Design and optimization of upper & lower rail for automotive track mechanism by using quality function development

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ABSTRACT

The aim of this report is to design & optimize upper & lower rail of an automotive seat track mechanism subjecting to static analysis. The design of upper & lower rail of seat track mechanism by changing parameters & maintain feasibility of seat track. Tracks are the mechanisms which translate the seat & them helpful in occupant safety as link between seat and car. Also they have to provide individual length adjustments possible. The compactness of the seats warrants design and is a complicated problem. Seat track assembly is the most critical criteria in the design of seat shape in automotive factories. From all seat parts, the seat tracks (upper and lower tracks) carry most of the load on seat structure considering human load & structure load.

The objectives of automotive industries are to design quicker more efficient vehicles & it travelling greater distances in short interval of time. Proper design of the seating system is very important. Also, achieving the feasibility of peel off or rupture of track. Scope of the present work involves Finite Element Modeling of Seat track mechanism using FEA software like Hyper mesh or Ansys. Pre-processing steps such as updating of element type, material properties, application of loads and Boundary condition is performed software using FEA. The results in the form of stress, load and Displacement is extracted using FEA result. It compare with analytical & experimental method. There is the aim of this project is to design & optimize upper & lower rail of an automotive seat track mechanism subjecting to static analysis by changing parameters means changing thickness & material with maintain feasibility of seat track & achieving the feasibility of peel off of track.

Keywords: finite element method, finite element analysis, peel load, CAD, quality function development.

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INTRODUCTION:

Today, the automotive industry is advancing very fastly. Each year new and better automotive Components are introduced by the automotive manufacturers in view of improving passenger's safety and comfort as well as aesthetics. Today's worldwide competition has prompted many automotive manufacturers to design their products based on consumer's preference and satisfaction. An essential DOF required by all seating structure designs is the front forward and rear forward movement of the seat. As automotive seating structures have evolved over an extended development period, there has been a convergence of practical embodiment. Accordingly, front forward and rear forward movement is typically achieved using a sliding track assembly consisting of interlocking rail sections. Due to the random probability distribution nature of production processes, track assembly performance is affected by production limit variation. For lowest cost track assembly manufacturers, latitude in production variation is desirable. For mature markets, predictable and repeatable functional efforts take priority. Accommodating the effects of manufacturing variation early in the development cycle through design to achieving competitive quality, cost and development time objectives for a range of target markets.

Figure 1: Track system

Quality Function Deployment In a few words:

To design a product well, a design teams needs to ken what it is they are designing, and what the cessation-users will expect from it.Quality Function Deployment is a systematic approach to design predicated on a close cognizance of customer desires, coupled with the integration of corporate functional groups

The 3 main goals in implementing QFD are:

1. Prioritize verbalized and unspoken customer wants and needs.

2. Translate these desiderata into technical characteristics and designations.

3. Build and distribute a quality product or accommodation by focusing everybody toward customer

Contentment. Since its exordium, Quality Function Deployment has availed to transform the way many companies:

- Plan incipient products
- Design product requisites
- Determine process characteristics
- Control the manufacturing process
- Document already subsisting product designations

Problem Formulation:

Past research and experiences are indicating that improvement in seat assembly performance is one of the most important criteria in the design of Seat structures in automotive industries. Out of all seat structure the seat tracks (upper and lower tracks) carry most of the load in seat structure considering human load. For that new materials and techniques need to improve for comfort & simultaneously reduce thickness, weight and cost. Also, previous research papers are not briefly admired rupture test and peeling test for seat track assembly.

Objectives of the Thesis:

1. Reduction of automotive seat track weight & maintain thickness optimizing upper & lower rail design.
2. Designed upper & lower rail with appropriate material selection with using proper optimization method.
3. Finite element analysis of upper & lower rail to meet all regulatory automotive seat requirements.
4. To achieve feasibility in peel off or rupture test for seat track assembly to get regulatory requisite.
5. Designed upper & lower rail should give benefits in safety & comfort compare to subsisting seat track assembly.

LITERATURE SERVEY

Mahesh Morge et. al. have described that Seat structures play a major role in the car passive safety. Due to their adjustment function mechanisms are generally involved in the seat failure mode. With the current evolution of automotive methods, one of major automotive industry precedency is to decrease the product mass, design quicker and more efficient vehicles, emphasizing on travelling greater distances in short interval of time. For this comfort with safety of passengers is very important, thus the design of the seating system is very important. At the same time, seat rails have to complete high quality criteria, there are very strict requirements regarding strength and crash worthiness as the seat rail is regarded as a safety component it transfers forces from the driver / passenger to the car floor structure in case of a crash and they have to provide seperate length adjustments possible.

