BAANG

DEPARTMENT OF REVERSE ENGINEERING AND ADDITIVE TECHNOLOGIES

TiAl6V4 bistable mechanism produced by Laser Powder Bed Fusion

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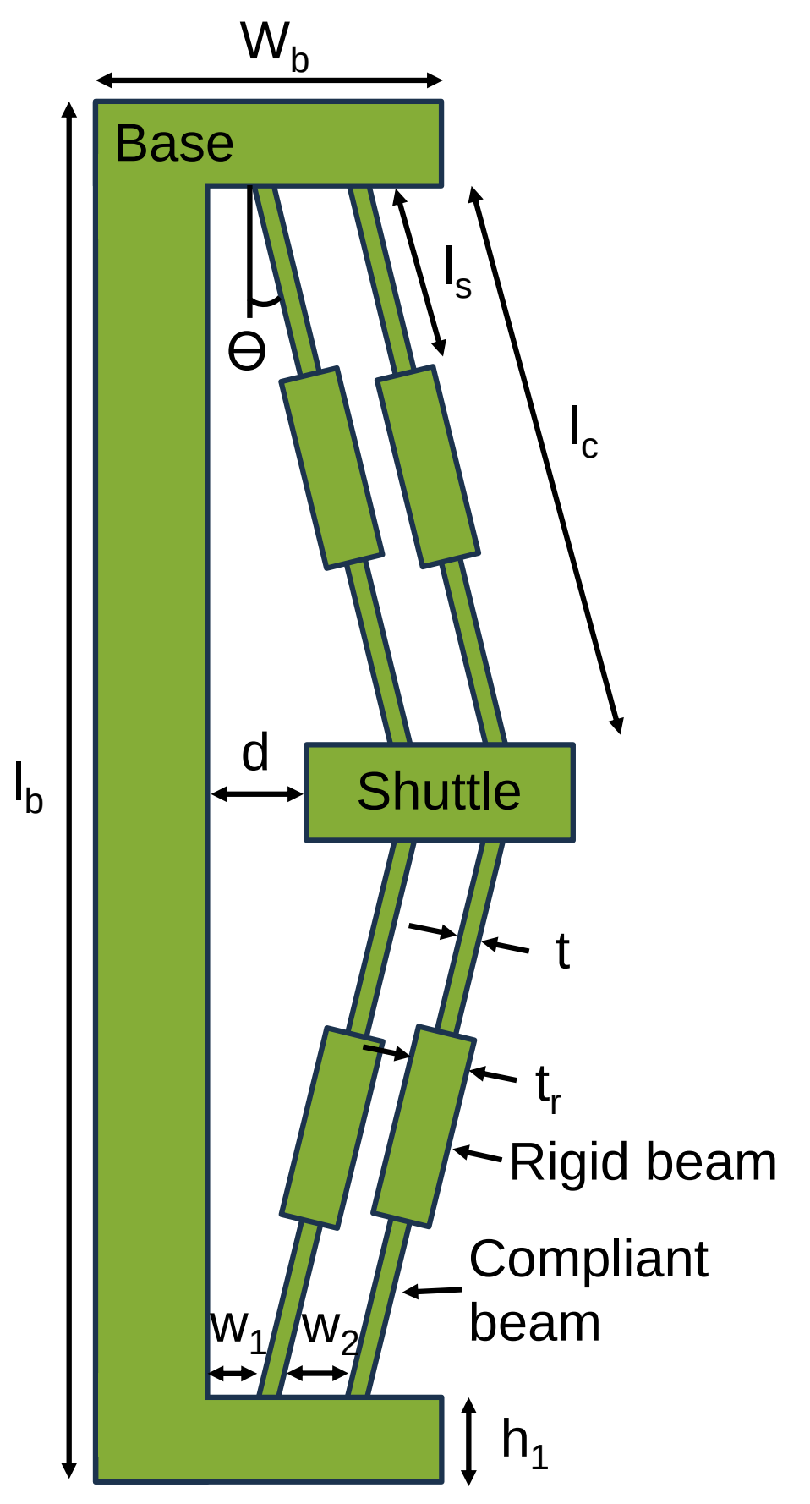
MOTIVATION

