Overcoming Interior Design Challenges to Improve the Comfort of Future Vehicles

Jérôme REGNAULT[1], Caroline BOROT[1*], Christian MARCA[1]

[1]ESI Group, France

*Corresponding author: Tel +33(0)4 42 97 65 30; fax +33 4 42 97 65 39

Abstract The automotive industry is experiencing a major transformation driven by societal and environmental trends leading to an acceleration of autonomous driving, electrification and new mobility solutions. Therefore, car manufacturers and OEMs are facing new challenges to make vehicles more comfortable and personalized. Indeed, they need to provide solutions for vehicle of the future respecting standards and certifications without physical prototypes while optimizing time and costs development.

The main purpose of ESI interior solution is to use virtual prototypes based on a single core model enabling to test static, thermal and acoustic comfort of passengers in any position inside the cabin while minimizing energy consumption of vehicle and this at the early stage of interior and seat development process. This paper presents the approach that is used to virtually test new innovative equipment inside a vehicle interior.

1 Introduction

Mobility is fast evolving. In recent years, we have rethought car usage to fit multiple usages supporting environmental and societal welfare, from car sharing to electric, hybrid vehicles and autonomous cars. Automotive interior engineers must reinvent cabin design, without ever compromising occupant comfort.

Different use cases are emerging to allow both driver and passengers to interact differently, which can greatly impact the interior layout. Interior design and engineering teams must deliver new and innovative cabin designs and control their impact on various in-car systems. Teams need to iterate quickly and work towards optimum solutions on several scenarios without impacting the final delivery schedule.

With the prohibitive cost of hardware prototyping and associated delays, simulation is the key to help engineering teams face these new challenges. To meet expectations, ESI proposes a Virtual prototyping solution for seats and interiors applicable from the early stage of the development cycle. Engineering teams test occupant static, dynamic, thermal, and acoustic comfort.

2 Static Comfort of Car Occupants

Many challenges dealing with the advent of autonomous vehicles concern static comfort of passengers. Lots of automotive manufacturers and suppliers will integrate seats enabling to change inclination. This option will permit to switch from a usual to a lying position. Moreover, the interior layout could be changed during journey. It will be possible to be face to face or to be in a classical disposition. Finally, with the democratization of car sharing, comfort must be more and more individualized.

Usually, companies use human volunteers and analyze pressure map distribution to test and certify all parameters linked to static comfort. However, these technics have several drawbacks. Indeed, seats must be adapted to several anthropometries. Moreover, results depend also on the volunteer’s mood. Finally, it is necessary to build a seat model. As it comes late in the development process, if seat does not deliver right performances, modifying design at this stage could require costly countermeasures and associated delays.

1.1 *Lying position*

1.1.1 Pressure map distribution

Using a set of scalable comfort human models, included in Interior Solution, makes it possible to estimate the seat comfort performance through pressure mapping with integrated and customizable comfort criteria. Discomfort can thus be evaluated for several anthropometries and variants of seats can be easily compared.

We have done a static comfort test with a dummy in a lying position (Figure 1). The aim of this study was to compare influence of inclination on static comfort.

Fig. 1. Lying Position

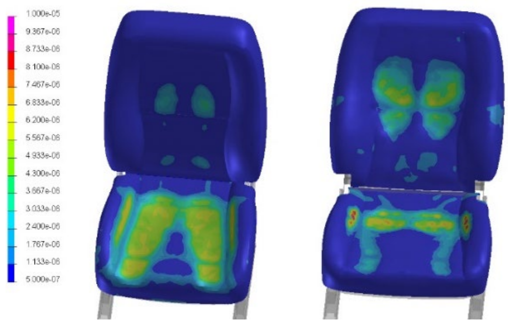

Fig. 2. Pressure map distribution. On the left in usual position, On the right in lying position

We can observe (Figure 2) that there are two pressure pics on backrest in lying position. Engineers have new issues on backrest and must reinforce backrest.

1.1.2 Virtual Seat Model

To ensure a right level of static comfort, it is necessary to create a very realistic seat model, as it interacts directly with the occupant, representing a behavior close to a real one: it contains all the seat components: frame, suspensions, foam blocks, heating pads, cover and padding with related attachment systems. The frame is considered as rigid since the model will be used only for seating and thermal simulations, but all other components are deformable and connected with each other through joints and contacts. This modelling method has been extensively validated through comparison between simulations and real tests regarding pressure distribution measurements. [1] [2] [3]

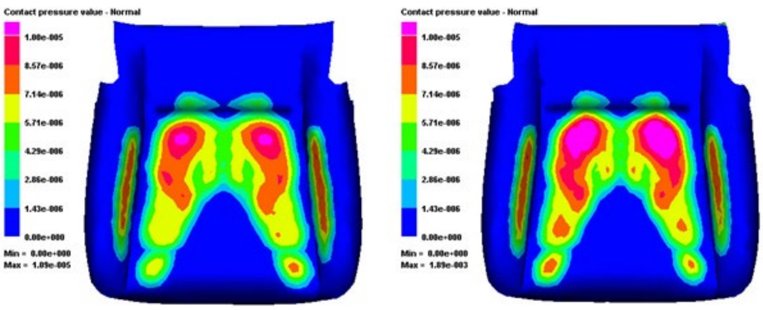

Fig. 3. Pressure map distribution. On the left without manufacturing effects, On the right with manufacturing effects

1.1 Individualized Comfort

1.1.3 Human Model

To deliver accurate results and enable individualized comfort, ESI has a complete library of humans developed specifically for comfort evaluation. They have deformable flesh and are fully articulated, and they correspond to real people that have been scanned. Several anthropometries are available and also overweight, elderly and disable population.