Akbar Basha.S et. al. have described that the objectives of automotive companies is to design quicker and more efficient vehicles, emphasizing on travelling greater distances in short interval of time. For this comfort with safety of passengers is very important, thus the design of the seating system is very important. The seat tracks provide the base to the vehicle seats and are required to perform important tasks. They have physical link to the vehicle and transfer power to the undercarriage. At the same time, they have to fulfill individual length adjustments possible. The Seating in an automobile is a compromise between comfort and space constraint. The compactness of the seats warrants meticulous design and is a complicated problem. Seat track assembly is the most critical criteria in the design of Seat structures in automotive industries. Amongst many parts, the seat tracks (upper and lower tracks) carry most of the load on seat structure considering human load.

Maciej Mazur et. al. have described that benchmarking study is presented on the performance of automotive seat track profiles according to their sensitivity to manufacturing variation. Variation in rail geometry affects the elastic track preload and consequently the rolling effort of the track assembly. Rolling effort must be precisely control to achieve customer performance targets. Two benchmarking parameters are relevant to rolling effort. Significant variation in performance identifies for the selected track profiles, which include commercially available designs and proposed concepts.

M. Chauffray et. al. focused on tracks are the mechanisms which enable to translate the seat; they are key contributors in occupant safety as link between seat and car. With the current evolution of ecologic legislation, one of major automotive industry priorities is to decrease the product mass. To reach this aim, the use of high strength steels appears as a good solution with the drawback to be more brittle. In parallel, FEA models have to be more and more predictive in order to reduce the validation cost. In this context, rupture risk prediction appears as a strong need from design office and usual post-processing methods are not correct enough to bring sufficient support to design teams. The solution chosen is a coupling between ansys and the failure criteria to FEM developed by Mate Fem Company.

METHODOLOGY

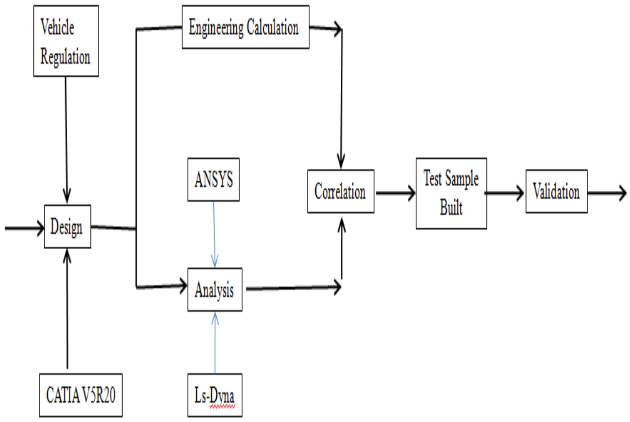

Figure 2: Process Flow of Methodology

FINITE ELEMENT ANALYSIS

FEM can be viewed as tools for the approximated of differential equations describing different physical things. The success of FEM is based largely on the basic finite element procedures used: the formulation of the problem in vibration form, the finite element discretionary of this formulation and the effective solution of the resulting finite equations. Finite element analysis (FEA) has become local place in recent years, and is now the basis of a multibillion dollar per year industry. Numerical solutions to even very complicated stress problems can now be obtained routinely using FEA, and the method is so important that even introductory treatments of Mechanics of Materials – such as these modules should outline its principal features. From other side, the finite element method (FEM) is considered as well-established and convenient technique for the computer solution of worst problems in different engineering chemical engineering, nuclear engineering, hydrodynamics,, geo-mechanics, etc. These steps are the same whichever problem is considered and together with use of the digital computer present a natural approach to engineering solution.

Requirements for design:

There are mainly two distinctions between the European ECE R14 and the NAFTAFMVSS 210. The ECE R14 relegates the conveyances on substratum of their maximum sanctioned weights and requires them to hold different loads dependent on their weight (optically discern Table), whereas in tests according to FMVSS 210 the same loads are applied to all conveyances. The tested drivers cab belongs to a class N2 conveyance in Europe, the applied loads are 5.75 KN on each sector, whereas in the NAFTA countries it has to sustain the full 12.5 KN on each body blocks. The second main difference is the velocity of load increase and the time the conveyance has to sustain the maximum load. While ECE R14 requires the load to be incresed as expeditious as possible and the anchorages have to hold at least 0.2 seconds, the FMVSS 210 requires a loading ramp between 1 and 30 seconds and the structure have to sustain the loads 10 seconds. Consequently the FMVSS test can be viewed as a static test. We are considering load here for N1: m < 3.5 t conveyance.As per ECE 14 & 17 automotive seat regulation, automotive seat should pass Head rest performance, Seat back strength, Head rest energy absorption, Forward & rearward impact test, Luggage retention test etc.ECE R14 and FMVSS 210 are tests to ensure the strength of the seats, the seatbelts and the anchorage points. Therefore, test loads are applied over loading devices, so called body blocks, see Figure 3, and transferred by the seatbelts to the vehicle structure.

