Shear Stress Sensor

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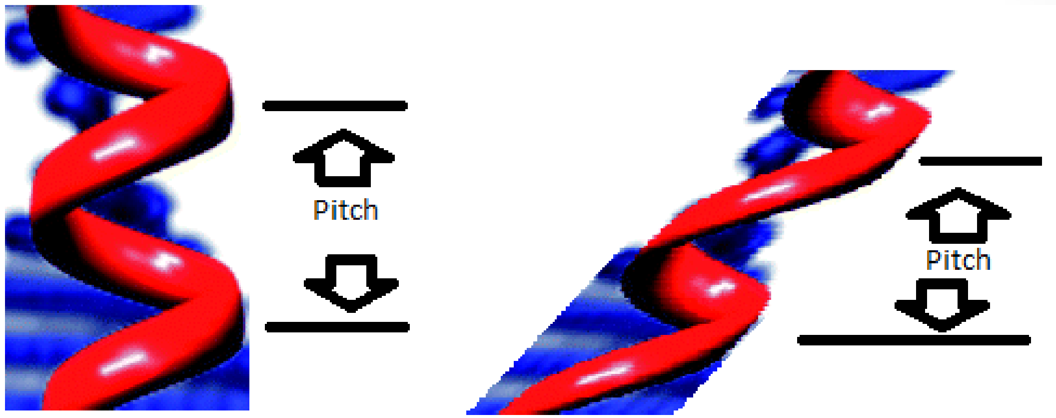
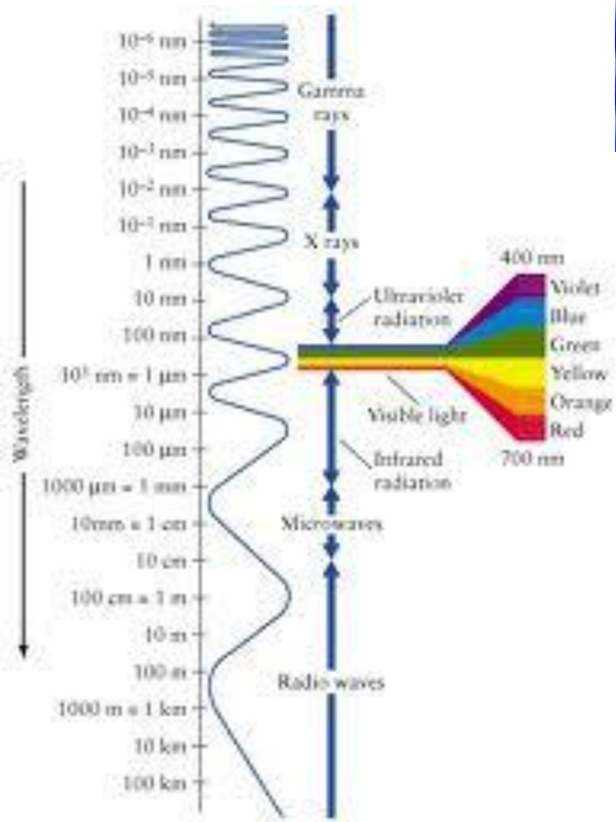
Design Problem

- Test cholesteric crystals to see if they can measure shear stress.
  - Create a testing apparatus.
  - Determine if cholesteric liquids decouple the pressure and shear stress for more accurate readings.
  - How the environment will affect the cholesteric liquid.
  - What range of the forces can be detected.
- Determine possible applications for the cholesteric crystals.

Theory





- By applying a shear stress to the liquid crystals the reflected light changes wavelengths.

