DYNAMIC MODELING OF HUMAN LUMBAR SPINE VIA MSC ADAMS®

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INTRODUCTION

Spine is a 3D structure responsible for supporting the skeletal body and protecting the spinal cord. The physical state of this supportive structure is vital to the overall health of the body. Due to its supportive role, external loadings and conditions can significantly affect the spinal functionality. For example, the individuals subjected to long-term vibrations in a seated posture, such as truck or tractor drivers, were shown to suffer more frequently from degenerative spinal diseases [1]. This is attributed to compromising effects of the compressive loads in the long run on the flow of nutrients to the intervertebral disks which will lead to the premature deterioration of the disk's annulus tissue.

The spine model in the dynamic analysis software MSC ADAMS® was developed to help evaluate these external loading conditions in various situations such as shocks induced from a bad road setting at the time of driving.

METHOD

In this study only the lumbar region of the spine was considered. The coordinates for the center of mass (CM) of the last thoracic, the five lumbar, and the first sacral vertebrae were derived from the published literature on the morphological and physical balance and alignment of the spine [2]. The inertial mass of each vertebrae in the model were considered as the mass of the vertebrae itself plus the tissues and viscera contained in the area covered by its height (for a typical 80 Kg individual) [3]. Each vertebra was represented as a sphere in ADAMS since only the 3D location of the CMs and their rotations are necessary for dynamic calculations.

The vertebral column has stiffness and damping properties in all the six degrees of freedom. The damping is a result of the viscoelastic properties of bone and intervertebral disks and acts as a kinematic energy absorber in the time of severe dynamic loadings. Several researchers studied such properties of the spinal column from which the translational and rotational stiffness data were elicited [4]. Specifically, the load bearing properties of the spine in flexion-extension, lateral bending, and axial rotation was taken into account as nonlinear equations determined by curve-fitting the moment-rotation experimental data (Figure 1) [4]. The disks were represented as two series *bushing* elements. The rheological model representing the axial mechanical behavior of the spinal motion segment was fitted as two series spring-dashpot blocks (Kelvin model) [5]. An equivalent force-moment was applied to the T12 to account for the weight of the head and the upper torso.

The developed model for the human lumbar spine is shown in Figure 2.

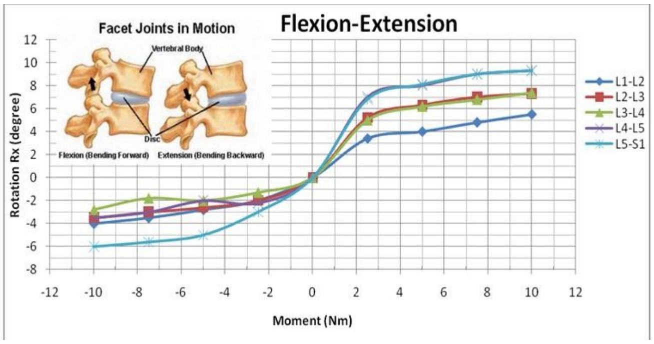

Figure 1 Experimental data representing segment stiffness properties in flexion and extension.

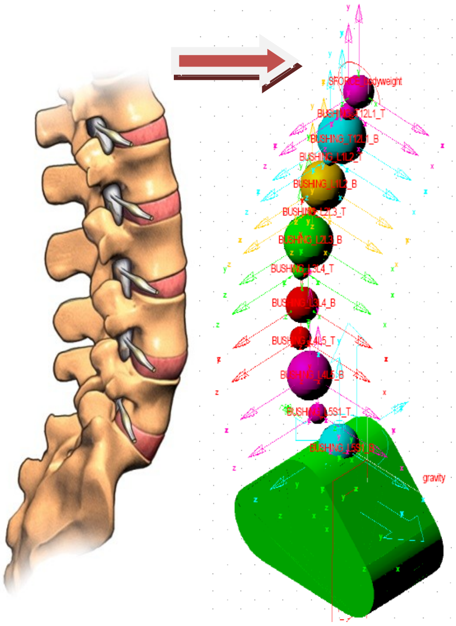

Figure 2 The 3D rigid-body model for the lumbar spine. The vertebral bodies (T12 to S1) are represented as spheres with corresponding inertial properties. Intervertebral disks are represented as two bushing elements in series.

RESULTS AND DISCUSSION

Positive axial shock

This loading case approximated the situation of driving on a bump and attempted to capture the load pattern exerted on the spinal levels in a sitting posture. An abrupt axial displacement was applied to the seat. Figure 3 demonstrates the various displacements in the lumbar levels with respect to time. It is noticeable that the damping properties of the spine diminished the oscillations immediately. Also, despite the fact that the load was applied in the vertical direction, the vertebral bodies underwent some oscillatory rotations and eventually settled back to their initial condition.

The forces which were transferred through the spine due to this shock are shown in Figure 4. This graph is also oscillatory in trend and illustrates the helpful effect of the damping in intervertebral disks that dissipated the external energy induced to the spine. The loads incurred were not of serious quantities compared to the tolerable loads by the motion segments.