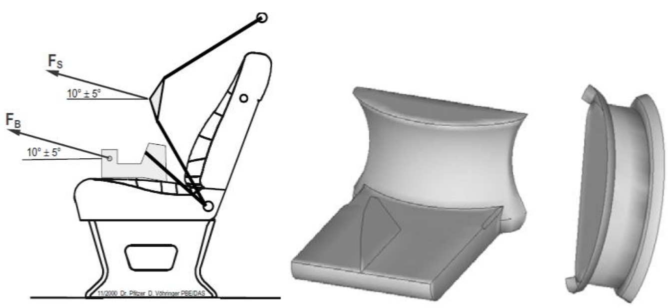

Figure 3: Seatbelts and the anchorage points

Table 1: Classification of vehicle and test loads

	CLASSIFICATION		
	N1 : m<3.5t	N2 : 3.5<m<12t	N3 : m>12t
Shoulder Block	12.5 kN	5.75 kN	3.5 kN
Lap Block	12.5 kN	5.75 kN	3.5 kN
Seat	20 x Seat Weight	10 x Seat Weight	6 x Seat Weight

Theoretical Analysis:

Hand calculations are a important part of an engineer's work when scoping out projects and checking FEA calculations. Before initiate with a complex simulation model, a first pass calculation using fundamental equations can invariably shorten the overall product development and assessment cycle. Additionally, as basic user mistakes can easily occur, it is always vital to undertake a reality check on the results from an FEA analysis for seatbelt anchorage test; three loads are acting on seat. In which, F_1 & F_3 are seat belt load which are acting on track assembly. F_2 is load of seat. Now, we want to calculate load on track under seat belts. Assume, track angle is 0° from horizontal & belt load are 45°from horizontal. Also we can consider weight of seat 20kg.

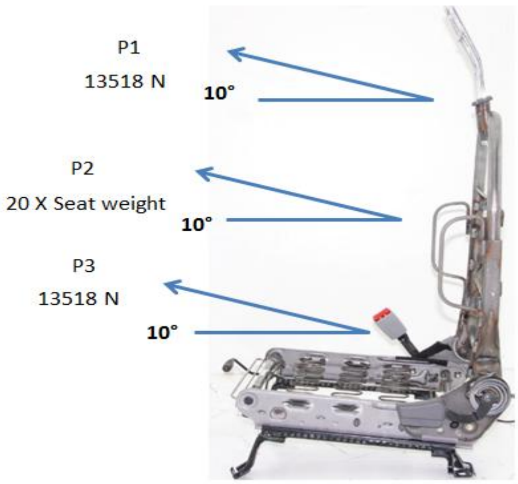

Figure 4: Load apply on seat belt anchorage

Peel load (F_P) on track can be estimated as

$F_P = (F_1 + F_3) \sin 45°$

=2 x 13518 x 0.707

=19114.45N

We take safety factor of 20% more

Factor of safety = 1.2

Peel load on track = F_P x 1.2

= 22937.37N

=22.9KN

Peel load on individual track = 22.9/2

=11.46KN

Hand calculations show that individual track should meet peel of strength more than 11.46KN.

Now, as per numerical calculation optimize track need to meet peel off strength at least 11.46 KN

CAD Modeling:

CAD stands for computer-aided design. Engineers, architects, and even artists utilize computers to avail in their design projects. Computers sanction them to visualize their designs and confront quandaries afore they have expended any of the resources indispensable to put them into physical form. CAD modeling is utilized by many designers to engender elaborate computerized models of objects afore they are physically engendered. CAD modeling takes many different forms depending on the type of project. Some models are simple two-dimensional representations of sundry views of an object.

CATIA provides a wide range of applications for tooling design, for both generic tooling and mold & die.Seat track assembly consists:

- Upper rail
- Lower rail

- Track riser bracket
- Floor mounting plate
- Fasteners

Figure 5: Seat track assembly

Upper rail and lower rail sheet metal has been design with CATIA V5R20 as per existing dimension of track.