Current Shear Stress Sensors

- Measurement of skin-friction
  – importance in aircraft industry
  – reduction in drag at cruise directly translates into a reduction in fuel consumption

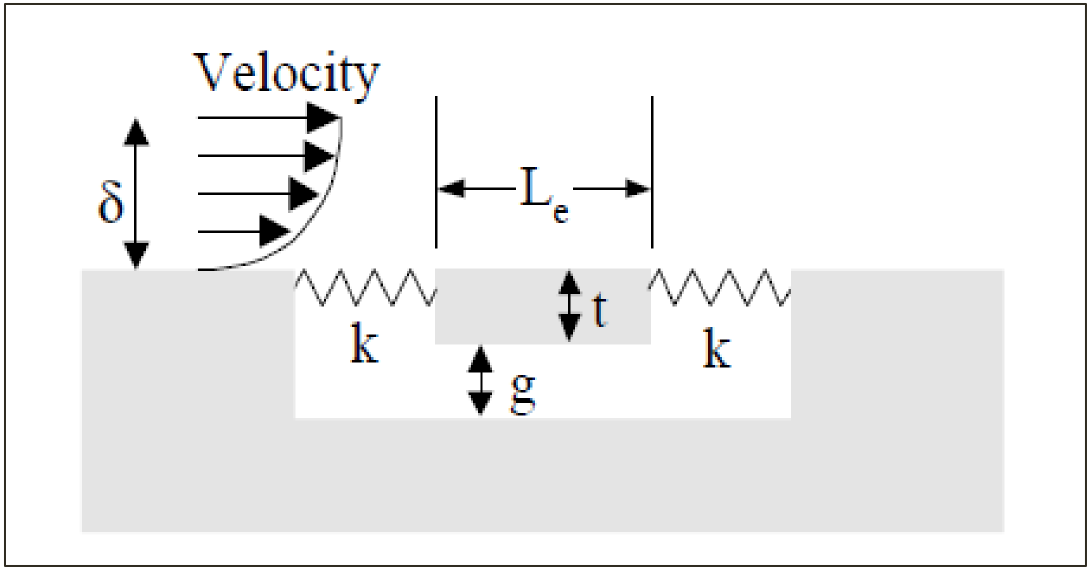
- Techniques
  - Micro-Machined Sensors (MEMS)
  - Thin-oil-film Techniques
  - Liquid Crystal Techniques

MEMS

- Devices that have been fabricated using silicon micromachining technology
- High-resolution, time-resolved, quantitative fluctuating turbulence measurements in a controlled wind tunnel environment
- Open nature of these sensors is not well suited for dirty environments in which debris may be trapped in the sensor gaps

MEMS

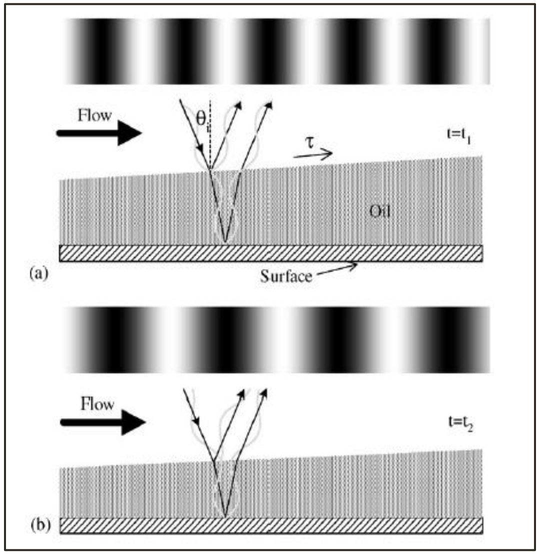
- Types – Direct sensors, thermal sensors and laser based sensors
- Direct sensors – Measure integrated force produced by the wall shear-stress on a flush movable “floating” element

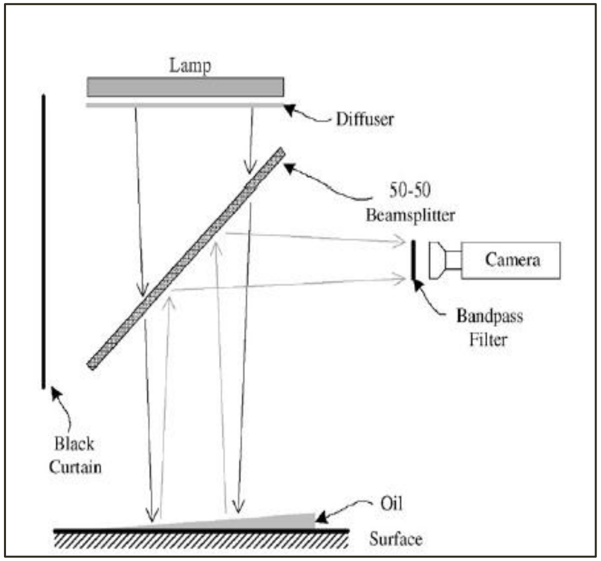


Displacement of the floating element – function of wall shear stress [1]

