IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

# Review Of Topography Optimization Of Cabin Floor Of Commercial Vehicle

Name of 1st Author-Rohit Anil Pharate, Name of 2nd Author- Dr.Anil Sahu

Designation of 1st Author- Student, [2]Designation of 2nd Author- Professor

Name of organization of 1st and 2nd Author- G H Raisoni College of Engineering and Management, Pune, affiliated to Savitribai Phule Pune University, Pune, INDIA

**Abstract:** The cabin floor is one of the most important structural components in a commercial vehicle Body-in-White (BIW), contributing significantly to global stiffness, vibration control, and passenger comfort. Due to its large and thin sheet metal geometry, the cabin floor is highly susceptible to low-frequency vibration and structural resonance, which negatively affect Noise, Vibration, and Harshness (NVH) performance. Traditional stiffness improvement methods such as thickness increase and additional reinforcements often lead to increased vehicle mass and manufacturing cost. To overcome these limitations, topography optimization has emerged as an efficient Computer-Aided Engineering (CAE) technique for improving stiffness through optimized bead generation without adding extra material. This review paper presents a comprehensive study of topography optimization methods applied to automotive floor structures, focusing on stiffness enhancement, natural frequency improvement, and NVH performance. Various research studies, optimization methodologies, design constraints, and commercial software tools used in topography optimization are reviewed. The study also identifies current research gaps related to commercial vehicle cabin floor applications and highlights future opportunities in vehicle-level optimization.

## Introduction

The automotive industry continuously demands lighter, stronger, and more refined vehicle structures to improve fuel efficiency, structural durability, and passenger comfort. Among various Body-in-White (BIW) components, the cabin floor is a critical load-bearing structure that directly influences the global bending stiffness, torsional rigidity, and vibration characteristics of the vehicle body. It also acts as one of the primary transmission paths for road-induced vibration into the passenger compartment.

In commercial vehicles, the cabin floor becomes even more critical due to larger panel dimensions, heavier operating loads, and increased exposure to road excitation. If the natural frequencies of the cabin floor coincide with the operational excitation frequencies, resonance occurs, resulting in excessive vibration amplitude, increased interior noise, and poor NVH performance.

Traditionally, structural stiffness is improved by increasing material thickness or adding reinforcement members. Although effective, these methods lead to weight increase and reduced design efficiency. Therefore, modern automotive engineering increasingly focuses on optimization-driven lightweighting methods. Among available structural optimization methods, topography optimization has gained significant importance because it enhances stiffness through localized geometric modifications such as bead formation, embossments, and ribs without increasing mass.

**Cabin Floor and NVH Relationship**

The cabin floor serves as a major vibration transfer path between road excitation sources and the passenger compartment. Road inputs generate structure-borne vibration, which propagates through suspension and body panels into the cabin.

If the cabin floor natural frequencies coincide with excitation frequencies, resonance occurs, causing:

- Higher vibration amplitude,
- Interior booming noise,
- Poor ride comfort,
- Reduced passenger satisfaction.

Therefore, improving cabin floor stiffness and shifting its natural frequencies away from operational excitation range is essential.

**Fundamentals of Topography Optimization**

Topography optimization is a structural optimization technique specifically developed for thin sheet metal components. Unlike topology optimization, which removes or redistributes material, and shape optimization, which modifies boundary contours, topography optimization introduces local geometric features such as beads, embossments, and ribs on shell structures.

These bead features increase local bending stiffness and improve global dynamic behaviour by increasing the moment of inertia of the panel. This method is highly suitable for automotive components such as floor panels, roof panels, door inners, and underbody structures.

**LITERATURE REVIEW**

| Sr. No. | Author | Year | Method | Aplication | Findings |
|---|---|---|---|---|---|
| 1 | Bendsoe & Kikuchi | 1988 | Homogenization-based topology optimization | Structural design optimization | Introduced topology optimization concept for optimal material distribution and structural stiffness improvement. |
| 2 | Suzuki & Kikuchi | 1991 | Shape and topology optimization | Structural optimization | Extended homogenization method for combined shape and topology optimization applications. |
| 3 | Wang et al. | 2020 | Literature review | Vehicle road noise | Reviewed structure-borne road noise mechanisms and highlighted importance of panel stiffness in NVH control. |
| 4 | Sharma & Kumar | 2019 | Experimental NVH analysis | Passenger vehicle booming noise | Identified low-frequency body resonance as a major |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | source of interior booming noise. |
| 5 | Lee et al. | 2021 | Experimental vibration analysis | Road-induced vibration | Investigated effect of road inputs on vehicle vibration and structural dynamic response. |
| 6 | SAE International | 2011 | CAE-based bead optimization | Vehicle floor panel | Demonstrated that floor bead optimization significantly improves low-frequency NVH performance. |
| 7 | Kumar & Patel | 2018 | Contribution analysis | Vehicle interior noise | Showed that floor panels significantly contribute to cabin noise and must be shifted away from excitation frequencies. |
| 8 | SAE International | 2003 | Road load development | Road noise analysis | Developed representative road input loads for accurate vehicle NVH analysis. |
| 9 | Gibson & Stölken | 2003 | Gibson & Stölken | Beaded sheet structures | Confirmed that bead features improve local bending stiffness of thin sheet structures. |

