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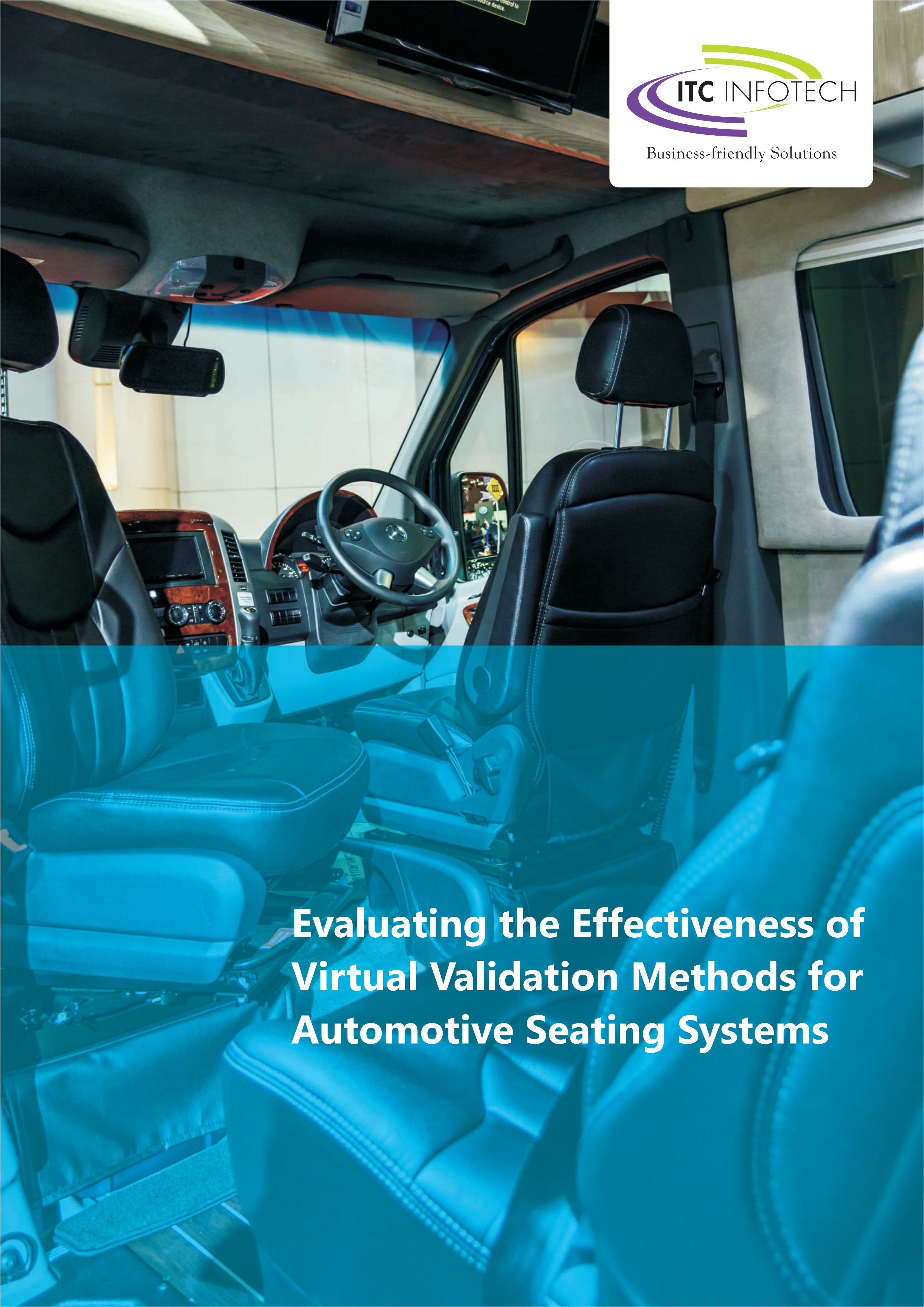


Evaluating the Effectiveness of Virtual Validation Methods for Automotive Seating Systems

EXECUTIVE SUMMARY

Designing automotive seats for any vehicle is challenging given the complex design parameters that merit consideration. The magnitude of the challenge simply increases when confronted with the vast array of vehicles in use today. In addition to the diverse categories of vehicles -- aircrafts, railways, SUVs, MUVs, buses, and passenger cars, are the many types of seats – front, rear, parallel, bench type, and split type – for which the design parameters and considerations are markedly different.

