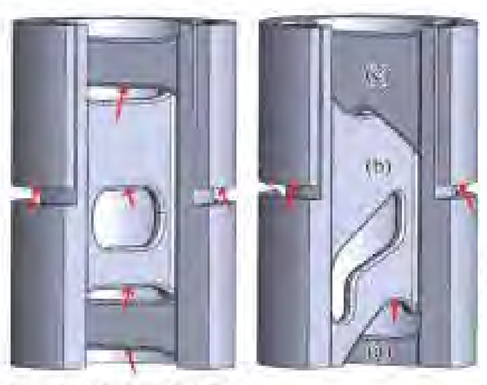
PRODUCTION BY LASER POWDER BED FUSION PROCESS

Material: AlSi10Mg

↑ **Maximum rotation = 7.4 degrees**

↑ **Mass = 18 g**

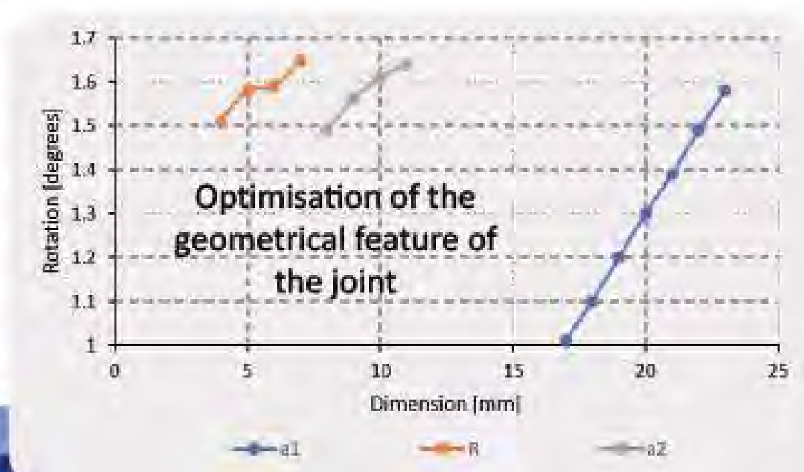
Supports only on the bottom surface

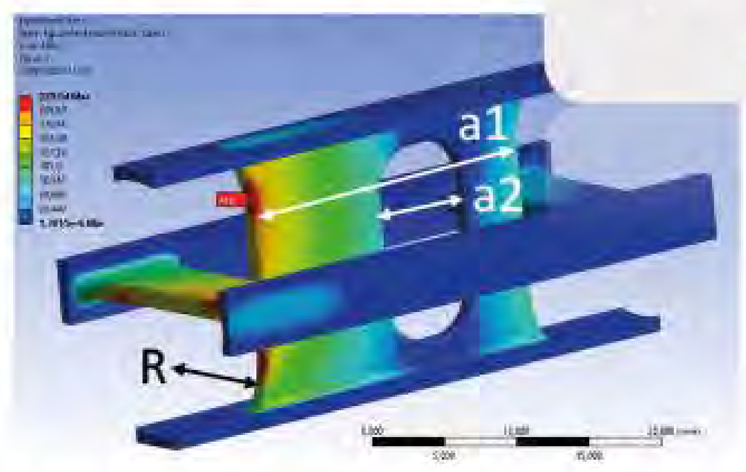


LESS WEIGHT but MAXIMUM ROTATION 2.4 degrees

BUILDING DIRECTION

MODIFICATION OF THE ORIGINAL DESIGN TO IMPROVE THE FEASIBILITY (surfaces that need to be supported) OF THE COMPONENT AND REDUCE ITS WEIGHT





RESPECT TO THE ORIGINAL DESIGN:

HIGHER PERFOMANCE (Lighter AND MAXIMUM FEASIBILITY BY AM PROCESSES (no support, no assembly operation, ready to be installed at low production time and cost)

