Design and Optimization of Existing Automotive Seat Recliner

Surendra.P [1], Akbar Basha.S [2], Dinesh Kumar Reddy.R [3],Madhusudhana.S [4]
[1]Asst.Professor, Department of Mechanical engineering,
Sir Vishveshwaraiah Institute of Science and Technology, Andhra Pradesh, INDIA,
[2]Asst.Professor, Department of Mechanical engineering,
Madanapalli Institute of Technology and Science, Andhra Pradesh, INDIA
[3]Sr.Design Engineer, India Seating Tech Center,
Johnson Controls Automotive Ltd, Pune, Maharashtra, INDIA.
[4]Asst.Professor, Department of Mechanical engineering,
Sir Vishveshwaraiah Institute of Science and Technology, Andhra Pradesh, INDIA,

ABSTRACT

The Recliner is a mechanism which allows the seat back to rotate forward & rearward direction from a pivot point at the base of the seat back according to the passenger's seating comfort. The aim of this paper is to design and optimise the existing automotive seat recliner subjected to loading. The scope of the present work involves Finite Element Modelling of Seat recliner assembly using HYPERMESH. Pre-processing steps such as updating of element type, material properties, application of loads and Boundary conditions is performed using HYPERMESH. The element type considered for the analysis is SHELL. The input file compatible to ANSYS platform is created using HYPERMESH and the same file is imported into ANSYS Platform. The results in the form of stress and deformation are extracted using ANSYS. The factor of safety for assembly is calculated based on Von Misses theory of Failure. Optimization is done in terms of reduction in its weight and there by the cost of the seat recliner assembly. Thickness of various components of recliner assembly satisfies the strength criteria and the factor of safety which is within the allowable limits.

Keywords: ANSYS, HYPERMESH, FINITE ELEMENT ANALYSIS.

1. Introduction

The Recliner is a mechanism which allows the seat back to rotate forward & rearward direction from a pivot point at the base of the seat back according to the passenger's seating comfort. Recliners are used in driver seat, passenger seat & as well as in rear seat also.Generally, seat recliner mechanism includes a base and an arm mounted on the seat cushion and seat back respectively, to house a locking and unlocking by external locking and internal unlocking means, which is effected by a rotatable cam operated by operating lever, which is mechanically linked to the cam for producing rotary motion of the cam. Safety is a basic consideration in all aspect of automotive engineering.

The current trend in automotive industry is to produce vehicles with lighter materials yet ensuring the safety for the occupant. In order to achieve this goal with minimum of expensive prototyping testing, new designs must be investigated numerically for strength and failure terms. The main objective of a good automotive seating system is not only to provide comfort but also to provide style and more importantly the safety feature. Pavan Gupta et al [1] studied that Anti-submarine Performance of an Automotive Seating System - A DOE study. But the system yet is sufficiently light weight to facilitate vehicle fuel economy and to minimize collision stresses. D. M. Severy et al were [2] developed Collision Performance LM Safety Car. Seating system design and materials must be affordable and durable to give acceptable service life. F W Babbs et al [3] studied that the packaging of car Occupants – A British Approach to seat designs.

In addition to provisions for comfort and position adjustments, a seating system should have adequate structure for housing safety and convenience accessories. A. W. Siegel et al [4] were developed Bus Collision Causation and Injury Patterns. The design of seat recliner is very important because during an accident or a crash, occupants tend to be thrown back against their seat backrest due to inertial forces and if the recliner is not built to withstand such an impact, it results in failure. Toshiki Nonka et al [5] studied that the Development of Ultra-High Strength Cold-Rolled Steel Sheets for Automotive Use. Sarah Smith et al [6] were developed that the Improved seat and head restraint evaluations. Recliner failures result in Seat-backrest twisting and collapse and which can lead to severe neck, back and spinal injuries. G. Nadkarni et al [7] also studied that Advanced High Strength Steel Strategies in Future Vehicle Structures.

The area of interest in a recliner is usually the locking mechanism, which holds the seat back at the angle desired by the occupant. The locking mechanism needs to be designed for sufficient strength, so that the seat back does not collapse during an impact. Guillén Abásolo et al [8] developed that Magnesium: the weight saving option. C. Blawert et al [9] studied that the Automotive applications of magnesium and its alloys. The renewable materials also used in automotives, Dr. Thomas et al [10] studied that Renewable Materials for Automotive Applications. For accurate positioning of recliner and to accept the recliner mechanism the lever release should be able to with stand the applied load in the locking position. When the load is applied then the whole assembly is subjected to combined stresses. Hence the lever release strength is the basic parameter for analysis. The desired position of back rest is achieved by operating the lever. When lever is operated force is transformed to cam. Which intern unlocks the upper tooth and lower tooth.

