# COMFORT DESIGN AND ANALYSIS OF DRIVER CAR SEAT USING FINITE ELEMENT ANALYSIS

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**Abstract** – *The work aims to analyze and optimize the comfort of driver car seat by examining the role of four factors such as foam hardness, suspension wires, number of wires and the position of the wires. A simulation study was conducted for 16 different combinations by varying the foam hardness, wire diameter, wire position and number of wires using finite element analysis. Virtual model preparation was done using ABAQUS and simulation test was conducted with the help of 95th percentile dummy (manikin). Further the results of the simulation test were analyzed using design of experiments which helped in determining the best possible combination. The primary objective of the project was to achieve the target H-point specified by the Original Equipment Manufacturers (OEM) which intern resulted in achieving the expected comfort level of the customer.*

**Key Words: simulation, virtual model, ABAQUS, 95$^{th}$ Percentile dummy, H-Point.**

## 1. INTRODUCTION

Seats are one of the most important and essential components of vehicles. Seating comfort is a major concern for drivers and other passengers as they are exposed to extended periods of sitting. As a result of which the customer's expectations for comfort in automobile seats is rising continuously. The Automotive seat design has always been a challenge for design engineers as design parameters are complex and increasing on daily basis [1] [2].

The choice of a passenger automobile depends on various factors, such as the type of vehicle, brand, its performance, interior space and design, trend, other features offered, etc. The manufacturers of vehicles have to quickly respond to market requirements and offer seats with higher quality and comfort [2].

When it comes to designing a car seat, it is very important to meet several requirements of Original Equipment Manufacturers (OEM). Driver's position is defined by several measures such as eyellipse, H-point etc.Eyellipse, which represent the field of vision and is the basis for defining the H-point. The point of intersection of the torso line and thigh line defines the H-point or hip point [3].

Automotive seats are usually constructed from metallic frames covered by foam. Cushions, backrests, headrests, armrests, and other foam parts that make up a vehicle seat are designed according to four principal criteria: integration within the vehicle, safety, aesthetics, and comfort. The design of seat back and cushion frame, however, is primarily based on safety requirements which dictate structural strength and stiffness targets [4].

The automobile seat manufacturers usually make prototypes for testing the comfort in order to achieve the desired output. This testing with prototypes proves to be costly and time consuming process. Application of modern-day software packages for virtual modeling of vehicle seat, as well as software products for simulation of processes reduces the time for testing of the new product. Hence contemporary testing of new vehicles starts with virtual testing of virtual models, using virtual humans (manikin) [5].

A valuable tool for facilitating and shortening the complex design process is numerical simulation using Finite Element Analysis (FEA). FEA is accepted across a wide range of industries as a crucial tool for product design and optimization. When designing car seats, most of the variables have to be considered related to either geometry or materials. Modeling the seats in a virtual environment integrates Computer Aided Drawing (CAD) with material databases and allows the input and evaluation of a variety of loads and stresses without the time constraints of reality testing. FEA can predict the response of a particular design under specific circumstances and supply data that can be used to optimize geometry and materials [6].

## 2. METHODOLOGY

The various ergonomics and human factors were studied when an occupant comes in contact with the seat structure. Suitable factorial design was chosen based on factors and their levels which affect the comfort of car seat [7]. The next step involved the preparation of the virtual car seat model using ABAQUS simulation software as per the dimensions of design team and also the manikin positioning was done with respect to the seating position. Further, the load case was defined and the material properties were assigned to the seat model. A finite element analysis was conducted and simulated. H-point of each experimental run was obtained. With the help of design of experiments, the optimum combination of levels and interaction effects of factors were determined. The Fig.1 shows the flow diagram of the methodology.

