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## A Review on Recent Design Optimizations of Truck Cabin to Reduce Interior Noise

Vishalagoud. S. Patil<sup>1</sup>, Dr. S. N. Kurbet<sup>2</sup>

Assistant Professor, Department of Mechanical Engineering, Government Engineering College, Haveri,  
Karnataka, India<sup>1</sup>

Professor and Head, Department of Mechanical Engineering, Basaveshwara Engineering College, Bagalkot,  
Karnataka, India<sup>2</sup>

**ABSTRACT:** Automobile styling and design has had an important impact on the world wide economy during the past century and millions of additional vehicles have been sold because of it. Much research work is being done on automobile interior design in comparison to other commercial or industrial designs. However, automobile design affects the journey of millions of passengers to a great degree, ergonomically, economically, culturally and comfort than many other subjects. Low noise level in the cabins is a comfort parameter of high importance. Therefore an attempt has been made in this paper to review the developments so far carried out in the field of optimization studies on reduction of noise in the truck cabins.

**KEYWORDS:** Design, CAD, FEM, Frequency, Noise, Vibration, Harshness, vibro-acoustic materials, toughness, hardness, brittleness, truck cabin, damping etc..

### I. INTRODUCTION

“Automobile styling and design has had an important impact on the world wide economy during the past century and millions of additional vehicles have been sold because of it. Much research are being done in automobile interior design in comparison to other commercial or industrial designs. However, automobile design affects the journey of millions of passengers to a great degree, ergonomically, economically, culturally and comfort than many other subjects.

Drivers comfort is not considered as a deciding factor in design of Indian truck. Driving condition in India such as roads and other factors are not good. Driving throughout the day in such conditions lead to accidents. So it is important to design cabin interiors considering, comfort, aesthetics and lower noise for drivers in Indian driving conditions. The task of design is usually split into three major aspects with respect to automobiles: exterior design, interior design and color and trim design.

Low noise level in the cabins is a comfort parameter of high importance. Since all most all places of work are subjected to regulations in the noise area, defining the maximum noise level a worker is allowed to be exposed to, the topic has become interesting.

In the design process one needs to go through for developing an appropriate noise reducing package treatment for a vehicle. In the design and development process one need to put proper emphasis on understanding the source, path and the receiver system. Then have an understanding of how to reduce the noise at required location. In terms of noise reducing treatments we should understand the fundamentals of acoustical materials, how they work and why one material performed differently than another. Interior vehicle noise can be caused by many sources. Primary excitation sources are:

- Engine / driverline
- Tyre / pavement

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In addition, there are secondary sources within the vehicles that cause noise issues, such as motors, pumps, brakes, climate control systems, actuators, and seat belt retractors.

As the time and distance of driving increases, noise reduction in the truck cabin becomes a critical problem for comfort improvement. Since the truck installs a high power diesel engine just below a floor panel in cabin, noise is more serious than a car. The rules insisted for lower noise from the Government of India has made the truck manufacturer to look for improvement in the cabin structure for lower noise.

In the cabin air quality testing is also important as the concentration of carbon monoxide (CO), oxides of nitrogen (NO<sub>x</sub>) and particulate matter, will leads to pollution inside the cabin while running and in the idle conditions.

Hence, improvement of a cabin body structure under the constraint of noise, vibration and harshness (NVH) behaviour is to be investigated.

## II. LITERATURE SURVEY

### Ling Zheng et al [1]

Have determined that, to reduce interior noise and to improve customer satisfaction, the structural acoustic modal was established and the response of sound pressure in frequency domain was obtained by FEM. The panel participation analysis was performed to find out the key panels as design variables and improve the efficiency of optimization computation. Response surface method (RSM) was utilized to optimize the vibro acoustic properties of vehicle body structure. It is observed that combination of geometry optimization for panels and topology optimization for the layout of constrained layout damping treatment will give rise to an effective control of interior noise.

### Fan Pingqinq et al[2]

Introduced the basic theory of model analysis. The modal analysis of truck cab were calculated based on FEM and results are compared with test results. It is observed that the natural frequencies and modal shapes obtained from the experiment and simulation were almost close to each other. The external excitations mainly come from road, engine, transmission of wheel etc.

