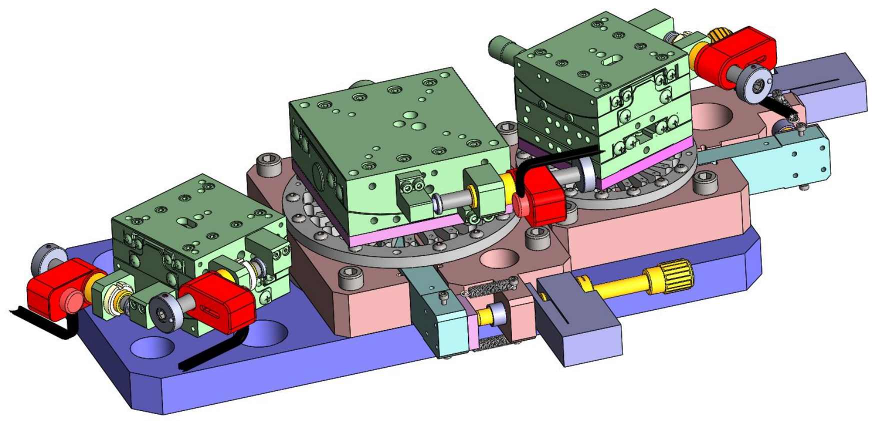
THE DESIGN OF A PRECISION MECHANICAL ASSEMBLY FOR A HARD X-RAY POLARIZER



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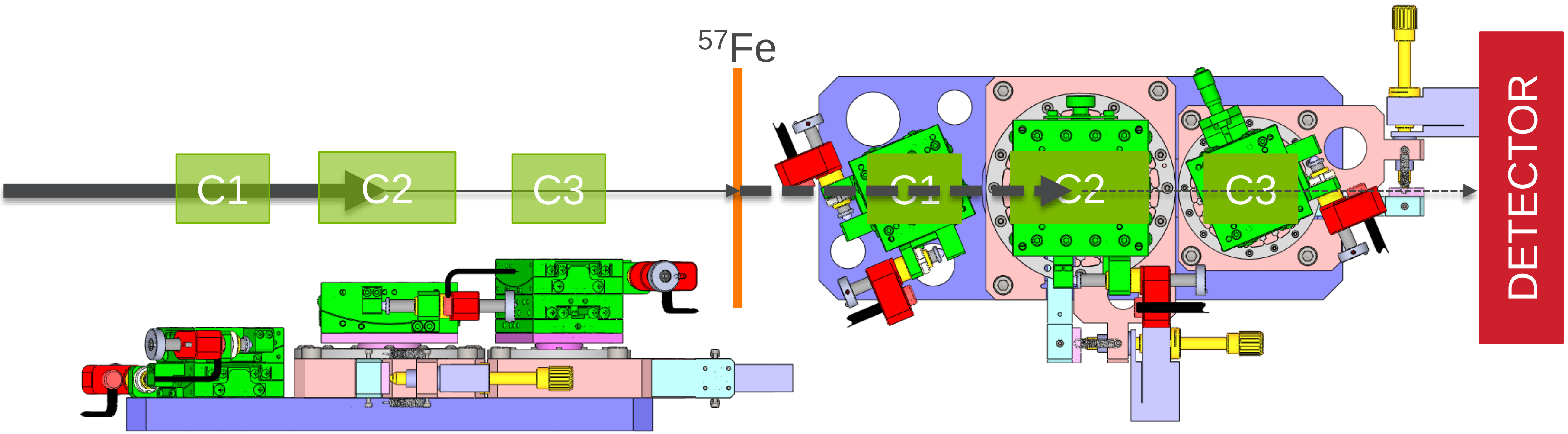
INTRODUCTION

What does the polarizer do?

Well… Quite simply it polarizes light.

How and why then?



Polarizer 1
Polarizes incoming photons

Polarizer 2 rotated 90°
Filters scattered photons

INTRODUCTION

Now the why.

- Allows for analysis of polarization state of scattered photons.
- Can be used as a narrow bandwidth 10^{-7} eV filter for 14.413 keV synchrotron radiation using ^{57}Fe resonance [1].
- This polarizer will be used for next-generation Mössbauer spectroscopy (MS) [2].
- The above will allow for energy spectra to be collected rather than time spectra.

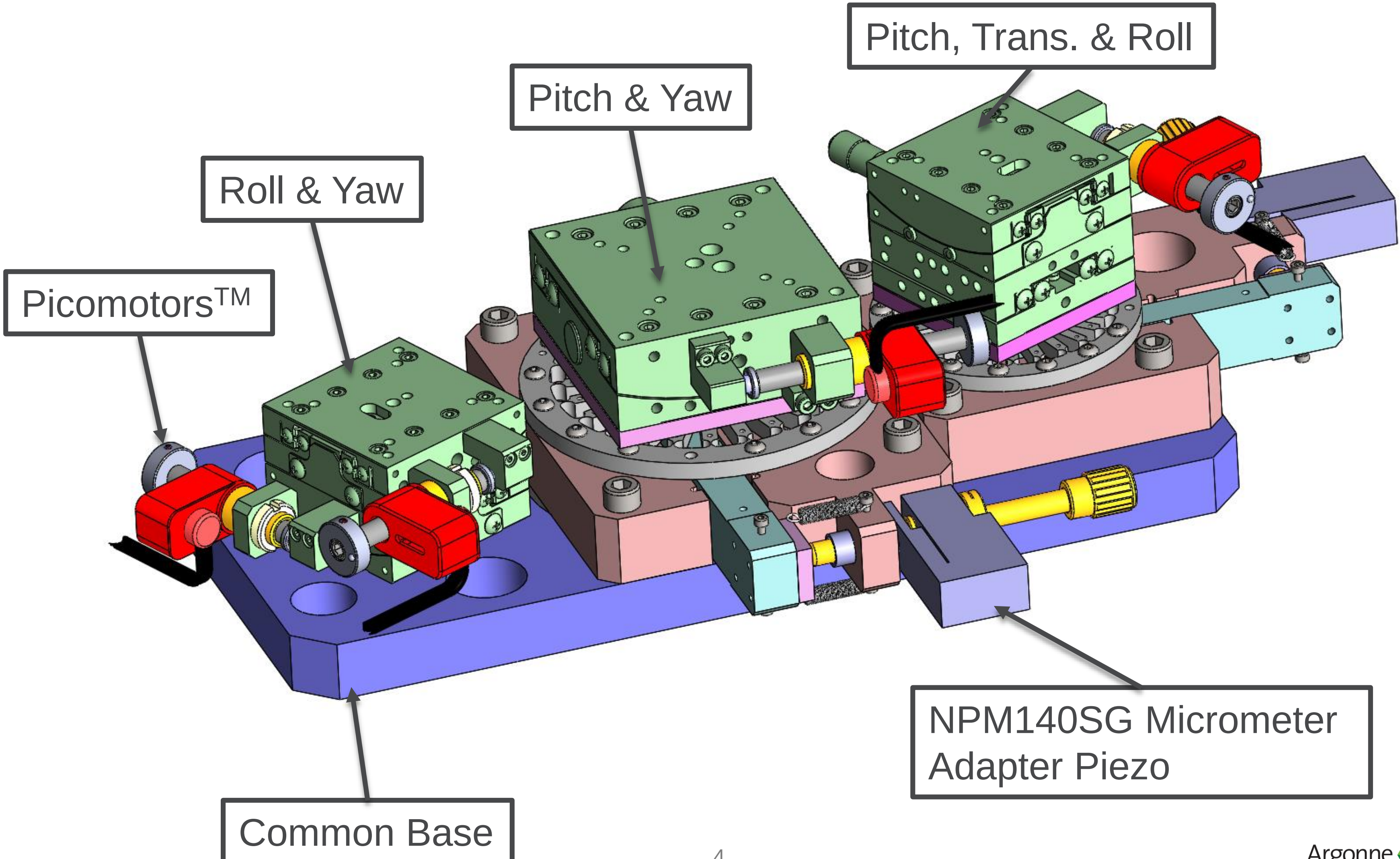
[1] T. Toellner *et al.*, *Applied physics letters,* vol. 67, no. 14, pp. 1993-1995, 1995.

