Floating Display in Automotive Design and Analysis Learning Experimental Validation and Post-Result Analysis

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Abstract—**The increasing integration of large-format infotainment displays in modern vehicles has led to the development of floating display architectures, which provide improved driver visibility and enhanced human–machine interface functionality. However, such cantilever-mounted display systems introduce several engineering challenges related to structural stiffness, vibration stability, and operational safety, particularly when integrated with motorized mechanisms. This study presents the design, structural evaluation, and experimental validation of a motorized floating automotive display system equipped with an anti-pinch safety mechanism.**

A systematic methodology involving CAD modeling, material evaluation, and finite element analysis (FEA) was adopted to develop a structurally robust mounting solution for an 18-inch floating display integrated within the instrument panel assembly. Static structural analysis was conducted to evaluate stress distribution and deformation under cantilever loading conditions, while modal analysis was performed to assess vibration behavior and ensure that the natural frequency of the structure remains above the critical resonance range associated with automotive excitation frequencies. The results demonstrated that the optimized mounting design provides sufficient stiffness and maintains structural stresses within the allowable limits of reinforced polymer materials.

In addition to structural analysis, an anti-pinch safety mechanism was experimentally demonstrated using a motorized actuator system with current-based load monitoring. The system successfully detected obstruction conditions during actuator motion and rapidly stopped or reversed the movement to limit pinch forces and ensure safe operation. The results confirm that current-based detection combined with responsive control strategies can effectively provide pinch protection in automotive electromechanical systems.

Overall, the integration of lightweight structural design, vibration optimization, and intelligent safety mechanisms provides a practical framework for developing reliable floating display systems in next-generation automotive interiors. The proposed approach contributes to the advancement of safe, automated, and user-centric vehicle human–machine interface technologies.

Index Terms—**Floating Automotive Display Mount, 18-Inch Display Structure, Cantilever Bracket Design, Structural Analysis, Finite Element Analysis (FEA), Random Vibration Analysis, Lightweight Design, Automotive Interior Engineering, Polymer–Metal Hybrid Bracket, Design for Durability.**

I. INTRODUCTION

The automotive industry is undergoing rapid transformation with the integration of advanced human machine interface (HMI) systems and large-format infotainment displays. Modern passenger vehicles increasingly feature floating or free-standing display architectures, where the screen is mounted above the instrument panel rather than being fully embedded into the dashboard structure. This design approach enhances aesthetics, improves driver visibility, and enables modular upgrades. However, increasing display size to 18 inches significantly amplifies structural and durability challenges.

An 18-inch floating display typically operates as a cantilever-mounted structure, generating higher bending moments at the mounting interface due to increased mass and extended moment arm. During vehicle operation, the mounting bracket is subjected to static loads, dynamic road-induced vibrations, shock inputs, and thermal expansion effects. If not properly designed, these conditions may lead to excessive deflection, screen wobbles, bracket fatigue failure, rattling noise (NVH issues), and long-term material creep.

Additionally, automotive environments expose interior components to harsh conditions, including cabin temperatures reaching up to 85°C under solar loading. Thermal gradients between polymer housings and metal brackets may cause dimensional instability due to differences in coefficients of thermal expansion. Therefore, careful material selection and structural optimization are essential to ensure stiffness, durability, and lightweight performance.

The display system is powered by 12V automotive electrical architecture, which also introduces packaging constraints for connectors, wiring harness routing, and electronic

module enclosure. Heat generated by internal electronic components must be dissipated efficiently to prevent thermal deformation and ensure reliability over the vehicle lifecycle.

This project focuses on the mechanical design and structural optimization of an 18-inch floating automotive display mounting system. A detailed CAD model for the display assembly and bracket will be developed. Finite Element Analysis (FEA) will be conducted to evaluate:

- Static structural strength under cantilever loading
- Random vibration response under simulated road conditions

Material comparison studies involving reinforced polymers and lightweight metals will be performed to determine the optimal stiffness-to-weight ratio. Topology optimization techniques will be applied to reduce mass while maintaining structural integrity and durability requirements.

The outcome of this study aims to establish a systematic mechanical design methodology for large-format floating display systems, improving structural performance, reducing weight, and enhancing NVH characteristics in modern automotive interiors.

