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Modeling and Simulation of the Driver's Biomechanical System Using Adams Software

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Abstract: This paper presents a way of approaching the modeling of multibody systems. The proposed model tries to reproduce as closely as possible the driver's skeletal system when a series of commands are activated on board the vehicle. Elements of this model were imported into the AutoCAD computer graphics program as polyface mesh entities. We transformed the entities into solid with the Inventor program by exporting from AutoCAD with the extension .iges and importing them into the Inventor program. The solid model made with the help of the Inventor program was exported again with the extension .dwg in AutoCAD. The result was 222 solid elements (corresponding to each human bone) for which the import procedures were followed in the MSC ADAMS software. With the help of STEP motion laws, we simulated changing the gears of the vehicle on the virtual model. The verification analysis at the end of the simulation showed that the created model has 104 degrees of freedom, 53 moving elements, 20 simple rotational couplings, 2 spherical rotational couplings, 15 fixed joints, 18 imposed movements and that all the kinematic restrictions introduced are valid. The virtual model created can be a tool for analyzing the biomechanical system of the driver for car manufacturers in order to improve the ergonomics of the seat.

Keywords: biomechanical system; Adams software; laws of motion

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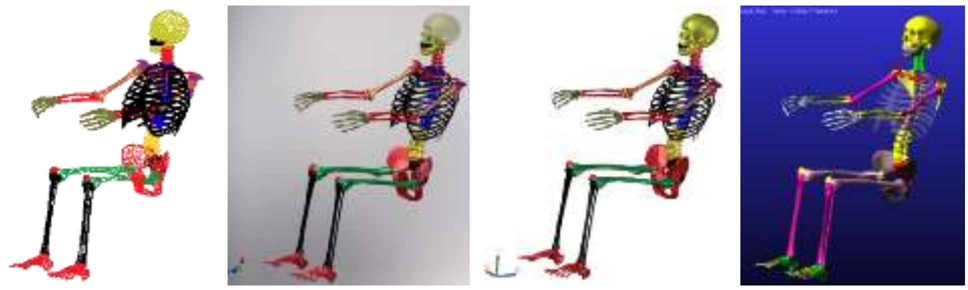
1. Introduction

For a more accurate modeling of the driver's bone system, we imported a geometric model made using the 3D StudioMax program, which can be found in the 3Dlancer virtual library. Elements of this model were imported into the AutoCAD computer graphics program as polyface mesh entities. We transformed the entities into a solid with the Inventor program by exporting from AutoCAD with the extension .iges and importing them into the Inventor program. The solid model made with the help of the Inventor program was exported again with the .dwg extension in AutoCAD. I preferred the transformation into solid by the Inventor program due to the smaller file size compared to the one transformed by AutoCAD. The result was 222 solid elements (corresponding to each human bone) for which the import procedures were followed in the MSC ADAMS software, figure 1.

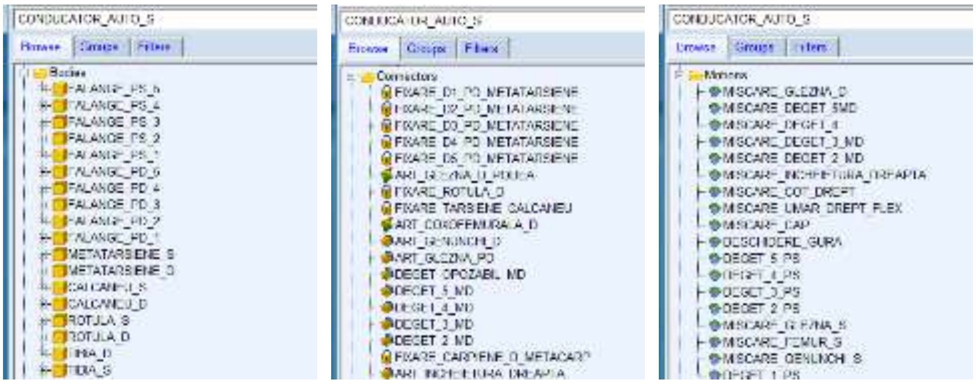


(a) (b) (c) (d)

