*Research Article*

# Development of Air Driver Seat for Use in M3/N3 Class Vehicles

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## Abstract

*At the present time, due to the high density of the population and the increase in traffic problems, the extend of the time spent on the road often forces people to prefer public transportation. It is most important to ensure the safety of the passenger in the vehicle. In order to achieve this, it is necessary to ensure the health, safety and comfort of the vehicle driver as a priority. Especially in long distance transportation, it is important to increase the time spent on the road, the correct driving position of the driver and the movements suitable for ergonomics are important in terms of not losing the workforce. Health and risk are always associated with occupational diseases. Vehicle drivers are at high risk for discomfort from long term sitting positions and vehicle vibration. In this study, a design that will improve ease of use, ergonomics and comfort for bus and truck drivers has been developed within the scope of ISO 16121-1:2012 directive for M3/N3 class vehicles. Dynamic and static load vibration analysis simulation (FAE) was applied with the ANSYS program on the CAD drawings of the developed driver's seat. Revisions were made according to the inconsistencies encountered in the vibration analysis simulations performed under dynamic load and the analysis was repeated. Prototype production was carried out to ensure the accuracy of the design. The works for the vibration tests, which will correspond to the bad road test equivalent to 1,000,000 kilometers over the prototype, are continuing. All other validation tests were applied to the prototype produced driver's seat and positive results were obtained.*

**Keywords:** Driver seat design, Ergonomi, Finite element analysis (FEA), Vibration tests

## 1. Introduction

Vehicle manufacturers design their vehicles according to consumer demands. In some cases, although these demands may differ visually, safety, functionality, comfort, performance and cost are among the most important demands. Consumers prefer products that can best meet these demands. Seat comfort is of extra importance for drivers and passengers. After the 70s, the development of seat has increased rapidly. At the present time, driver seats have a lifespan of approximately 900,000 km, depending on the strength of the vehicle and the weight of the driver. A new seat system, which can be adjusted according to the driver's weight and height, has been developed in order to support the spine with the supports in the waist part and to alleviate the loads on the hips and legs with the inclination and depth movements of the seat. Suspensions, damper and air bellows in the suspension are other equipment that provide comfort in the driver's seats (Pişgin, 2018). Due to the different weights of vehicle drivers, many anthropological studies have been carried out. Various riders' measurements such as arm, shoulder, seat height, back height, weight, hip width were taken and pressure maps were created to determine sponge density. Based on these, he developed designs (Pişkin & Solmaz, 2018). In passenger transport according to the standards; Class M2 defines a motor vehicle with more than 9 seats including the driver and a maximum weight not exceeding 5 tons, while class M3 is defined as a motor vehicle with more than 9 seats including the driver and a maximum weight exceeding 5 tons. In freight transport; class N2 is the category of motor vehicles with a maximum weight exceeding 3.5 tons but not exceeding 12 tons, while class N3 is motor vehicles with a maximum weight exceeding 12 tons (Doğan, 2021). Considering that commercial vehicles such as minibuses and buses spend almost 70% of the day on the road, it becomes clear how important vehicle comfort is when considering occupational diseases for the driver (Tuncel, 2008). Understanding how drivers are affected in terms of comfort is very important for design processes. Understanding how drivers are affected in terms of comfort is very important for design processes. He conducted studies to evaluate the comfort or how uncomfortable the driver is while driving. Kyung et al. In their study, 27 people performed tests for 2 different vehicles and 2 different seats, and they determined an evaluation score between 1-10 (according to the degree of comfort) for 4 different regions of the body. As a result of the evaluation, they emphasized that the comfort features expected from the sofa should be determined according to the usage conditions (Kyung et al., 2007). In addition, trucks, tractors, buses, cars, etc. The effects of body vibration affecting the driver from the seat in many vehicles have been investigated. With each seat interchangeable between vehicles, the effects of whole-body vibration were determined from the vertical acceleration measured on the floors and seats of the vehicles. As a result of their research, they suggested that body vibration values in many working environments can be reduced by improvements in sitting dynamics (Paddan & Griffin, 2001). Therefore, determination of comfort parameters and realization of revisions during the design phase before mass production also provides great gains in terms of cost and labor. In order to determine the comfort parameters of the seat at the design stage, the skeleton structure and sponge structure of the seat, which affects the comfort of the driver, were examined in detail with finite element model tests. Along with this study, they pointed out that comfort problems that may occur before the seat is produced can be prevented by making comfort analyzes at the design stage (Verver, 2004). Vibration behavior and stress distribution can be predicted mathematically using tools that are important today, such as the finite element model (FEM). FEM is indeed a powerful preliminary design tool, but its findings should always be validated by testing in laboratories. Vibration allows to describe motion (degrees of freedom or DOF) in thousands of positions and directions using only a limited frequency range and a small number of modes. Finite element software gives very important determinations in terms of the accuracy of the design and the reliability of the material selection. With this analysis, they calculated the crack initiation point and time-varying mesh stiffness of symmetrical and asymmetrical tooth profiles and determined the damage points that may occur under pressure beforehand (Doğan & Karpat, 2019).

