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NUMERICAL ANALYSIS OF HUMAN SPINE DURING DIFFERENT LEVELS OF VIBRATION

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Summary: *Vibrations are oscillatory movements of the mechanical system, in which displaments of points are small compared to the dimensions of the system. In transport, comfort is one of the important factors in the stady of the quality of the vehicle. It can be said that the comfort in the vehicle depends on the values and the way of transmission of vibrations to the man. After the measured values of vibrations is obtained an accurate account of deformation of the human body. In this paper we conducted measurements of the vibrations on the human body during the process of driving at different speeds. The measuremend values of vibrations are transmited to the spine of the human using a software package Ansys. Numerical analysis were determined Von Misses stresses and displaments of the spinal vertebrae driver, due to different levels of vibration.*
Key words: vibration, comfort, spinal vertebrae, numerical analysis

1. INTRODUCTION

While traveling by car, the passengers are exposed to whole body vibration and shocks. The magnitude of this vibration depends on the road surface, vehicle speed, and is transmitted to the occupants through all points of contact between the passenger and the vehicle (the floor, the automotive seat, the steering wheel). The degree of whole-body vibration felt by occupants is evaluated as ride comfort. Many technologies have been developed in order to reduce whole-body vibration exposure while traveling by car [1], [2]. The chronic health problems, caused by prolonged exposure to vibration in the 0.5 - 80 Hz frequency range, include low back pain, spinal disorders, abdominal pain, vision problems, etc [3]. The human body's perception of whole body vibration is a function of frequency, with greatest sensitivity to seated vertical vibration at frequencies between 4 and 8 Hz [4]. Researchers have found that these subjective evaluation for the perception of vibration are related to the biomechanical response of the body to whole body vibration [5].

Vibration magnitude is usually expressed in m/s^2 r.m.s (root-mean-square). Mathematically, the r.m.s. is defined as:

$$a_{r.m.s.} = \sqrt{\frac{1}{T}\int_0^T a^2(t)dt}$$

where $a_{r.m.s}$ is the acceleration and T the exposure duration.

Typical vibration magnitudes in vehicles that occur during driving on asphalt roads are between 0.2 and 0.6 m/s² r.m.s in vertical direction [6]. According to standard ISO 2631, between 1 and 10 minutes, there is little effect of vibration duration on comfort. The standard does not provide a time-dependency for vibration durations less than 1 minute.

Modern smartphones contain various sensors for measuring physical phenomena in their surroundings. Acceleration sensors placed into smartphones are increasingly being used in laboratories. In this study, using a mobile phone were measured the vibrations that occur in the body of the driver during driving on an asphalt road. After that, was modeled the 3D model of the human spine, according to real dimensions. Finally, we applied to mode a measured acceleration in order to study the Von Misses stresses and displacements of the spine.

2. METHODS

In this research was used vehicle RENAULT Megane 3. The car is driven on asphalt, on the right highway Kragujevac Batočina. All vibration measurements are carried out on the phone Samsung Duos 3 in the position shown in Fig. 1.

Fig. 1 *The position of the smartphone and 3 accelerometer axes*

Accelerometers used in this smartphone is highly miniaturised and measure the acceleration about three axis. It is a digital, tiaxial ±2g to ±16g sensor BMA 250, (dimensions 2mm x 2mm, height 0.95 mm), with intelligent on-chip motion–triggered interrupt controller, resolution of 10bit and sample frequency from 7.81 Hz to 1 kHz [7]. The typical temperature measurement range is -40°C up to 87.5°C. VibSensor application was used to measure vibrations. This application makes collecting, analyzing, and exporting high quality accelerometer data easy. Experiment included three driving speeds: 60, 80 and 100 km/h. The next section will show the results of these driving modes.

The dynamic behaviour of a human body under whole-body vibrations has been simulated using developed human vertebral column, also known as spine. A 3D computer model and numerical simulatios, of a human spine, was made using Ansys software package. The vertebrae in the human vertebral column are divided into different regions, which correspond to the curves of the spinal column. Our model consists of cervical spine, thoracic spine, lumbar spine (Fig. 2).