PRODUCTION BY SELECTIVE LASER SINTERING

Material: Nylon PA12

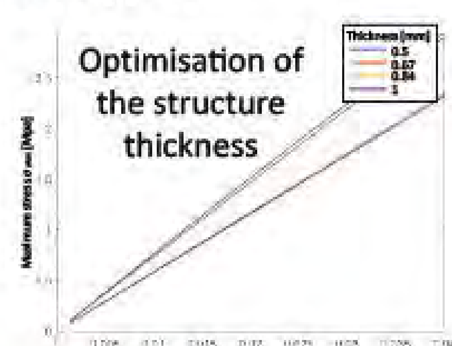
↑ **Performance Amplificator= 23.5**

↓ **Mass= 2.53 g**

↓ **Maximum stress = 3 Mpa**

↓ **Maximum strain = 1.12 x 10^{-3}**

No support

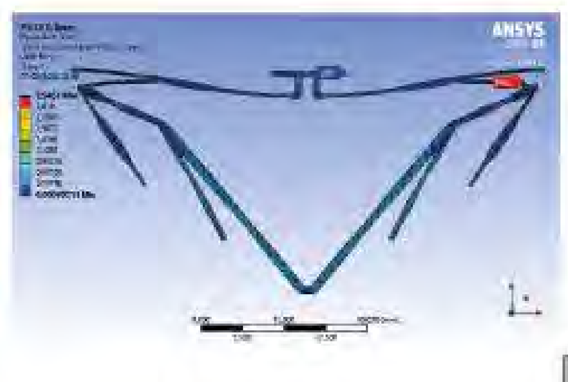


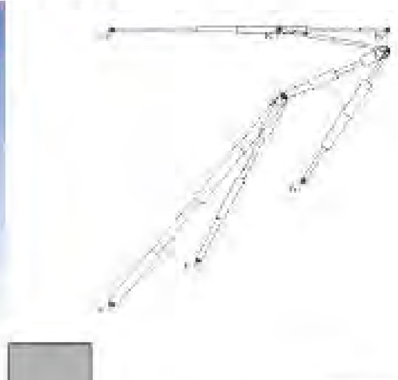
NEW DESIGN

TOPOLOGY OPTIMIZATION

Objective functions definition

Implementation of the proper optimization method





FEA

Problem modelling

Design domain

Boundary conditions definition

Design domain parameterisation

Discretisation of the design domain

Definition of project variables

METAL
CASE STUDY

ORIGINAL DESIGN

TRADITIONAL CANTILEVERED PIVOT

MAXIMUM ROTATION 3 degrees

CAST ALUMINIUM ALLOY

Mass = 30g

POLYMER
CASE STUDY

ORIGINAL DESIGN

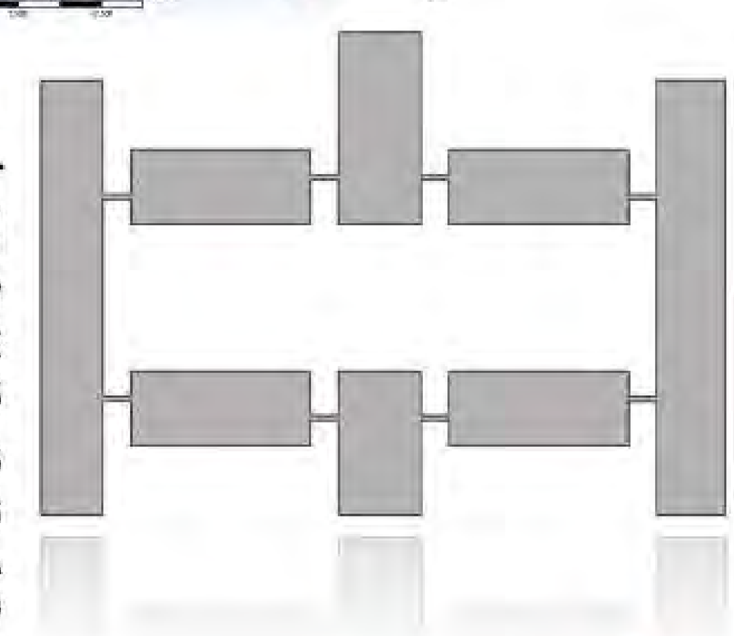
COMPLIANT MECHANISMS TO AMPLIFY THE DISPLACEMENT PRODUCED BY THE PIEZOELECTRIC ACTUATORS

PERFORMANCE AMPLIFICATOR = 12.5

Mass = 3.74 G

Maximum stress = 6 MPA

Maximum strain = 2 X 10^{-3}



Engineering analysis task via extensive use of design, FEM simulation and CAM software