### Kirankumarpedmallu et al[3]

Performed tests on noise reduction of can by NVH studies and improvement in drivers comfort point of view regarding safety aspects. It is observed that with testing and simulation using RADIOSS, number of design iterations are carried out with much lesser time to get the best optimum design for cab structure in terms of interior noise.

### L Andrenet all [4]

Here Loudspeakers were mounted inside the cabin of a fork lift-truck to produce the secondary noise field. To sense the residual noise, microphones were installed close to the driver's head. The aim is to create a zone of reduced noise around the head. Since, a large portion of the noise inside the cabin can be related to the engine, an active control system based on a feedforward solution is possible. Experimental results show that the noise level in the low frequency region can be reduced significantly.

### ShahramAzadiet all [5]

Modeled a car body geometry in a CATIA software and meshed in HYPERMESH software. Then, a modal analysis between 0-50 Hz is done by MSC NASTRAN. By using factorial and response surface methods (RSM), optimization of the NVH performance is accomplished. At last, in order to verify the present algorithm, forced vibration is analyzed under real road inputs for the model and after improvements.

### Joshua S. Fu et all [6]

Heavy duty diesel vehicles were measured for the noise level, whole-body vibration from the driver's seat, and in-cab air quality while the vehicles were parked with engine idling at a rest area and while they were driven.

### Nobuyuki OKUBO et all [7]

Here, an efficient and practical design approach of floor panel is performed to suppress the transmission of emission sound from engine for the frequency range of interest. An actual truck floor panel is used to find out the best rib position and installed to validate the improvement under engine running conditions.

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## Amiya R. Mohanty et al [8]

A CAE method is developed for noise prediction in a truck cab interior. The finite element (FE) and the boundary element method (BEM) are used to characterize the acoustic field of a truck cab interior in terms of its natural frequencies and mode shapes. Structural vibration response of the cab are computed for excitations at the cab mounts in a frequency range from 50 to 250 Hz. Then interior noise levels at the driver's right ear location are computed using the BEM.

## C R Fredoet et al [9]

Here, a method for panel embossing optimization with respect to NVH is outlined and exemplified for a truck cab floor. The selection of embossing shape functions from mode shapes yield sufficient control to guide the natural frequencies of unwanted noisy modes into selected frequency bands.

## D. Williams et al [10]

Here, comparisons are made between dB (A) and linear sound pressure levels under motor way conditions at 30, 40, and 50 mile/h. The data were collected and the results confirm that high levels of infrasound exist in the cabs and these levels are influenced by the ventilation of the cab and road speed.

## A S Sarigul et al [11]

Acoustical characteristics of a truck cabin were determined for both hard and impedance wall boundary conditions by using BEM. The sound pressure levels to which the truck driver may be subjected were calculated and two resonances were detected in the examined frequency range. The beneficial effect of the sound absorbent material on the interior acoustics of the cabin is presented through the considerable reduction in the sound pressure level.

## Hiroai Hoshino et al [12]

In this study, the load transfer in a cab structure of a heavy-duty truck was investigated using the load path analysis and the relationship between the reduction of vibration and the improvement of load transfer paths was discussed.

### III. RECENT RESEARCH

The engine noise includes combustion noise and mechanical noise that can be both airborne and structure borne. Road noise is generated from the vibration of the tire casing due to irregularities of the road surface. These irregularities are due to structural excitation, and unless proper care is taken to address the issue at the beginning, vibration will radiate as structure borne noise. [1]

With rapid growth of the buildings, long range transportation and logistics, the truck has a huge development in the automotive industry because of the dead weight. In the running process, the external and motivations, induced by the uneven surface of road, the change of speed and direction, the vibrations coming from wheel, engine and transmission system, the impact of gear and so on easily cause a strong vibration of a cab. The vibration brings many disadvantages such as making the driver and passenger feel uncomfortable, bringing noise and failure of components, damaging the protective layer and sealing capacity and weakening the corrosion capacity of the cab. Also the high comfort for the driver on the cab is an important feature [2]. In experiment the excitation points were measured by triaxial sensor, and the pick-up points were tested in seven batches. Each batch included 30 moving sensors to test along x, y, z three directions as shown in the figures below.

