



**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**FINITE ELEMENT OF HUMAN SPINE  
CAD MODEL ANALYSIS**

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Manufacturing Engineering (Manufacturing Design) with Honours.

by

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## **APPROVAL**

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Design) with Honours. The members of the supervisory committee is as follow

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## ABSTRACT

In industry, there are many major industrial accidents. One of these is lower back pain. These injuries are responsible for the bulk of compensation money spent. Statistically problem in lower back pain of workers will affect the productivity of work. The activities such as lifting, pulling, pushing and sitting in the long period of time will cause low back pain problem. In industrial, this can be avoided by designing proper ergonomic workplace. There is a need to devise way to reduce the incidence and prevalence of back pain disorders, especially in the workplace. A proper investigation is done to a spine regarding this problem. Usually there is two types of experiment involve in analyzing the spine which are:

1. Using vitro models (cadaveric and mathematical)
2. Using investigation of software

In this thesis, Finite Element Method used CAD model to be analyzed.

Finite Element is the best method can be used to visualize stress distribution on the lumbar spine. The finite element method of numerical analysis has enabled researchers to solve many problems. Continuous advancements in numerical technique as well as computer technology have made the finite element method a versatile tool for biomechanics application. In this paper, the Finite Element Analysis (FEA) is done in Patran Nastran software. The lumbar spine model is generated in Solidworks software so that it eased the exporting procedure to send the model of lumbar spine. From the FEA, it can conclude that the end plate at 5<sup>th</sup> lumbar is experiencing maximum stress. 4<sup>th</sup> and 5<sup>th</sup> lumbar also affected by the various load applied. To avoid the low back pain problem, a person is advisable to maintain good posture in sitting, standing, walking, lifting object and other daily activities.

## ABSTRAK

Terdapat banyak kemalangan utama dalam sektor perindustrian. Salah satu daripadanya ialah kesakitan di bahagian pinggang. Kecederaan ini memerlukan kos perbelanjaan yg tinggi untuk pulih. Secara statistiknya masalah kesakitan di bahagian pinggang pekerja-pekerja akan menjejaskan produktiviti kerja seharian mereka. Aktiviti-aktiviti itu seperti mengangkat, menarik, menolak dan duduk dalam tempoh yang panjang itu akan menyebabkan masalah di bahagian pinggang berlaku. Perkara ini boleh dielak dengan menyediakan tempat kerja yang ergonomi dan selesa. Terdapat satu keperluan untuk menyelesaikan masalah bagi mengurangkan kesakitan di bahagian pinggang, terutama sekali di tempat kerja. Terdapat 2 jenis analisa yang selalu digunakan, antaranya :

1. Menggunakan vitro pelbagai model (kadaver dan matematik)
2. Menggunakan analisa perisian komputer.

Dalam tesis ini, Kaedah Unsur Terhingga digunakan model CAD untuk dianalisa. Elemen terhad adalah kaedah terbaik untuk mendapatkan taburan tegasan pada spina lumbar. Kaedah unsur terhingga analisis berangka itu telah berupaya untuk menanggapi pelbagai masalah. Kemajuan selanjut dalam teknik berangka serta teknologi komputer telah membuat kaedah unsur terhingga itu satu alat serba guna untuk kemajuan biomekanik. Dalam tesis ini, FEA yang digunakan adalah perisian Patran Nastran. Spina lumbar model dihasilkan dalam perisian Solidwork supaya ia mudah menghantar model spina lumbar untuk dianalisa. Daripada Analisis Unsur Terhingga, dapatlah disimpulkan bahawa plat hujung 5<sup>th</sup> lumbar mengalami tekanan maksimum. Plat hujung 4<sup>th</sup> dan 5<sup>th</sup> lumbar juga terjejas oleh beban yang besar. Untuk mengelak kesakitan di bahagian pinggang, seseorang perlu mengekalkan postur yang baik dalam keadaan sama ada duduk, bangun, berjalan, mengangkat objek dan aktiviti-aktiviti harian lain.