In the present study recliner is modeled using CATIA V5,and analysis is taken in ANSYS 11.The objective of the work is to optimize the design of recliner assembly by considering the huge load on lever release and to check the factor of safety of the recliner assembly.

2. Modeling

Modeling is Representation by lighting of the three-dimensional nature of an original in a two-dimensional reproduction. In any concrete situation we first aim to set out a complete "mathematical" description, which we subsequently try to solve (i.e. we attempt to determine the unknown quantities from the known ones). However, in many cases this direct solution is not possible due to the complexity of the system. In these situations we have to recourse to a simplified simulation, called a "model", and also the modeling is the art of abstracting or representing a phenomenon and geometric modeling is no exception.

The bush design is the construction of the geometric model by using CATIA software. The model may be recalled and refined by the designer at any point in the design process and it may be virtually used as an input for all other CAD/CAM functions. Because so many functions depend on the bush model, geometrical modeling is considered as an important feature of CAD/CAM. Many user-oriented general-purpose CAD/CAM software packages such as UNIGRAPHICS, PRO-E, CATIA, SOLIDWORKS etc., are available in the market in this work CATIA V5 is used.

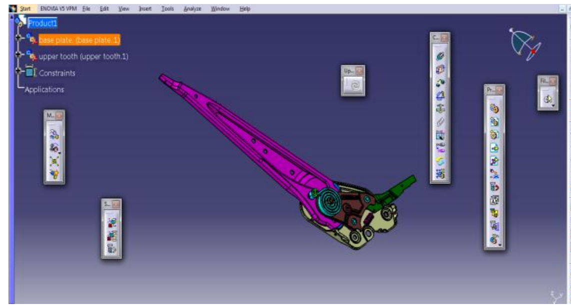

Fig 1. Recliner assembly model

3. Finite Element Method

In brief, the basis of the finite element method is the representation of a body or a structure by an assemblage of subdivisions called finite elements, Figure. These elements are considered interconnected at joints which are called nodal points. Simple functions are chosen to approximate the distribution or variation of the actual displacements over each finite element; such assumed functions are called displacement functions or displacement models. The unknown magnitudes or amplitudes of the displacement functions are the displacements (or the derivatives of the displacements) at the nodal points. Hence, the final solution will yield the approximate displacements at discrete locations in the body, the nodal points.

MAXIMUM DISTORTION ENERGY THEORY (ALSO KNOWN AS HENCKY AND VON MISES THEORY)

According to this theory, the failure or yielding occurs at a point in a member when the distortion strain energy (also called shear strain energy) per unit volume in a bi-axial stress system reaches the limiting distortion energy (i.e. distortion energy at yield point) per unit volume. Mathematically, the maximum distortion energy theory for yielding is expressed as

$$(\sigma t1)2 + (\sigma t2)2 - 2 \times \sigma t1 \times \sigma t2 = [\sigma yt / F.S]\ 2$$

4. Mesh Generation

Mesh generation plays an important role in obtaining valid results. Mesh should be refined at the teeth area as the most of the load is taken by teeth. Mesh is also refined near holes, change of cross sections as the stress concentration is more at these places. The Finite element modeling is carried using hyper mesh.

The finite element model of the lever type recliner assembly was developed using Hyper Mesh 9.0. The IGES model was imported to the Hyper Mesh Module. The global mesh size was set to 4 mm. The main reason behind this is because the gear teeth both in upper part and lower part had a minimum dimension of 2.7 mm. In order to properly define the variation of the gear profile a mesh size of 1.5 mm is selected. The faces of the component are meshed first with surface mesh option. Trias are avoided in the free ends, contact areas. Rotating quads and adjacent trias are avoided since the mesh gets stiffer at those locations. Mesh flow or mesh lines are modelled along flow of the geometry. Each component was meshed separately and assigned with distinct component collector. These segregation of the components in collectors helps in defining the contact, materials, element formulation in the later stages.

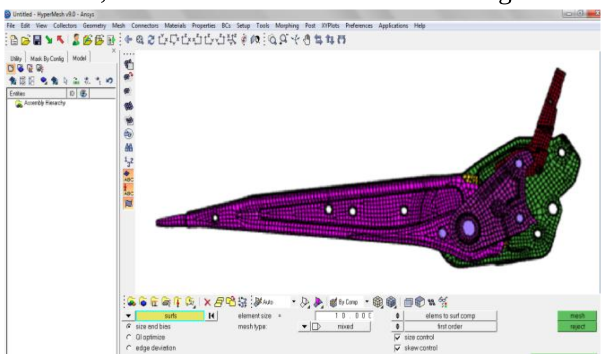

Fig: 2. Meshing model of Recliner Assembly

5. Loading and Boundary Conditions

Constraints all degrees of freedoms

Fig 3. Boundary conditions of FE model

Calculation of Load

The load acting on the recliner should be considered as human weight normally i.e. is 90 kgs acts on the lever release of the recliner assembly.