With people spending longer hours driving today, it is imperative that three pre-requisites of seat design be focused on as the designing process commences – comfort, safety, and health. While early studies on seat design were centered round reducing lower back stress, there is little research to prove that the lumbar support created keeping these specifications in mind actually resulted in the postures they were intended for. What is most important, however, is that good seat designs offer the driver unhindered vision and unfettered access to all control mechanisms; and accommodate all shapes and sizes of bodies while being comfortable and safe.

This document specifies a variety of validation methods (Physical Testing) and the equivalent Analytical Approach (FEA/CFD) used to test the strengths of vehicle seats used by different types of transportation systems such as cars, trucks, tractors, trains, and aircrafts. It also assesses the various design validation plans and their applications using virtual validation methods like the Finite Element Method.

CHALLENGES

Automotive seat design has come a long way from simply focusing on including spinal support to emphasizing comfort, health, and safety of the occupants in a vehicle. Given the multitude of vehicles being driven today, designing seats that cater to all three aspects can prove challenging especially since these are perhaps some of the most important components of vehicles and play a vital role in transferring the load and road-induced vibrations from the vehicle body to the occupant.
Occupant comfort and safety is largely dependent on the seating system and hence, accurate design of seats and its aggregates leads to enhanced passenger safety.

An official study by the United States Department of Labor found that vehicle drivers (especially truck drivers) frequently worked 50 hours or more per week and travelled long distances, leading to almost an average of 2350 hours driving time per year. Given such extensive driving time, automotive seats have come to play key roles in improving the comfort and work environment of a driver as well as his passengers.

Some of the key aspects tested and analyzed in this document are – the Head Restraint Performance and Strength, Seat-Back Strength, Seat Anchorage Dynamic and Strength, Armrest Strength, and Operating Effort so that vehicle seats are comfortable, provide effective spinal support and stability especially in the event of crashes, and keep the occupants in-position in the case of accidents particularly rear end collisions.

ADDRESSING THE CHALLENGES

In a bid to address the above challenges, engineers experienced in automotive seat design subject the design to a battery of rigorous and intensive tests that constitute thePhysical Test and FEA Simulation. Some of these critical tests include:

Head Restraint Performance and Strength Test

Seat Head Restraints are checked for strength and performance with a Head form Impact Test where the Head form is anchored at point 'R' and is set to hit the head restraint with a pre-defined moment of 37.3 daNm about the 'R' point. To check the effectiveness of the head restraint, the initial load specified above (37.3daNm) is increased to 89 daNm unless the seat or seat-back breaks or is damaged earlier.

Requirement

It is required that the head restraint and its anchorage shall be such that the maximum backward displacement X of the head permitted by the head restraint is less than 102 mm.The head restraint and its anchorage shall be strong enough to bear -- without breakage -- the load specified above to check the effectiveness of the head restraint.

Seat-Back Strength

A force producing a moment of 53 daNm in relation to the R point shall be applied longitudinally and rearwards to the upper part of the seat-back frame through a component simulating the back of the manikin.

Requirement

No failure shall be shown in the seat frame or in the seat anchorage, the adjustment and displacement systems or their locking devices during or after the tests. Permanent deformations, including ruptures, may be accepted, provided these do not increase the risk of injury in the event of a collision and the prescribed loads are sustained.

Seat Anchorage Dynamic Strength Test

A longitudinal horizontal deceleration of 20 g shall be applied for 30 milliseconds in the forward direction to the entire vehicle shell. Also,the structure is analyzed using a manufacturer-provided test pulse.