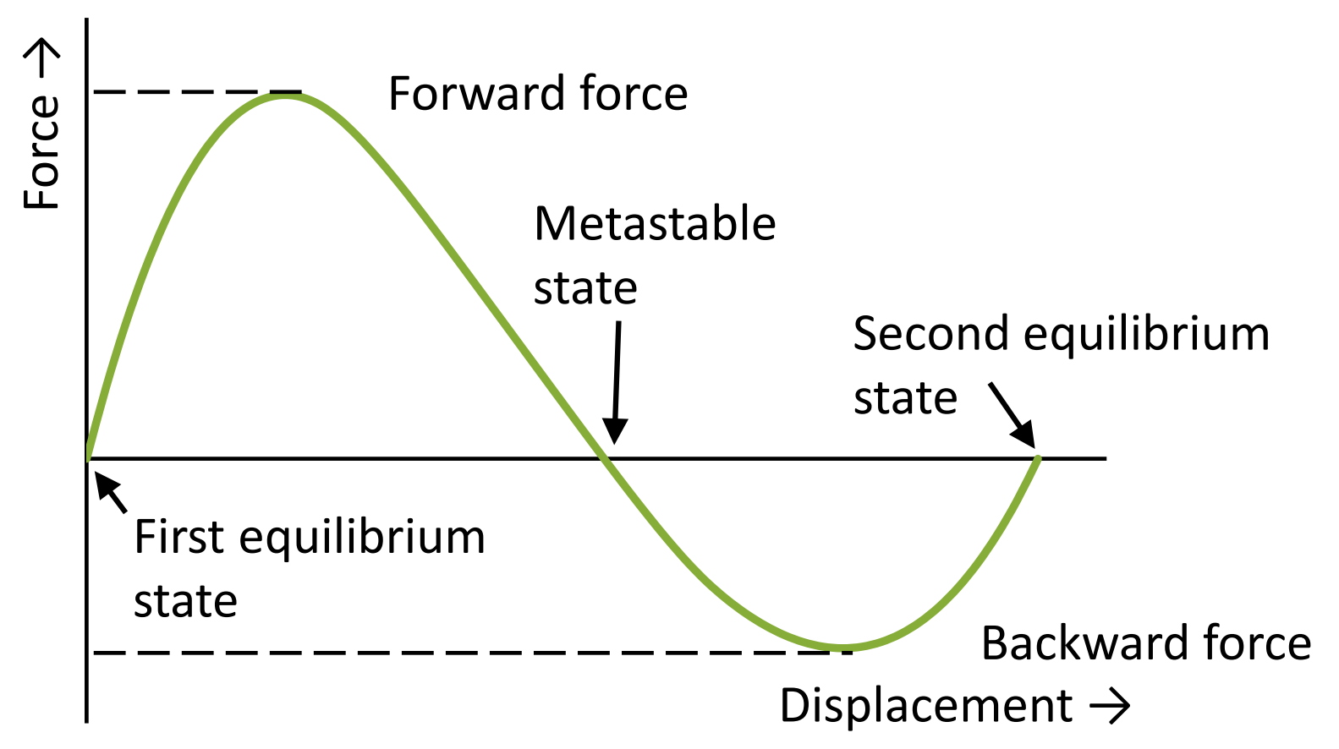
- Mechanism for compliant wing actuation
- Two equilibrium states without the need for external energy supply
- Elastic deformation that eliminates friction
- Suitable for many applications such as switches, grippers, energy harvesters and soft actuators [1-6]

