Evaluation and Refinement of a Simulator Design for Laboratory Investigations of Spine Motion

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BIOMECHANICAL · TESTING · LABORATORY

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Design Objective

- To assess and improve the efficiency of an existing spine simulator with respect to its ability to apply pure bending moments to generate physiological motion *in vitro*

Background Information

- Spine simulators are useful laboratory tools that increase our understanding of spine motion pathways and how they are affected by surgical intervention (Figure 1).
- The current gold standard for spine simulator design is to generate motion through the application of pure bending moments that remain constant along the spine's length. [1]
- The bending moment efficiency of the existing spine simulator (a modified Instron® 8874 materials testing machine) has not been evaluated. [2]
- By allowing the end of the spine, which is currently fixed to the testing frame, to translate, undesirable shear forces will be reduced and it is hypothesized that the bending moment efficiency will increase (Figure 2).

Concept Generation

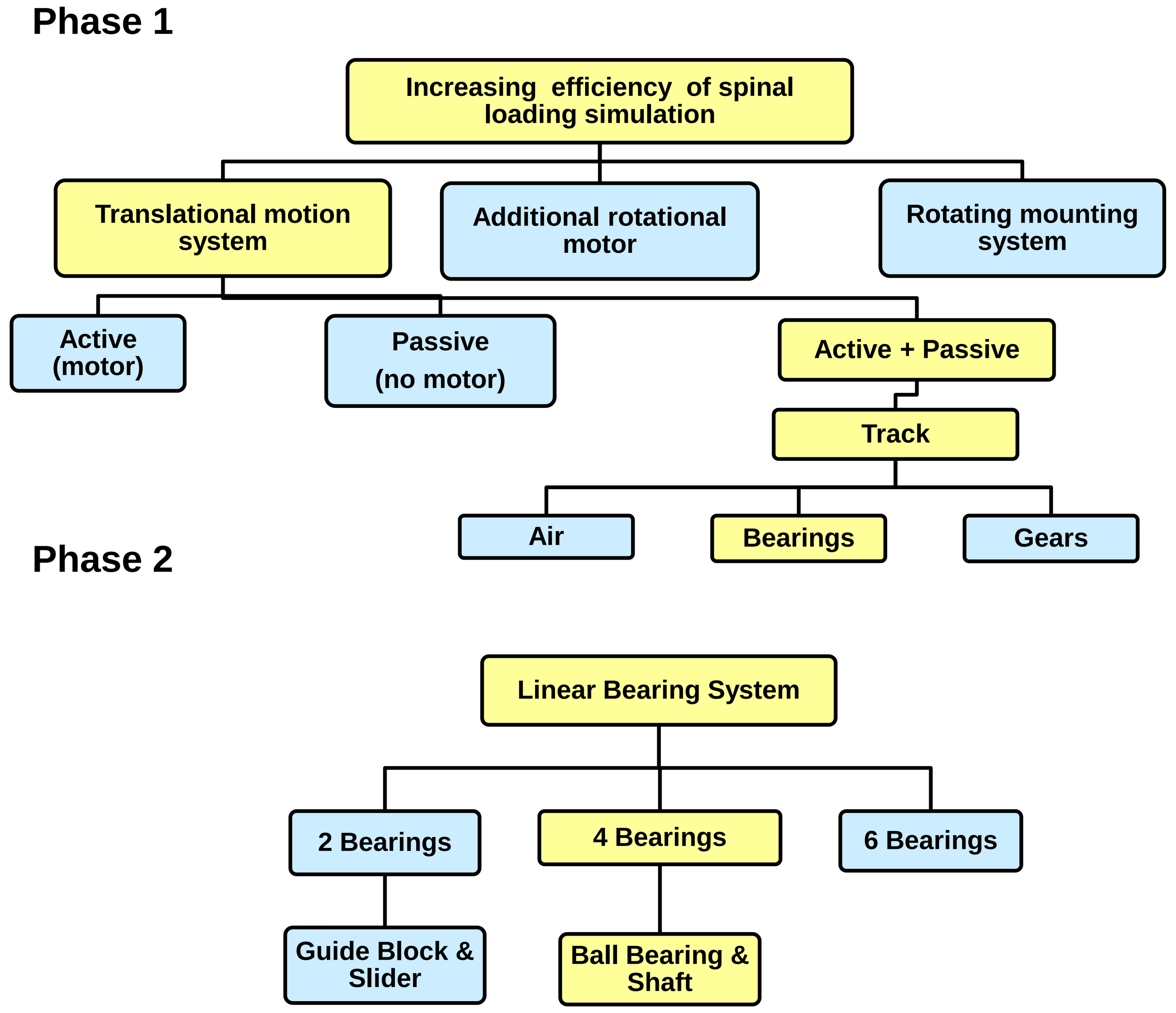


Figure 3: *Concept flowchart. Yellow blocks indicate path taken.*

Concept selection methods used: decision matrices, go / no go screening, and advantages/disadvantages analysis.