Thin-Oil Film

- Quasi direct means of measuring skin-friction
- The motion of oil film is sensitive to shear-stress, gravity, pressure gradients, surface curvature of the oil and surface tension





Oil thickness is measured via interferometry – function of the local skin-friction [1]

Thin-Oil Film

- Types - Single points, line and image techniques (1D and 2D)

-Image techniques 2D analysis

- Surface imaging skin-friction - SISF

-Advantages

- Range of 4% of uncertainty – two images during a single run
- Method is only sensitive to shear stress

-Limitations

- It requires at least two images acquired during a test
- Complexity

Liquid Crystal Coating

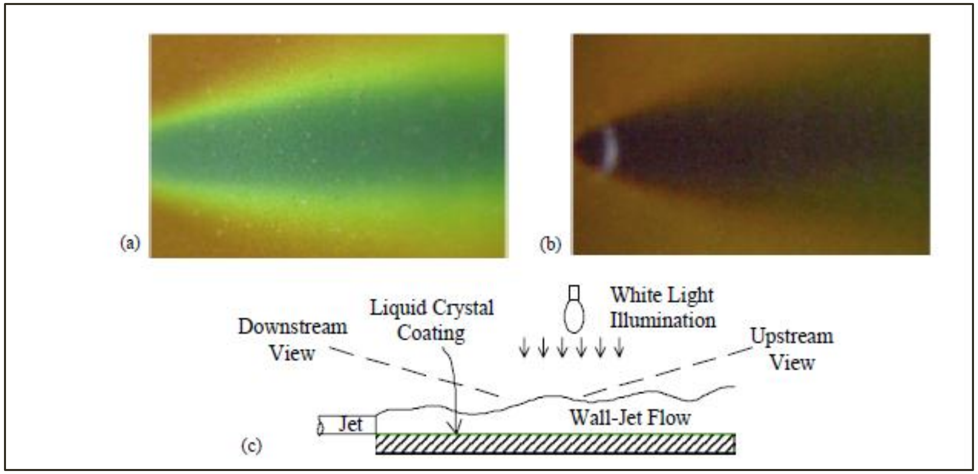
-Advantages

- Exhibit chemical stability so that they perform well over a reasonable interval
- Can be used in dirty environments as it is not dependent on electricity

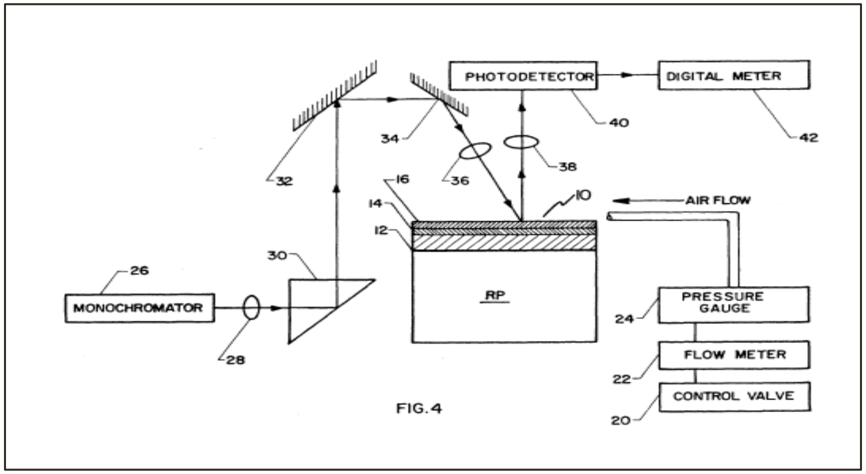
-Limitations

- Optical access, calibration and accuracy
- The color observed is dependent on illumination and observation angles
- The coating degrades with time, and, due to the exposure of shear sensitive liquid crystals to the flow, reapplication is often necessary