## **DEDICATION**

*For my beloved family, friends and UTeM*

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## **LIST OF ABBREVIATIONS, SYMBOLS AND SPECIALIZED NOMENCLATURE**

3D	-	Three Dimension
ASIA	-	American Spinal Injury Association
CAD	-	Computer Aided Design
CAE	-	Computer Aided Engineering
CT	-	Computed Tomography
FEA	-	Finite Element Analysis
kg	-	Kilograms
MRI	-	Magnetic Resonance Imaging
N	-	Newton
NIOSH	-	National Institute of Occupational Safety and Health



# CHAPTER 1

## INTRODUCTION

### 1.1 Project Background

Cervical spine injuries occur as a result of impact or from large inertial forces such as those experienced by military pilots during ejections, carrier landings, and ditching. Other examples include motor vehicle, diving, and athletic related accidents. Reducing the likelihood of injury by identifying and understanding the primary injury mechanisms and the important factors leading to injury motivates most research in this area. Because of the severity associated with most cervical spine injuries, it is of great interest to design occupant safety systems that minimize the probability of injury. To do this, the designer must have quantified knowledge of the probability of injury due to different impact scenarios, and also know which model parameters contribute the most to the injury probability. Although complex numerical such as finite element models are becoming more widely used as a means of augmenting and extending laboratory testing, most are deterministic in that they do not quantify the effect of uncertainties on the computed model responses. Stress analysis plays a critical role in understanding the mechanics of injury and the effects of degeneration as a result of disease on the structural performance of spinal segments and finite element analysis (FEA) is the method of choice to conduct these analyses.

The advantages of using FEA are complex geometry and boundary conditions can be modeled, inhomogeneous and non-linear materials simulated, parametric studies isolating the effect of one or more variables can be performed, and delineating the stress distributions in the various components of the biological structure can be accomplished. This information may serve as a basis to evaluate the response of the normal structure and the effects of degeneration or surgical interventions. In many structural systems, however, there is a great deal of uncertainty associated with the environment in which the structure is required to function. This variability or uncertainty has a direct effect on the structural response of the system. Biological systems are an archetype such as uncertainty and variability exist in the physical and mechanical properties and geometry of the bone, ligaments, cartilage, as well as uncertainty in joint and muscle loads.

An extensive amount of experimental work has been conducted using isolated vertebra, cervical spinal columns, and cadavers to better understand the mechanisms of cervical spine injury, and to measure material properties for use in developing and validating numerical models. Static experiments have been conducted by many researchers for purposes of understanding the basic kinematics of spine motion and for use in verifying numerical models. Many test programs have measured the response of the cervical spine under dynamic loading as well. Unfortunately, nearly all static or dynamic experiments concentrate on the measurement of the gross overall motion rather than detailed stresses and strains, which are generally more useful for validating numerical models. Some experimental work has been performed to assess the role of ligaments on the stability of the spine and to determine the paths of predominate load transmission through the vertebra and discs.

## **1.2 Problem Statement**

In industry, there are many major industrial accidents. One of these is lower back pain. These injuries are responsible for the bulk of compensation money spent. Statistically problem in lower back pain of worker will affect the productivity of work. The activities such as lifting, pushing and sitting in the long period of time will cause low back pain. In this thesis, Finite Element method use CAD model to be analyzed. Finite element is the best method that can be used to visualize stress distribution on lumbar spine. So we will know as much as which lumbar spine capable to holding heavy load.

## **1.3 Objectives**

The aims of this thesis are:

1. To construct 3D computer model of lumbar spine by using CAD software (Solidworks 2009).
2. To analyze 3D finite element model by using CAE software (Patran Nastran).
3. To investigation the Von Mises stress and displacement when erect posture and 35° back inclined in lumbar spine.