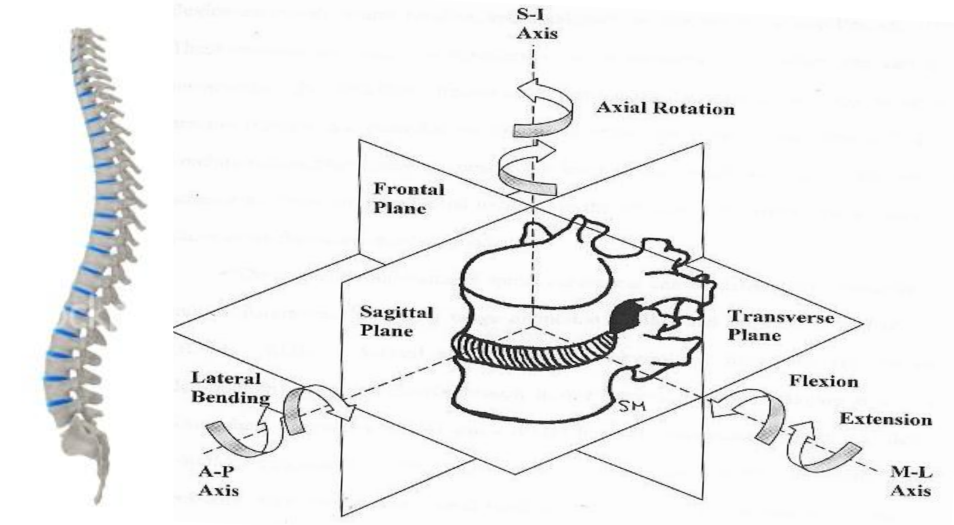


Figure 1: The three physiological rotations of the spine are flexion-extension, lateral bending and axial rotation