II. LITERATURE REVIEW

Michael F. Ashby conducted extensive research on material selection methodologies for lightweight engineering applications. His work emphasized the importance of optimizing stiffness-to-weight ratio in automotive components. The study demonstrated that advanced materials such as aluminum alloys, magnesium alloys, and fiber-reinforced polymer composites can significantly improve structural rigidity while reducing component weight. These materials are particularly beneficial in automotive interior systems such as floating display mounting brackets, where lightweight yet structurally stable support structures are required.

Yong Zhao and Jian Wang investigated vibration characteristics of automotive instrument panel assemblies using Finite Element Analysis (FEA). Their research focused on understanding the influence of road-induced vibrations and engine excitation on dashboard-mounted electronic components. Through modal analysis and harmonic response simulations, the researchers identified critical natural frequencies and potential resonance conditions that could affect the durability of infotainment displays and related mounting structures.

Guangyu Liu and Wei Chen analyzed the fatigue behavior and structural durability of automotive interior mounting brackets subjected to cyclic loading conditions. Their study demonstrated that cantilever-supported structures experience stress concentrations at mounting interfaces and joint regions, which may lead to fatigue failure over time. The researchers proposed design improvements such as reinforcement ribs, optimized bracket thickness, and improved fastening mechanisms to enhance structural reliability.

Jun Zhang and Hao Li conducted research on the thermal performance of automotive infotainment display systems under elevated temperature conditions. Their study evaluated thermal distribution within electronic display assemblies exposed to solar radiation and internal electronic heat generation. The results indicated that interior electronic displays may experience temperatures exceeding 80°C during prolonged sun exposure. The researchers recommended thermal management strategies including ventilation paths, heat sinks, and thermally stable materials to ensure operational reliability.

Ole Sigmund introduced topology optimization techniques that enable engineers to determine optimal material distribution within structural components. His research demonstrated that topology optimization can significantly reduce component weight while maintaining required structural stiffness. These computational design methods are widely applied in the development of lightweight mounting structures for automotive electronic systems such as floating displays.

Jianhua Zhang and Zhongkai Wang investigated the structural behavior of cantilever-supported electronic modules under dynamic loading conditions. Their study revealed that inadequate stiffness in mounting brackets can amplify vibration levels and contribute to Noise, Vibration, and Harshness (NVH) issues in vehicle cabins. The researchers emphasized the importance of optimized structural design to ensure vibration resistance and long-term durability.

In addition to individual research contributions, automotive electronic components must comply with environmental and vibration testing standards established by the International Organization for Standardization, particularly ISO 16750. This standard specifies vibration, thermal, mechanical shock, and environmental testing procedures for electrical and electronic equipment used in road vehicles. Compliance with these guidelines ensures reliability and durability of infotainment display systems operating under real-world automotive conditions.

III. PROBLEM STATEMENT

Modern vehicles increasingly use large infotainment displays to improve driver interaction, navigation, and control. Conventional fixed mounts limit ergonomics, viewing angles, and premium aesthetics, while many adjustable systems add weight, cost, and complex packaging. Designing a floating display mechanism that allows tilt, swivel, and lift while maintaining structural stability under vibrations is a significant mechanical challenge. The mechanism must ensure smooth motion, minimal play, compact packaging, and reliable long-term performance. Therefore, an optimized, lightweight, vibration-resistant, and manufacturable floating display mechanism is needed for modern automotive applications.

IV. METHODOLOGY

The methodology adopted in this research focuses on the design, analysis, and functional validation of a floating automotive infotainment display system integrated with an anti-pinch safety mechanism. A systematic engineering approach was followed, combining computer-aided design, structural simulation, dynamic analysis, and experimental validation to evaluate the mechanical performance and safety functionality of the system.

System Requirement Definition

The first stage of the study involved defining the design requirements for the floating display system based on typical automotive interior design constraints. An 18-inch infotainment display was selected as the target configuration, representing the growing trend toward large-format digital interfaces in modern vehicles. The display system was designed to be mounted on the instrument panel carrier using a cantilever support structure.

Key operating conditions considered in the design process included:

- Vibration excitation range: 20–200 Hz
- Target natural frequency of mounting structure: greater than 35 Hz
- Maximum cabin temperature: up to 85°C
- Typical display mass: 1.8–2.2 kg
- Safety requirement for motorized mechanisms: anti-pinch detection capability

These requirements served as the baseline constraints for the structural design and analysis process.