## **1.4 Scope of Project**

This project focus on lumbar spine with is 1<sup>st</sup> lumbar till 5<sup>th</sup> lumbar. The purpose of this project is construct a 3D computer model of lumbar spine drawn by CAD software (Solidworks 2009) and analyze 3D finite element model by using CAE software (Patran Nastran). This project also focuses on average person in industrial work which is male age around 40 years with weight is 70kg.

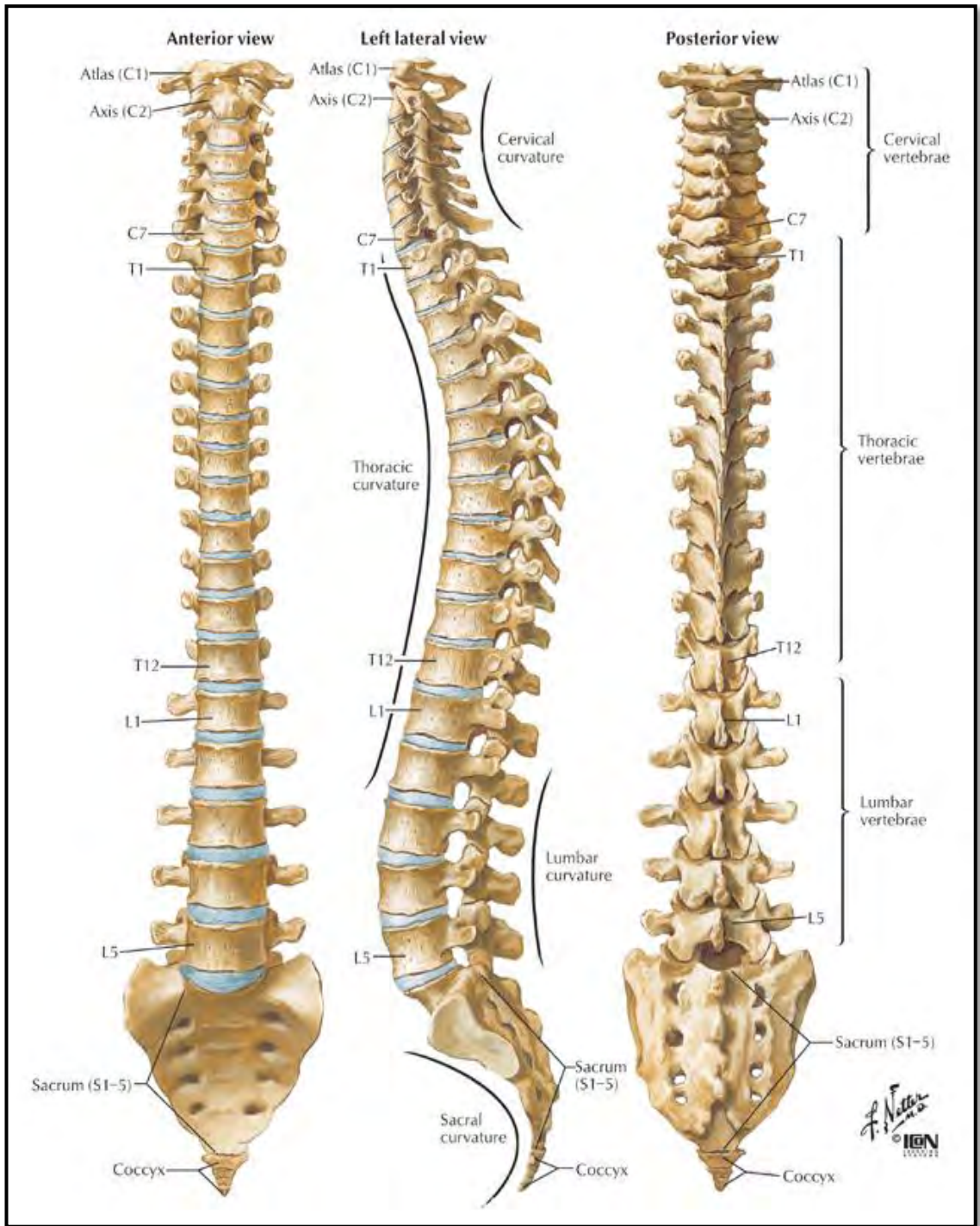


Figure 1.1 : Human Spine with all view

(Rhys Tranter, 2008)