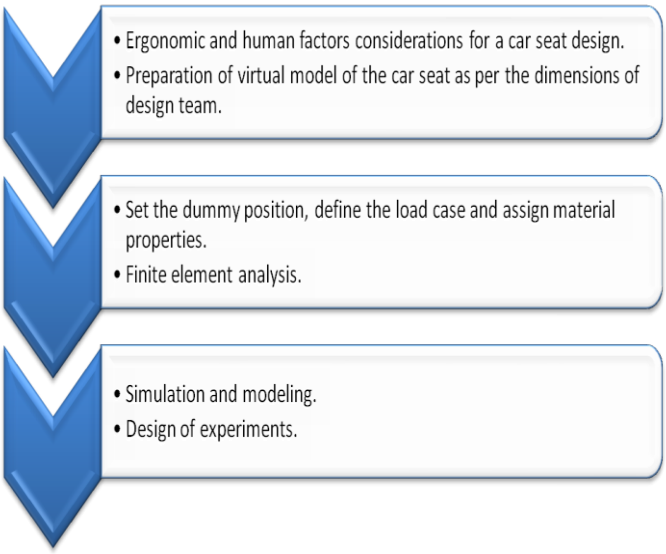


**Fig.1:** Flow diagram of methodology.

## 3. FACTORS AND LEVELS

For the comfort design of a car seat the hardness of foam and suspension wire parameters play a crucial role. In this work, four factors each with two discrete possible values or levels were considered. Available foam hardness values are 4.5 kPa and 5 kPa, suspension wire diameters of 5mm and 6mm, 2 and 3 wires each in back and cushion, and the wire was positioned in upper and lower regions of back and cushion. These factors and levels are shown in Table 1.

Table 1: Factors and levels

| Factors | Level 1 | Level 2 |
|---|---|---|
| Foam hardness(kPa) | 4.5 | 5 |
| Wire diameter(mm) | 5 | 6 |
| Number of wires | 2 | 3 |
| Wire position | up | down |

### 3.1 Multilevel factorial design

The Table 2 shows the randomized physical layout of simulation obtained from the MINITAB software for the four factors and two levels.

## 4. MANIKIN SPECIFICATIONS

A Manikin is a virtual model which resembles a human being. During comfort analysis it is very important to locate the manikin in accurate position with respect to the seat structure, as it defines the H-point and torso angle. There are three different types of manikins available, they are 95$^{th}$ percentile which resembles an adult man, 50$^{th}$ percentile which resembles an adult women and 5$^{th}$ percentile dummy which resembles a teenager. The data shown below were obtained by positioning the manikin on the seat. These specifications of the manikin were used to carry out the simulation test. The mechanical properties of the materials used for seat is shown in Table 3. The 95$^{th}$ percentile manikin and model of car seat are shown in Fig.2 and Fig.3 respectively.

- Type of manikin = 95$^{th}$ percentile (Adult man)
- Test procedure=SAE J826
- Heel point = x=1556.790, y=-390.500, z=495.008
- Back angle=14 degree
- Foot angle =58 degree
- Knee angle=101degree
- Hip angle=85 degree

Table 2: Randomized physical layout of experimentation

| Run order | Foam hardness (kPa) | Wire diameter (mm) | Number of wires | Wire position |
|---|---|---|---|---|
| 1 | 4.5 | 6 | 2 | Up |
| 2 | 4.5 | 5 | 2 | Up |
| 3 | 4.5 | 5 | 2 | Down |
| 4 | 5 | 6 | 2 | Up |
| 5 | 5 | 6 | 3 | Down |
| 6 | 5 | 5 | 3 | Up |
| 7 | 5 | 6 | 2 | Down |
| 8 | 4.5 | 6 | 2 | Down |
| 9 | 5 | 5 | 3 | Down |
| 10 | 5 | 5 | 2 | Up |
| 11 | 4.5 | 5 | 3 | Down |
| 12 | 5 | 6 | 3 | Up |
| 13 | 4.5 | 5 | 3 | Up |
| 14 | 5 | 5 | 2 | Down |
| 15 | 4.5 | 6 | 3 | Down |
| 16 | 4.5 | 6 | 3 | Up |