[2] T. S. Toellner, A. Alatas, E. E. Alp, M. Hu, and J. Zhao, LDRD Report, 2015-164-N0, 2015

POLARIZER DESIGN

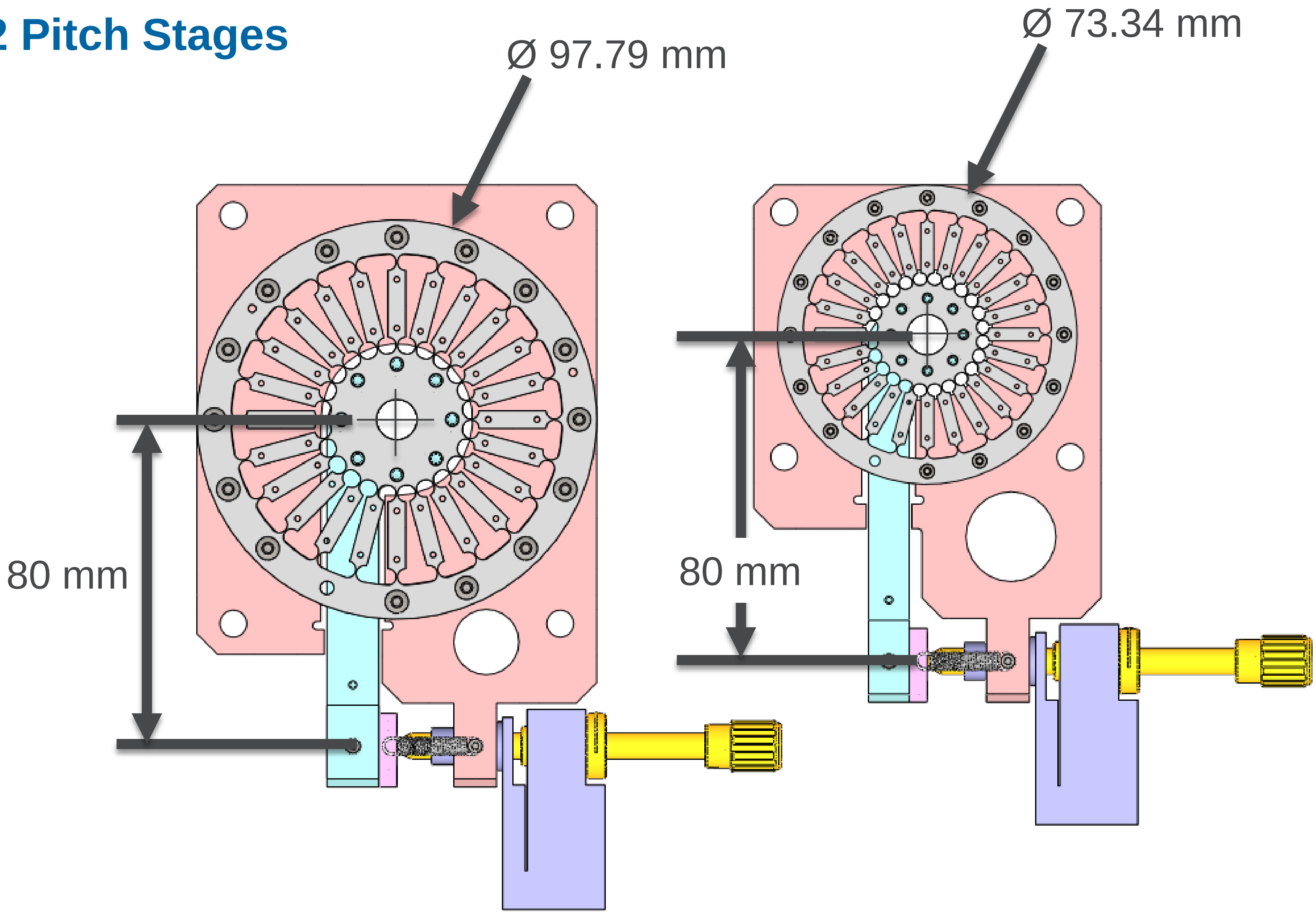
Complete Assembly – Z4-4600

7DOF total for 3 Independent crystals (not shown)