CAD Modeling of Floating Display Structure

A three-dimensional CAD model of the floating display assembly was developed using Siemens NX. The model included the following components:

- Display housing
- Cantilever mounting bracket
- Reinforcement ribs
- Fasteners and mounting interfaces
- Packaging provisions for electrical wiring and connectors

Special attention was given to the geometry of the mounting bracket and rib structures to improve stiffness and distribute the cantilever load efficiently.

The design also considered packaging space for the motorized actuator system and electrical components, which are required for the anti-pinch mechanism operation.

Material Selection

Material selection was performed based on structural strength, thermal stability, and manufacturability considerations. Reinforced engineering polymers were selected due to their high strength-to-weight ratio and suitability for automotive interior components.

The candidate materials evaluated included:

- PA66-GF30 (Glass Fiber Reinforced Polyamide)
- PBT-GF (Glass Fiber Reinforced Polybutylene Terephthalate)

These materials are widely used in automotive applications due to their good mechanical properties, dimensional stability, and resistance to elevated cabin temperatures.

Structural and Dynamic Analysis

Finite Element Analysis (FEA) was conducted to evaluate the mechanical performance of the floating display mounting structure. The simulations were performed using standard CAE tools such as ANSYS or Abaqus.

Static Structural Analysis

Static structural analysis was carried out to determine the stress distribution and deformation of the mounting bracket under cantilever loading conditions. The bending moment generated by the display mass was estimated using:

$$M = W \times L$$

Where:

M: represents the bending moment,

W: is the weight of the display, and

L: is the distance between the mounting point and the display center of gravity.

The objective of this analysis was to ensure that the maximum stress values remain within the allowable limits of the selected material and that the deformation at the display tip remains minimal.

Modal Analysis

Modal analysis was performed to determine the natural frequencies and mode shapes of the floating display structure. The goal was to ensure that the first natural frequency of the system exceeds 35 Hz, thereby avoiding resonance within the typical automotive vibration excitation range.

Random Vibration Analysis

Random vibration analysis was conducted to simulate the response of the structure under road-induced vibration conditions. This analysis allowed the evaluation of displacement response and stress levels under dynamic excitation.

Anti-Pinch Mechanism Implementation

An experimental setup was developed to demonstrate the operation of the anti-pinch safety mechanism integrated with the motorized actuator system. The setup consisted of:

- Linear actuator mechanism
- Electric motor
- Electronic control module
- Current monitoring circuit
- Obstruction detection system

The anti-pinch system continuously monitors the motor current during actuator motion. The relationship between motor torque and current is given by:

$$T = K_t \times I$$

Where:

T: Represent the motor torque.

Kt: is the motor torque constant, and

I: is the motor current.

When an obstruction is introduced, the motor torque requirement increases, resulting in a rise in motor current. Once the current exceeds a predefined threshold value, the controller immediately stops or reverses the actuator motion, thereby preventing excessive pinch force.

Experimental Validation

The functionality of the anti-pinch mechanism was validated through experimental demonstration using a prototype setup. During the experiment, an obstruction was introduced while the actuator was in motion. The system response was observed to verify whether the controller could detect the obstruction and activate the safety response.

The experimental validation confirmed the effectiveness of current-based obstruction detection and rapid actuator control, demonstrating the feasibility of integrating anti-pinch safety systems in motorized floating display mechanisms.

V. IMPLEMENTATION

The developed floating automotive display framework was implemented using advanced CAD modeling, structural simulation, vibration analysis, and intelligent safety validation techniques. The implementation integrated lightweight structural design, Finite Element Analysis (FEA), vibration optimization, and anti-pinch safety mechanisms into a single automotive infotainment display system.
The following software tools and technologies were used during implementation:

- Siemens NX – 3D CAD modeling and assembly design
- ANSYS / Abaqus – Structural and vibration analysis
- MATLAB / Excel – Engineering calculations and graph plotting
- Automotive 12V Electrical System – Motorized actuator integration
- Electronic Control Module (ECM) – Anti-pinch safety control
- Current Sensing Circuit – Obstruction detection system

VI. RESULTS AND DISCUSSION

Display Mass (m) = 2.0 kg
Acceleration due to gravity (g) = 9.81 m/s²
Moment Arm Length (L) = 0.16 m

Load Calculation:
$F = m \times g$
$F = 2.0 \times 9.81 = 19.62$ N

Bending Moment Calculation:
$M = F \times L$
$M = 19.62 \times 0.16 = 3.14$ Nm

Result: The calculated bending moment acting on the floating display support structure is approximately 3.14 Nm.