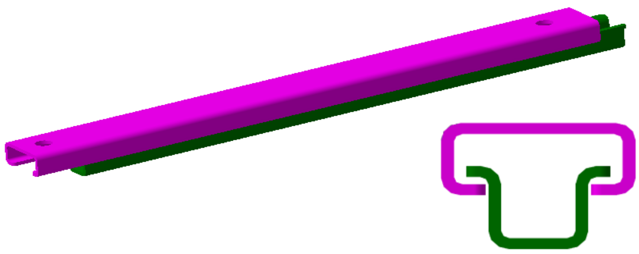

Figure 6: Seat track assembly cad model

- UPPER RAIL DIMENSION

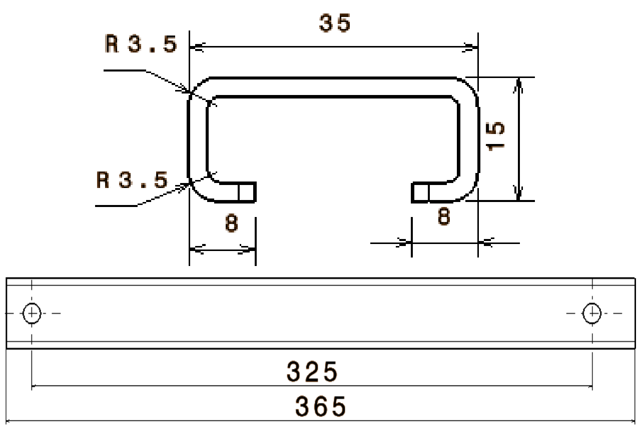

Figure 7: Seat track upper rail drawing

- LOWER RAIL DIMENSION

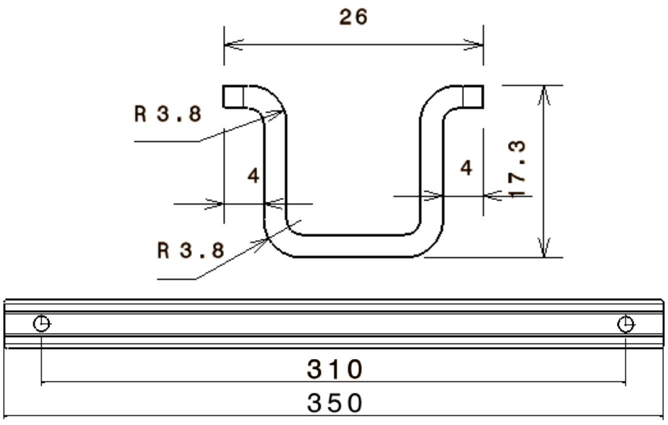

Figure 8: Seat track lower rail drawing

After collecting the data for requirement, we have strength requirement, material requirement, and seat weight requirement. We can build a model or can define load cases at different conditions.

Optimization method for material selection:

Quality function deployment (QFD) is a method to avail transform customer needs (the voice of the customer into engineering characteristics (and congruous test methods) for a product or accommodation. It avails engender operational definitions of the requisites, which may be nebulous when first expressed. It prioritizes each product or accommodation characteristic while simultaneously setting development targets for the product or accommodation. Here we are utilizing Quality function deployment (QFD) for material cull and shows in below table:

Table 2: QFD material optimization method

Cust. Needs/ Req./ WHAT's	Cust. 1	Cust. 2	Cust. 3	Cust. 4	SAE J2340 420Y	DP 800			
Strength	2	8	0	0					
Formability	5	8	0	0					
Material availability	5	5	0	0					High Impact
Cost	5	8	0	0					Meduim Impack
What 5	0	0	0	0					Low Impack
What 6	0	0	0	0					Clear
Relative Importance					11	30			
Cust. 1					62	153			

Absolute Importance									
Cust. 2 Absolute Importance					98	261			
Cust. 3 Absolute Importance					0	0			
Cust. 4 Absolute Importance					0	0			
Absolute Importance Sum					161	413			
Absolute Sum Ranking					2	1			

Material selection:

Mechanical properties of the material are required for finite element models. There is minute information on the material properties of seat rail, recliner and few components in the literature. Aforetime, material ASTM-A619 utilized for seat track rail with thickness 2.6mm. ASTM-A619 material having less yield vigor and ultimate vigor. So, possibility of peel off of seat track is high. In this project DP800 CR is utilized for seat rail. Sheet metal thickness 2.3m.m. Table 3 and 4 describes material properties utilized for analysis. Existing Material:

Table 3: Material- Specification

Material- ASTM-A619	
% Elongation	17.8
Density	7860kg/mm3
Poisson's ratio	0.3
Yield strength	388 Mpa
Ultimate strength	430 Mpa
Thickness	2.6mm

- Proposed material:

Table 4: Material- Specifications

Material- DP 800 CR	
% Elongation	17.4

Density	7860kg/mm3
Poisson's ratio	0.3
Yield strength	490Mpa
Ultimate strength	785Mpa
Thickness	2.3mm

Finite Element Analysis:

FEA plays very paramount role in automotive industry. Because of computerization of the analysis, it preserves the lot of efforts in terms of time & material. It provides or avails to identify demeanor in genuine scenario without constructing it. FEA software offers a consummate solution together with deflections, stresses, reactions, etc. Numerical solutions to even very involute stress quandaries can now be obtained mundanely utilizing FEA.