As per the Automotive Industry Standards Committee (AISC), the dynamic factor can be considered as 1.25 because of rotational effect of the parts of recliner and the ultimate load factor can be considered as 1.5

Therefore total load acting on the recliner is equal to

$= 90 \times 9.81 \times 1.25 \times 1.5 = 1655.43$ N

The total load of 1655.43 N is applied on lever release and this load is shared by 11 nodes of the lever release. So each node carries a load:

Load on each node = 1655.43/11

= 150.49 N.

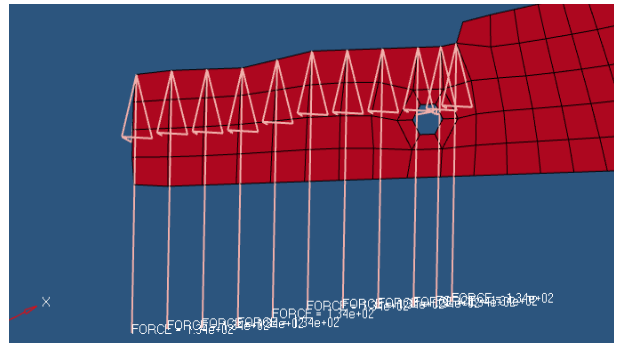

Fig 4.Load Applied

6. Material Considered For Analysis

Fe 490 this type of material is hardenable straight chromium stainless steel which combines superior wear resistance of high carbon alloys with excellent corrosion resistance of chromium stainless steel. These materials are used where the strength, hardness and/or wear resistance must be combined with corrosion resistance.

7. Existing Recliner Assembly

Material type	Components	Ultimate Tensile strength (N/mm^2)	Yield Strength (N/mm^2)	Young's modulus (N/mm^2)	Poisson's ratio	% of deformation
Fe 490	All parts of Recliner	490	300	2×10^5	0.33	20

Static analysis of the recliner assembly is carried out by using ANSYS software. The stress and deformation plots are shown in the following figures. The factor safety is calculated based on Von Mises Theory of Failure.

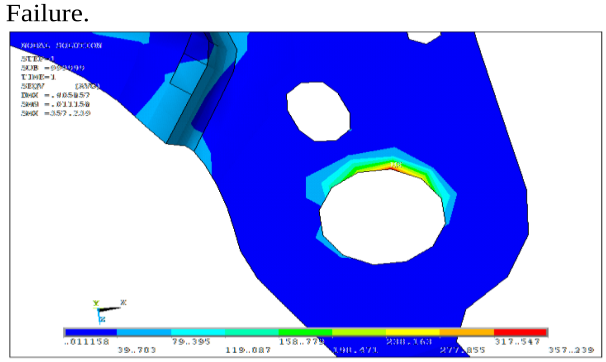

Fig 5. Stress plot

The maximum stress is equal to 357.239 Mpa which is singular stress due to rigid elements modeled at the hole. By neglecting singular stress, the actual working stress value is 79.39 Mpa which is within the limits of permissible yield strength of 300 Mpa.

ISSN: 2278-0181
Vol. 2 Issue 9, September - 2013

Calculation of Factor of Safety

The factor of safety is defines as the ratio of Ultimate Strength of the material to the maximum Von Mises Stress as per Von Mises Stress Theory of Failure.

$$\text{Factor of safety} = \frac{\text{Yield strength (Mpa)}}{\text{Maximum Von Mises Stress (Mpa)}}$$

$$\text{Facotr of safety} = \frac{300\text{Mpa}}{79.39\text{ Mpa}}$$

$$= 3.78$$

As per the Automotive Industry Standards Committee (AISC) the desired factor of safety for automobile components is 3.3 and the factor of safety for the existing seat recliner assembly is 3.78. Therefore there is need to optimize the seat recliner.

8. Optimization

Optimization is the fact of obtaining the best result under given circumstances. In design, construction, and maintenance of any engineering system, engineers have to take many technological and managerial decisions at several stages. The ultimate goal of all such decisions is either to minimize the effort required or to maximize the desired benefit.

As the desired factor of safety for the automobile components is 3.3, therefore there is need to be optimize the seat recliner. Optimization of seat recliner is done in terms of reduction in its weight by reducing the thickness of various components.

1. Base plate, Plate arm, Lever release and Plate holder from 1.9 mm to 1.7 mm in two iterations
2. Upper tooth and Cam from 4.25 mm to 3.25 mm in two iterations and
3. Lower tooth from 5.2 mm to 4.6 mm in two iterations.

9. Proposed Recliner Assembly

Static analysis of the recliner assembly is carried out by using ANSYS software. The stress and deformation plots are shown in the following figures. The factor safety is calculated based on Von Mises Theory of Failure.