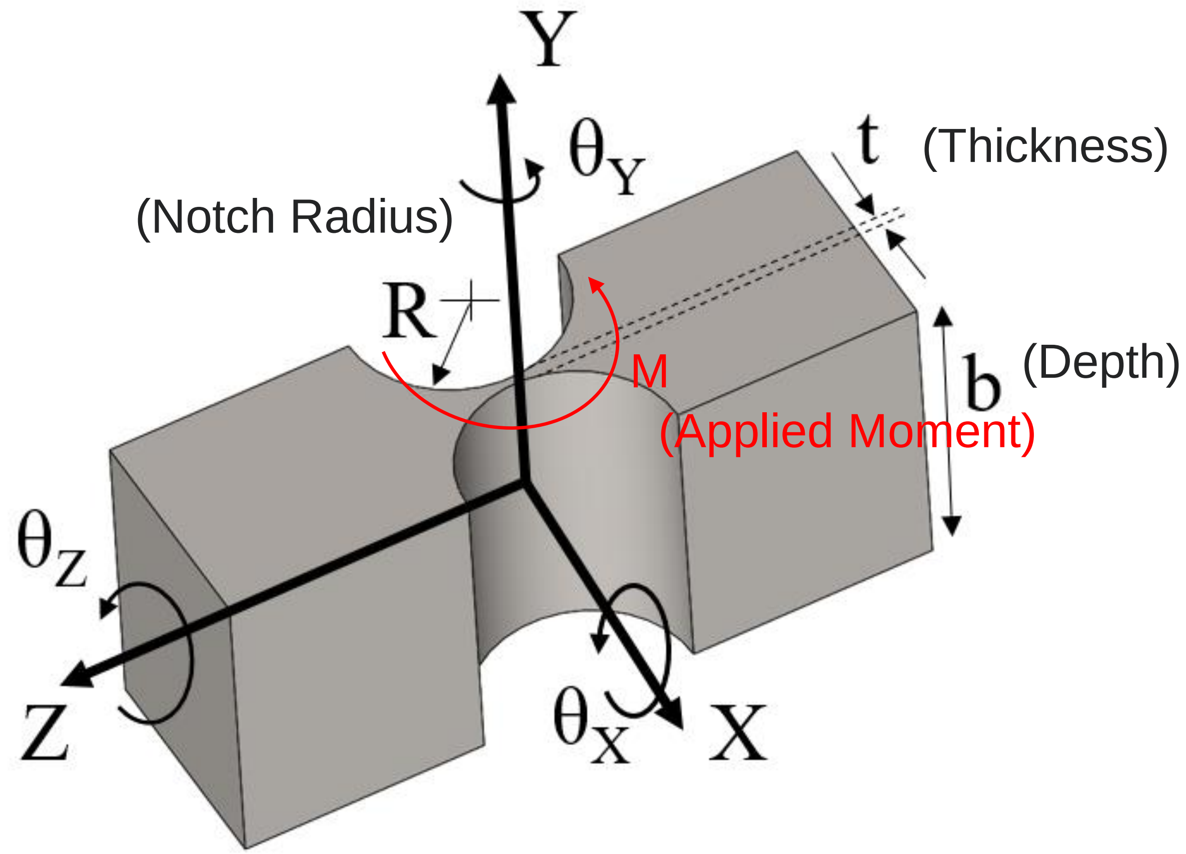
POLARIZER DESIGN

2 Pitch Stages



DESIGN ANALYSIS

Flexure Modeling



DESIGN ANALYSIS

Flexure Modeling

Not Approximated (Ling's Method [3])

$$K_{\theta_Y} = \frac{M}{\theta_Y} = \frac{2EbR^2}{3f(\beta)}$$

$$f(\beta) = \frac{1}{\Delta}\left\{\left(\frac{3+4\beta+2\beta^2}{\gamma\Delta}\right) + \left(\frac{6\gamma}{\Delta^{3/2}}\right)\tan^{-1}\sqrt{\frac{2+\beta}{\beta}}\right\},$$

$$\beta = \mathrm{t/(2R)}, \quad \gamma = 1+\beta \quad \Delta = 2\beta+\beta^2,$$

$$\sigma = K_t \sigma_{nom}$$

$$K_t = (1+\beta)^{9/20}$$

Approximate Method

$$K_{\theta_Y} \approx \frac{M}{\theta_Y} = \frac{2Ebt^{5/2}}{9\pi R^{1/2}}$$

$$\sigma_{nom} = \frac{6M}{t^2 b}$$

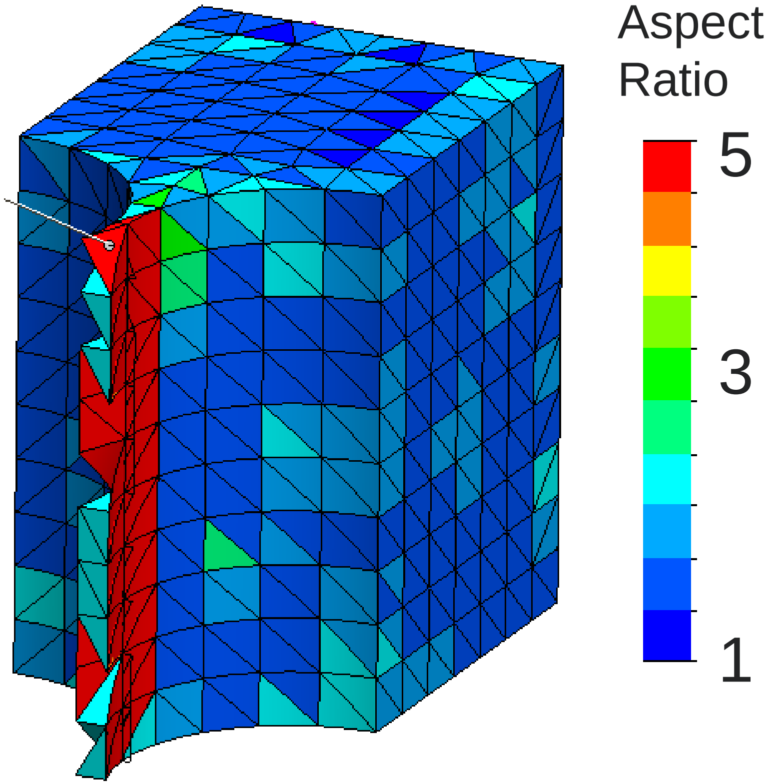
t = 0.115, b = 4.572, R = 1.524 mm, M = 1 N mm, E = 204 GPa

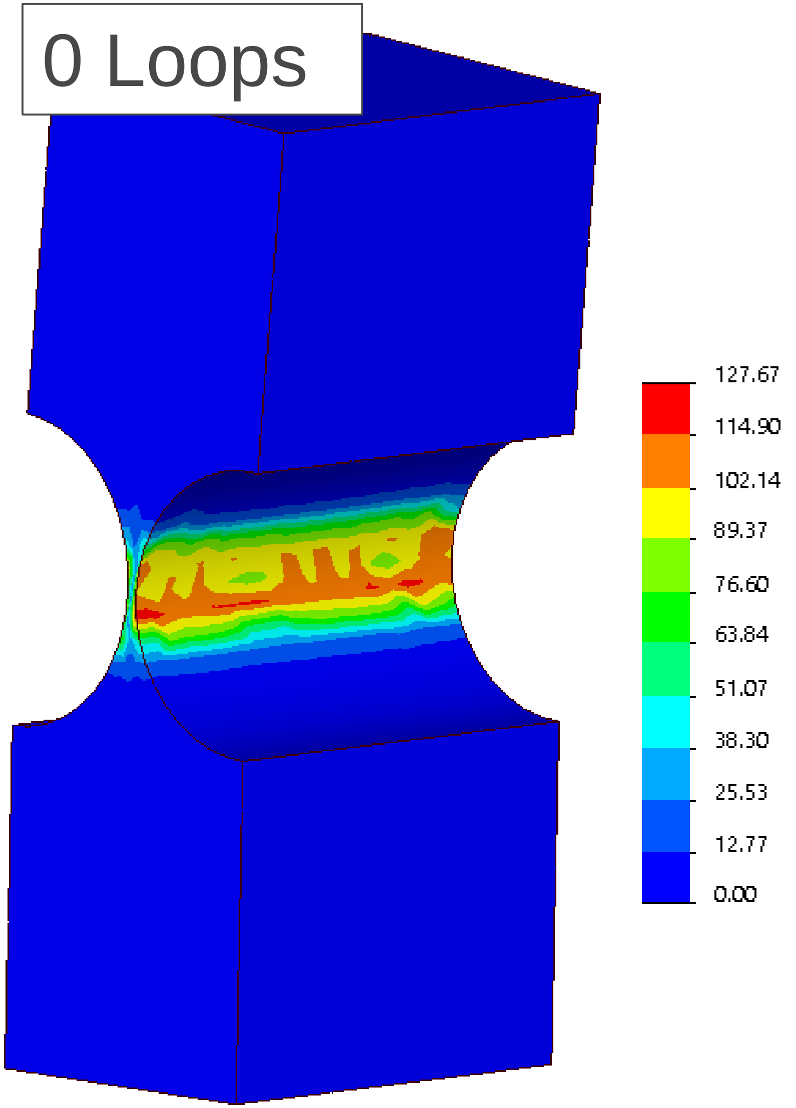
Method	**Stress [Mpa]**	**Angle [°]**	**Torsional Stiffness [N·mm/°]**
Ling's	100.9	0.25	4.07
Approx.	99.2	0.24	4.18
% Error	-1.65	-2.68	2.70