Requirement

No failure shall be shown in the seat frame or the seat anchorage, the adjustment and displacement systems, or their locking devices during or after the tests. Permanent deformations, including ruptures, may be accepted, provided these do not increase the risk of injury in the event of a collision and the prescribed loads aresustained.

Armrest Strength and Operating Effort

A force of 98N (or OEM as specified) is applied to an armrest in the vertically downward and lateral directions to analyze the integrity of the armrest structure.

Requirement

There should not be any breakage or crack on the structural components or the visible permanent set.

SOLUTION

The design verification or validation phase is an integral part of the product development and design lifecycle of an automotive vehicle. Once the designer researches the vehicle systems or sub-systems through a combination of study and benchmarking, the validation engineers step in to validate the products under various design criteria. Some of the significant analytical methods applied to the system under consideration depend on a host of factors spanning -- the type of application, operating environment, probable failure modes and physical phenomenon during the test or validation.

The analytical methods used here include:

- Finite Element Analysis (FEA)
- Computational Fluid Dynamics (CFD)
- Kinematic Analysis of Mechanisms
- Tolerance Stack Up Analysis

Design Validation / Finite Element Method

Using this method, engineers undertake various categories of analyses to offer users better understanding of seating dynamics and its behavior patterns. The details of the dynamic and crash analysis for safety and durability are provided below for the seating system examined. A typical design validation plan for seating systems includes two kinds of analyses:

Analysis I: Crash and Safety

- Seat-back Strength
- Seat Anchorage Dynamic Strength Test
- Seat Structural Dynamic Strength Forward
- Energy Dissipation Test for Seat-back
- Strength of Seat Belt Anchorage
- Luggage Retention / Partitioning Test
- Child Restraint Test Forward&Lateral
- Head Restraint Energy Dissipation Test
- Head Restraint Performance &Strength Test
- Seat-back Load Floor Test for Retention

Analysis 2: Durability

- Head Restraint Lateral &Longitudinal Stability
- Vertical Load Strength of Cushion Frame
- Seat Ornamentation &Knob Pull-off Strength
- Actuator Strength in the Direction of Operation
- Seat-back Map Pocket Static Strength Requirements
- Seat-back Torsion Strength
- Seat-back Snack Trays Test
- Jounce Test (Cushion &Back)
- Armrest Strength &Operating Effort
- Cup Holder Environmental and Mechanical Stability Test
- Latch Catch Spring Test
- Track Lock and End Stop Strength
- Jump Seat Strength
- Fatigue Resistance (seat structural fatigue durability test)
- Seat System Modal Separation
- Vibration Test for Resonance Point Detection
- Thermal Cycle Ageing Test or Creep Test

Some of the solutions formulated on the basis of key FEA seating tests and their benefits are elaborated below:

Natural Frequency Simulation

Scope: To identify and analyze natural frequency and mode shapes of the seating system

Validation Criteria: The first natural frequency of the seating system should fall between the specified range of frequencies as per Class of Vehicle and Automotive OEM Directives

CAE Simulation: Natural frequencies can be extracted for a seating system using the EIGEN (L) method. Seating system will be discretized to capture all the parts, features, mass of the components, and the CG of the entire seating system. Appropriate connection strategies will be deployed to simulate connections and free/blocked DOFs. The analysis will involve the use of appropriate solution sequences like SOL 103 (Nastran) to extract natural frequencies and the respective mode shapes.

Proposed Solutions:

There are various techniques to troubleshoot problems or shortfalls:

- Optimizing Stiffness to Mass Ratio
- Stiffness Enhancement at Appropriate Zone
- Problem Identification by Analyzing Mode Shapes

FMVSS207 / FMVSS210

Scope: FMVSS 207 and 210 applies to automotive seats and their attachment assemblies and seat belt anchorage assemblies. These regulations ensure their proper location for effective occupant restraint, and it also minimizes the possibility of anchorage failure due to forces resulting from a vehicle crash.