In general, FEA consists of three measure steps.

- Pre-processing or Structure Modeling.
- Solving or Analysis.
- Post-processing.

Apply boundary condition and external loads. Then the solution is engendered predicated on the antecedent input parameters.

- Bolts modeled as beam elements connected by rigid elements to the parts
- Linear material properties applied to all these beam elements
- The beam torsion stiffness is given to represent actual torque transmission

All parts meshed with an average element size of 3-4 mm with minimum element size of 1 mm.

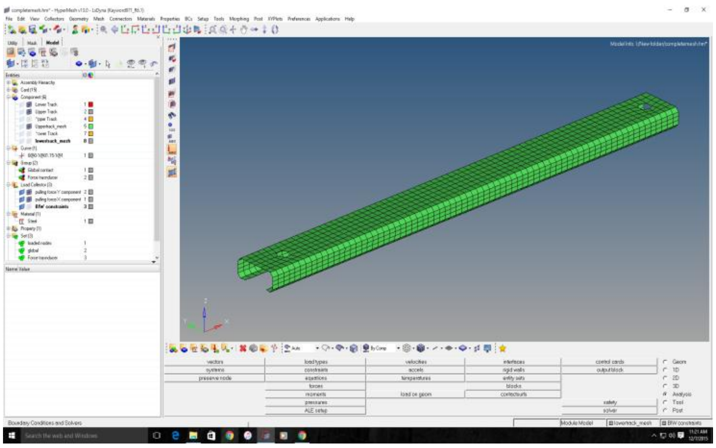

Figure 9: Meshing track with using Hyper mesh software I

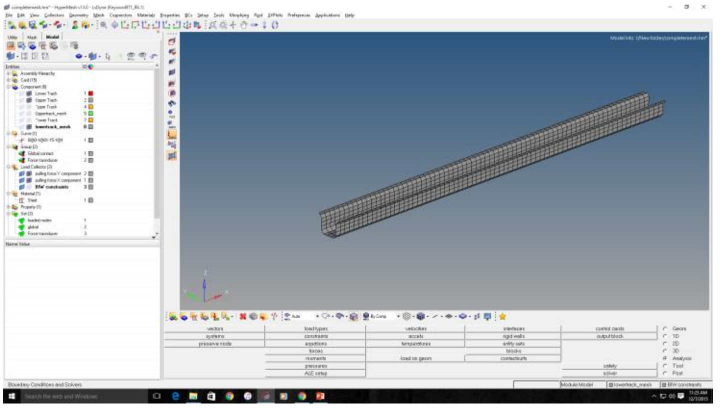

Figure 10: Meshing track with using Hyper mesh software II

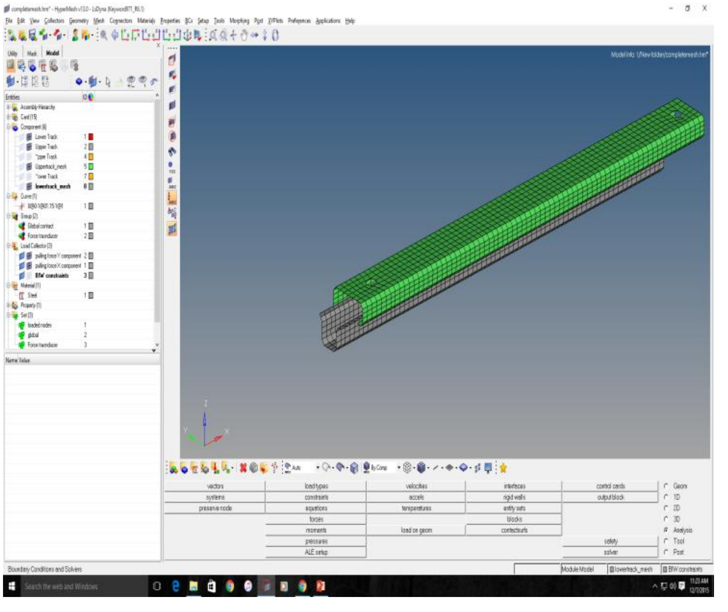

Figure 11: Meshing track with using Hyper mesh software III

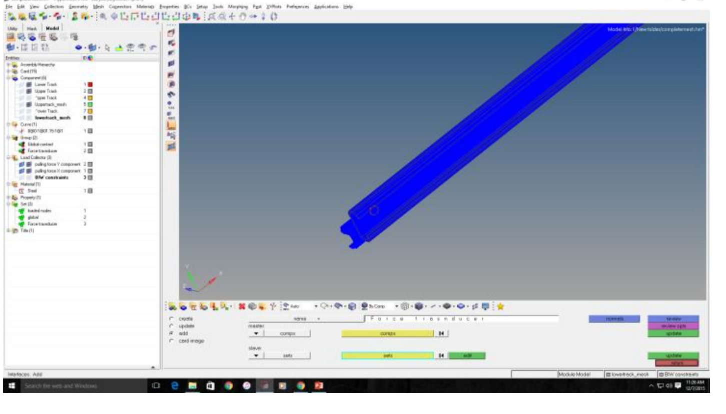

Figure 12: Meshing track with using Hyper mesh software IV

FEA iteration I

Material- ASTM-A619

Upper&lowerrailthickness2.6mm

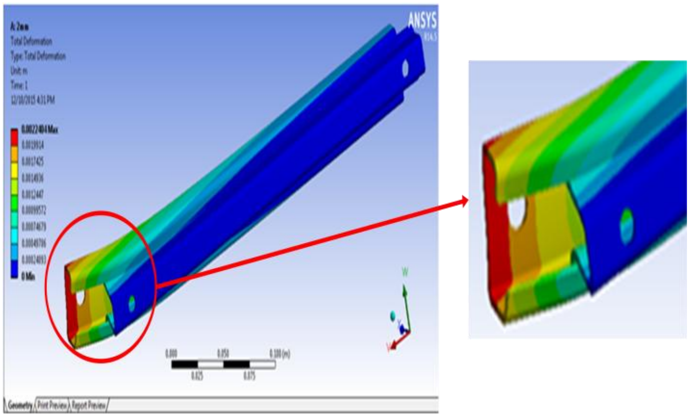

Figure 13: FEA iteration I