[3] C.-B. Ling, "On the stresses in a notched strip," *J. of Appl. Mech. Trans. ASME*, vol. 19, no. 2, pp. 141-146, 1952

DESIGN ANALYSIS

FEA Flexure Mesh Validation

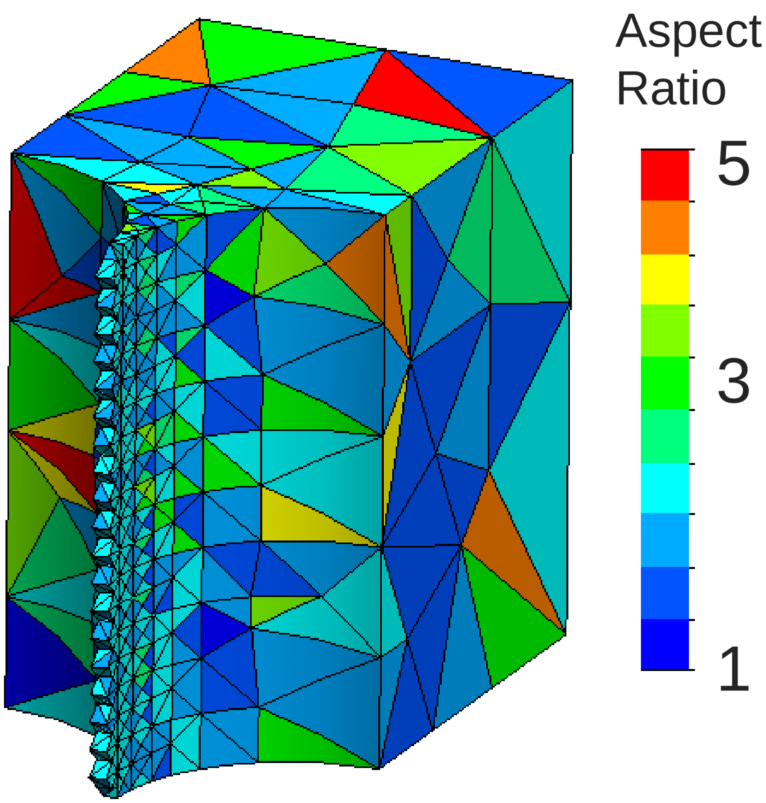


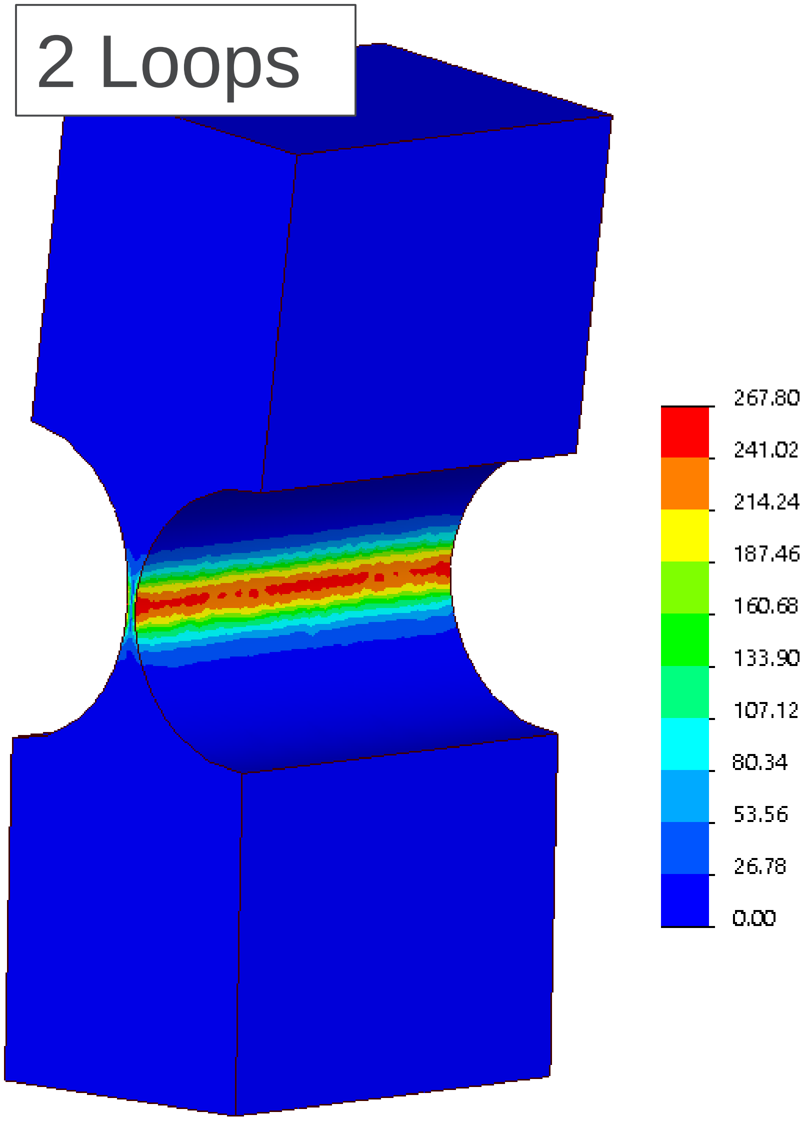


t = 0.115, b = 4.572, R = 1.524 mm, M = 3 N mm, E = 204 GPa

DESIGN ANALYSIS

FEA Flexure Mesh Validation





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DESIGN ANALYSIS

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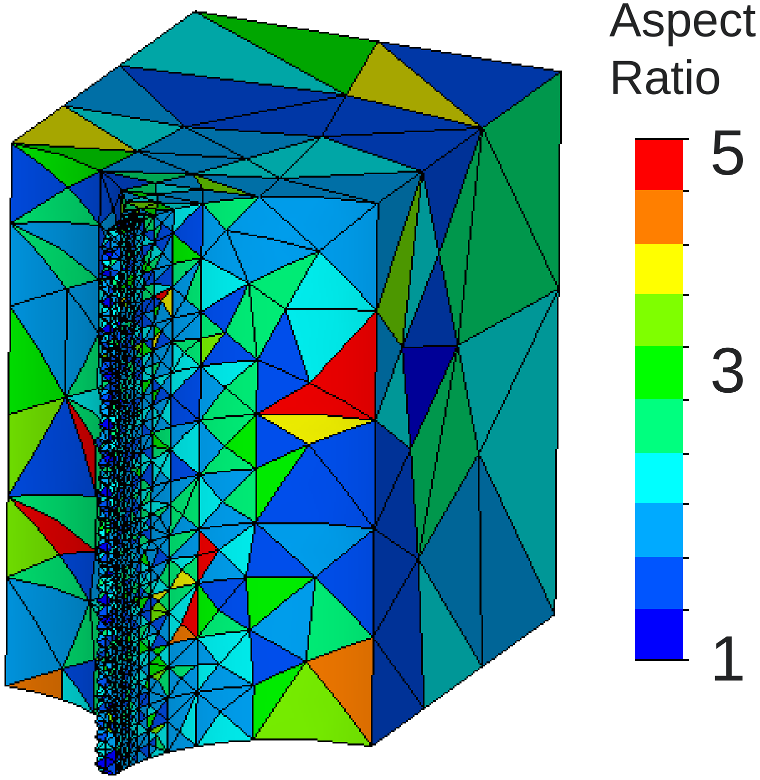