The primary aim of this study is to evaluate the ergonomics of M3/N3 class vehicle drivers and to develop a design that will improve ease of use, ergonomics and comfort for drivers within the scope of ISO 16121-1:2012 directive. With the finite element analysis (FEA) software of the designed air driver's seat, analyzes were made on the critical parts subject to load and vibration at 6 degrees of freedom (6 DOF), and revisions were made in order to improve comfort. While the vibration bad road test (shaker test) studies on the prototype seat were continued, positive results were obtained by applying all other validation tests that confirm the design. As a continuation of this work, we will continue to provide driver comfort and focus on vehicle mitigation in line with net zero carbon emission targets.

## 2. Methods

A driver's seat has been designed for M3/N3 class vehicles in order to meet the requirements of the ISO 16121 European standard and to increase driver comfort by considering primarily Germany and the entire foreign export market. In my previous designs, the horizontal and vertical adjustment range does not comply with ISO 16121 norm criteria. Compliance with the standard was analyzed with the design improvements made. Some critical equipment is specified in the driver's seat designed as shown in Figure 1.

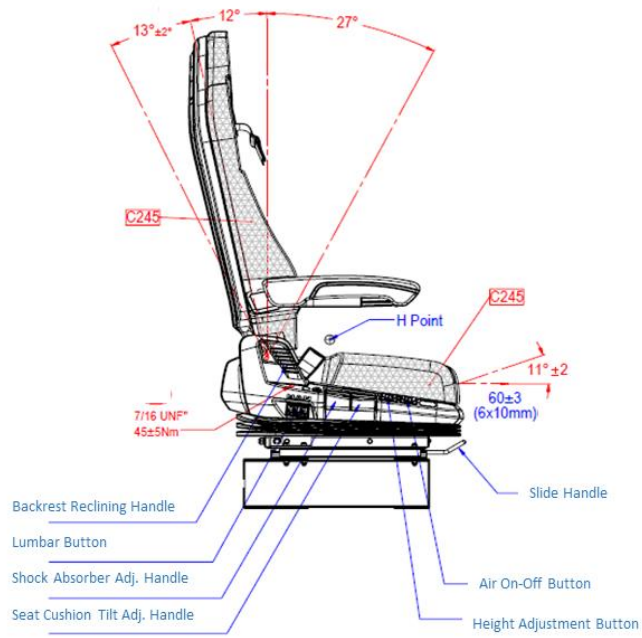


*Figure 1 Important parts of the designed driver's seat*

The analysis model of the designed driver's seat was prepared based on the STP data, and the sheet metal parts were modeled according to the shell theorem. In Figure 2, welding connections, critical parts and material definitions of these parts were made over the simplified CAD image, the driver weight was determined as 80 kg, and the analysis was carried out with ANSYS, a finite element software with 6 degrees of freedom (6 DOF). 1G static analysis and PSD (Power Spectral Density) vibration analysis were performed by checking the critical area contacts in detail on the seat structure and making the correct source definitions. When the results of the analysis are examined, revisions have been made to comply with the ISO 16121 standard and improvements have been recorded as a result of the revisions.