Liquid Crystal Coating

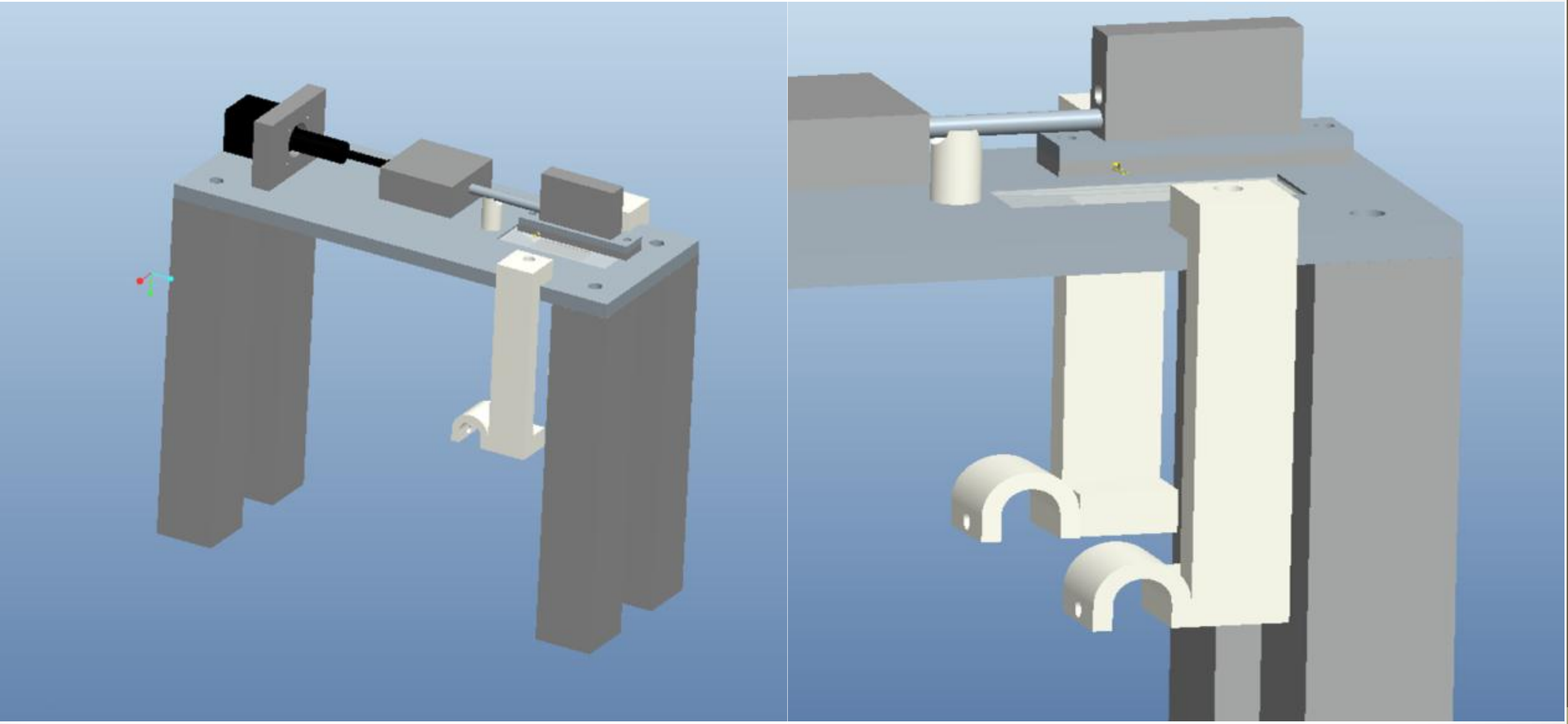


(a) Downstream view, (b) upstream view, (c) schematic of the flow field [1]