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Introduction of Human Spine**

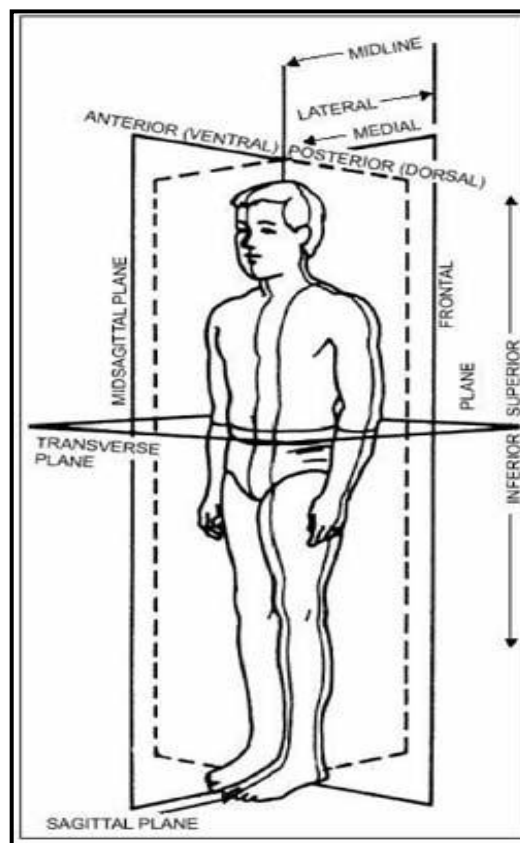
The spine is a complex and functionally significant segment of the human body. It protects the central nerve, which runs through an opening in each of the interconnecting vertebrae. It also serves as the axial support for the skeleton and provides for the flexibility and bending of the back. There many function of human spine and the each part of the spine have their own characteristic. (McIntosh 1998). The function and characteristic of human spine will discuss in this chapter.

##### **2.1.1 Anatomy and Function**

The mature human vertebral column usually consists of 24 pre-sacral vertebrae, the remainder being arranged into five fused sacral vertebrae and three to four coccygeal vertebrae. In addition to the bony structures there are 23 intervertebral discs between each vertebra and associated ligaments, muscles, and tendons. This thesis focuses on the osseous or bony spine which will be discussed in detail. (Douglas P. Breglia, 2006)

Before continuing, some basic anatomical terms must be addressed. There are three primary planes used and numerous directional terms referenced to a body in

anatomical position. The planes are referred to as the transverse or horizontal plane, the frontal or coronal plane, and the median sagittal or median plane as. The transverse plane divides the body into upper and lower or superior and inferior parts. The median plane divides the body into left and right portions. The body has a single median plane and many sagittal planes that are parallel to the median plane. The anatomical term medial means closer to the median plane, while lateral means farther from the median plane. Finally the coronal or frontal plane divides the body in to front and rear portions, where anterior is towards the front or face and posterior is toward the rear or back.