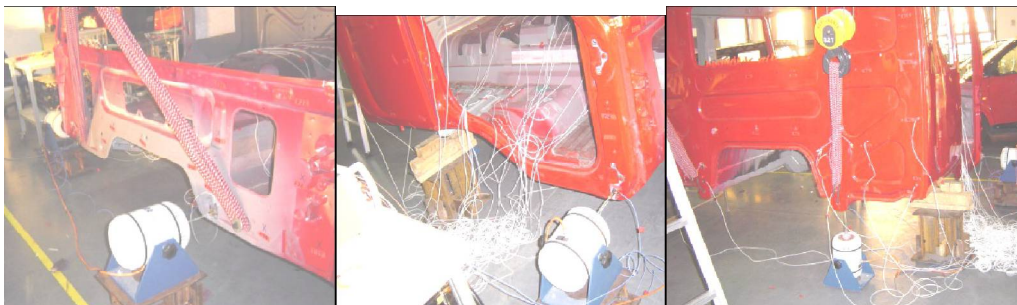


Fig.1 The exciting point in X-direction

Fig.2 The exciting point in Y-direction

Fig.3 The exciting point in Z-direction

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213 collection points were identified as shown in fig 4 below and the distribution were 40 points located in firewall, 64 points lied in side plates, 43 points lied in floorboard, 29 points in roof panel and 37 points in rear quarter panel. The FE model of the truck cab is shown in fig.5.

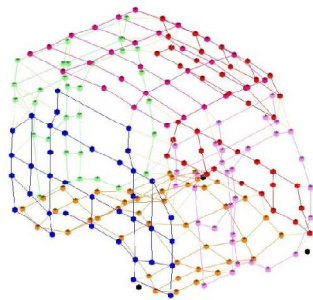


Fig.4 The layout of test points



Fig.5 Finite Element Model of truck cab.

As the time and distance of driving increases, noise reduction in the truck cabin becomes a critical problem for comfort improvement. Since the truck installs a high power diesel engine just below a floor panel in cabin, noise is more serious than a car. The rules insisted for lower noise from the Government of India has made the truck manufacturer to look for improvement in the cabin structure for lower noise. [3]

The structure borne noise reduction of the commercial vehicle cab in comparison with the benchmark vehicle available in the market, the Finite Element Method (Vibro-acoustic) can be used for the prediction of the interior noise. Sound pressure level (SPL) and different panel contributions can be identified for critical frequencies. Area of improvements are identified accordance with the different panel contributions to the response. Optimization of the critical panels are done at critical frequencies using optistruct and feasible design modifications are suggested for the areas which are contributing to the vibrations. [4]

Active noise control in a cabin is a possible solution to reduce low frequency noise in a fork lift-truck. Since, the cabin noise is mainly airborne, the approach is to use loudspeakers and microphones in the active noise control system. The active noise control system attenuated the truck noise with approximately 10 dB SPL at 1800, 2000 and 2220 rpm of the engine. [5]

Heavy duty diesel vehicles were measured for the noise level, whole-body vibration from the driver's seat, and in-cab air quality while the vehicles were parked with engine idling at a rest area and while they were driven. In the cabin air quality testing is also important as the concentration of carbon monoxide (CO), oxides of nitrogen (NO<sub>x</sub>) and particulate matter, will leads to pollution inside the cabin while running and in the idle conditions. During driving on public roadways, in-cab concentrations were lower than those measured during the extended parked-idling conditions.

### Air Quality:

Air quality data were collected from a total of 27 trucks. Collocation experiments involving the PM2.5 analyzers demonstrate that a linear equation ( $R^2 \sim 0.91$ ,  $p < .0001$ ) was the best-fit line between the OPC and TEOM data, and a two-level polynomial or quadratic equation ( $R^2 \sim 0.94$ ,  $p < .0001$ ) was the best-fit line for the DRam and TEOM data. Thus, the actual PM2.5 data from the DRam and OPC were corrected to TEOM values. The  $R^2$  value between the TEOM-corrected OPC and DRam data was approximately 0.86, which was reasonable ( $p < .0001$ ). [6]