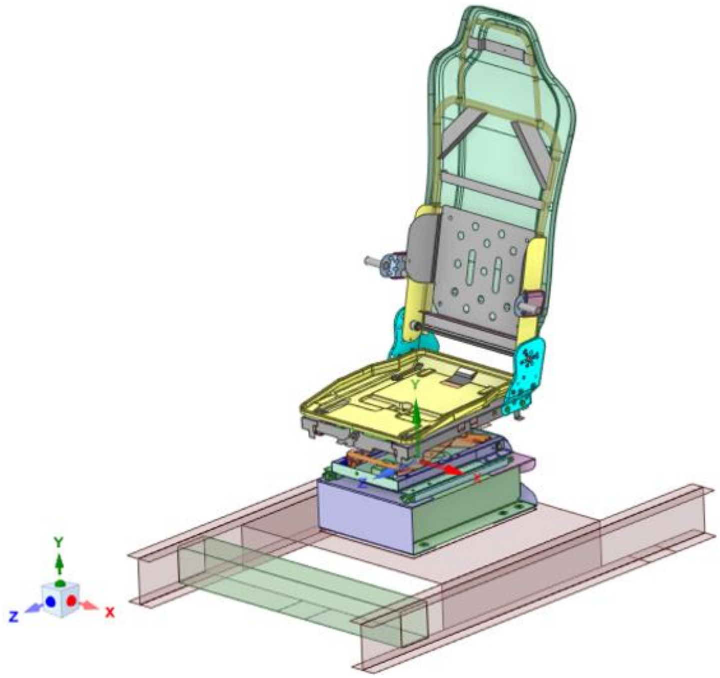


*Figure 2 Simplified CAD view of the designed driver's seat*

Applications of 6 degrees of freedom (3 pistons under the seat, 2 pistons from the sides and 2 pistons from the rear) vibration test (shaker test) applied in the scope of vehicle bad road data in order to perform the confirmatory tests of finite element analyzes made on the software, equivalent to 1,000,000 kilometers of road. continues. Validation tests were carried out in order to verify the design in the R&D Center test laboratory on the driver seat prototype suitable for M3/N3 class produced within the Pilot Taşıt Koltukları company. Necessary preparations were made for the armrest strength test in the pneumatic test device, and the armrest was connected to the machine as in Figure 3 and the test was carried out with 10,000 cycles. As shown in Figure 4, the test was carried out on the same machine by repeatedly applying pressure on the cushion with a load of 75 kg on the cushion and 300,000 cycles.

*Figure 3 View of the armrest connected to the pneumatic tester*

*Figure 4 Cushion durability test image*

Testing was carried out in accordance with ISO 7096 and EN 13490 standards with a test device that only vibrates vertically on the z-axis on the prototype seat. The test was carried out at 3 million repetitions with a load of 1000 N (102 kg) on the seat.

*Figure 5 Application of vertical vibration test*

## 3. Results

Static analysis was applied with ANSYS software on the air driver seat designed. The driver's weight is 80 kg, the gas shock absorber pre-stress is 2000 N and the airbag pre-stress value is 2000 N. After the zone contacts were made, it was checked that the correct welding definitions were made. As a result of the first analysis, the amount of displacement with the load applied on the total seat was measured as 1.3524 mm. A revision was made because the displacement amount on the total seat was within the critical value range. According to the repeated test after the revision, the total displacement amount was reduced to the range of 0.20-0.90mm. In Figure 6, the displacement values with the total load applied to the seat before and after the revision are given.