Spine Simulator

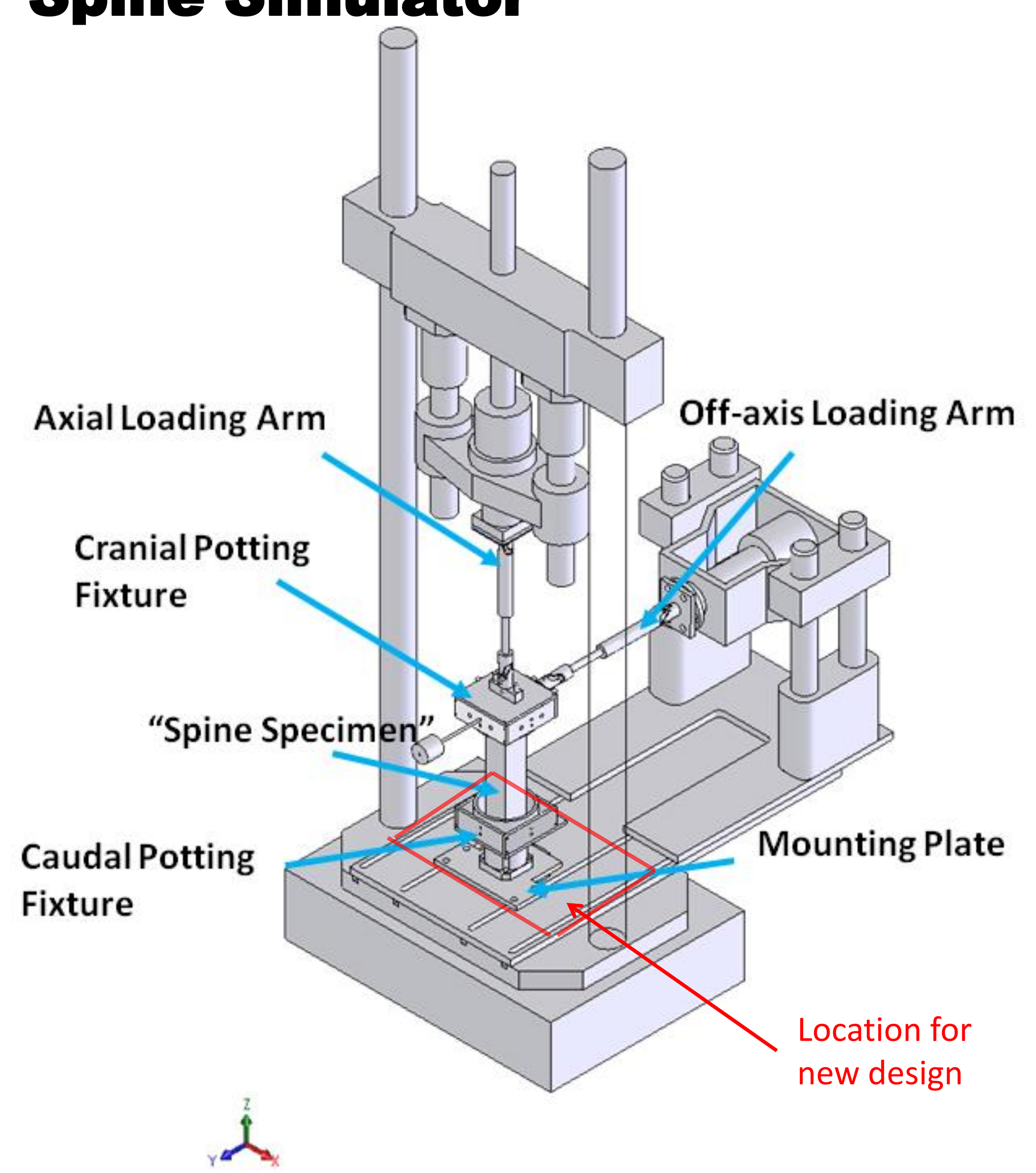


Figure 2: *The current spine simulator (based on an Instron® 8874) requires one end of spine to be fixed to the testing table; allowing translation in the horizontal plane is expected to increase bending moment efficiency.*

Major Design Requirements

Minimize friction generation
Lock and unlocking mechanism

Maximum compressive load:	1000 N
Maximum destructive torque:	30 Nm
Maximum applied torque:	7.5 Nm
Maximum translation:	± 5 cm

Linear Bearing System

- A linear bearing system was designed to interface with the testing platform of the current simulator

Item No.	Part Name	QTY.
1	Top Plate – Stainless Steel	1
2	Middle Plate – Aluminum	1
3	Bottom Plate – Aluminum	1
4	0.5" Diameter Shaft – Steel	4
5	Linear Bearing	4
6	Shaft Support	8