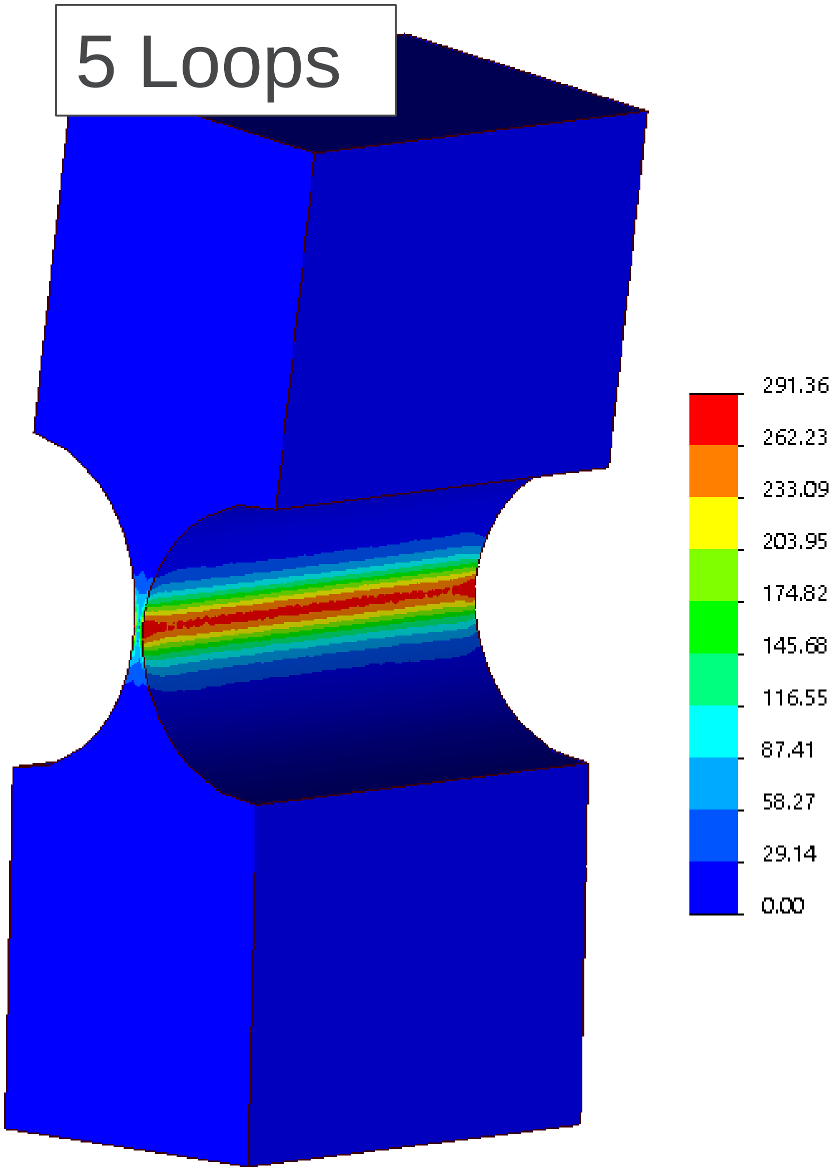

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