Fig. 4. ESI's human models library

1.1.4 Optimal Seating Experience

Lots of companies want to design an innovative seat concept maximizing comfort and reduce muscular fatigue, while improving the posture of the occupant. To create such new concept, including an innovative air bladders system used to promote good posture for each occupant morphology, it is necessary to use innovative simulation tools. They have created a system controlled by an app enabling auto adjustment of the bladders in the seat based on sensor data and personal settings. They used Interior Solution to model the inflation of the bladders and predicted how the bladders affect the posture of the occupant. By simulating the inflation of the bladders and the impact on the occupant's posture, Lear was able to optimize their seat concept. [4]

Fig. 5. LEAR Seat Prototype

2 Thermal Comfort

Many changes concern also the thermal management. Indeed, because of seat's orientation, the usual climate system as well as some thermal equipment will be not able to provide a right level of thermal comfort. Moreover, with the advent of electric vehicles, it is necessary to reduce energy consumption of thermal system to improve autonomy.

2.1 Individualized Comfort

2.1.1 Virtual Seat Model

As conduction depends on several mechanical phenomena, it is important for having accurate prediction of the thermal exchange, to consider all these phenomena during simulation. First the conduction between the seat and the occupant depends on the surface of contact between the human and the seat, but also on the distance between the human and the seat. The conductivity is also dependent on the strain conditions. So, to obtain accurate results through simulation, it is very important to perform a good seating simulation which will correctly predict the contact area between seat and human, the seat deformation and the associated mechanical interaction between the seat and the occupant.

The model includes heating pads on the seat which is deformable and connected to the other components. A thermostat rules has been integrated to on/off heating pads and fans to reproduce several scenarios. [5]

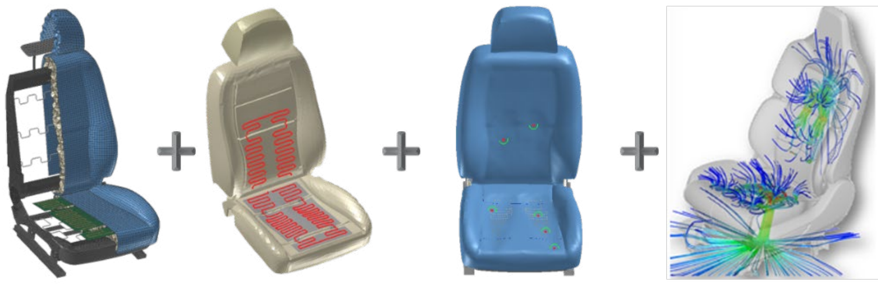

Fig. 6. ESI's seat model

2.1.2 Human Models

The human body can be considered as the combination of 2 thermal systems: A passive system and an active system. The active system models the conduction, blood circulation convection and radiation with the environment. The thermoregulation reflects the thermal response of the human body.

Thanks to these detailed models, we can have access to data that can give us at the end the levels of thermal sensation and comfort. The sensation range between -4 and +4 from a very cold to a very hot temperature. [6]

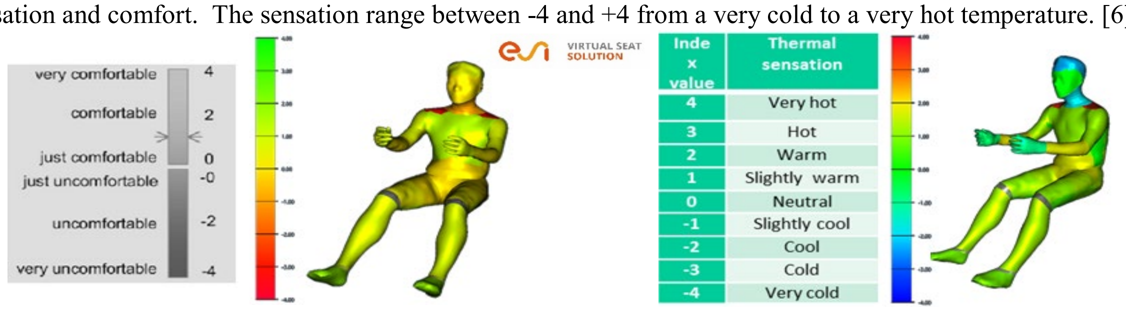

Fig. 7. Thermal score

2.2 Manage different positions of the seat

In real conditions, air blows, air temperature and thermal management can fluctuate. For this reason, air dynamics are simulated using CFD techniques. It enables to make sure that the exchanges between air and human, or between air and seat are accurate. This resolution is transient, and computes simultaneously heat exchanges within and between all domains, making results more accurate.