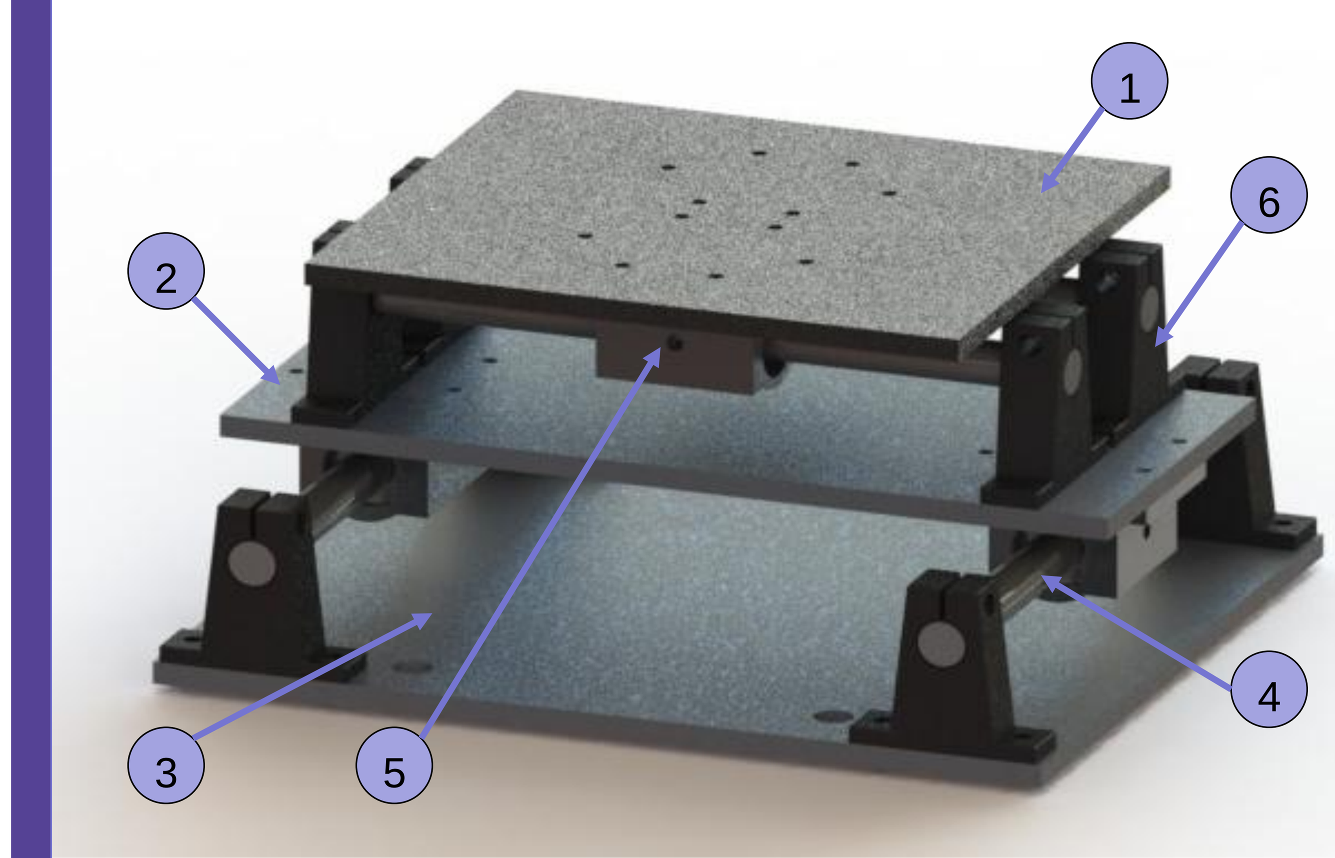


Figure 4: *Rendered model of the linear bearing system with a bill of materials.*