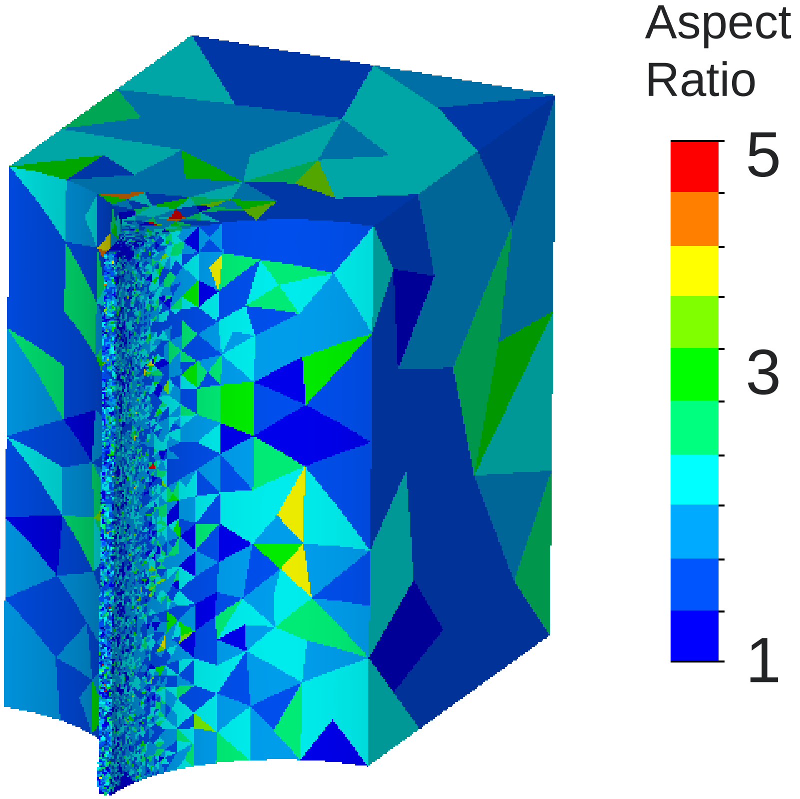
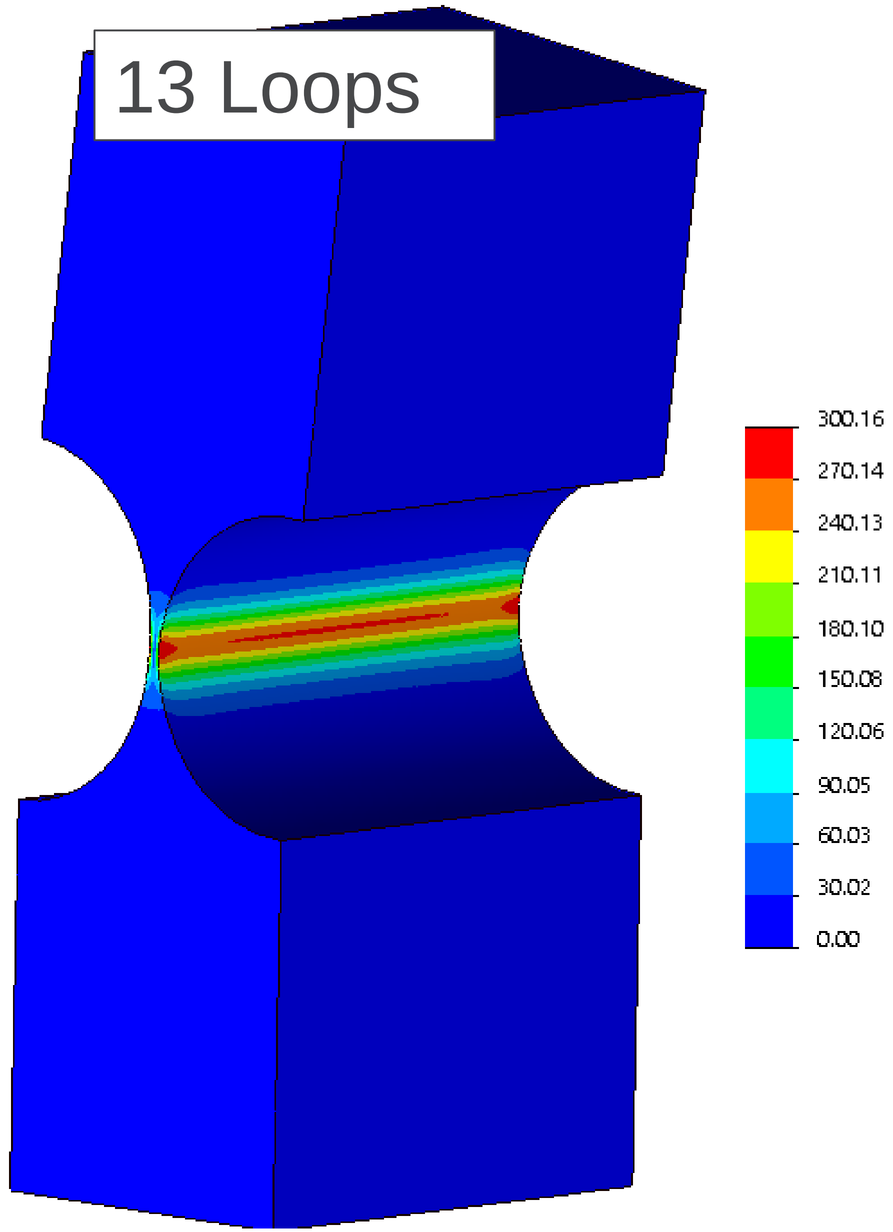
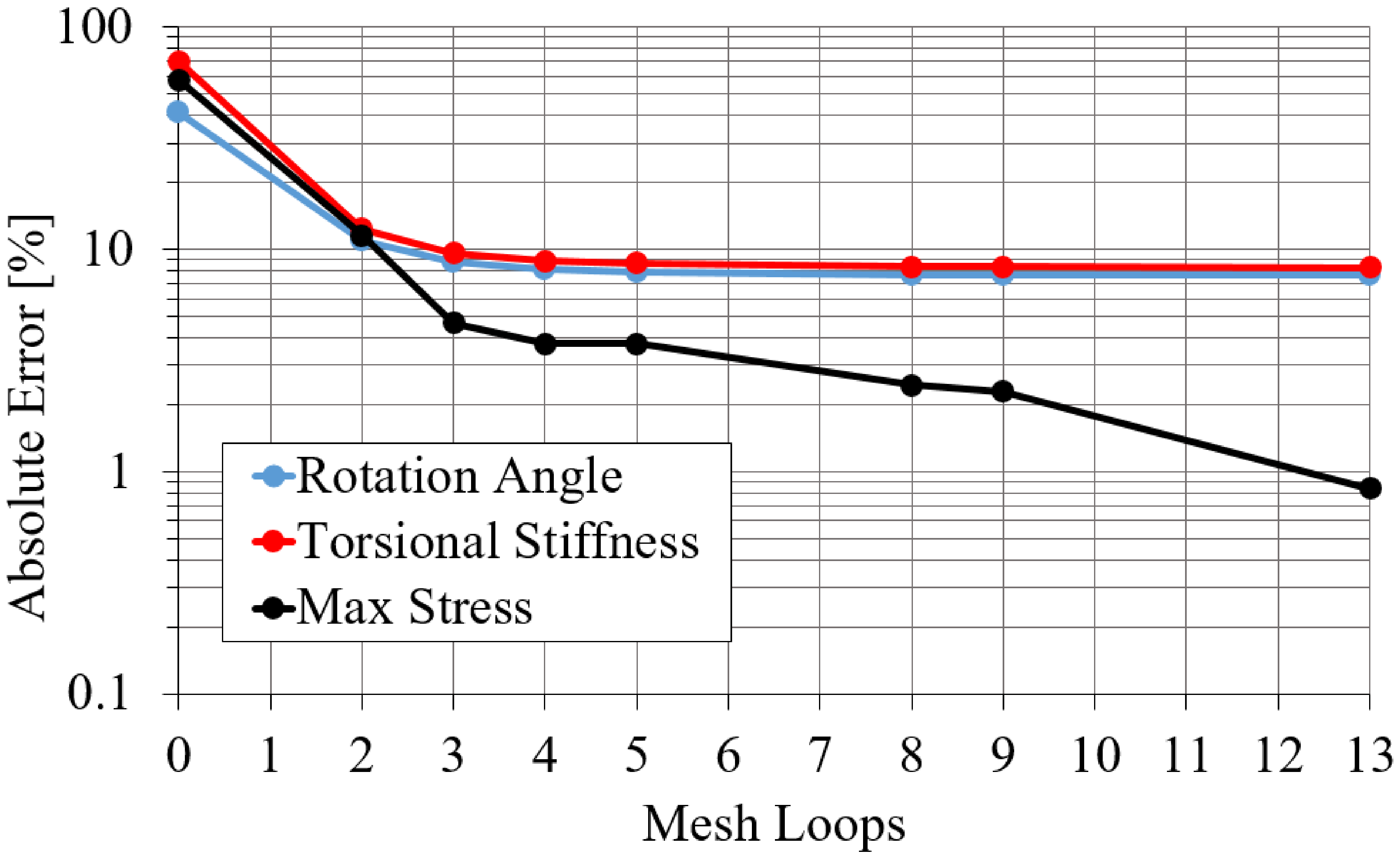