Figure 1. Stages of modeling the driver's biomechanical system (a) polyface mesh model (b) Inventor solid model (c) AutoCAD solid model (d) MSC ADAMS virtual model

2. Related Work

The solid kinematic elements of the virtual model, imported into MSC Adams, were connected via the kinematic torques provided by the program. Depending on the number of degrees of freedom allowed by the anatomical structure, spherical, rotational, or translational kinematic couplings were used, figure 2.



(a) (b) (c)

Figure 2. Data of the virtual model of the driver
(a) rigid kinematic elements (b) kinematic couplings (c) imposed laws of motion

In order for the kinematic subassemblies of the driver created to have a kinematic behavior as close as possible to the real behavior of the driver, during the operation of different devices, we assigned to the models solid movements that reproduce as accurately as possible the human movement. The kinematic constraints were applied to the sagittal movements, movements defined by laws of motion that represent the variations in time of the articular parameters of the kinematic torques of rotation.

With the help of STEP motion laws we simulated changing the gears of the vehicle on the virtual model. The general form of the STEP function offered by MSC Adams is:

$$STEP(A, x_0, h_0, x_1, h_1) \quad (1)$$

where:

A - defines the set of values of the variable x;

x0 - the initial value of the set A for the initial angular value h0;

x1 - the value of the variable x in which the angular variation h1 is reached.

For simulation, we considered the independent variable, x, the time required for the movement, and as a dependent variable the angular variation, h. The interval A is between the initial time which has the value 0 seconds and the final time 5 seconds (maximum time measured for changing gears).

The verification analysis at the end of the simulation showed that the created model has 104 degrees of freedom, 53 moving elements, 20 simple rotational couplings, 2 spherical rotational couplings, 15 fixed joints, 18 imposed movements and that all the kinematic restrictions introduced are valid.

The virtual model created can be a tool for analyzing the biomechanical system of the driver for car manufacturers in order to improve the ergonomics of the seat. With the help of this model it is possible to study the position of the driver and to highlight possible movement constraints due to the devices to be operated.

To verify the model made in the MSC Adams software, we made measurements of the angles of the joints and the travel times of the elements when performing the maneuver to change gears with mechanical clutch. The measurements were performed on a car stand with analog means (level - laser reporter, stopwatch).

We obtained the obtained data in the quantification of the parameters of the STEP type motion laws as follows:

1. Left ankle movement

• STEP(time , 2.5 , 0 , 3.0 , -40d)+STEP(time , 3.1 , 0 , 3.2 , +5d)+STEP(time , 3.2 , 0 , 4.0 , +30d)

2. Left knee movement

• STEP(time , 2 , 0 , 3.0 , -40d)+STEP(time , 3.6 , 0 , 4.8 , 40d)

3. Left thigh movement

• STEP(time , 1 , 0 , 2 , -5d)+STEP(time , 2 , 0 , 3.3 , 20d)+STEP(time , 3.6 , 0 , 4.5 , -20d)+STEP(time , 4.5 , 0 , 5 , 5d)

4. Right leg movement

• STEP(TIME , 3 , 0 , 3.5 , 15d)+STEP(TIME , 3.8 , 0 , 5.5 , -20d)

5. Straight shoulder movement

• STEP(time , 2.5 , 0 , 3 , 20d)+STEP(time , 3.8 , 0 , 4 , 5d)