Since, truck installs a high power diesel engine just below a floor panel in cabin, noise is more serious than a car. The airborne noise is of great importance especially for the frequency range about 200 – 500 Hz. Therefore an efficient and practical design approach of floor panel is strongly desired to suppress the transmission of emission sound from engine for the frequency range of interest. An actual truck floor panel is used to find out the best rib position and installed to validate the improvement under engine running conditions. [7]

Further work CAE method can be developed for noise prediction in a truck cab interior. The finite element (FE) and the boundary element method (BEM) are used to characterize the acoustic field of a truck cab interior in terms of its natural

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frequencies and mode shapes. Structural vibration response of the cab are computed for excitations at the cab mounts in a frequency range from 50 to 250 Hz. Then interior noise levels at the driver's right ear location can be computed using the BEM. Cab mounts play a very important role in noise control, since they are the major paths through which structure-borne energy enters the cab and in turn produces noise. For the normal mode analysis of the cab interior air mass, the air mass is modelled as a fluid using bulk properties of speed of sound in air and the density of air. The air mass in the interior of the cab is modelled with tetrahedral, pentahedral and hexahedral solid elements in MSC/NASTRAN. The model has in total about 4000 solid elements. The seats present in the cab are also included in the model. Ten acoustic modes of the air-mass are obtained in frequencies up to 250 Hz [8].

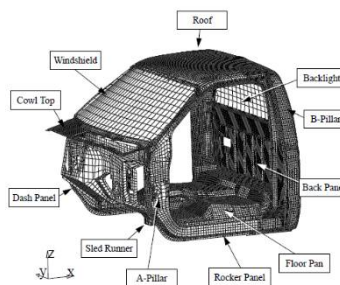


Fig.6 A MSC/NASTRAN FE model of truck body

A method for panel embossing optimization with respect to NVH can be outlined and exemplified for a truck cab floor. The selection of embossing shape functions from mode shapes yield sufficient control to guide the natural frequencies of unwanted noisy modes into selected frequency bands. The floor weight gets optimized since the embossing pattern replaces the reinforcing cross beams. [9]

Comparisons may be made between dB (A) and linear sound pressure levels under motor way conditions at 30, 40, and 50 mile/h. The data can be collected and the results confirm high levels of infrasound exist in the cabs and these levels are influenced by the ventilation of the cab and road speed. It is found that, on the grounds of the risk of hearing loss, and possible effect on vigilance, for a reductions in the levels of cab noise below 90+dB (A) reaches in some cases. The infrasonic sound will present many problems. The reduction of the low frequency component of the overall noise represents a challenge to all those concerned with vehicle improvement and ultimately, safety on the roads. [10]

Interior acoustics of truck cabin can also be determined with acoustic linings in order to improve the interior comfort. Acoustical characteristics of a truck cabin were determined for both hard and impedance wall boundary conditions by using BEM. The sound pressure levels to which the truck driver may be subjected were calculated and two resonances were detected in the examined frequency range. The beneficial effect of the sound absorbent material on the interior acoustics of the cabin is presented through the considerable reduction in the sound pressure level [11]. The boundary element discretization model of the truck cabin is as shown in fig.7.

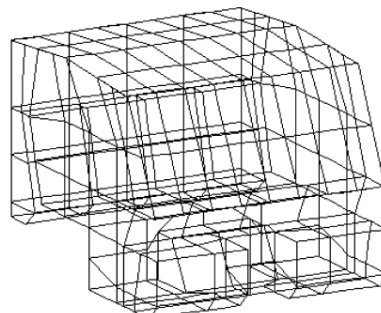


Fig.7 Boundary element discretization model of the truck cabin



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The vibrations in the cabins can be reduced by investigating the load transfer paths in the cabin structure of heavy-duty trucks under static loading conditions. It is found that the floor panel vibration is closely related to the stiffness of the front cross-member of the floor structure. Load path analysis using FEM will give the results that low stiffness of the front cross member is caused by discontinuities and nonuniformities in the load paths. [12]

Hence, improvement of a cabin body structure under the constraint of noise, vibration and harshness (NVH) behaviour is to be investigated.