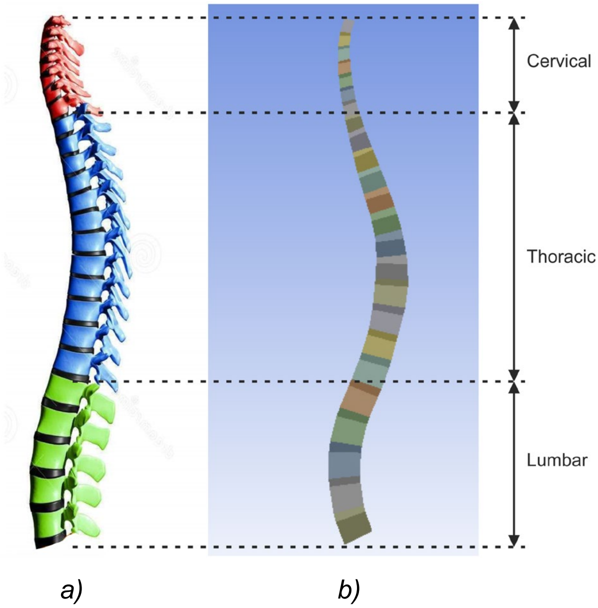


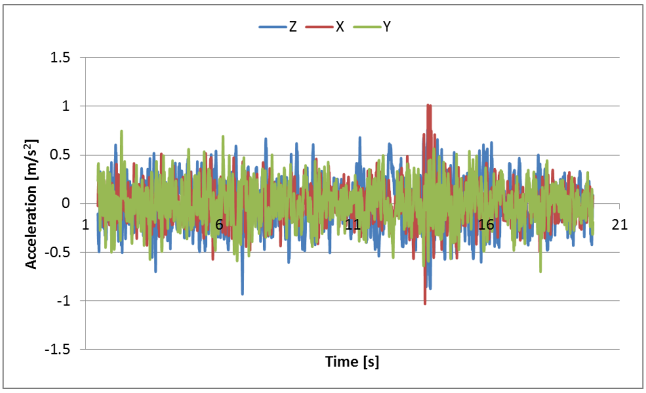
Fig. 2 *Human spine: a) real model, b) developed model*

After creating a 3D model, the next step was to producting 3D mesh. Linear tetrahedron was used as the final element. Finite element mesh consists of four groups of elements: finite elements that represent cortical bone, finite elements that represent cancell bone, finite elements that represent nucleus and finite elements that represent anulus. Mechanical properties assigned to the each material are summarized in Table 1.

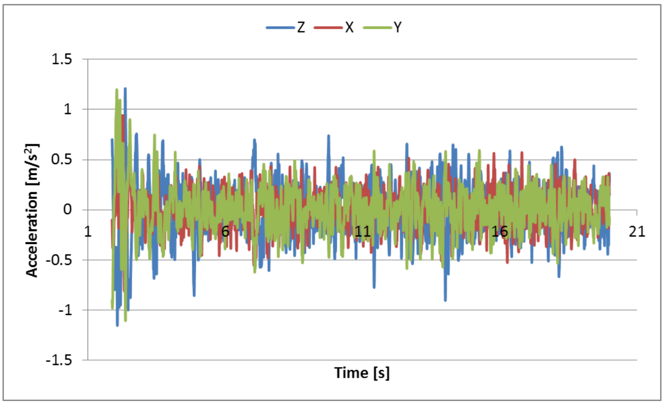
Table 1 *Material properties of components of the spine [8], [9]*

Name of component	Young's Modulus [MPa]	Density	Poisson's ratio
Cortical bone	12000	2020	0.3
Cancell bone	200	1000	0.45
Nucleus	1.3	1090	0.499
Annulus	4.2	1090	0.45

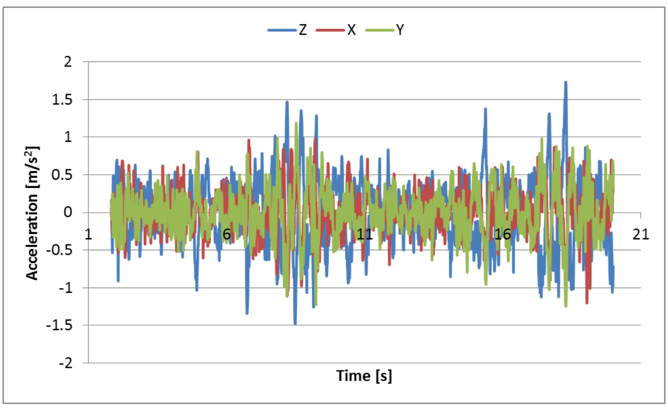
The boundary condition was defined by setting the measured acceleration in the lower spine (Fig. 3), while on the upper surface of the model set the certain value of weight of the upper body ~ 5.5 kg (head + neck) [10]. Experimental measurements were performed over a period of 20min.