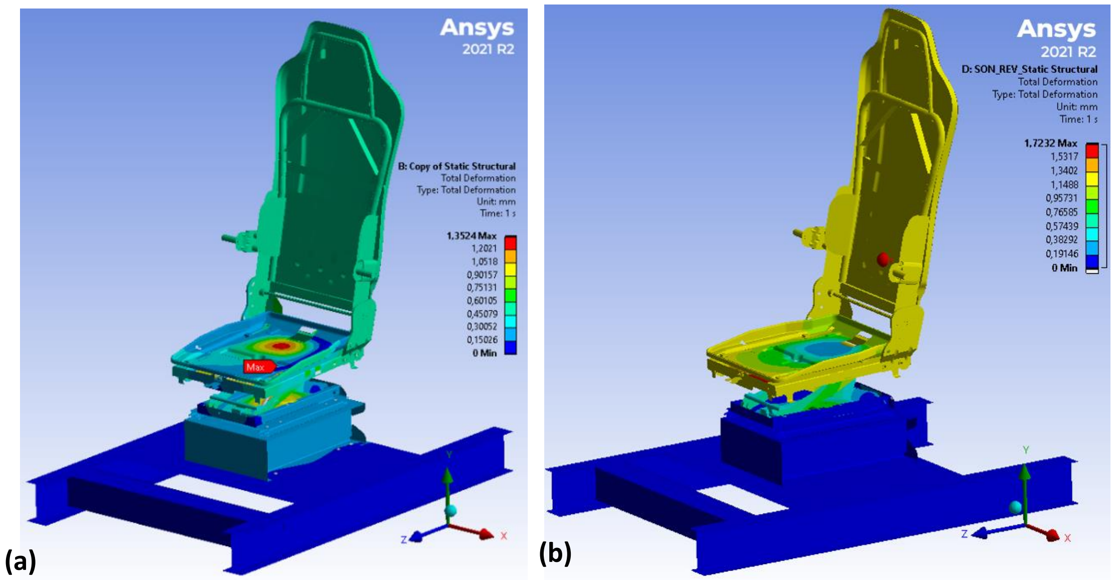


*Figure 6 Total deformation values on the seat, (a) Before revision, (b)After revision*

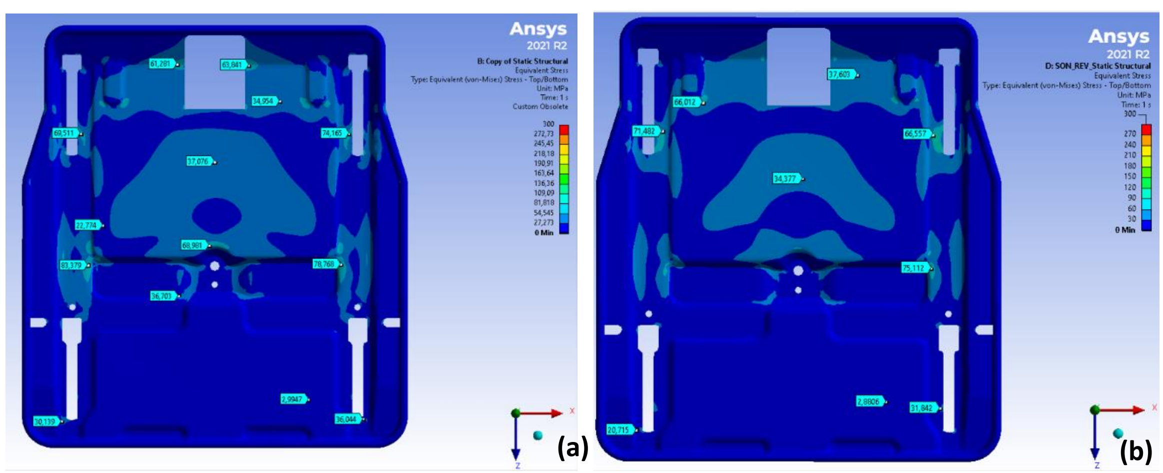


*Figure 7 Tension view of the seat sheet metal, (a) Before revision, (b)After revision*

The material shown in Figure 7, known as the seat bottom plate sheet, which forms the seat frame, is produced from cold rolled flat steel DIN 1.0338 (ERD 7114). Analysis was carried out on software in 1 hour. Critical stress values were not determined within the scope of the analysis. Regional improvements were observed after the revision.