Validation Criteria: Criteria to assess successful FMVSS 207/210 entails avoiding complete failure in the seating system during the phenomenon till the designated force levels are reached.

CAE Simulation: The CAE method is widely used to simulate the FMVSS 207/210 on component as well as on complete seat-system levels. Quasi-static simulation using LSDYNA is one of the methods chosen to simulate the requirement. The simulation set-up consists of two load application devices known as Body Blocks. These comprise a shoulder block and a lap block, which represent the chest and torso of thevehicle's occupant. A high strength seatbelt wraps around the shoulder and the body block to hold them in place and attach them to the seatbelt anchor points.

Fig. 1 shows a detailed CAE set-up for the FMVSS 207/210.Mainly, the analysis is intended to showcase any chances of failure in terms of cracks or excessive bending in the seating system. The main results analyzed will be effective plastic strains, stress, deformations and energies.

Proposed Solutions:

Proposed solutions to arrest problems emerging as a result of FMVSS 207/210 are:

- Local reinforcement or gauge enhancement to avoid excessive deformations
- Load path analysis to study load traverse from source to support
- More detailed modelling/simulation of recliner mechanism

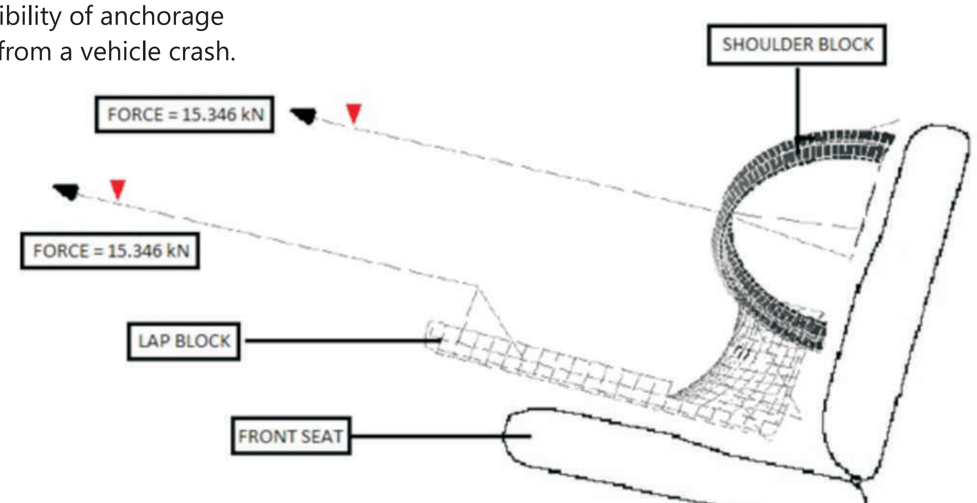


Fig. 1

Sled Test

Scope: The sled test is performed to test the strength of the seat anchorage and the adjustment, as well as the locking and displacement systems. A longitudinal, horizontal deceleration of not less than 20g is applied for 30 milliseconds in the forward direction to the entire shell of the vehicle. Alternatively, the manufacturer's test pulse may be used to perform the sled test.

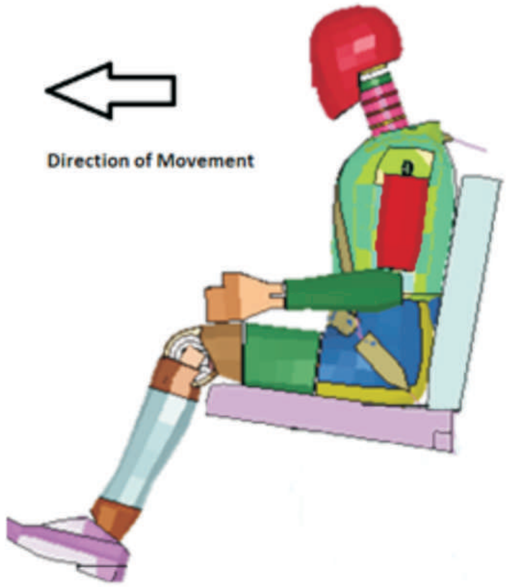
Validation Criteria: Criteria to pass the sled test entails avoiding failure or breakage from the perspective of structural integrity. Alternatively, body force and injury parameters are assessed from the point of view of occupants' safety.