a) The vehicle speed of 60 km/h



b) The vehicle speed of 80 km/h

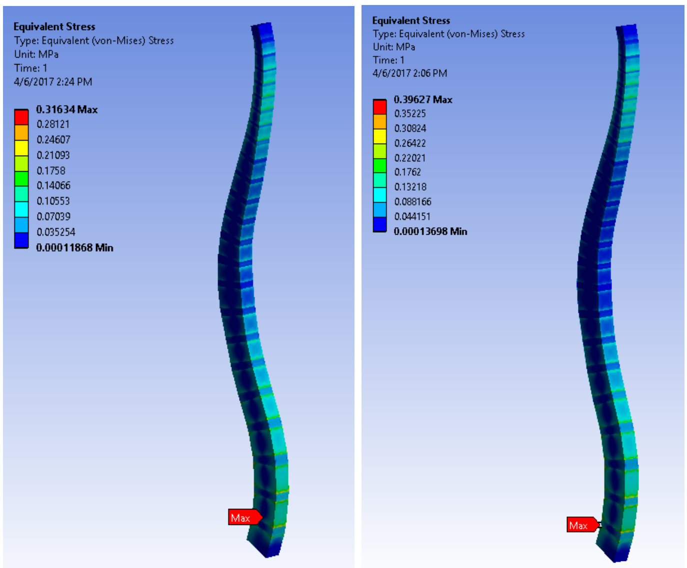


c) The vehicle speed of 100 km/h

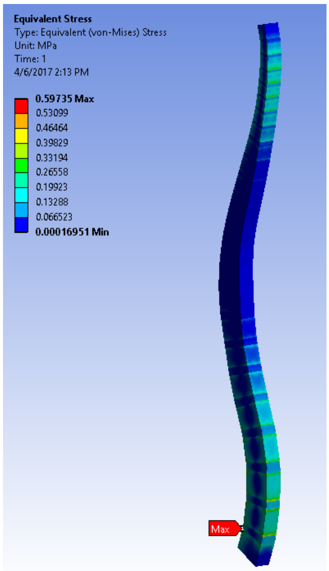
Fig. 3 *Measured values of acceleration in three cases*

3. RESULTS

Numerical analysis of the impact of vibration on the human spine, was carried out using the software package Ansys. The finite element mesh consists of 16534 nodes and 99204 elements. Fig. 4 show results of numerical simulation of Von Misses stresses for the three cases: 60 km/h (Fig 4a), 80 km/h (Fig 4b) and 100 km/h (Fig 4c). First case (Fig 4a) show that the maximum value of stress is in lumbar part of the spine, in the area od L4-L5 vertebrae. Here is recorded the maximal stress of 0.316 MPa. Also, it should be noted that in cervical part of the spine, there is an increased value of the stress that goes to 0.244 MPa. Second case, Fig. 4b, show that the maximum value of stress is also in the lumbar part of the spine where the largest stress value is 0.396 MPa. In the cervical part was measured 0.326 MPa of Von Misses stress. Finally, third case, gives the largest values of stress. In the lower part of the spine, in the lumbar region, was recorded value of the stress of 0.597 MPa, while in the cervical part was 0.459 MPa. Display results confirm that after a long drive, can occur fatigue and pain in the lower part of the spine.



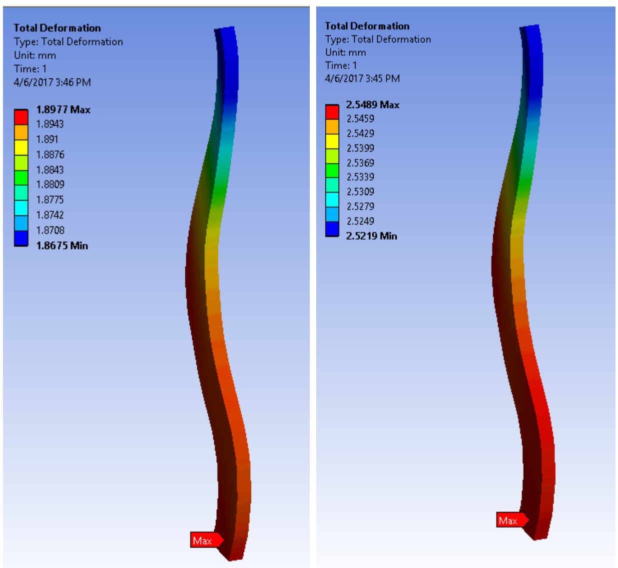
a) b)



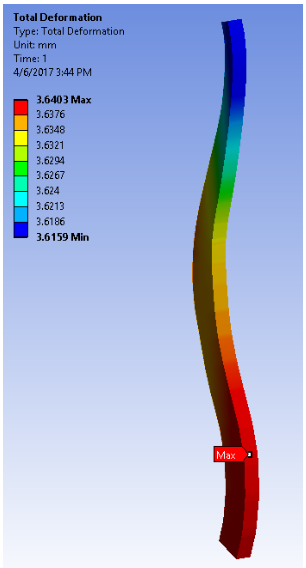
c)

Fig. 4 *Von Misses stress distibution along the human spine*

Fig. 5 show the total deformation along the spine exposed to vibration. At a speed of 60 km/h, the highest recorded deformation was 1.89 mm, while in the other two cases were 2.54 and 3.64 mm, respectively.



a) b)



c)

Fig 5 *Total deformation along the human spine*

4. CONCLUSION

The FEA performed in this study demonstrated pattern of von Misses stress distribution and displacement through the human lumbar spine during different car speed. Using smartphone, we measured the vibration from asphalt and studied the impact on the modeled 3D model of human spine. Results of this study, for the car speed of 60 km/h, showed that the displacement of lumbar spine is 1.89 mm, while the highest von Misses stress has a value 0.316 MPa. At a speed of 80 km/h, the greatest displacement is 2.54 MPa, while the stress was 0.396 MPa. Finally, third case, 100 km/h gives a displacement of 3.64 mm, and Von Misses stress 0.597 MPa.

These results gives a clearer picture of the impact of vibrations on the human spine and its main parts. It would be interesting to see how the different types of road influence the behavior of the spine while driving.. Our future research will go in that direction

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