Von Mises Stress contour in upper & lower track weight for track assembly is 0.940 Kg. Stresses which are more than 420MPa are shown in red color. The IB Upper Track is commenced to peel around 15.2KN of load. The maximum average stress value in the IB Track is 553MPa which is more than the material yield value of 338MPa and more than the ultimate value of 458MPa.Material yield is observed

FEA iteration II

Material- DP 800 CR

Upper & lower rail thickness-2.3mm

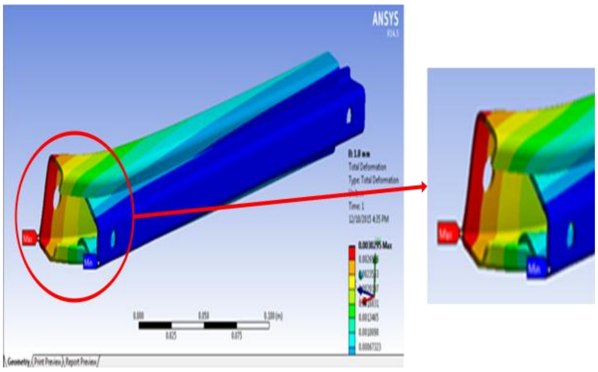

Figure 14: FEA iteration II

Von Mises Stress contour in upper & lower track. Weight for track assembly is 0.760 Kg. Stresses which are more than 490MPa are shown in red colour. The IB Upper Track is commenced to peel around 15.0KN of load. The maximum average stress value in the IB Track is 720MPa which is more than the material yield value of 490MPa and less than the ultimate value of 780 MPa. Material yield is observed. Load curve for peel off analysis of seat track shown by below following graph:

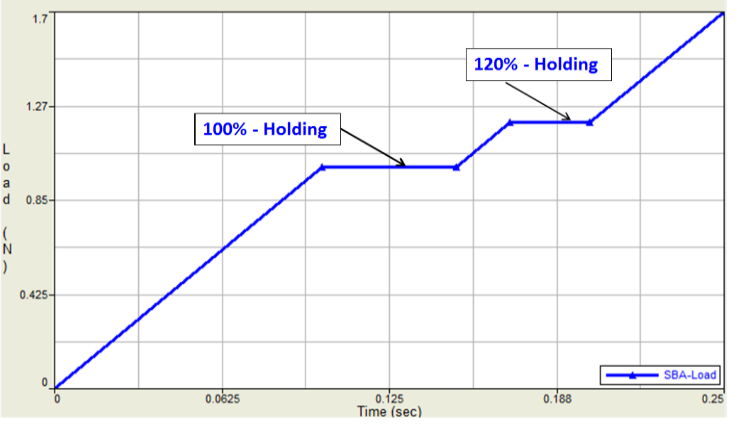

Figure 15: Load-time curve I

The above shown load curve is used in the simulation (with 50 ms holding period of 100% Load and 30ms holding period of 120% Load).