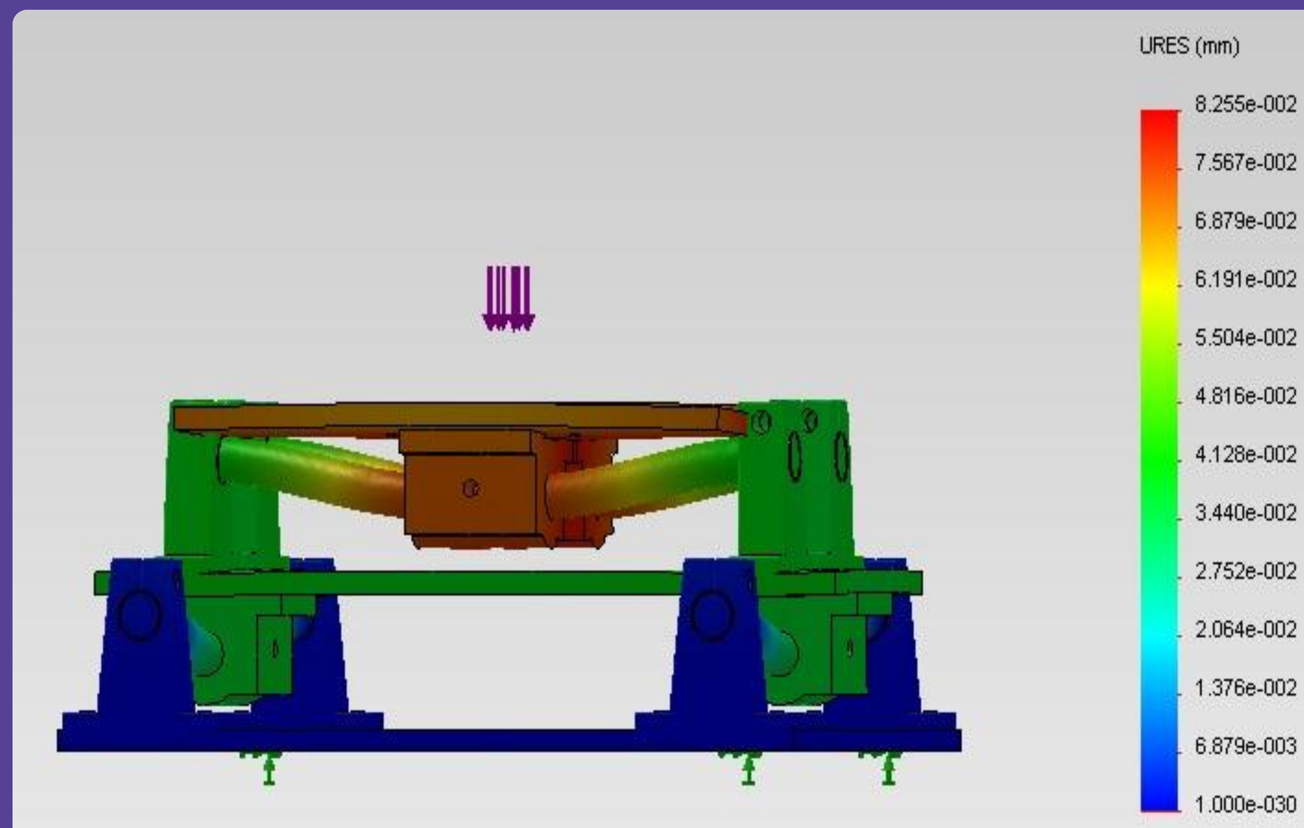
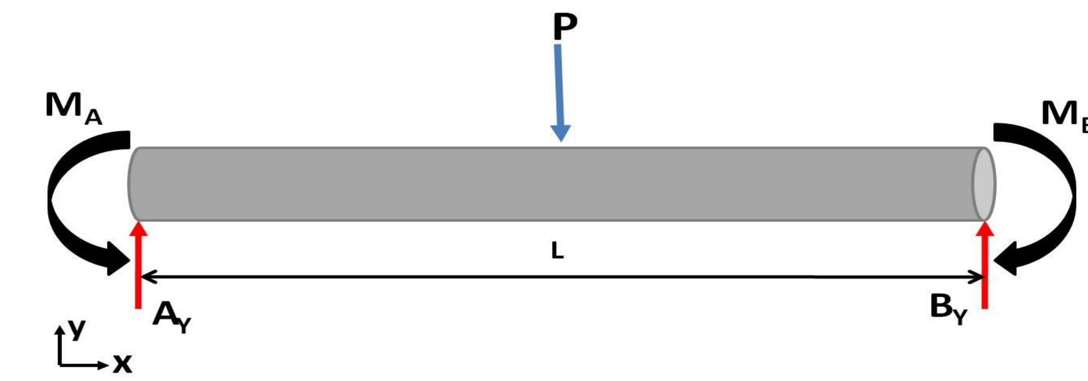


Figure 5: *FEA displacement plot with a load of 1000 N and the bottom plate fixed. Maximum displacements were of 0.084 mm magnitude expressed as the red regions.*

Engineering Validation

Free body diagram of a single shaft from system



- P: Applied load (position can vary along L)
- A and B: Fixed shaft supports

Loading Condition	Applied Load (N)	Factor of Safety	Maximum Deflection (mm)
Symmetrical loading P at x = 0.5L	520	5.3	0.09
Maximum offset loading P at x =0.5L ± 50 mm	520	4.9	0.04
Worst case scenario P at x =0.5L ± 50 mm	1040	2.4	0.07
Destructive torque loading	30 Nm	2.3	N/A

Quantifying Frictional Losses

$$Frictional\ Loss = (\mu \times W) + F$$

μ = coefficient of friction = 0.003
W = Load on bearing = 520 N
F = resistance intrinsic to a linear motion system = 4.4 N
Total Force Input = 1000N; Frictional Loss = 23.7 N

Future Plans

- Tests on a cadaveric specimen will be conducted to quantify bending moment efficiency:

$$Efficiency = \frac{moment\ at\ table}{applied\ moment} \times 100\%$$

- Efficiency calculations will be performed for various loading scenarios (flexion-extension, lateral bend, axial rotation) and configurations (locked vs. free).
- Conceptually incorporate motors to the design allowing for an active translation setting.

References

[1] Wilke HJ, Wenger K, & Claes L. (1998). Testing criteria for spinal implants: recommendations for the standardization of in vitro stability testing of spinal implants. *European Spine Journal* (7), 148-154.

[2] McLachlin SD. (2008). Design and Development of *In Vitro* Tools To Asses Fixation and Motion in the Spine. *Master of Engineering Science University of Western Ontario*, 1-104.