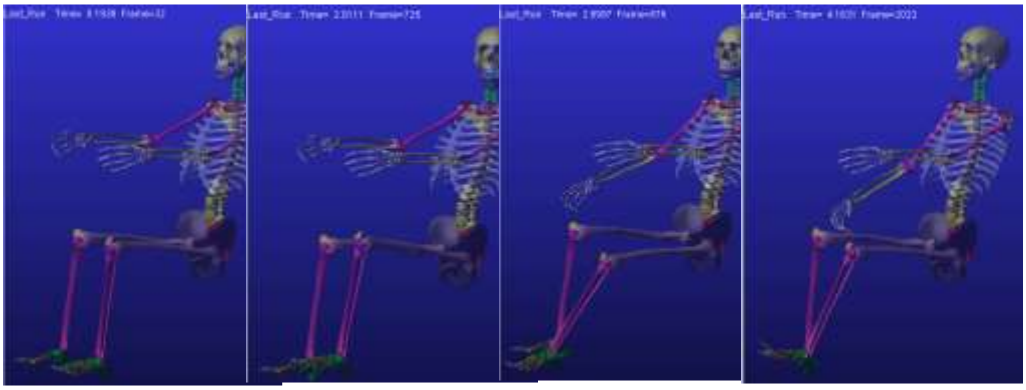
6. Right elbow movement

• STEP(time , 2.1 , 0 , 2.8 , 5d)

7. Right hand wrist movement

• STEP(time , 3.4 , 0 , 3.6 , -15d)

The kinematic constraints of the laws of motion were realized in the sagittal plane, figure 3.



(a) (b) (c) (d)

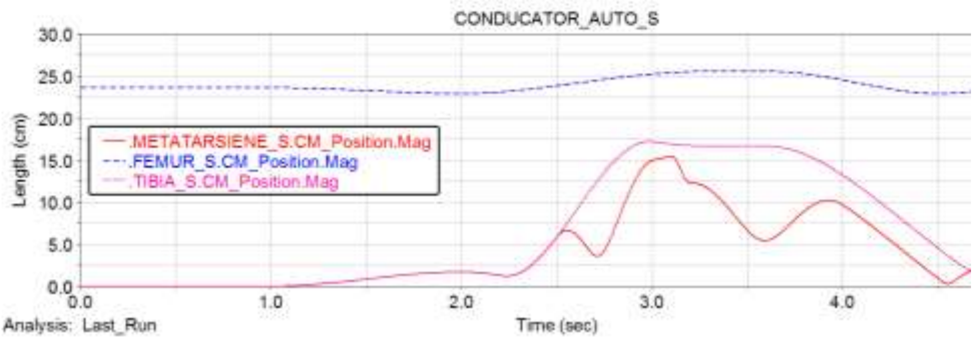
Figure 3. Simulation of gear changes with MSC Adams
(a) initially (b) left limb flexion (c) left lower limb extension and right leg flexion (d) right upper limb extension

3. Result

Following the verification simulation of the driver model, the following were found:

• the amplitude of the displacement of the center of mass of the tibia of the left foot has the highest value, approximately 175 mm, while the metatarsals move the least, approx. 20 mm, figure 4;

• for the upper part of the body, when actuating the gear lever, the center of mass of the metacarpals moves by approximately 57 mm, figure 5;



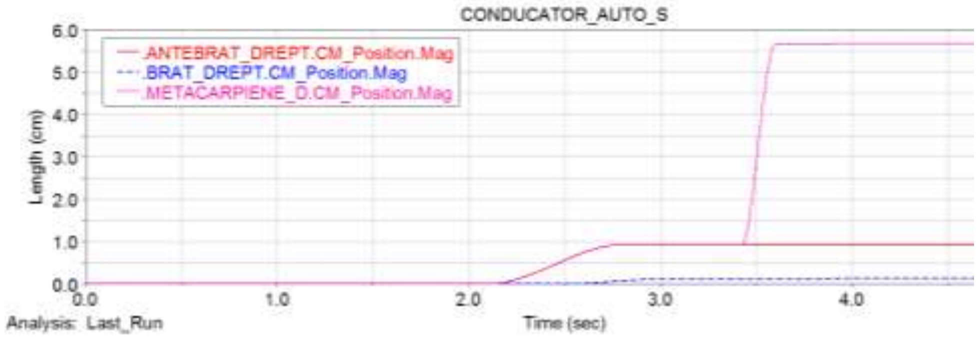


Figure 4. Displacement of the center of mass of the kinematic elements of the driver