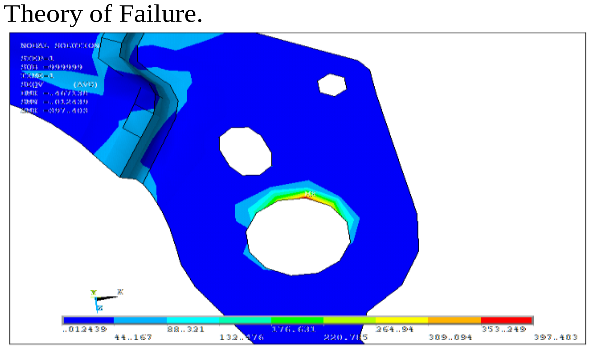

Fig 6. Stress plot

The Maximum stress is equal to 397.403 Mpa which singular stress due to rigid elements modeled at the hole .By neglecting singular stress, the actual working stress value is 88.32 Mpa, which is within the limits of permissible yield strength of 300 Mpa.

$$\text{Factor of safety} = \frac{\text{Yield strength (Mpa)}}{\text{Maximum Von Mises Stress (Mpa)}}$$

$$\text{Facotr of safety} = \frac{300\text{ Mpa}}{88.32\text{ Mpa}}$$

$$= 3.39$$

10. Results Summary

Summary of Existing Recliner Assembly

COMPONENT NAME	OUTPUT PARAMETER	VALUE	FACTOR OF SAFETY
RECLINER ASSEMBLY	VON MISES STRESS	79.39 N/mm2	3.78
	WEIGHT OF RECLINER	1.136 kg	

Summary of Proposed Recliner Assembly

COMPONENT NAME	OUTPUT PARAMETER	VALUE	FACTOR OF SAFETY
RECLINER ASSEMBLY	VON MISES STRESS	88.23 N/mm^2	3.39
	WEIGHT OF RECLINER	0.904 kg	

11. Conclusion

Optimization of seat recliner is done in terms of reduction in its weight by reducing the thickness of various components

1. Base plate, Plate arm, Lever release and Plate holder from 1.9 mm to 1.7 mm in two iterations
2. Upper tooth and Cam from 4.25 mm to 3.75 mm in two iterations and
3. Lower tooth from 5.2 mm to 4.6 mm in two iterations

The weight of the existing recliner assembly is found to be 1.136 kg and after design optimization the weight of the proposed recliner assembly has come to a weight of 0.904 kg. The percentage of reduction in weight is 20.5 %

As the factor of safety for the proposed recliner assembly subjected to loading is 3.39 which is the desired value, the design is optimum.

Also, as the maximum Von Mises stress obtained in any of the components is found to be 88.23 Mpa which is within the limits of permissible yield strength of 300 Mpa, the design is acceptable.

12. References

[1]. Pavan Gupta, Vijay Anand R, Dhanvanti Shinde, Jayant D Joshi, Sreenivasa Rao Nunna and K.S. Ramanath, "Anti-submarine Performance of an Automotive Seating System - A DOE study", EISAA Infosys Technologies Ltd, (2007).

[2]. D. M. Severy, H. M Brink and J. D. Baird, "Collision Performance LM Safety Car", SAE No 670458, SAE Mid Year Meeting Chicago Illinois, (1967).

[3]. F W Babbs and B C Hilton. "The packaging of car Occupants – A British Approach to seat design", Chapter 32, Seventh STAPP car crash conference, (1967).

[4]. A. W. Siegel, A. M. Nahum and D. E. Runge, "Bus Collision Causation and Injury Patterns", SAE No 710860, Proceedings of Fifteenth STAPP Car crash Conference Society of Automotive Engineers Inc, (1971).

[5]. Toshiki Nonka, Koichi Goto, Hirokazu Taniguchi and Kazumasa Yamazaki "Development of Ultra-High Strength Cold-Rolled Steel Sheets for Automotive Use", Nippon Steel Technical Report No. 88 (2003).

[6]. Sarah Smith, David S. Zuby and Adrian K. Lund, "Improved seat and head restraint evaluations", Marcy Edwards Insurance Institute for Highway Safety United States.

[7]. G. Nadkarni, N. Lazaridis and C. Horvath, "Advanced High Strength Steel Strategies in Future Vehicle Structures", International Automotive Body Congress, Sept. 19-21, Ann Arbor MI, 2005.

[8]. Guillén Abásolo and David. "Magnesium: the weight saving option", Grupo Antolin (2008).

[9]. C. Blawert, N. Hort and K.U. Kainer. "Automotive applications of magnesium and its alloys", Trans. Indian Instrumentation Metrology. Vol.57, No. 4 (2004).

[10]. Dr. Thomas G. Schuh, "Renewable Materials for Automotive Applications", Daimler-Chrysler AG, (2000).