Simulation of the Interaction between Driver and Seat

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Received December 20, 2012; revised August 13, 2013; accepted September 5, 2013

Abstract: Test is one of methods to acquire human-seat pressure distribution in driving, with the deficiency of being uneasy to obtain the stress information of soft tissue inside human body and the sheer force of interface between human and seat, which can be obtained by simulation. But current simulation method focuses mainly on calculation itself other than combining it with posture prediction and cab packaging parameters, which cause it difficult to acquire accurate pressure calculation results without accurate posture of human body, and make it almost meaningless to design optimization. Therefore, a human body geometric model with posture change capability is built and linked up with Cascade Prediction Model (CPM), which takes cab packaging parameters as inputs. A detailed finite element model of driver human body is constructed and used to conduct the driver-seat interaction simulation between human body and seat. Good accordance of pressure distribution is observed between simulation and test, which validates the simulation. In addition to the distribution pattern, curves on key sections are used to analyze the pressure and shear stress on the seat surface, as well as soft tissue stress inside human body. The simulation shows that the maximum stress of buttocks locates under the ischial tuberosity, and the maximum stress of trunk occurs near the scapula posterior and the lower waist. These are the places where fatigue usually occurs. The maximum pressure of seat appears at the driver-seat contact area corresponding to the driver’s maximum skin tissue stress. In order to guide the seat design and cab packaging and study the influence of posture to pressure distribution, finite element models for different levels of cab packaging parameters are created by using CPM. The pressure distributions are calculated and their tendencies varying with cab packaging parameters are obtained. The method presented provides a new way to accurately simulate the interaction between driver human body and seat, and to guide the seat design and cab packaging so as to improve seating comfort.

Key words: seating comfort, pressure distribution, posture prediction model, packaging parameters

1 Introduction

The car seat is the most important man-machine interface, which influences seating comfort and driving safety directly[1]. Many experiment studies(such as PARK, GYI, MILIVOJEVICH, INAGAKI, HARTUNG, MERGL, VOS, ZHANG, VINCENT, et al) [2–11] have found that significant correlations exist between driver-seat pressure distribution characteristics and seating comfort. Therefore, pressure distribution of driver-seat interface is increasingly used in the evaluation of seating and seat comfort.

Pressure distribution between driver and seat can be acquired by test or by simulation. For pressure distribution test, the major deficiency is that it is almost impossible to obtain the information about the level of muscular load, subcutaneous tissue stress and the shear force between human and seat. These information have strong influences on comfort feeling and should not be ignored in practical applications. In order to acquire these information for in-depth study of seating comfort mechanism and to overcome the deficiencies of the test, researchers developed finite element models of human body and body parts to simulate the interaction of human body and seat[12–18]. CHOI, et al[12–13], developed a full occupant finite element model (PAM-Comfort model) with deformable tissues to assess seating comfort and to analyze the sensitivity of pressure distribution and cab packaging parameters. Aim at making human models scalable and can be located easily, BIDAL, et al[14], developed M-COMFORT based on HUMOS 2 human model. In CHENG’s study, key problems of finite element modeling of human body were addressed[15]. SIEFERT, et al[16], used a full body finite element model CASIMIR to analyze the static and dynamic characteristics of occupant seat. Different from above simulation method of using full body model, in TANG’s study, a simplified two-dimensional buttock-thigh model was adopted to simulate the mechanical response of buttocks and thigh muscles under vertical vibration[17]. These models were successfully used to calculate the pressure distribution and to get the information that can’t be achieved by test method to some extent.

Realistic pressure distribution simulation studies can not
only overcome the inadequacies of the test study, but also
can reasonably and effectively guide seat design and cab
packaging in the design phase, and can effectively analyze
physical response of seating and improve seating comfort.
In addition, simulation research of pressure distribution can
help researchers and designers understand the disorder and
lesion mechanism of the drivers’ spine musculoskeletal
system, especially the generation mechanism of sitting
sores of professional drivers. But realistic simulation of
pressure distribution not only depends on accurate
modeling of body shape, structure and material
characteristics, but also depends on correct human posture
and boundary conditions. As for design optimization, it is
important to link up target performance (for example, the
pressure distribution, as a typical measure of physical and
psychological comfort of seating) with design parameters
such as seat parameters and cab parameters, which
influence driver posture and the results of pressure
distribution calculation.

As a part of a series study, the main purpose of this paper
is to establish a detailed, postured driver human body finite
element model, driven by human body anthropometry and
cab packaging parameters, which introduce the posture and
anthropometry factors into the pressure distribution
simulation. Currently the model is mainly used to study
some fundamental problems of pressure distribution
numerical simulation, such as driving posture prediction,
human body and foam materials simulation, boundary
conditions setting, etc., which are very important for
human-seat pressure distribution simulation and comfort
factors identification.

Because different individual has different anthropometry
and driving posture when driving, the differences among
individuals should be reflected in the simulation. Thereby,
it is basic work of this research to establish a model with
posture and anthropometry adjustment capability. The
model used for current study has the body size of 50
percentile Chinese male, but with strong posture adjustment
capability. The scaling and morphing are still under
research for anthropometric accuracy.

## 2 Digital Human modeling

### 2.1 Geometric modeling

Biomechanical systems used for human-seat interface
pressure distribution calculation include the skeleton of
bones, skin, muscle and other soft tissues. Firstly, the
parametric three-dimensional human geometric model was
established according to the structure of human anatomy. In
building such kind of geometric model, several methods
exist at present, including anatomy-based method, 3D
scanner-based method, and digital image-based method etc.
As a typical kind of digital image-based modeling method,
the section-based modeling is usually used for building the
internal body structures, with laborious work and extensive
difficulty to collect large sample of population data. While,
3D scanner-based human modeling can only be used to
build surface model, without the internal structure of bones,
muscles and other soft tissues.

How to achieve human body anthropometric data is not
the main focus here. The human geometric models in Poser
software were used as geometric database of biomechanical
modeling to obtain the geometric information of human
skin, muscle and skeleton, which would be adjusted and
validated to achieve good accordance with human body
dimensions used in this study. To ensure the accuracy, the
model was firstly validated using stature, body mass, and
other major human anthropometry variables. And then
necessary adjustments were made for the body parts with
larger deviations according to the actual size of
corresponding limbs. Geometric modeling results of body
surface and skeletons are shown in Fig. 1.

![Fig. 1. Geometric model of body skin and skeletons](image)

The assembly relationships between skeleton and surface
models were defined according to REED’s research.
Since accurate posture and anthropometry are two key
factors of the pressure distribution simulation, the
geometric model was parameterized to facilitate posture
adjustment and anthropometric scaling. For current study,
the model was assigned with Chinese 50 percentile male
anthropometry data, as listed in Table 1. The reference
point of modeling was defined using the middle point of
left and right hip joint center. Taking this reference point as
the starting point, the human model was positioned and
postured by using the Cascade Prediction Model (CPM).

<table>
<thead>
<tr>
<th>S/(\text{mm})</th>
<th>(m/\text{kg})</th>
<th>(H/\text{mm})</th>
<th>(L_1/\text{mm})</th>
<th>(L_2/\text{mm})</th>
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<tr>
<td>1735</td>
<td>68</td>
<td>890</td>
<td>445</td>
<td>415</td>
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</table>

### 2.2 Biomechanical modeling

Based on above geometric models, the whole body
biomechanics model was established including body
surface, bone and muscle models, with posture adjustment
capability driven by cab packaging parameters. In human
body finite element modeling, to ensure the authenticity of
the simulation, reasonable level of division should be
conducted. The human body model was divided into three