THEORY

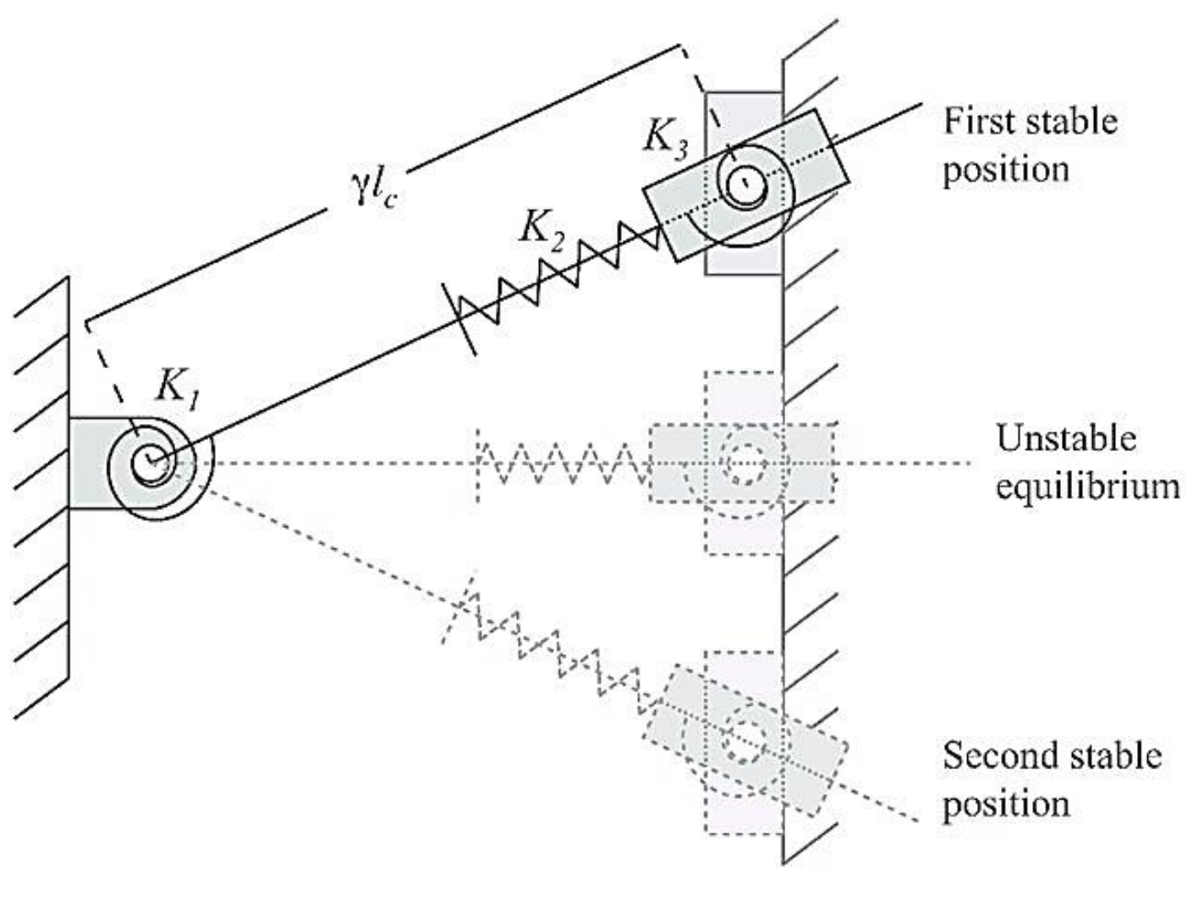
- Geometry of a compliant bistable mechanism



- Typical force-displacement response



- Analytical pseudo-rigid-body model of the compliant mechanism for the displacement and rough approximation for the stress [7]
- The compliance of the mechanism is defined by torsional and linear springs [7]
- Limitation for only compliant beams (without rigid beams that increase the force response)



$$K_1 = K_3 = \frac{2\gamma K_\Theta EI}{l_c}$$

$$K_2 = \frac{3EI_b}{w_1^3}$$

$$K_\Theta = 2.67617$$

$$\gamma = 0.8517$$

$$I = bt^3/12$$

$$I_b = bh_1^3/12$$

REFERENCES

1. Yan, L. et al. Applied Sciences (Switzerland) 13, (2023)
2. Liu, M. et al. Micromachines 13, (2022)
3. Chang, P. L. et al. Mech Mach Theory 152, (2020)
4. Chen, K. et al. Mech Syst Signal Process 188, (2023)
5. Li, B. et al. Advanced Intelligent Systems 4, (2022)
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RESEARCH OBJECTIVE

Design and manufacture of a bistable mechanism capable of maintaining a load of 175 N in the second equilibrium state

- Laser powder bed fusion process to produce a bistable mechanism from a TiAl6V4 alloy
- The base of the mechanism is machined with defined dimensions

l_b	w_b	h_1	w_1	w_2
(mm)	(mm)	(mm)	(mm)	(mm)
164	60	15	16.5	3.4

RESEARCH PLAN

FEA of the bistable mechanism with rigid beams

- 2D representation
- Default parameters with one parameter variable
- Force and stress response to identify the influence of the variable parameters