• the linear displacement speeds of the torques associated with the joints have the highest values for those that are positioned topographically distally (the ankle and wrist joint)

• the speed of movement of the hip joint is approximately 0.12 m / s in accordance with the small displacement of the femur (figure 5);

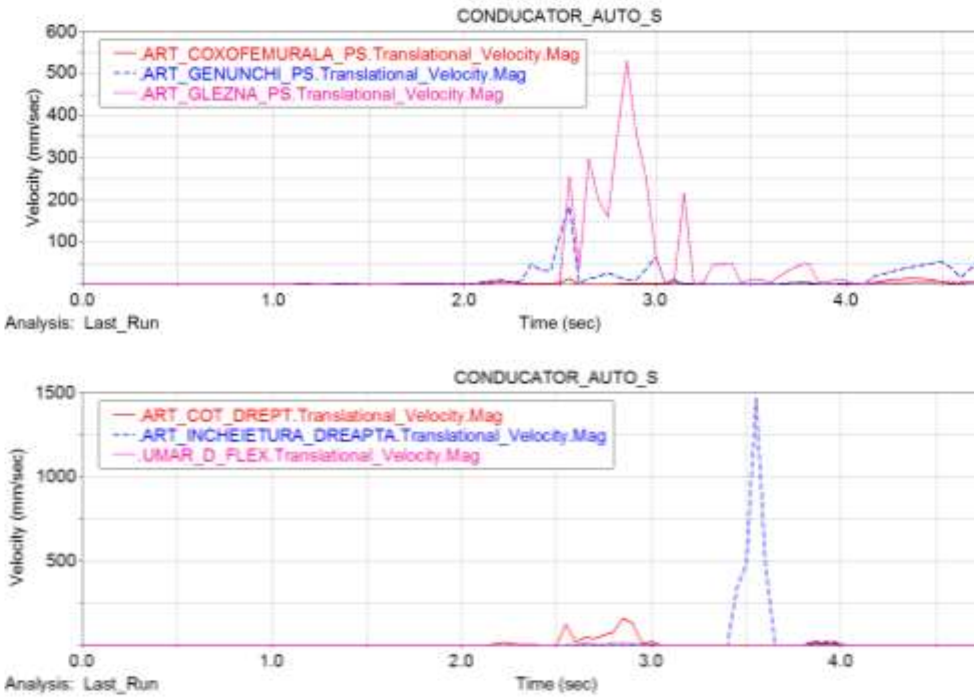


Figure 5. Linear Velocities of the Driver's Joints

• the angular velocities of the kinematic elements at the bottom behave like a connecting rod-crank mechanism (the angular velocities are realized at the same time) the highest speed is achieved by the ankle due to the small angular variation in a short time;

• in the case of the upper limb flexion - extension of the arm and flexion - extension of the forearm takes place sequentially (angular velocities are achieved at different times), and the angular velocity of the wrist has the highest value, about 2 rad / sec, figure 6.