## IV. CONCLUSIONS

- The natural frequencies and mode shapes obtained from experiment and simulation provides the important design basis to improve truck cab.
- A number of design iterations can be carried out to get the best optimum design for the cab structure in terms of interior noise.
- Active noise control in a cabin is possible solution to reduce low frequency noise in a truck. The active noise control system attenuated the truck noise with approximately 10 dB SPL at 1800, 2000 and 2220 rpm of the engine.
- The noise from tires, engine rpm, and wind impacting the cab at higher road speed contributed to elevated noise levels measured during travel.
- Cab mounts play a very important role in noise control, since they are the major paths through which structure borne noise enters the cab and in turn produces noise.
- The selection of embossing shape functions from mode shapes yield sufficient control to guide the natural frequencies of unwanted noisy modes into selected frequency bands.
- Acoustical characteristics of a truck cabin were determined for both hard and impedance wall boundary conditions by using boundary element method.

## V. FUTURE DEVELOPMENTS

Current research is focussing on development of user-friendly truck cabin which has almost zero noise in the cabin. The structural-acoustic model is established and the response of the sound pressure in frequency domain is obtained by using finite element method. The minimization of sound pressure near the driver's right ear depends on the geometry of the vehicle body structure and the layout of damping treatments. The panel participation analysis is performed to find out the key panels as design variables and to improve the efficiency of optimization computation. Geometry optimization problem of panels is described and solved to minimize the interior noise in vehicle. In the optimization model, the first mode frequency, the bending and twisting stiffness as well as weight are considered as constraints. Physical tests are performed and the data are collected. The data are used to correlate the performance of FE model in numerical simulation under similar loading conditions. The baseline FE model will be used for further design iterations and virtual testing is performed. By performing this virtual test, the final design configuration can be achieved and the final physical test is carried out to verify the design performance

## ACKNOWLEDGEMENT

The study is for improving diesel truck cabin interiors to reduce fatigue, noise and improve driver health and performance. The authors would like to thank all the staff for their support and guidance in making this work and paper.

## REFERENCES

- [1]. Ling Zheng, Zhanpeng Fang. "The design Optimization of Vehicle Interior noise through Structural Modification and constrained layer damping" 2015.
- [2]. Fan Pingqing, Wang Yansong, Zhao Linlin. "Modal Analysis of a Truck Cab using the Least Squares complex exponent Test Method" Shanghai University of Engineering Science, Shanghai.

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- [3]. Kirankumar Peadmallu, Manoj Purohit and Dr.D.W.Pande "Interior Noise Reduction of CAB using RADIOSS (Implicit)". Altair Technologies Conference, 2013 India.
- [4]. L Andren, S. Johansson, M. Winberg and I. Claesson. "Active Noise Control Experiments in a fork-lift truck cabin"
- [5]. Shahram Azadi, Mohammad Azadi, Farshad Zahedi "NVH Analysis and Improvement of a Vehicle Body Structure using DOE method" Journal of Mechanical Science and Technology 2009 Springer.
- [6]. Joshua S. Fu, James A. Calcagno III, Wayne T Davis and Albert Alvarez "Evaluation of Noise Level, Whole-Body, Vibration, and Air Quality Inside cabs. of Heavy-Duty Diesel Vehicles" Journal of transportation research board pp 29-36, 2010.
- [7]. Nobuyuki OKUBO, Takeshi OKUMORA and Takeshi TOI "Noise Reduction in Truck Cabin by Design Change of Floor Panel" IMAC-XXVII 2009 Society of Experimental Mechanics Inc.
- [8]. Amiya R. Mohanty, Barry D. St. Pierre and P. Suruli-Narayanasami "Truck Interior Noise Prediction by FEM and BEM" Ford Motor Company, Vehicle centre 5, Dearborn, MI 48126 USA.
- [9]. C R Fredo and Anders Hedlund "NVH optimization of truck cab floor panel embossing pattern" 2004 SAE International
- [10]. D. Williams and W. Tempest "Noise in a Heavy Goods Vehicles" Journal of Sound and Vibrations 1975
- [11]. A S Sarigul and Z. Kiral "Interior acoustics of a truck cabin with hard and impedance surfaces" ELSEVIER page no 769-775, 1999.
- [12]. Hiroai Hoshino, Toshiaki Sakurai and Kunihiro Takahashi "Vibration reduction in the cabins of heavy-duty trucks using the theory of load transfer paths" in ELSEVIER 2002.