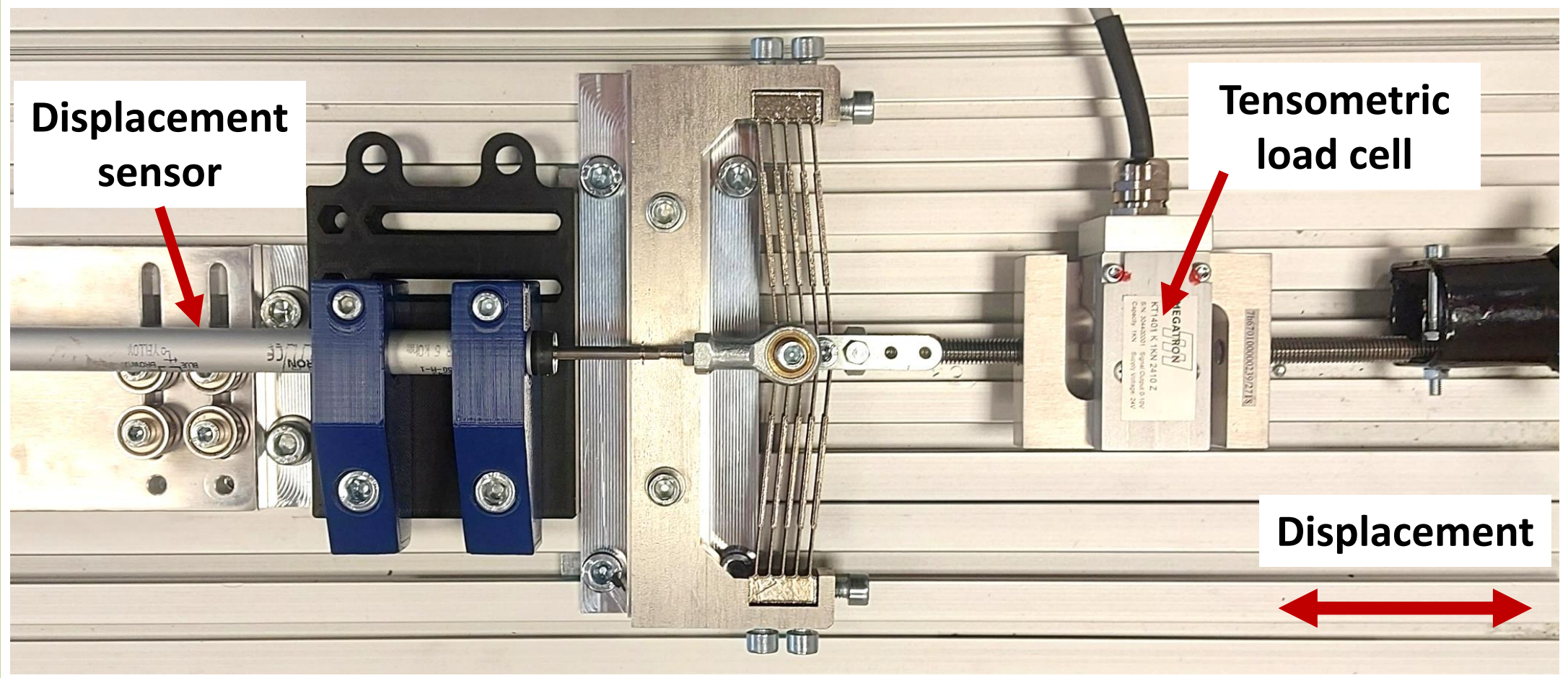
	Beams	Ɵ	l_s	t	t_r
	(-)	(°)	(mm)	(mm)	(mm)
Default p.	3	95	15	0.6	1.5
Variable p.	1-5	92-98	10-20	0.4-1	1-2