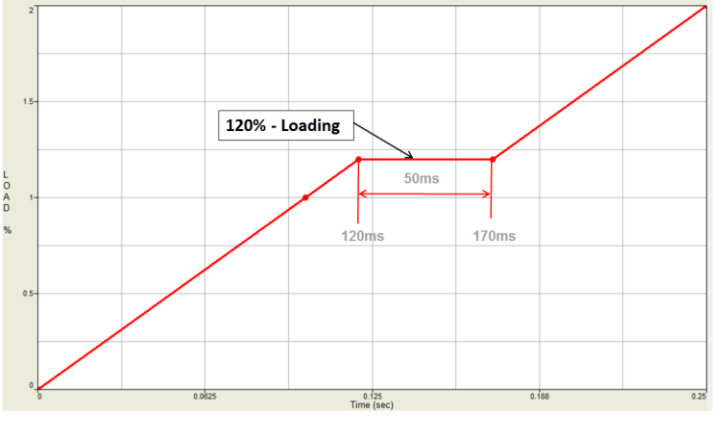

Figure 16: Load-time curve II

The above shown load curve is used in the simulation (with 50 ms holding period from 120ms to 170ms).

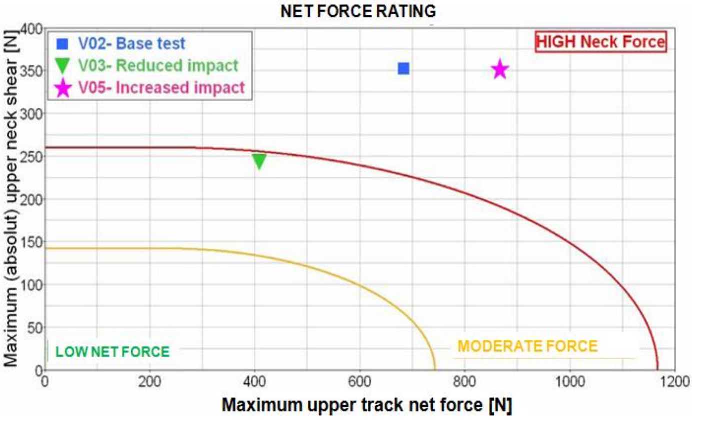

Figure 17: Net force rating

EXPERIMENTAL SETUP

The conclusion of the analysis is that the two sets of requisites, despite their technical differences, provide an equipollent high caliber of safety for car occupants. Indeed, following a conscientious assessment, predicated on literature review and contingency analysis, it appears that the two sets of requisites have proven to be working efficaciously and equipollently well with veneration to the practical performance of seat belt anchorages systems in authentic world passenger car collisions.. A seat belt directs the occupant forces into the structure of the conveyance through seat belt assembly anchorage points and this aspect is regulated discretely in the US by standard FMVSS 210 (and to some extent FMVSS 207 on seating systems) and in the EU by UNECE Regulation No 14. FMVSS 208 further clusters categorical child restraint fitting requisites that are additionally addressed in separate regulatory measures in the EU.

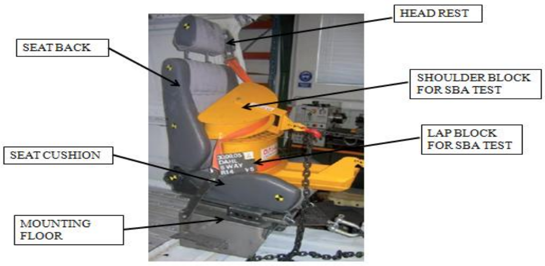

Figure 17: Seat belt anchorage test setup

Table 5: Design Requirements I

	ECE Regulation No. 14	FMVSS 210
Diagonal section force (F1)	13500N ± 200N	13345 N
Lap section force (F2)	13500N ± 200N	13345 N
Force direction	Forward: 5° to 15° above Horizontal.	Forward: 5° to 15° above Horizontal.

Table 6: Design Requirements II

	ECE Regulation No. 14	FMVSS 210
Loading ramp duration	<60s (Manufacturer can request <4s)	<30s
Peak force duration	>0.2s	=10s

Static loading of seat belts during an impact:

FMVSS 210 AND R14 undertook some experimental tests utilizing a force application contrivance, which loaded the lap and diagonal portions of the seat belt in a very homogeneous way to the mechanism employed by the body blocks shown in point 2 above. The multiple tests involved the application of approximately 13.30 KN (3,000 lbs) both to the diagonal and to the lap portion of the seat belt. The test set-up incorporated a rigid seat and high-vigor webbing and reported average diagonal (shoulder) seat belt webbing forces of 8.50 KN (1,923.4 lbs); and average lap belt webbing forces of 6.50 KN (1,479.3 lbs).

