Design Considerations for a Multi-DOF Kinematic Spine Simulator

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INTRODUCTION: The kinematic analysis of the spine remains the subject of dialogue among researchers because of its complex biomechanics. As the industry for spinal devices and therapies continues to grow there is an increased need to accurately characterize the response of the spine.

A 6 Degree-of-Freedom, 8 controlled-axes Kinematic Spine Simulator has been designed to evaluate the functional kinematics of the spine under various simulated conditions. The simulator combines axial loading and rotation along with flexion/extension, lateral bending, and anterior-posterior and left-right translations. Typical applications for the Kinematic Spine Simulator include, but are not limited to, research of spinal fixation methods, interbody fusion, intervertebral disc research, and general spine biomechanics research.

METHODS: The Spine Simulator utilizes a servo-pneumatic axial/torsion testing system as its base platform and utilizes a combination of translational and rotational actuators with special restraint fixtures. Up to 8 actuators can be configured within the system and 24 channels of data are acquired. Each axis is independently controlled and incorporates independent measurement capabilities (including loads, moments, torques, and rotations). Table 1 describes the simulator forces and motions.

Table 1. 6 DOF, 8-Axes Kinematic Spine Simulator Forces and Motions

	Load	Motion
Axial	±5.6 kN	±50 mm
Rotation	±74 Nm	±50°
Flex./Ext.	±15 Nm	+120°/-60°
Lat. Bend	± 15 Nm	±60°
Ant./Post.	±1000 N	±50 mm
Left/Right	±1000 N	±50 mm

RESULTS: Figure 1 shows representative test data and includes the forces, torques, displacements, and rotations associated with axial loading and rotation, A-P and left-right translation, flexion-extension, and lateral bending. A unique feature of the simulator is its ability to provide pure bending in both flexion/extension as well as lateral bending. Figure 2 is actual testing performed under this pure bending mode.

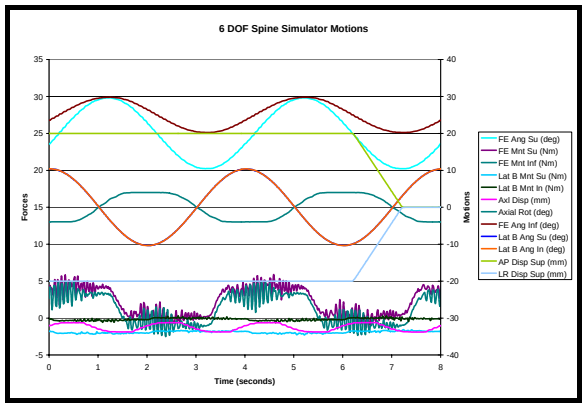

Fig. 1: Motion and Force plot from the Kinematic Spine Simulator.

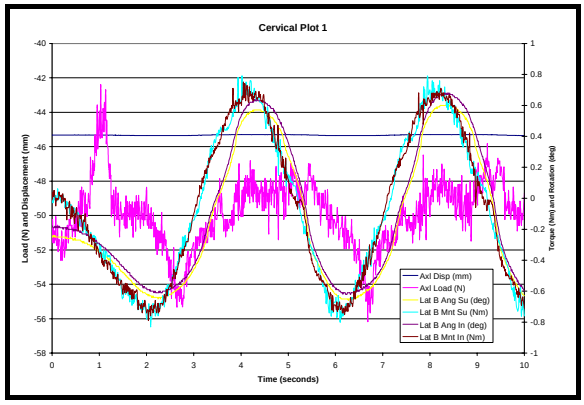

Fig. 2: 50 N Compression on a cervical spine segment with ±1.5 Nm of lateral bending.

DISCUSSION & CONCLUSIONS: The 6 DOF Full Spine simulator was designed to allow the researcher to perform a variety of tests related to spine kinematics. The development goal was to provide a system configuration that was suitable for quasi-dynamic simulation of typical spine kinematics and representative load bearing activities.

Various characteristics of the spinal components (single or multiple FSU) can be measured. These measurements can be useful for population of stiffness matrices indicating the spinal response to multiple loading conditions. This information can be useful in comparison between normal physiologic response and response after spine alteration, e.g. fusion and implants.

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