FEA of the final bistable mechanism

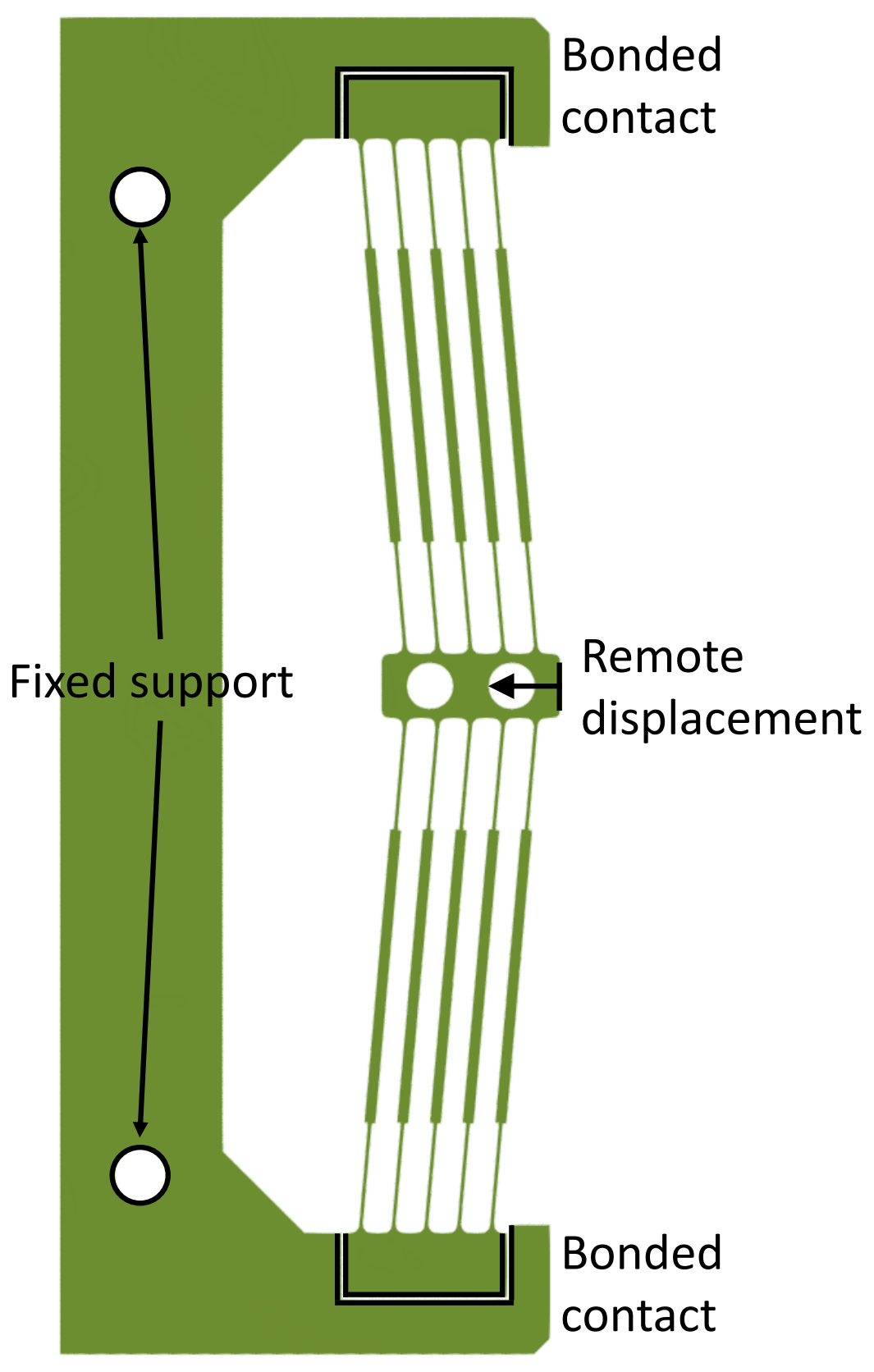
- Material defined based on the lamellas tested in bending with a thickness of 0.6 mm tested in bend (established production)
- Force and stress response