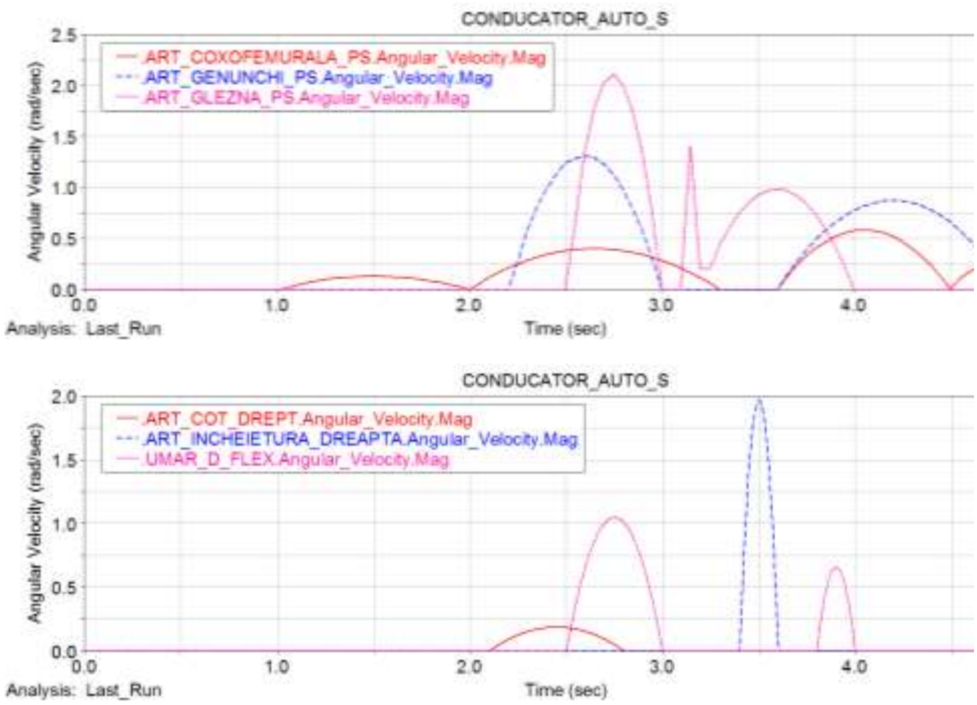


Figure 6. Angular Velocities of Kinematic Torques

It is recommended that Scientific Papers have explicit sections for Abstract, Keywords, Introduction, Related Work, Problem Statement, Concept and Terms, Solution Approach, Analysis of Results, Conclusions, Future Work, Acknowledgement and References.

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

4. Conclusions

For a more accurate modeling of the driver's biomechanical system, we excluded schematic modeling and imported a geometric model composed of 222 elements. The results of the simulation of the multibody model were obtained in the conditions in which the STEP type motion laws were imposed on the joints, and the data were obtained with the help of analog measurements and data provided by the Kinovea system. The multibody model created by the complexity and fidelity with which it was modeled, can be considered a reliable tool in the study of kinematics and dynamics of the driver's biomechanical system.

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References

Amortila, V.; Mereuta, E.; Humelnicu, C. & Gingarasu, M. (2018). Driver's biomechanics influence on air pollution. *International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management*, SGEM, vol. 18, no. 4.3, pp. 251–258.

Drăgulescu D. (2005). *Modelarea în Biomecanică/Modeling in Biomechanics.* Ed. Didactică şi Pedagogică, Bucharest.

Ganea D.; Mereuță C.; Tudoran M. S. & Mereuță, (2011). Experimental method for determining the ground reaction and the orthostatic position. *Annals of "Dunarea de Jos" University of Galati*, Fascicle XV, pp. 27-32.

Ganea, D.; Mereuță, E.; Vereșiu, S.; Rus M. & Amorțilă, V. (2017). Analysis Of Reaction Forces In Human Ankle Joint During Gait. *Matec Web of Conferences 112*, 07019.

Mereuta, E.; Ciubucciu-Ionete, L.G. & Tudoran M.S. (2009). Principles of MBS Analysis in Biomechanics. *The Annals of "Dunărea de Jos" University of Galaţi*, Fascicle XV ISSN 1454-9832, pp. 123-127.

Shabana, A. (2005). *Dynamics of Multibody Systems*. 3rd Edition. Cambridge Univ Press.

Shalom S., et al. (2010). *Cone carving for surface reconstructio. ACM Trans. Graph*., 29(6), 150:1–150:10.

Valero-Cuevas, F. (2003). Towards a realistic biomechanical model of the thumb: the choice of kinematic description may be more critical than the solution method or the variability/uncertainty of musculoskeletal parameters. *Journal of Biomechanics*, vol. 36, no. 7, pp. 1019-1030.