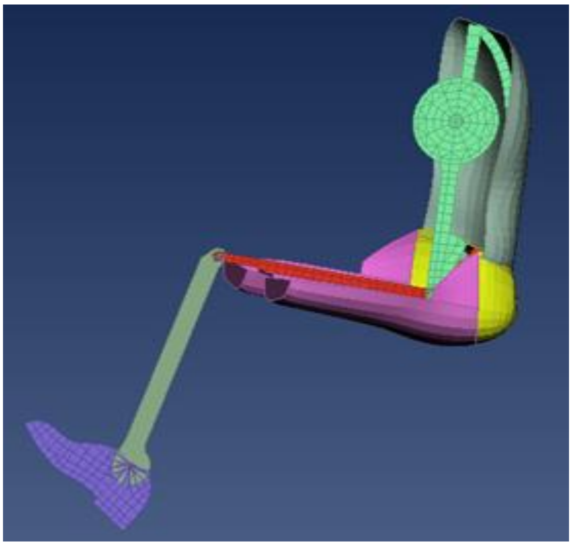

**Fig.2:** 95th percentile manikin used for simulation test

Table 3: Mechanical properties of materials

| Part | Material type | Poisson ratio | Young's modulus (GPa) |
|---|---|---|---|
| Foam | PU material | 0.40 | 0.5 |
| Suspension Wires | steel | 0.30 | 210 |
| Trim | leather | 0.46 | 1.5 |
| Structure | steel | 0.30 | 210 |
| Side members | plastic | 0.42 | 2.6 |
| Back panel | steel | 0.30 | 210 |
| Cushion pan | steel | 0.30 | 210 |

## 5. FINITE ELEMENT ANALYSIS OF CAR SEAT

Finite element analysis was carried out using ABAQUS Simulation software. It is a tool used for virtually calculating the H-point for given foam and seat structure. The simulated model for the experimental run order 5 is shown in Fig.4. The finite element analysis and simulation for 16 different combinations of randomized run order resulted in obtaining 16 response values in x, y, z co-ordinates. The response, H-point, obtained from the simulation test is shown in Table 4.

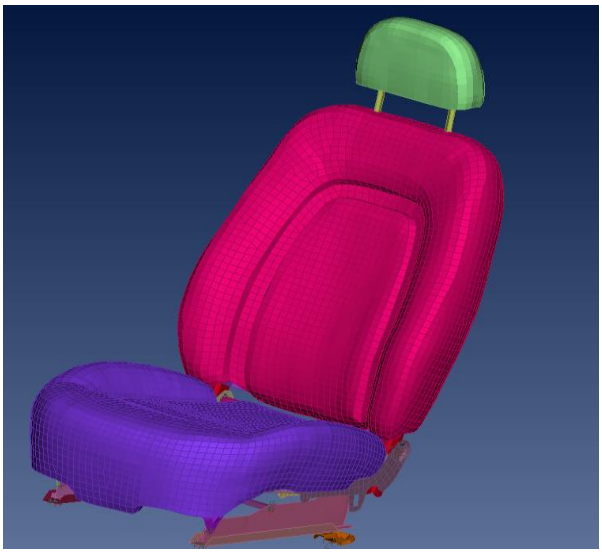

**Fig.3:** Model of car seat.

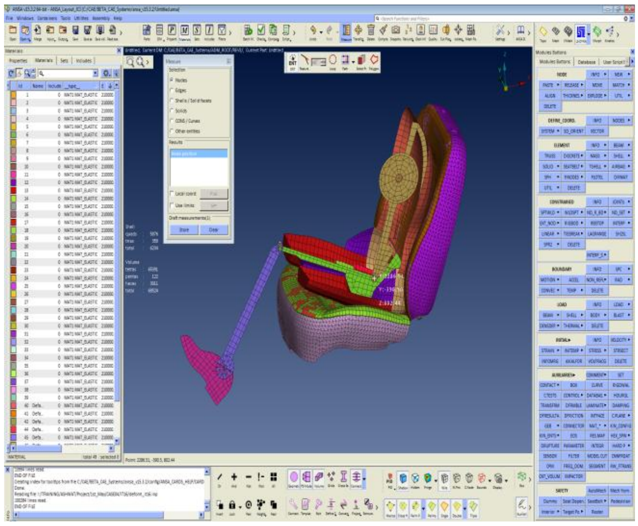

**Fig.4:** Simulated model of car seat.

## 6. TARGET H-POINT

The target H-point values are as specified by the OEM which is given below along with the tolerance limit. The primary aim of this work is to achieve target H-point by finding the optimum combination of foam hardness, wire diameter, wire position and number of wires in order to reach the comfort level of the occupant.