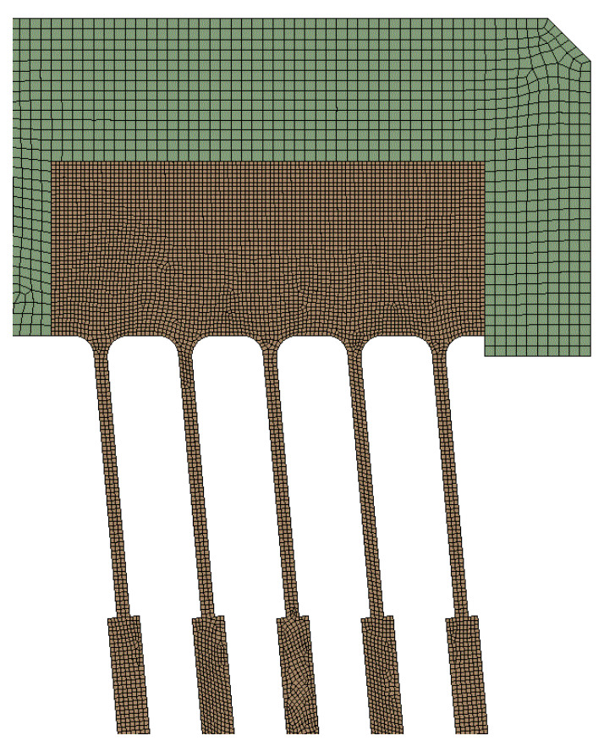
Experimental measurement of the final bistable mechanism