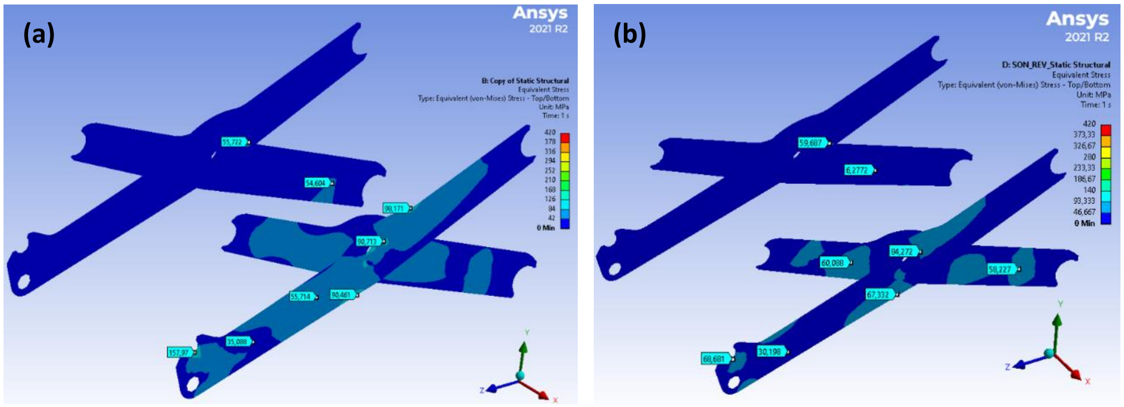


*Figure 8 Tensile view of the seat truss sheet, (a) Before revision, (b)After revision*

The right-left parts of the critically important seat truss sheet metal located at the suspension point in the underarm area are shown in Figure 8. The part in the image is manufactured from high strength steel that can be cold formed according to DIN EN 10149-95. In the 1G static analysis, the stresses that occur when the driver is sitting have a factor of safety of 2.67. After the revision, improvements were seen in different regions. The airbag sheet is another important part of the seat frame. Manufactured from DIN 1.0980 (S420MC) flat steel. While the stress values were at the highest value of 167 MPa in the measurement taken from the important points in the first design, it reached the minimum level at the same point after the revision (Figure 9) It was determined that the stresses occurred when the 1G static driver was seated after the revision increased from 1.52 to 3.01.

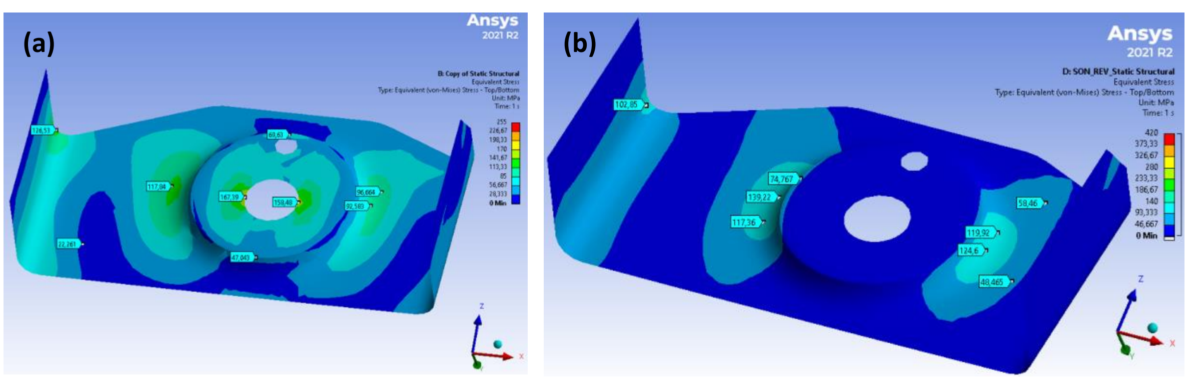


*Figure 9 Tensile view of the seat airbag sheet, (a) Before revision, (b)After revision*

No nonconformity was determined in the revision results applied after the FEA analysis on the design data of the air driver seat. Prototype production of the air driver seat has been realized. In order to verify the analysis, the studies of the 6-degrees-of-freedom (3 pistons under the armpit, 2 pistons from the sides and 2 pistons from the rear) vibration test (shaker test) continue.