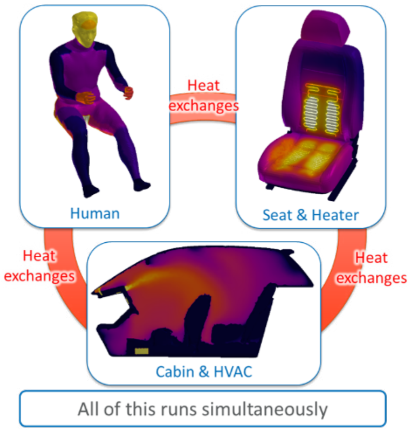

Fig. 8. Coupling Process

2.3 Energy consumption

To minimize HVAC energy consumption in cold weather, it is possible to decrease the global car cabin temperature and add a seat heating system to compensate and maintain the thermal comfort of the occupant. Simulation can be used to test such scenario and find an optimum thermal management system.

An active heating seat could contribute in keeping the same level of comfort for the occupant without having to increase the overall car cabin temperature. A study was focused on the improvement of local thermal comfort in the lower abdomen area, by activating a heating pad system in the virtual seat prototype. The heating pad was piloted by a thermostat, used to control heating cycles (the on/off status) and maintained the temperature between two limit values. The heating pad staid ON until the seat has reached the maximum prescribed temperature and it was then turned off until the seat temperature was lower than the minimum temperature limit.

The use of virtual seat prototyping with digital human model helps finding the solution to reduce the cabin temperature (in this case of 3°C), without decreasing thermal comfort of the occupant. Such solution will contribute to reduce the car energy consumption and thus the range of electric car vehicle. Applied on a car such as the Nissan Leaf, it can be calculated that:

- In cold weather, by activating the HVAC to maintain the car cabin temperature, the EV car loses more than 40 % of its autonomy, which is equivalent to 1 kWh.
- On the other hand, a standard heating pad with electric power of 40 W will consume 80 Wh in 2 hours, thus much less than the saving performed with the cabin global temperature diminution.

This means that the car energy consumption by the HVAC system in electrical vehicles can be reduced and the vehicle range increased, all this without any thermal discomfort.

3 Acoustic Comfort

Problematic: Electric vehicle noise +Sound Zone

Audio personalized space is becoming more and more important in modern vehicles representing new challenges for acoustic designers. Car sharing, for example, contributes to reduced air pollution by optimizing the number of rides and results in strangers sharing the same space, with a clear need to preserve privacy. Soon the deployment of the autonomous car will become increasingly popular, approved by governments and accepted by drivers. In this context the driver will not be fully focused on driving the vehicle, resulting in perceived noise previously largely ignored becoming more annoying. Another important consideration is that customized audio and video streaming will become more accessible, making online services available from personal or car devices available during the journey. Classic noise reduction techniques that rely mainly on passive systems, such as noise control treatments or structural countermeasures to control noise sources are not suitable to create a personalized sound area for each car occupant. Active Noise Cancellation systems (ANC) have been widely studied and developed in the last two decades to generate anti-noise from speaker locations to ensure the minimum noise level for vehicle occupants. Simulation can help in the design and validation process of an ANC reducing the number of protypes and complementing the testing phase.

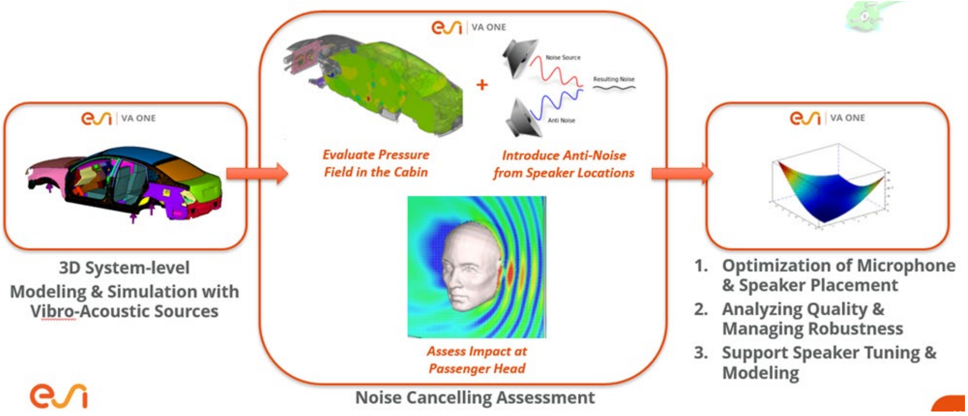

Fig. 9. Noise cancelling Assessment

In the ANC simulation process a full frequency 3D car model is developed using different techniques depending on the frequency range of interest (FE, BE, Ray-tracing). The sound pressure level in the cabin is predicted and combined with the effect of placing anti-noise speakers that minimize noise at the passenger headspace. An optimization process is used to evaluate optimal control microphones positions and speaker locations.A typical outcome of an ANC simulation process using realistic noise sources is a prediction of the expected noise reduction within a designated 'Sound Bubble'. This can present some concerns, as adjacent passengers can be subject to unwanted anti-noise.

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