- Force response for comparison with FEA

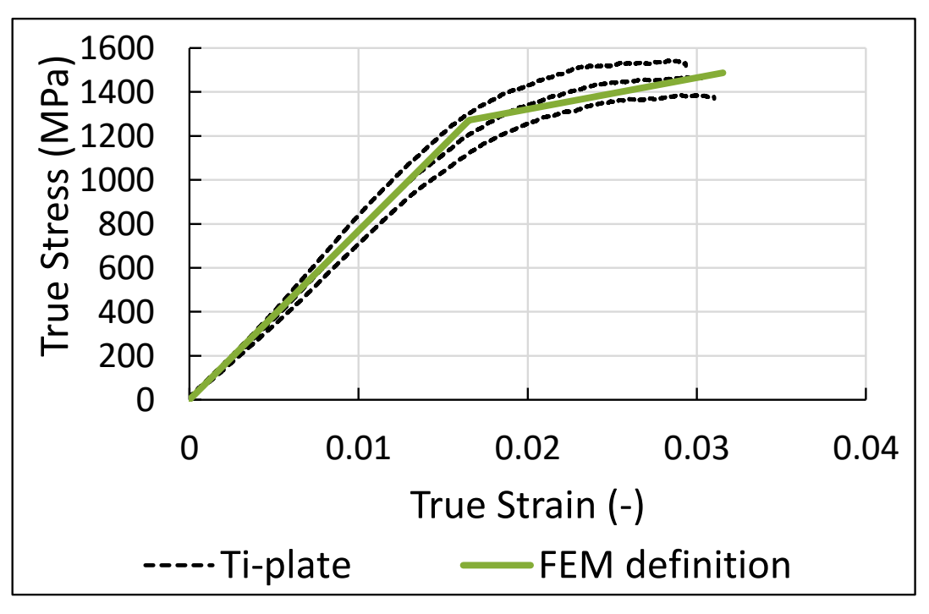


FEA BOUNDARY CONDITIONS AND MATERIAL DEFINITION





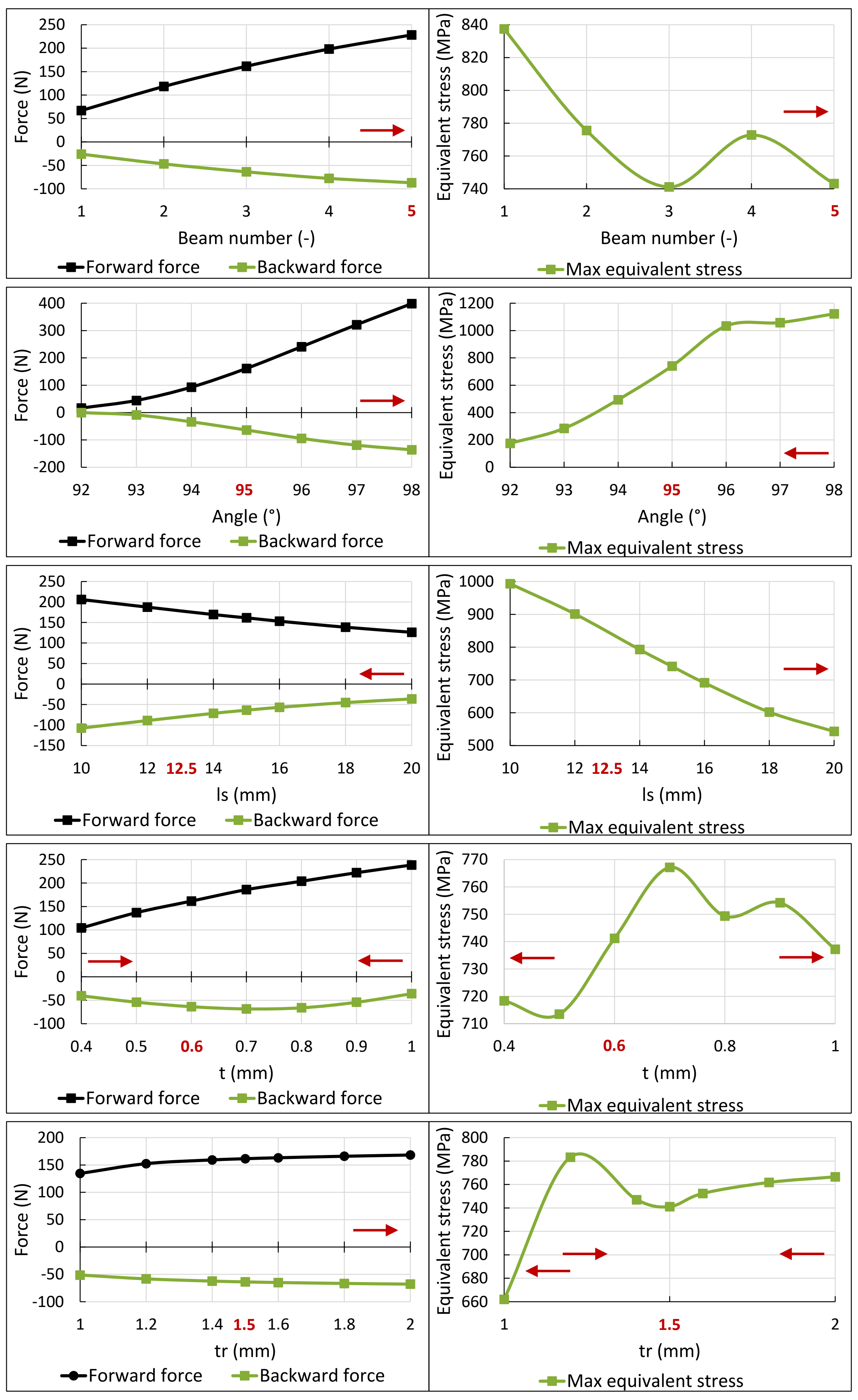
- Quadratic elements
- PLANE 183
- 3 elements on the thickness



- Bilinear material definition
- E = 76.9 GPa, Re = 1272 MPa, v = 0.36

RESPONSE OF THE BISTABLE MECHANISM PARAMETERS

- Identify the parameters that increase the backward force and lead to low equivalent stress