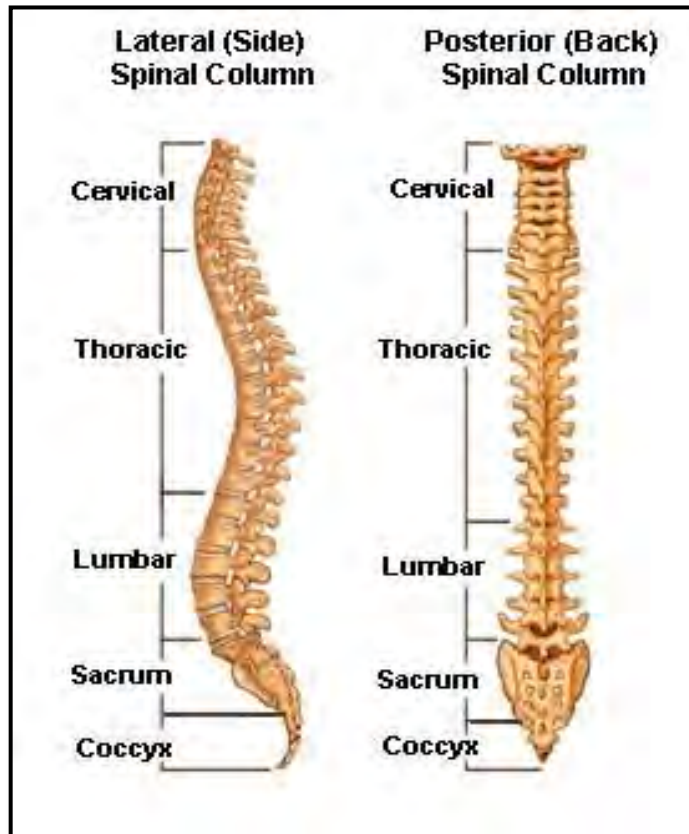
**Figure 2.1** : Transverse, Frontal and Sagittal Plane

(Highschoolanatomy.org)

Other common terms used are proximal, which is toward the center of the body, and distal, which is away from the center of the body. Some terms not involved with direction are foramen which is a hole or opening, and tubercle, which is a protuberance.

### 2.1.2 Section of the Spine

The spine is divided into five sections: the cervical, thoracic, lumbar, sacral and coccygeal spine as seen in figure below.



**Figure 2.2** : Segments of the Spine, Medial View and Frontal View

(Atlas of Anatomy)

The cervical spine is the most superior section, which means it is closest to the head, and the coccygeal spine is the most inferior, or closet to the feet. The cervical section of the spine is comprised of the seven neck bone. Next is the thoracic spine which is the 12 bones of the chest to which the ribs attach. Then the lumbar spine made of five bones in the lower back. Next the sacral spine which is a single bone made from five fused sacral segments attached to the pelvis, and finally the coccygeal spine.

As seen in **Figure 2.2**, there are three primary curves of concern in the medial plane of the spine. The cervical and lumbar sections have a lordosis, or a curve that is



convex toward the posterior. The thoracic spine has a kyphosis, or a curve convex towards the anterior of the body.

This project focuses on the vertebrae that have very similar geometry. This include the lumbar spine because of extremely load.

### 2.1.3 Regional Characteristic of Vertebrae

The vertebrae in each region of the spine are characterized by differences in elements and geometry. The following are some of the characteristics that distinguish one vertebra and one region from another. (Jenna Bowling, 1998)

*Cervical vertebrae:* The cervical vertebrae are the first (upper) seven in the vertebral column. The first cervical vertebra is the atlas shown on **Figure 2.3**; the name is atlas because it directly bears the weight of the skull. The second vertebra is called axis shown on **Figure 2.4** because it admits the rotation of the skull by allowing the atlas to pivot upon it. The other five cervical vertebrae have no names, but are called by their number, (i.e., third cervical vertebrae). Each of the cervical vertebrae features a body (anterior, or frontal, portion) and an arch (posterior, or rear, portion) shown on **Figure 2.5**. The body each vertebrae in the column bears the weight of the vertebrae above it (end the skull), while the arch serves to create a canal like area along to house and protect the spinal cord. Every cervical vertebra has a foramen (opening) in each of its transverse processes (lateral protrusions) the arch of the vertebra features a small knob or prominence, called an anterior tubercle. The anterior tubercles on the sixth cervical vertebra are particularly large and are known as the carotid tubercles.