SIMULATION OF HUMAN MOTION, MUSCLE FORCES AND LUMBAR SPINE STRESSES DUE TO WHOLE-BODY-VIBRATION: APPLICATION OF THE DYNAMIC HUMAN MODEL CASIMIR FOR THE DEVELOPMENT OF COMMERCIAL VEHICLES AND PASSENGER CARS

Steffen Pankoke and Alexander Siefert Wölfel Beratende Ingenieure GmbH + Co., Höchberg, Germany

Introduction: Occupant modeling

In the development of commercial vehicles as well as of passenger cars, the effects of vehicle vibrations on operating safety, health and comfort can only be predicted by numerical simulation when appropriate occupant models are available. Such models must be based on human anatomy and have dynamic properties of real humans in order to achieve realistic results. Since human dynamic behavior depend on posture and percentile, the occupant model needs to be adjustable to these parameters with respect to geometry and dynamic properties [1,2].

Dynamic Human Finite-Element-Model CASIMIR

CASIMIR is a non-linear, dynamic finite-element-model of the human body. It consists of a dynamic model of the upper torso with head, neck, shoulders and arms as well as of a dynamic model of the lower extremity with pelvis and legs. The most important part is the lumbar area with dynamic non-linear models of the lumbar spine and of back and abdominal musculature. The frequency-dependent characteristics of the intervertebral discs and the effects of muscle activation and non-linear frequency-dependent muscle properties are included. In the latest stage of development, CASIMIR has been equipped with a compliant model of the body surface in the contact areas to the seat. This results in a very realistic transmission of static and vibrational forces into the human body, see fig. 1. Intense model verification and validation has been performed in all stages of model development, starting with validation of small components like intervertebral disc, ending with validation of whole-body-vibrations using measurements of the dynamic mass / mechanical impedance [4]. For an in-detail examination of stresses in the vertebral bodies and discs, a non-linear submodel of the lumbar spine with an increased number of degrees of freedom can be coupled to the whole-body-model, enabling the researcher to examine local effects of vibrations and single shocks on the lumbar materials.







Fig. 2: CASIMIR f05, m50, m95

Since it is well known that human dynamic behavior is significantly affected by anthropometric data and posture, CASIMIR can be individualized to the anthropometric status of single individuals or to the mean values for specific percentile groups. Furthermore, posture can be adjusted to the seating conditions applicable to a specific vehicle. Posture modification capabilities include the variation of the lumbar lordosis [3].

Static Seating: Muscle Activation and Static Forces in the Lumbar Spine

Due to non-linearities of human body and seat a qualified simulation of the static seating procedure is a prerequisite of any simulation of dynamic responses of the human body and seat. During static seating simulation, the human model takes the desired posture on the seat, muscles are activated in order to maintain this posture and thus the non-linear biomaterials of the human body as well as the non-linear foam materials in common seats of commercial vehicles and passenger cars are loaded in an appropriate trim point. This ensures automatic selection of the correct tangent stiffness for the succeeding vibration analysis. A static seating simulation gives a number of valuable results with respect to the human body:

- muscle activation / muscle forces: ergonomic judgment of the body posture
- static forces and static stresses: relevant for damage in the vertebral discs
- pressure distribution (comfort, fig. 3) and H-point-location (package, safety)

Multiaxial Dynamic Excitation: Motions, Forces and Stresses

After static seating simulation, dynamic excitations in multiple axes (x,y,z) can be applied on the human model or the model of the occupied seat (seat + human). Usually, an excitation is selected that is typical for the seat slide (or the seat surface) of the specific vehicle under investigation. For commercial vehicles with higher amplitudes of excitation, a non-linear solution procedure has to be applied while comfort simulations may be covered with linearised procedures. Results to be analysed are motions of the body with respect to operational safety of commercial vehicles, dynamic forces in the musculature with respect to operational performance and dynamic forces / stresses (with submodel) in the lumbar spine with respect to health, fig. 4.



Fig. 3: Static seat pressure



References

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