CAE Simulation: The sled test is performed with a comprehensive and assembled seat with a designated dummy positioned on it. Some portion of the BIW floor and firewall is included in the simulation as pulse and this is applied to the body structure. The sled test is also performed in the forward and rearward directions with different seat positions.

Proposed Solutions:

The solutions proposed to arrest possible issues in the sled test performance include:

- Local reinforcement to achieve strength at designated location
- Load Path analysis to understand higher force region



Physical Testing Co-relations

In the automotive segment, the physical tests enumerated below are performed on the product based on its application:

- Deflection Measurements
- Strain Gauging
- Tri-axial Vibration Testing
- Measuring Fluid Flow Parameters
- Temperature Measurement
- Accelerated Durability Testing
- On-road Vehicle Testing
- Four-post Vehicle Testing
- Frequency Response Measurements

A set of prototypes –preferably a minimum of 8 – conforming to the requisite dimensional specification sare required for the physical testing procedure. These include:

- Development and validation of seating systems / sub-systems along with tooling-based enhanced design support
- Proven Test – FE correlation study
- Close association with Testing Authorities in India which will help in –
  - Well-built correlation exercise
  - Reduction in actual physical prototype preparation for testing
- Experience in analyzing the structure for VA/VE proposals like light-weighting, performance improvement for newer regulations

ACHIEVEMENTS

The tests resorted to have yielded unprecedented and spectacular results as attested to by the Test-FE Correlation data given below. Some of the learning and achievements have been –

- Correlation of 87% to 92% for recorded maximum displacement in the test and simulation
- Higher strain / stress regions correlated with regions where crack or breakage is seen
- Permanent deformation recorded in the tests was correlated with residual displacement from simulation
- Failures and deformation observed during the Sled Test correlated well with the Sled Test simulation
- Event-mapping was done for test and simulation
- Permanent set recorded in the tests are correlated with residual displacement from simulation

CONCLUSION

Given the growing concerns around the rapid increase in driving times the world over and the need to focus on making vehicle seats comfortable, safe, and flexible, design engineers are striving to improve seat patterns to offer drivers the strength, stability, spinal support, and complete access to control mechanisms.

Since seat structures and the restraints attached to them are often the deciding and crucial elements in choosing a vehicle, it is important to formulate optimal solutions and evaluate them by subjecting the models to stringent testing. This ensures that they meet the various safety norms before the vehicle is rolled out into the market.

While seat designs should be lightweight, smart, and compliant with safety norms, they should also be structurally robust, vibration and noise absorbent, and should protect the occupant in the event of a crash. Seeing how the world is moving toward sustainability and vehicular weight reduction, most attempts to launch effective seat designs ensure these factors are all considered and involved.

AUTHOR PROFILES

Swanand Jawadekar has more than20 years of experience in Computer Aided Engineering, project execution, training, deep dive technical studies, and offshore consulting. With clients like Ford and JLR, Swan and has played key customer facing roles when developing solutions over the long term. He has also been akey Account Manager and Business Transformation catalyst for major global customers, enabling value creation by providing solutions and services with a focus on the Automotive, Aerospace, and Industrial Machinery sectors.

Prasad Balgaonkar is a Mechanical Engineer with over 12 years' experience in the areas of CAE Analysis for Full Vehicle and BIW &System Level Validation plans. Experienced in Crash Simulations and NV & Durability Analysis, he has been engaged in various automotive vehicle programs such as Seating System, Instrument Panel, BIW Development, Front Fascia Exterior Development, etc. His key competencies in CAE Driven Design Validation &Optimization, Test-FE correlation, and Crash Simulations have enabled him to work with domestic and international clients including Tata Motors and Chrysler, as well as some European OEMs.

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