**Research Gap**

Although significant research has been carried out in the field of structural optimization and automotive body stiffness improvement, several important research gaps still exist in the application of topography optimization for commercial vehicle cabin floor structures.

Most of the available literature on topography optimization has primarily focused on general automotive sheet metal components such as roof panels, door inners, underbody panels, and passenger vehicle floor structures. However, very limited published work specifically addresses commercial vehicle cabin floor panels, despite their critical role in structural stiffness, vibration control, and passenger comfort. Commercial vehicle cabin floors differ significantly from passenger vehicle floors due to their larger dimensions, higher loading conditions, and increased exposure to severe road-induced excitation, requiring dedicated investigation.

Another major gap identified in the literature is the limited emphasis on dynamic stiffness improvement through modal frequency enhancement. While several studies report structural optimization results, many focus mainly on weight reduction or general stiffness improvement without detailed analysis of lower-order natural frequencies, which are most critical for cabin floor vibration behaviour and NVH refinement.

A further limitation is the inadequate representation of realistic boundary conditions in existing studies. Many published works adopt simplified or idealized constraints, which may not accurately represent actual vehicle assembly conditions. In real automotive structures, the cabin floor is connected through multiple spot weld joints and structural interfaces, which strongly influence modal characteristics. Limited research has incorporated such practical connection modelling into topography optimization studies.

In addition, manufacturing feasibility constraints are not consistently addressed in available literature. Parameters such as bead width, draw height, draw angle, and forming limitations are often simplified or ignored, resulting in optimized designs that may not be directly suitable for production-level implementation. This creates a gap between simulation-based optimization and practical automotive design application.

Another important research gap is the limited availability of application-specific optimization methodologies for commercial vehicle BIW components. Most studies discuss topography optimization in a generalized manner, but few provide a complete and systematic methodology—from baseline modal analysis to design variable definition, optimization setup, and post-optimization validation—for direct industrial implementation.

Finally, although CAE-based optimization is widely reported, there remains a need for more industry-oriented case studies demonstrating the practical implementation of topography optimization on real automotive components. Such studies are essential to bridge the gap between theoretical optimization methods and actual engineering application.

Therefore, the present research focuses on addressing these gaps by developing a structured and practical topography optimization methodology for a commercial vehicle cabin floor, considering realistic boundary conditions, manufacturable bead design constraints, and modal-performance-based stiffness improvement.

**Conclusion**

Topography optimization is an efficient CAE-based structural optimization technique for improving cabin floor stiffness and NVH performance without increasing material thickness or introducing additional reinforcements. By generating optimized bead patterns on thin sheet metal structures, it enhances local and global stiffness through intelligent geometric modification, making it highly suitable for automotive Body-in-White (BIW) applications where lightweight design and structural efficiency are equally important.

The literature reviewed in this study confirms that topography optimization has strong potential for achieving multiple engineering objectives simultaneously, including stiffness enhancement, natural frequency improvement, vibration reduction, and overall dynamic performance improvement. Compared to conventional methods such as thickness increase or additional reinforcements, topography optimization offers a more efficient and cost-effective approach because it improves structural behaviour without significant mass addition, thereby supporting modern automotive lightweighting requirements.

Although significant progress has been made in this field, further studies on commercial vehicle applications and vehicle- and subsystem-level implementation are still required to fully understand the real-world benefits of topography optimization under actual operating conditions. Future research integrating full vehicle NVH assessment, subsystem interaction, and experimental validation will further strengthen the industrial application of this optimization technique.

Overall, topography optimization represents a highly promising and industrially relevant design methodology for developing lighter, stiffer, and dynamically superior automotive structures, making it an important tool for future vehicle development programs.