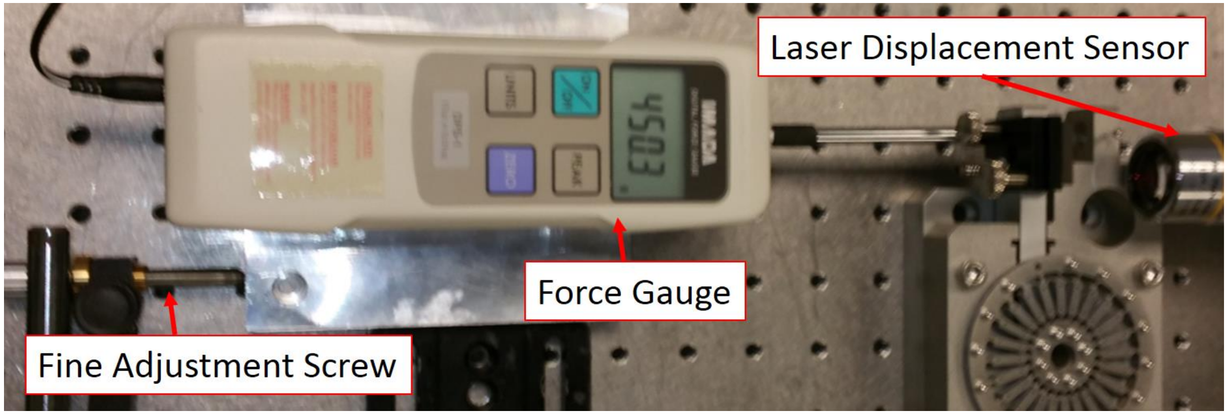
DESIGN ANALYSIS

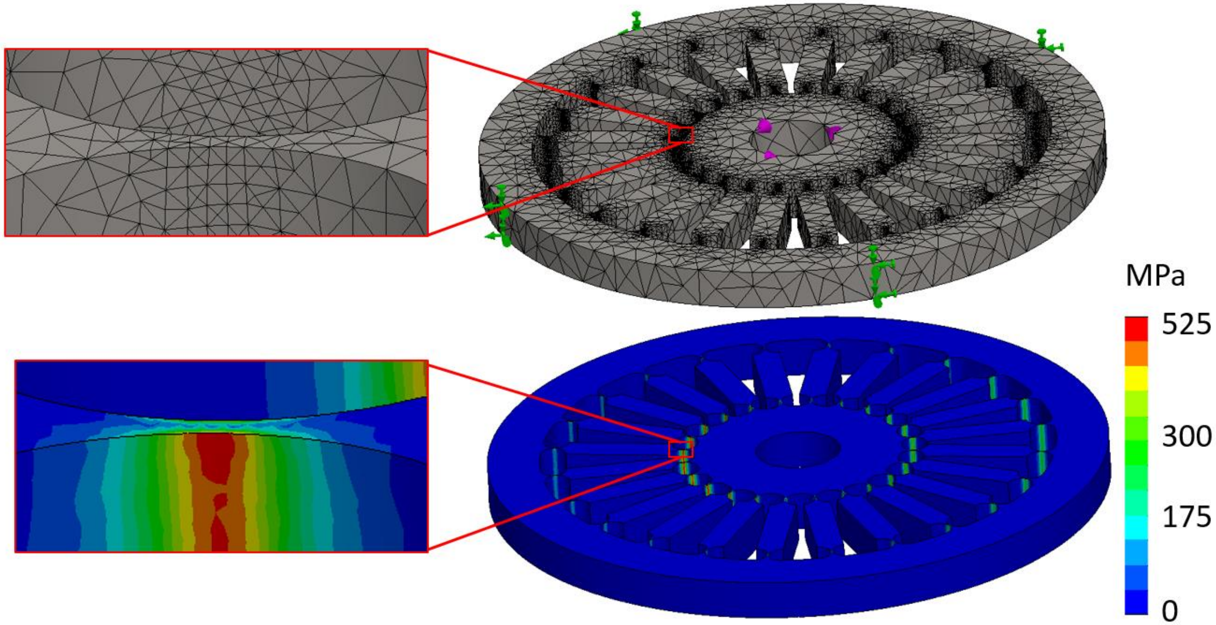
FEA Flexure Mesh Validation



DESIGN ANALYSIS

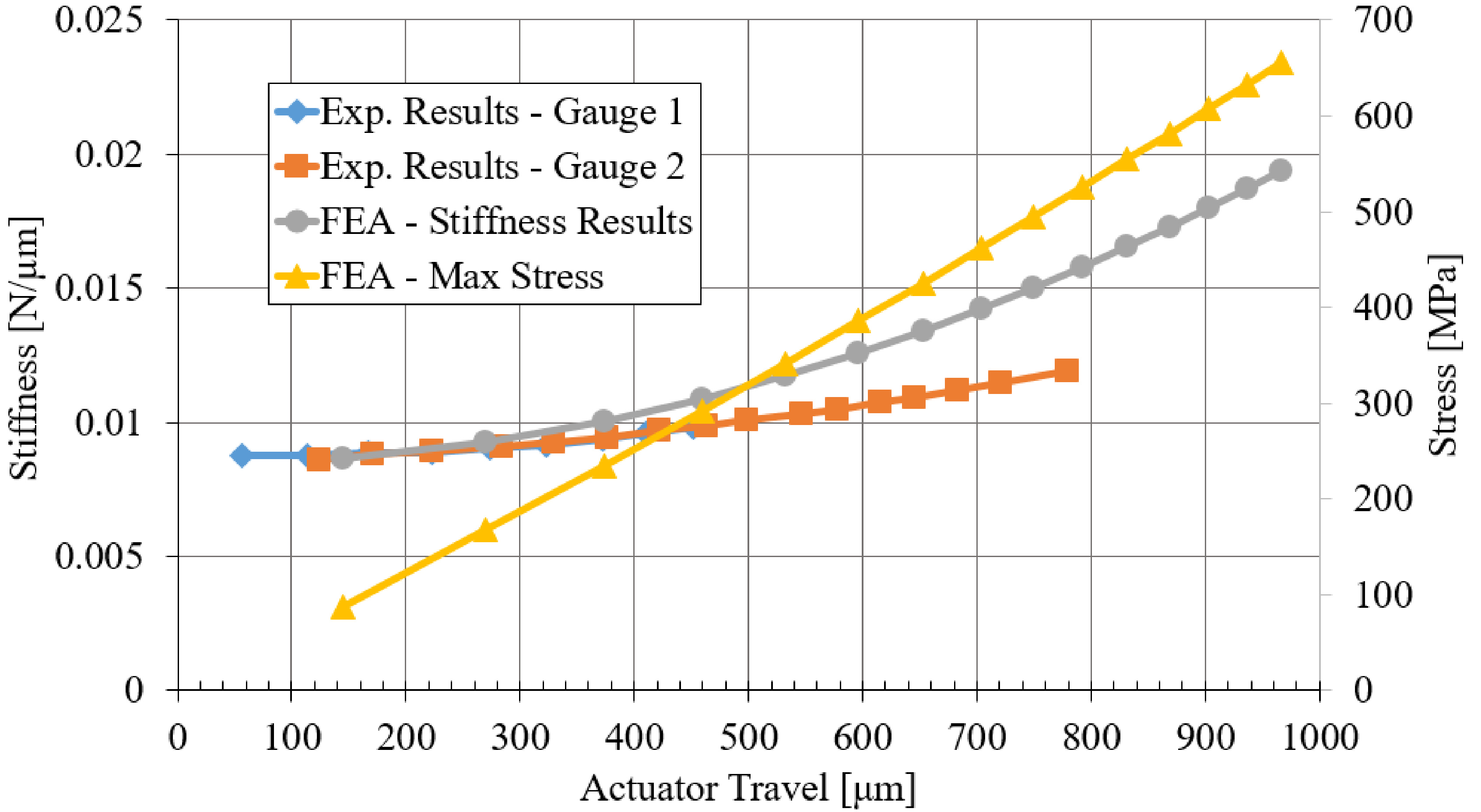
FEA Weak-Link Model Validation and Simulation





