

Virtual Assessment of Occupied Seat Vibration Transmissibility

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ABSTRACT

This paper presents an integrated simulation process which has been performed in order to assess the riding comfort performance of a vehicle seat system virtually.

Present methods of seat comfort design rely on the extensive testing of numerous hardware prototypes. In order to overcome the limitations of this expensive and time-consuming process, and to fasten innovation, simulation-based design has to be used to predict the seat comfort performance very early in the seat design process, leading to a drastic reduction in the number of physical prototypes.

The accurate prediction of the seat transfer function by numerical simulation requires a complete simulation chain, which takes into account the successive stages determining the final seat behaviour when submitted to vibrations.

First the manufacturing stresses inside the cushion, resulting from the trimming process, are computed. Due to the highly non-linear behaviour of the foam material, these stresses modify the behaviour of the foam blocks, when further loaded by the occupant weight.

The pre-stressed seat model is thus used as a starting point to simulate the static seating of a 50th percentile human occupant. This human model includes all body segments, with anatomically precise features such as bones, full spine, ligaments, organs, muscle effects, deformable soft tissues around thighs, hips and trunk. The contact pressure distribution, and the resulting strain and stress distribution throughout the seat, are computed. As the foam dynamic behaviour is highly strain-dependant, the exact strain distribution at the end of the static stage has to be taken into account, to predict a correct behaviour of the foam blocks when further submitted to vibrations.

The resulting, static equilibrium between the seat and the occupant is then used as a starting point to simulate the vibration transmission to the occupant through the seat. A vertical acceleration signal is applied at the basis of the seat. The seat transfer function is computed and compares well with the experimental one.

This integrated simulation process takes into account the detailed seat characteristics and is predictive enough to consider a virtual seat design process for occupied seat vibration transmissibility. This predictiveness will have to be confirmed with other seats analysis.

INTRODUCTION

The avoidance of back disorders is at the heart of the design process for any vehicle seat system. The customer health, comfort, and overall satisfaction, for a professional or a personal use of the vehicle, is strongly related to the capability of the seat to prevent such frequent disorders such as low back pain, often resulting from prolonged driving periods.

Seat design has long been driven by some subjective evaluations of hardware prototypes by a limited number of volunteers. Some efforts have been put recently to improve the objective judgement of an automotive seat from a comfort point of view. A close connection between the static pressure distribution on the seatpan and some discomfort feelings has been established [1,2] and confirmed by in vivo measurements of the pressure in the spinal disc [3].

But the load in the spine induced by the sitting posture is amplified by the vibrations transmitted to the occupant through the seat [4] – particularly the vertical transmissibility at low frequencies (1~20Hz) which are not filtered by the tires or suspensions, and which have to be minimized thanks to proper seat design.

The seat transmissibility is dominated by the dynamic behavior of the springs and of the foam cushion, coupled with the specific eigenfrequencies and modes of the human body.

In parallel to these steps toward discomfort understanding and objectification, numerical simulation has started to be applied to seat comfort design, which has long been relying on the extensive testing of numerous hardware prototypes. The objective is to reduce the development costs and time-to-market drastically, by predicting the seat performance on a digital mock-up and minimizing the number of prototype builds.

For this purpose, a predictive numerical tool, PAM-Comfort, devoted to virtual seat comfort assessment, has been previously developed and validated on various types of seats [5]. This tool enables to accurately predict some comfort-related parameters, including seat pressure distribution and meat-to-metal clearance, before any hardware seat prototype is built.

This aim of the work described in this paper is to validate PAM-Comfort predictiveness for occupied seat vibration transmissibility. As previous works in this field mainly focused on human modeling for such simulations [6,7], this paper focuses on seat modeling, and particularly on the complex foam cushion behavior. Due to this complexity, the accurate prediction of the occupied seat transfer function requires a complete simulation chain, taking into account all the seat components and their interactions, the effects of the trimming process, the detailed, tri-dimensional deflections under the body weight, and the specific, dynamic foam behavior when submitted to vibrations.

When all these phenomena (cushion manufacturing, static seating, vibration loading) are usually handled numerically by a patchwork of separate, non-communicating applications, PAM-Comfort technology enables to chain all these stages, keeping the memory of these successive loadings of the foam, and the history of the cushion, to accurately predict the final seat behavior and transmissibility, providing a complete and coherent tool for seat design.

This paper describes the full chain used for the virtual assessment of the occupied seat vibration transmissibility. First, the trimming process is simulated. It provides the manufacturing stresses inside the cushion along with some trimming parameters (foam overbuilds). Due to material non-linearities, the manufacturing stresses modify the foam block behavior when loaded by the occupant.

This pre-stressed seat model is then used as a starting point to simulate the static seating of a 50th percentile, deformable human occupant. The contact

pressure distribution and the strain distribution throughout the seat are computed, in addition to some other helpful indications for comfort (meat-to-metal clearance). As the foam dynamic behaviour highly depends on strains, the strain distribution at the end of the static stage determines the foam block behavior when submitted to vibrations.

The static equilibrium between the seat and the occupant is then used as a starting point to simulate the vibration transmission to the occupant. A vertical acceleration signal is applied at the basis of the seat, and the occupied seat transfer function is computed.

TRIMMED SEAT MODELING

The seat used for this study is the one of a middle-class BMW vehicle. A complete description of the seat and of its finite element model is given in [5].



Fig.1: BMW vehicle seat (left) and finite element model (right)

In addition to the metallic frame and the deformable suspensions, all the details of the cushion and the backrest are modelled, including: the different foam and trim types, the seam lines and trim attachment system, the padding layers of different thicknesses, the backing material, and the contact interfaces between all seat components. As it has been found that the friction phenomena between the padding and the foam, and between the foam and the suspensions, influence the results, all these contact interfaces include non-linearities and friction modeling. All material parameters were determined through preliminary tests by the laboratories of the BMW Group on foam or cover samples.

Starting from the Seat Trim Outline (STO), the foam A-surface, with overbuilds (Fig. 2), is first computed,