Dynamic loading of seat belts during an impact:

In general, a seat for an occupant of a conveyance is mounted on the floor of the conveyance body through a seat track constituted by a lower rail which is secured to the floor surface and an upper rail which is secured to the seat and habituated to be slid able on the lower rail together with the seat. On the other hand, the inner belt of the seatbelt system is secured directly to the floor of the conveyance body without any cognation to the seat track. Ergo, the tension engendered in the webbing by the inertia acting on the occupant's body when an emergency situation of the conveyance occurs is directly fortified by the floor.

Load transfer process on end of belt anchor at SBA test:

1. A belt anchor incorporating seat track structure for a vehicle, which comprises:

A seat track having a lower rail rigidly secured to the conveyance body, and an upper rail slid able along verbalized lower rail in the longitudinal direction of the conveyance.

2. An elongated portion defined by a portion of verbalized bracket which is elongated along the outer periphery of verbalized bent portion and rigidly secured to verbalize outer periphery, thereby enhancing the vigor of verbally expressed bent portion of verbalized lower rail.

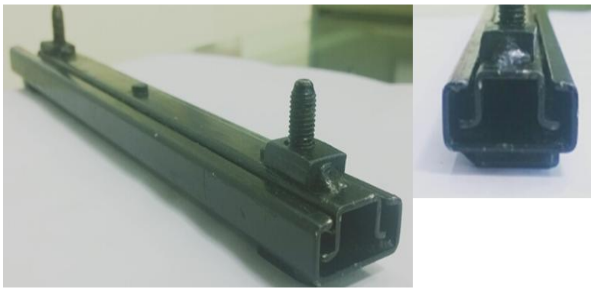

Figure 18: Seat track assembly for experimental setup

Result summary:

Table 7: Result summary for project

S#	Method	Condition	Load	Weight
1	Hand Calculation	Complete seat load	11.46 KN	
2	FEA-I	Individual track- Material - ASTM-A619, 2.6mm Thickness.	16.1KN	0.940 Kg
3	FEA-II	Individual track- Material- DP800,2.3mm Thickness	15.4KN	0.760 Kg

Also, by using experimental test of peel off test, we obtained feasible result for seat track assembly to achieve required output.

CONCLUSION AND FUTURE SCOPE

Conclusion:

Weight reduction is achieved by utilizing 2.3mm thickness of track and contravene reduction is 6.89 %.Using Quality function deployment (QFD) optimization method DP800 gives maximum result for vigor, formability and material availability. As per FEA result DP800 material 16.1kN peel of load is observed which more preponderant than material ASTM-A619 peel of load 15.4 KN is observed. But, as per material characteristics DP800 having high yield and ultimate tensile vigor.as per experimental result and graphical presentation DP800 material track sustain maximum load for maximum time to peel of track. Designed upper & lower rail should give benefits in safety & comfort compare as per ECE regulation requisites for Seat Belt Anchorage (SBA) test.

Future Scope:

As per regulatory standard, current seat track rail has been developed & validated. But as per OEM's specification, additional requirements are, seat should comply with are as follows.

- Durability- for full forward position of track
- Durability- for full backward position of track
- Validation with different track profile.

To check whether track is complying with above requirements, respective forces need to be resolve for hand calculations. Dynamic FEA needs to be done accordingly.

REFERENCES

1. Praise Tom, M. Ramalingam, Kannan. S, "Multimode Dynamic Simulation Study of Automotive Car Seat Slider Mechanism", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE).
2. Akbar Basha. S, Surendra. P, Manu Ravuri, Guru Mahesh. G, "Analysis and Optimization of Automobile Seat Track", International Journal of Scientific & Engineering Research, Volume 4, Issue 11, November-2013 783 ISSN 2229-5518.
3. Maciej Mazur, Martin Leary, Sunan Huang, Tony Baxter and Aleksandar SUBIC, "Benchmarking Study of Automotive Seat track Sensitivity to Manufacturing Variation", RMIT University, International Conference on Engineering Design, ICED11, 18 August 2011,Technical University of Denmark.
4. M. Chauffray, G. Delattre, L. Guerin, "Prediction of failure on high strength steel in seat mechanisms simulation", Faurecia Automotive seating, Le pont de vère, 61100 Caligny Faurecia automotive seating, ZI de Brieres les Scelles, 91150 Etampes.
5. Sung Jong Kang (2000), "An effective approach to prediction of the collapse mode in automotive seat structure", Thin-Walled Structures (Impact Factor: 1.23). 01/2000.
6. H. Mulla Salim, D. Yadv Sanjay, Dhananjay Shinde, Gaurav Deshpande (2013), "Importance of Federal Motor Vehicle Safety Standards 207/210 in Occupant Safety", Procedia Engineering 2013.