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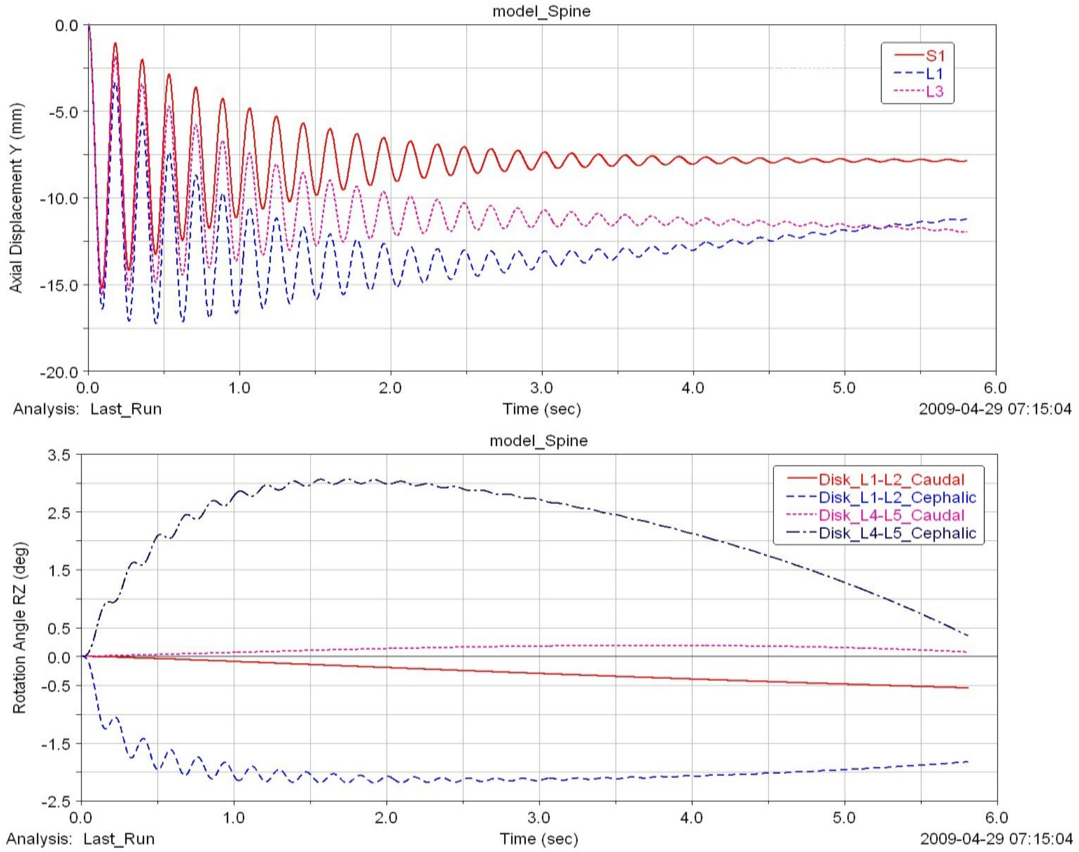

Figure 3 Displacements and rotations in represented vertebral bodies due to a small axial shock applied to the seat.

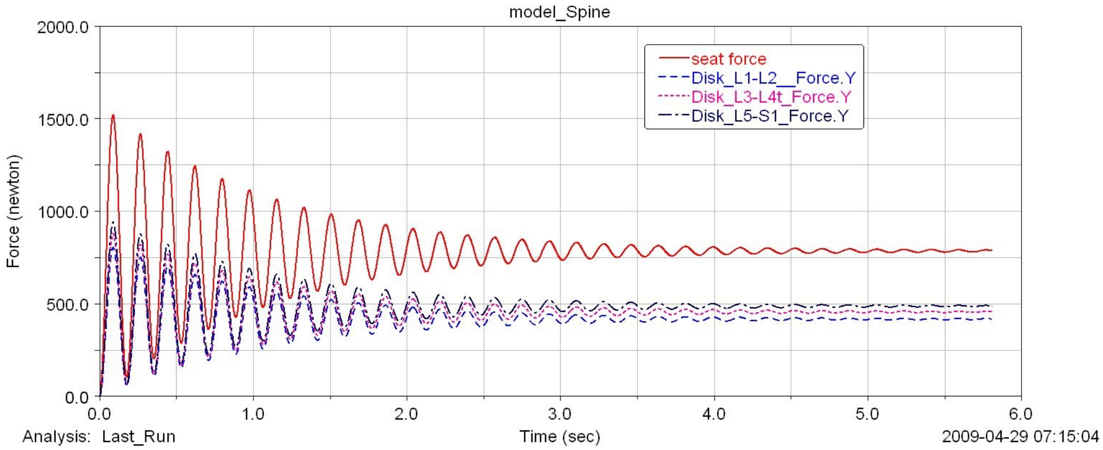

Figure 4 magnitudes of forces transferred in the disks as a result of the axial shock.