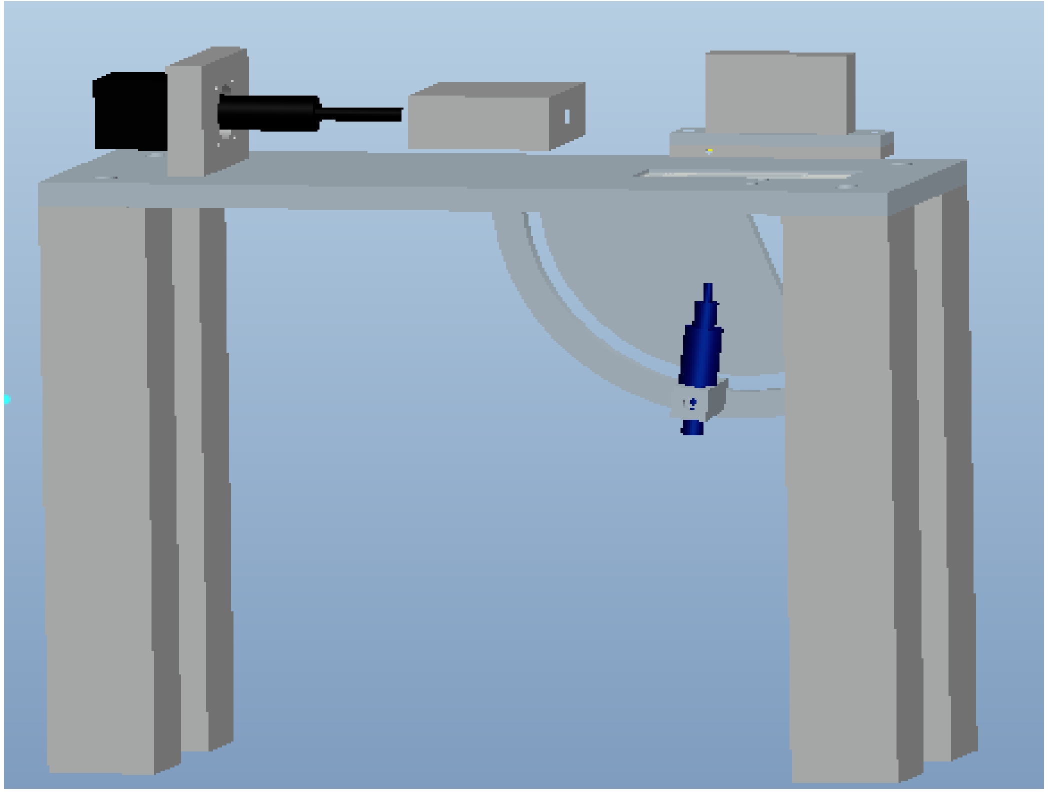


Patent Number 5223310 - The laminate structure comprises a liquid crystal polymer substrate attached to a test surface of an article [3]