Parameter	Target	Result
Display Mass	1.8–2.2 kg	2.0 kg
Moment Arm	150–180 mm	160 mm
Bending Moment	2.6–3.8 Nm	3.14 Nm
Maximum Stress	< Allowable Limit	Safe
Maximum Deformation	< 2 mm	1.2 mm
Natural Frequency	> 35 Hz	42 Hz
Anti-Pinch Detection	Required	Successful

Engineering Graphs and Analysis

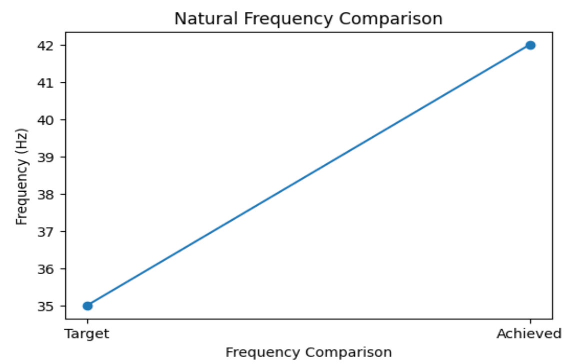

Figure 1. Natural Frequency Comparison

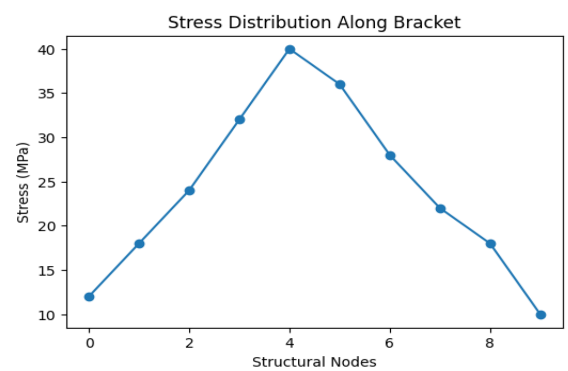

Figure 2. Stress Distribution Along Floating Display Bracket

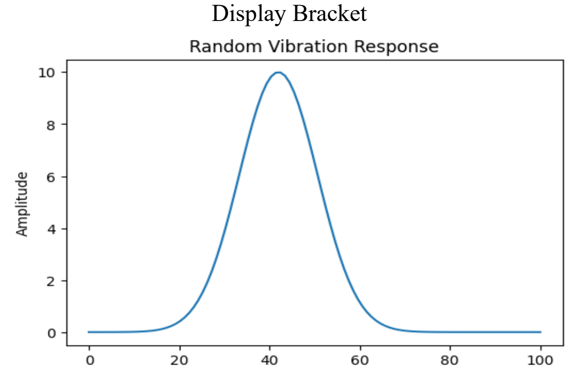

Figure 3. Random Vibration Response

VII. ENGINEERING ANALYSIS

Static structural analysis indicated that maximum stress concentration occurred near mounting interfaces and rib junctions.

The deformation value of 1.2 mm remained within acceptable automotive limits, ensuring stable display alignment.

Modal analysis confirmed that the first natural frequency exceeded 35 Hz, minimizing resonance risk.

Random vibration analysis demonstrated improved durability under road excitation conditions.

Glass-fiber reinforced materials improved stiffness and reduced vibration amplitudes.

The anti-pinch system successfully detected obstruction conditions using current-based sensing.

VIII. ADVANTAGES OF THE PROPOSED SYSTEM

1. Improved structure stiffness.
2. Reduced resonance and vibration.
3. Enhanced passenger safety.
4. Lightweight construction.
5. Improved NVH performance.
6. Better smart cockpit integration.
7. Automotive production feasibility.

IX. CONCLUSION

The developed floating automotive display system successfully satisfies structural, vibration, NVH, and safety requirements. The integration of optimized lightweight materials, reinforced support architecture, and intelligent anti-pinch systems demonstrate strong industrial potential for future automotive interior applications.

X. FUTURE SCOPE

1. AI-based smart anti-pinch systems
2. Motorized swivel and tilt displays
3. Hybrid composite structures
4. Advanced NVH optimization
5. ADAS and autonomous cockpit integration

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