FINAL BISTABLE MECHANISM

Geometry

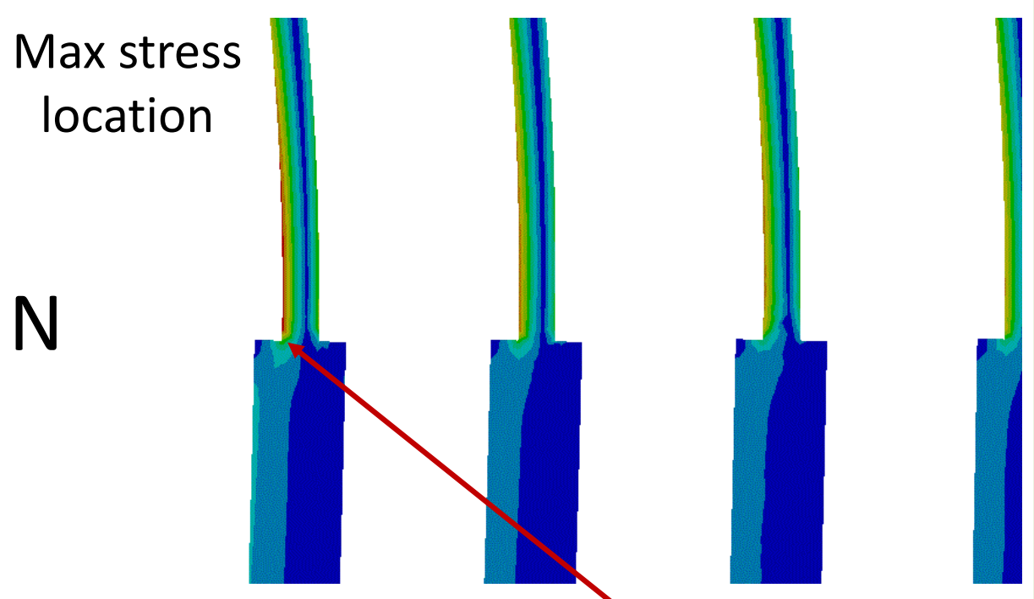
Beams	Ɵ	l_s	t	t_r
(-)	(°)	(mm)	(mm)	(mm)
5	95	12.5	0.6	1.5

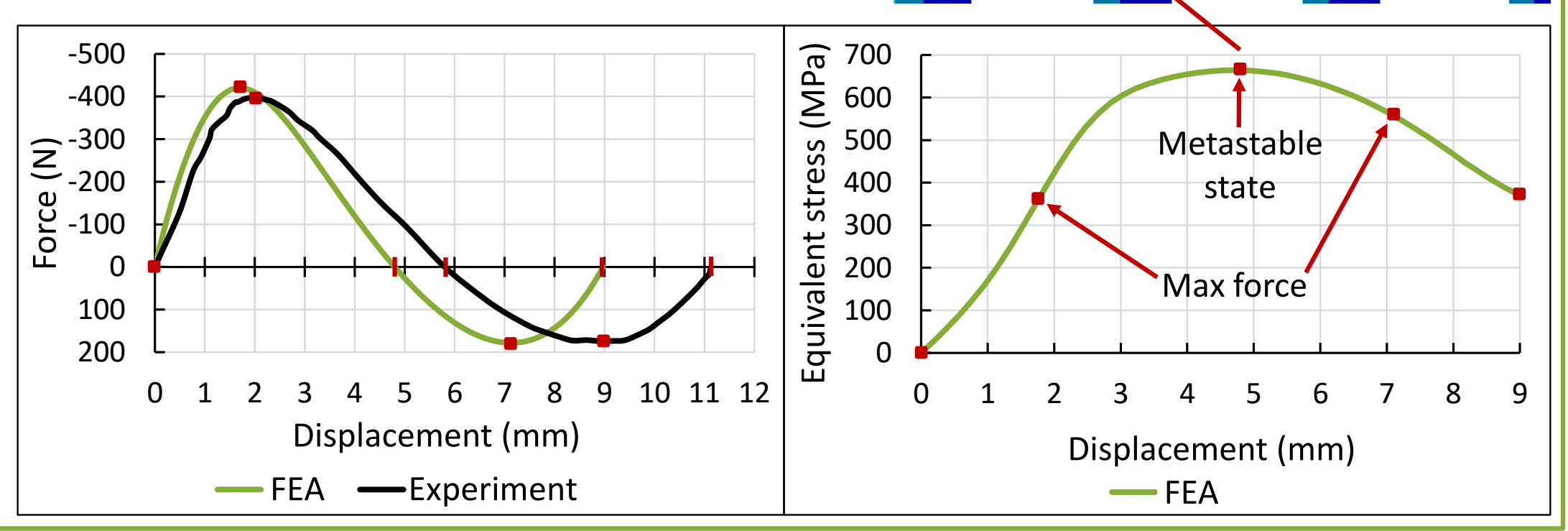
Backward force

- FEA 177.77 N
- Experiment 173.85 N

Maximum stress

- FEA 664.29 MPa





CONCLUSION

- The experimental data showed a very good agreement with FEA for forces (5.3% and 2.2%)
- The displacement showed a deviation of the experiment from the FEA (1 mm and 2.17 mm)
- The safety factor for the material was 1.91

Funded by the European Union