**H-point:**

Target X=2286.00 mm

Target Y=-390.00 mm

Target Z=802.00 mm

**Tolerance limit =+2 mm and -2mm**

Table 4: Simulation Run Results

| Run order | Response X(mm) | Response Y(mm) | Response Z(mm) |
|---|---|---|---|
| 1 | 2286.23 | -390.53 | 796.773 |
| 2 | 2284.90 | -390.53 | 794.856 |
| 3 | 2285.40 | -390.53 | 793.727 |
| 4 | 2287.63 | -390.53 | 798.934 |
| 5 | 2286.51 | -390.53 | 802.440 |
| 6 | 2285.23 | -390.53 | 800.368 |
| 7 | 2288.09 | -390.53 | 798.871 |
| 8 | 2278.36 | -390.53 | 814.416 |
| 9 | 2285.53 | -390.53 | 800.676 |
| 10 | 2283.80 | -390.53 | 796.909 |
| 11 | 2286.11 | -390.53 | 797.464 |
| 12 | 2284.13 | -390.53 | 801.932 |
| 13 | 2283.88 | -390.53 | 798.158 |
| 14 | 2287.03 | -390.53 | 799.953 |
| 15 | 2289.28 | -390.53 | 792.184 |
| 16 | 2279.53 | -390.53 | 810.915 |

## 7. RESULTS AND DISCUSSIONS

The simulation results were further analyzed with the help of design of experiments in order to determine the optimum combination.

### 7.1 Scatter plot

The Fig.5 shows the scatter plot of H-position-X versus H-position-Z. The X-axis of the plots represents the H-point values for X-coordinates and Y-axis of the plots represents the H-point values for Z-coordinates. The various points on the scatter plot represent the simulation run order result values for 16 different combinations. The plot shows that the run order 5, 6, 9, and 12 are lying within the tolerance limit of target H-point values. Among these H-point values run order 5 is close to target H-point values.

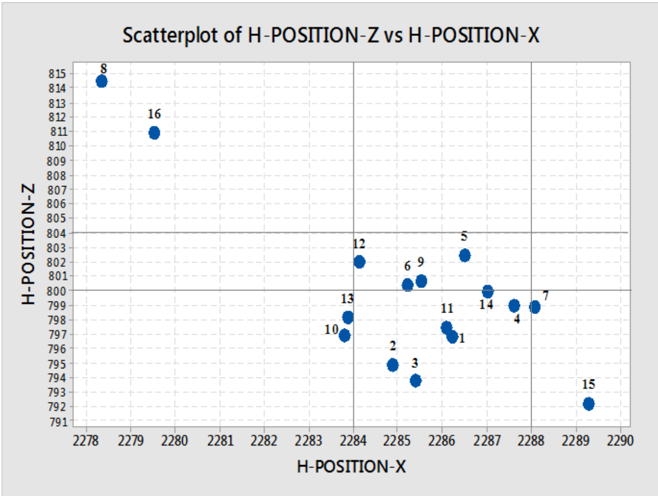


**Fig.5:** Scatter plot diagram of H-position-Z versus H-position-X

### 7.2 Main Effects plots

The main effects plots are used to determine the differences between level means for one or more factors. There is a main effect when different levels of a factor affect the response differently. The Fig.6 and Fig.7 show the main effects plots of H-position-X and H-position-Z respectively. The main effects plot of H-position-X shows that the foam hardness and wire position are playing a critical role in back whereas the wire diameter and number of wires do not play any role. Similarly the main effect plots of H-position-Z shows that the wire diameter is playing a major role in the cushion of the seat structure whereas the other three factors are not playing a significant role.