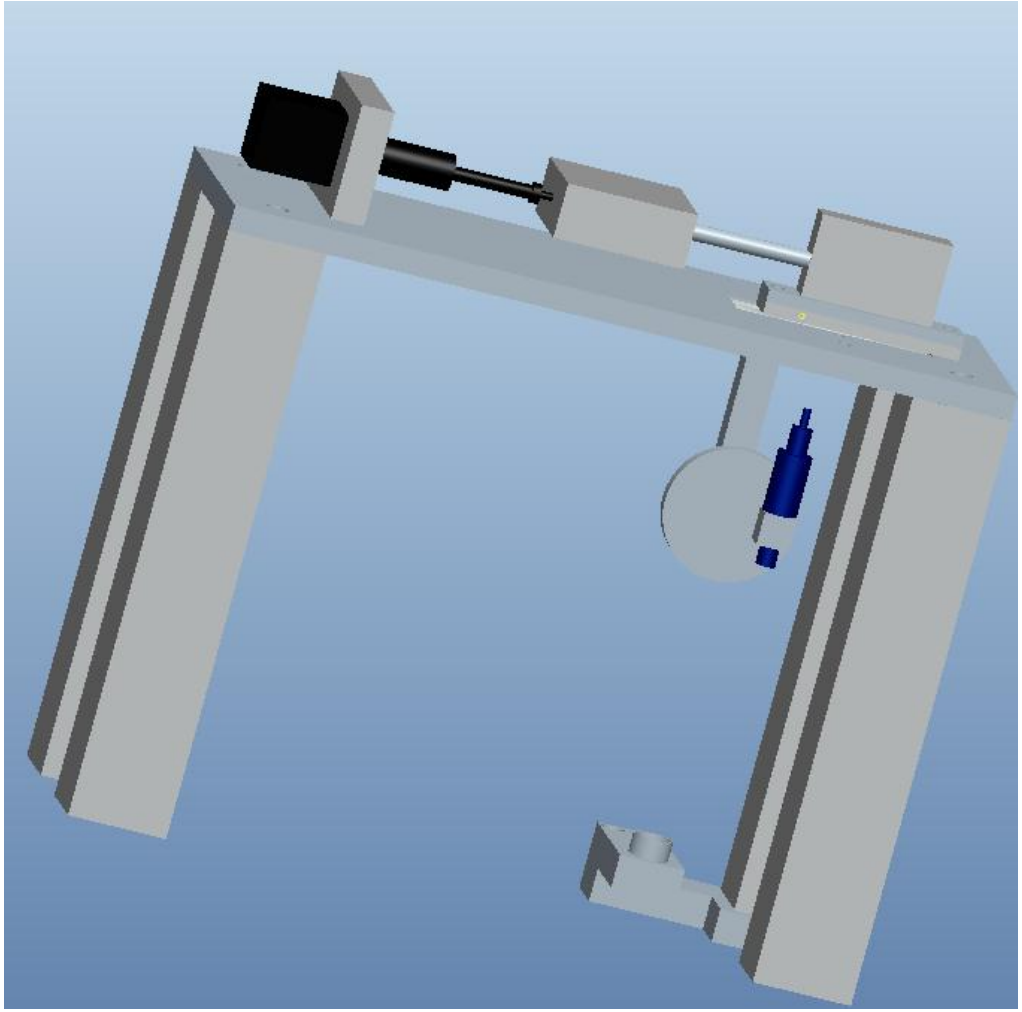
Concept 1



Concept 2



Concept 3

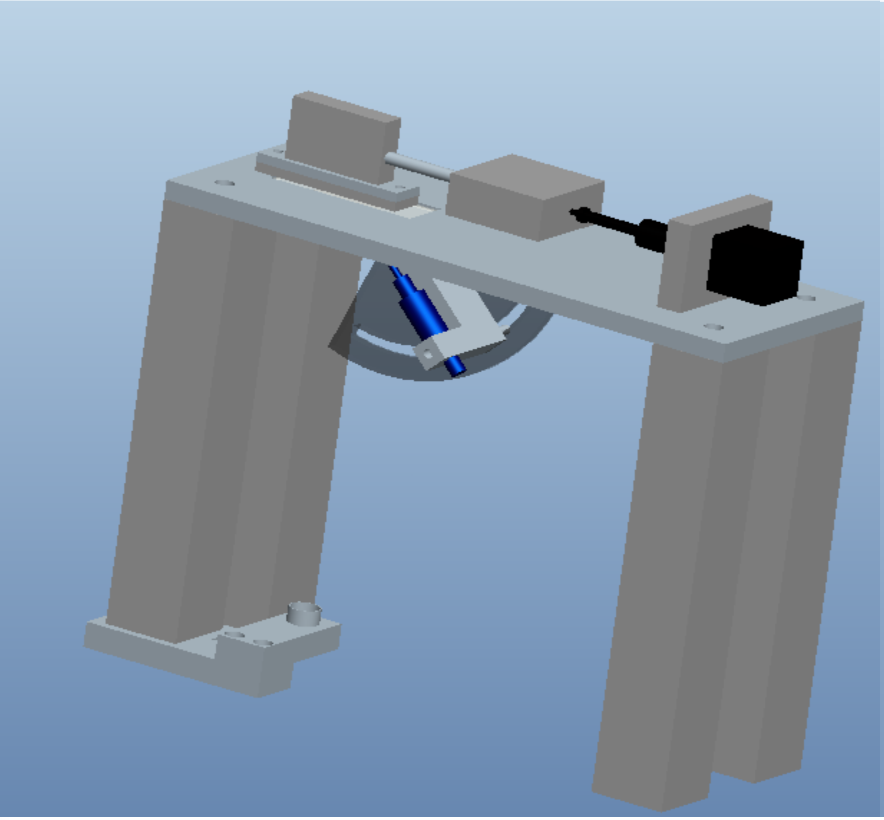


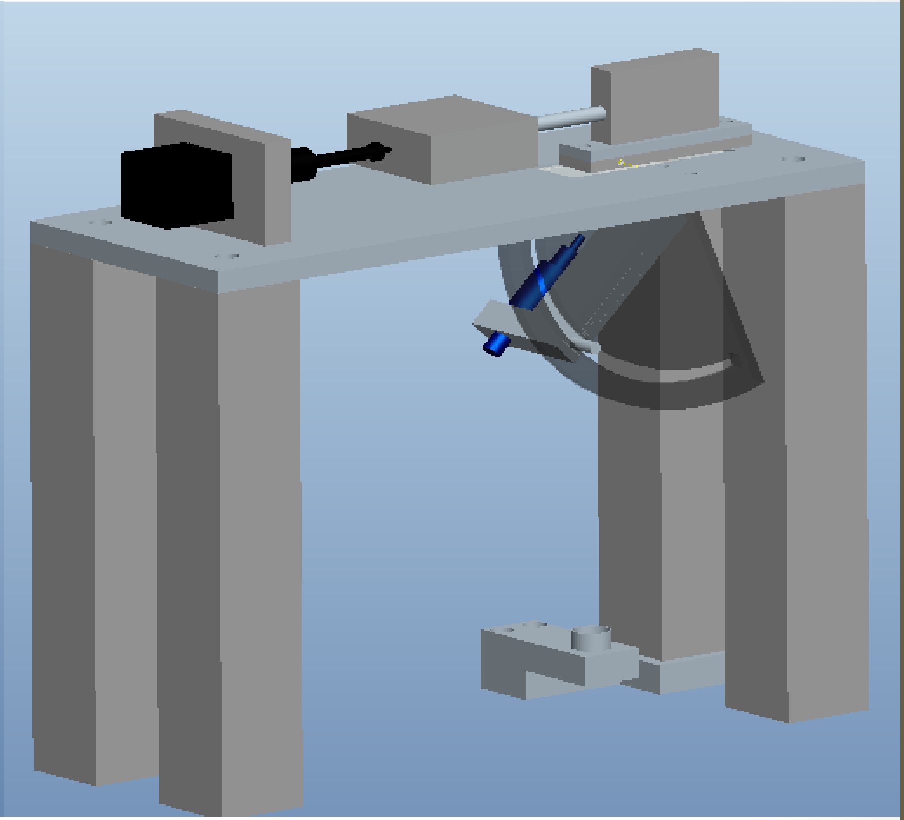
Decision Matrix

Score Range (1-5) Higher scores correlate to more ideal

		Concept 1		Concept 2		Concept 3	
	Weight	Score	Weighted	Score	Weighted	Score	Weighted
Simplicity	0.20	2	0.40	4	0.80	4	0.80
Feasibility	0.20	3	0.60	5	1.00	4	0.80
Accuracy	0.40	2	0.80	4	1.60	1	0.40
Cost	0.15	3	0.45	2	0.30	3	0.45
Size	0.05	2	0.1	3	0.15	4	0.20
Total	1.00		2.35		3.85		2.65

Final Design





Work Cited

- [1] Naughton JW, Sheplak M. Modern developments in shear-stress measurement. Progress in Aerospace Sciences 38, 515-570, 2002.

- [2] Finkelmann H, Kim ST, Muñoz A et al. Tunable mirrorless lasing in cholesteric liquid crystaline elastomers. Advanced Materials 14, 1069-1072, 2001.

- [3] United States Patent, Number 5223310, Date Jun 29, 1993.

Questions