DESIGN ANALYSIS

FEA Weak-Link Model Validation and Simulation



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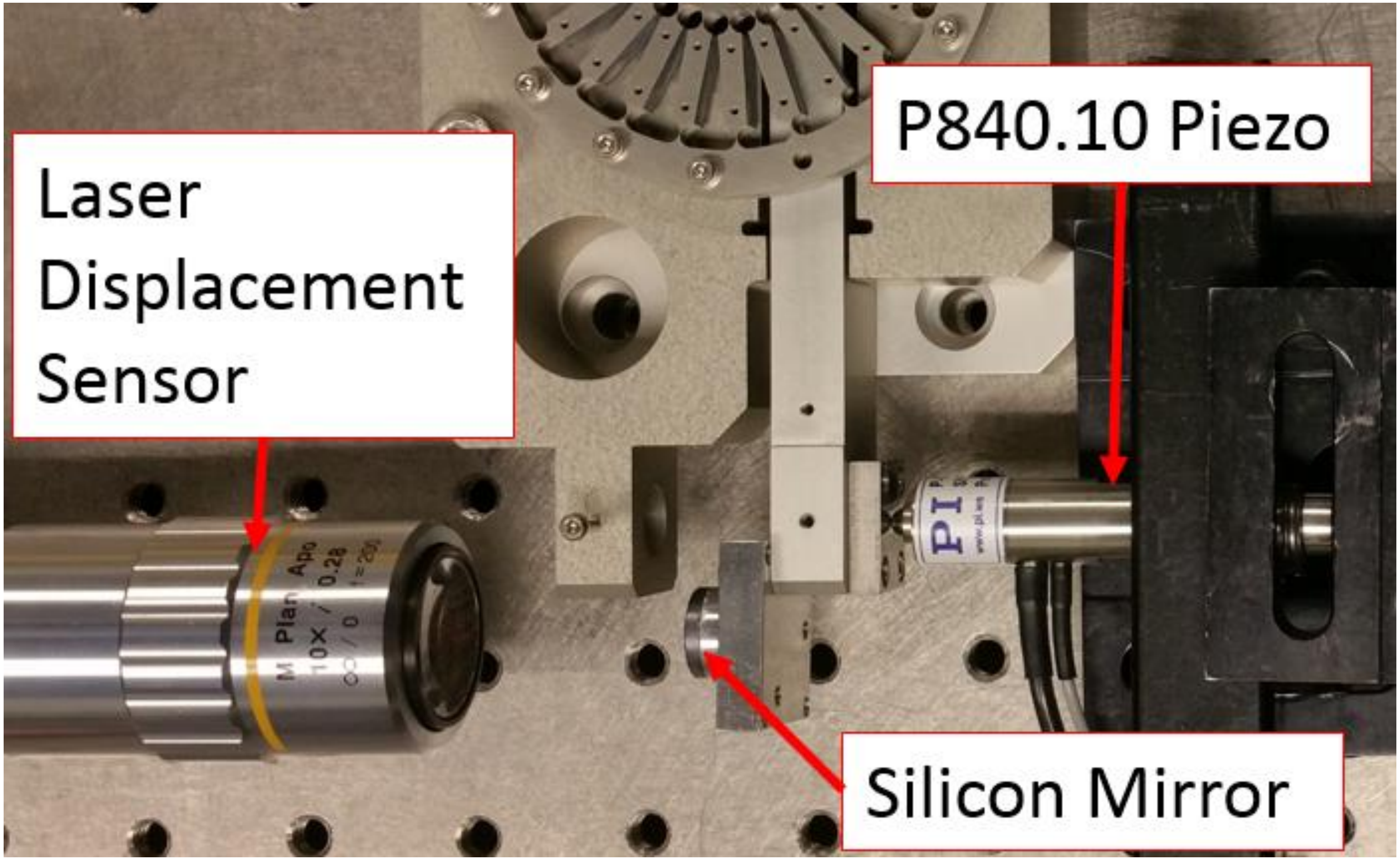
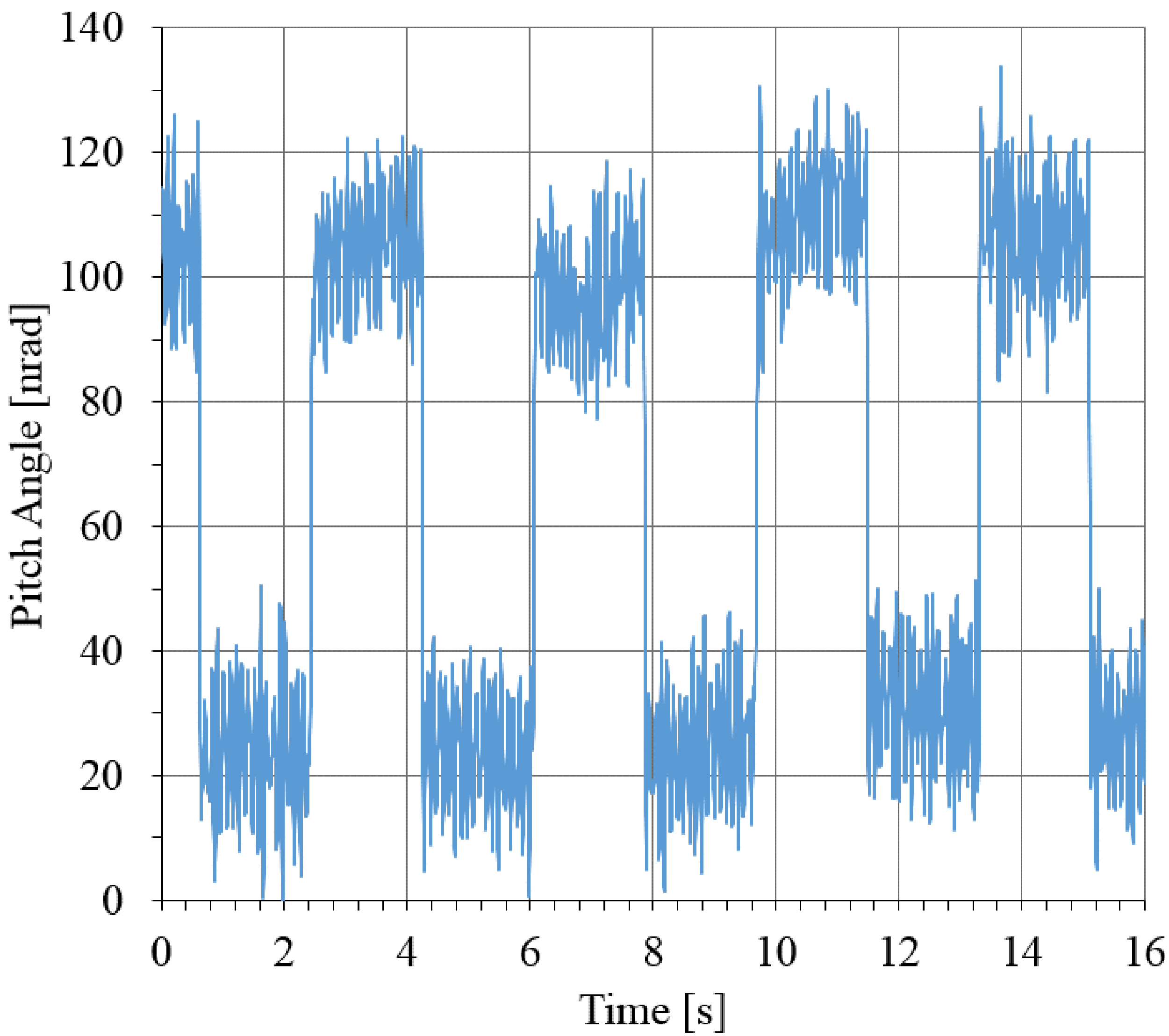
EXPERIMENTAL RESULTS



EXPERIMENTAL RESULTS



CONCLUSION

- 5 adaptive mesh loops reduce stress error to ~5%.
- Too fine of a mesh can start to increase stress error.
- Only small deformations in the FEA model, on the order of 12% of yield, agree with measurements.
- Final resolution of pitch stage could be as low as 5-10 nrad

THANK YOU!

QUESTIONS?

FUNDING SUPPORT

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