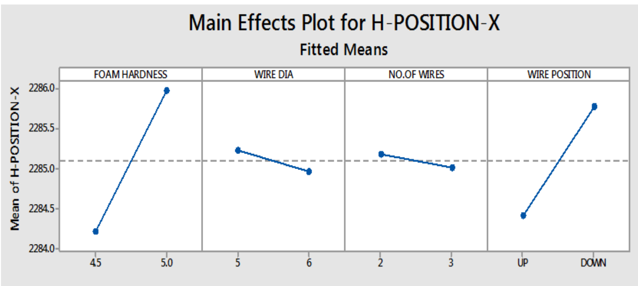


**Fig.6:** main effects plot of H-position-X

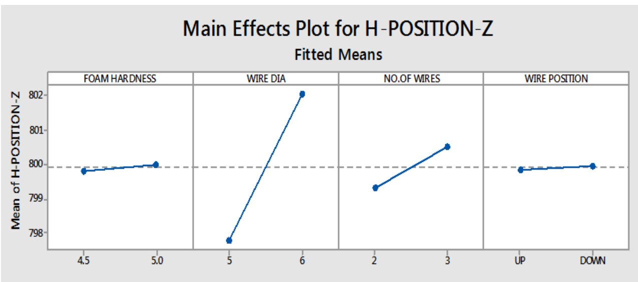


**Fig.7:** main effects plot of H-position-Z

### 7.3 Interaction plots

An interaction plot shows the relationship between one categorical factor and a continuous response depends on the value of the second categorical factor. The Fig.8 and Fig.9 shows the interaction plots of H-position-X and H-position-Z respectively. This interaction plot of H-position-X indicates that there is an interaction between foam hardness and wire diameter, foam hardness and number of wires, number of wires and wire position and hence these factors play a vital role in obtaining the target H-point whereas the other three combinations are found to be parallel to each other which means there is no interaction.

The interaction plot of H-position-Z shows that there is a major interaction between number of wires and wire position whereas the other combinations are having a minor interactions and do not play a significant role.


**Fig.8:** Interaction plot of H-position-X

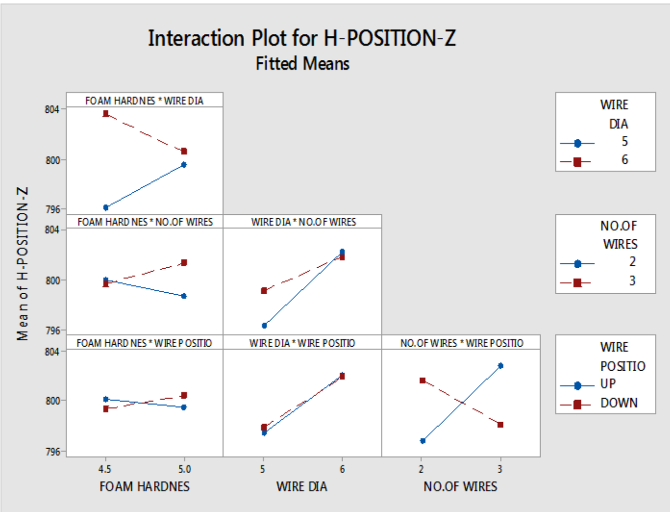


**Fig.9:** Interaction plot of H-position-Z

## 8. CONCLUSION

On conducting simulation test and design of experiments for comfort car seat design, it was found that the combination of 5 kPa foam hardness, 6 mm wire diameter, 3 wires and lower position of the wire was found to be optimum which in turn has resulted in better stiffness of back and cushion foam. This combination has resulted in achieving the target H-point specified by original equipment manufacturers. Foam hardness, wire diameter and wire position are contributing significantly, and there is also interaction among these factors, whereas number of wires is not playing a significant role.

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