As a result of the armrest strength test performed within the scope of validation tests to verify the design on the prototype air driver seat, there was no breakage on the armrest, no loosening of the fasteners, with the armrest movement repeated 10,000 times. The arm continues to function properly even after testing.

Cushion strength test was carried out by hitting the seat 300,000 times under a repetitive load of 75 kg. In the analyzes made after the test, any cracks, fractures, deformations, etc. on the seat. No occurrence of error types was observed.

One of the most important equipment that will affect driver comfort and ergonomics in vehicles is seat suspensions. In order for the suspension values on the seats not to pose a problem for the driver, the seat must be fully functional after completing the vertical jump test with 3,000,000 repetitions under a load of 102 kg. After the test, it was tested that the loss of function on the seat was less than 20% and no problem was observed in the functionality of the seat.

## 4. Conclusion

6 degrees of freedom (3 pistons from under the seat, 2 pistons from the sides and 2 pistons from the back sides) based on the design data of the air driver seat, which has been designed in accordance with the ISO 16121-1:2012 standard for motor vehicles with more than 9 seats including the driver and with a maximum weight exceeding 5 tons. FEA analyzes were performed. In the static-dynamic analysis tests performed on critical parts of the air driver seat over the CAD data, the amount of displacement applied on the seat sheet metal was improved by approximately 85%. In order to define the accuracy of the analysis, vibration test (shaker test) studies, which will correspond to the bad road test equivalent to 1,000,000 km, are continuing.

No deformation was observed in the armrests and cushions from other validation tests applied to the prototype production air driver seat. The validation tests of the air driver's seat were successful, since less than 20% loss of function was observed in the vertical jump test suspension test, which was applied with 3,000,000 repetitions under a 102 kg load. After the vibration test is concluded, a decision will be made about the accuracy of the FEA analysis and its compliance with the ISO 16121 standard.

## 5. Acknowledge

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## References

[1] Doğan, Y. 2021. Emniyet kemeri yükseklik ayar ve omuz ayar mekanizmalarına sahip ticari araç sürücü koltuklarının tasarımı ve sonlu elemanlar yöntemi ile analizi (Doctoral dissertation, Bursa Uludag University (Turkey)).

[2] Doğan, O., & Karpat, F. (2019). Crack detection for spur gears with asymmetric teeth based on the dynamic transmission error. Mechanism and Machine Theory, 133, 417-431.

[3] Kyung, G., Nussmaum, M.A., Babski-Reeves, K. 2007. Driver sitting comfort and discomfort (part I): Use of subjective ratings in discriminating car seats and correspondence among ratings. *International Journal of Industrial Ergonomics*, 38: 516-525.

[4] Paddan, G.S., Griffin, M.J. 2001. Effect of seating on exposures to whole-body vibration in vehicles. *Journal of Sound and Vibration*, 253: 215-241.

[5] Pişgin, E. (2018). Farklı Regülasyonlara Göre Ağır Ticari Araç Sürücü Koltuğu Geliştirime Çalışmaları (Doctoral dissertation, Bursa Uludag University (Turkey)).

[6] Pişgin, E., & SOLMAZ, E. (2018). FMVSS 210 Normuna göre sürücü koltuğu geliştirilmesi. Uludağ Üniversitesi Mühendislik Fakültesi Dergisi, 23(1), 353-368.

[7] Tuncel, H. O. (2008). Kamyon Kabin Süspansiyonunun İncelenmesi Ve Konfor Optimizasyonu (Doctoral dissertation, Fen Bilimleri Enstitüsü).

[8] Verver, M.M., de Lange, R., van Hoof, J., Wismans, J.S.H.M. 2004. Aspects of seat modelling for seating comfort analysis. *Applied Ergonomics*, 36: 33-42.