Design optimization of LVPH Coach Locomotive

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Abstract— This research paper delves into the design optimization of a Low-Floor Passenger Handling (LVPH) Coach with the objective of reducing the tare weight by a minimum of 2 tons. The LVPH Coach is a critical component of public transportation, and enhancing its efficiency by reducing weight contributes to improved energy efficiency, operational costs, and overall sustainability. The study employs advanced design optimization techniques and simulation tools to achieve the targeted weight reduction without compromising safety, structural integrity, or passenger comfort.

Index Terms- LVPH Coach, Design Optimization, Tare Weight Reduction, Finite Element Analysis, Simulation, Sustainable Transportation.

I. INTRODUCTION

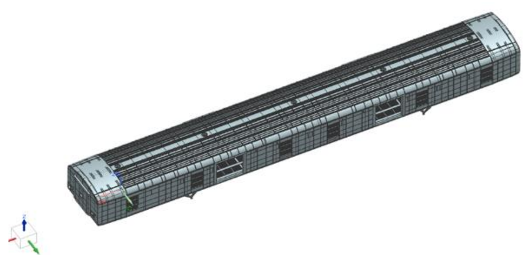

Fig 1.1: CAD model of locomotives

The introduction provides an overview of the current state of the railway industry, emphasizing the need for more efficient and environmentally friendly locomotives. It introduces the LVPH Coach Locomotive as a promising solution and outlines the objectives of the research paper.

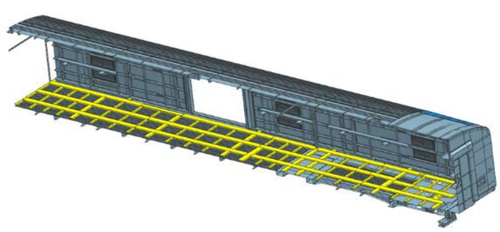

Fig 1.2: Half section view of locomotive

2.1 Objectives:
The research paper defines specific optimization objectives, such as improving energy efficiency, reducing greenhouse gas emissions, enhancing operational performance, and ensuring cost-effectiveness. These objectives guide the subsequent optimization process.

II. LITERATURE REVIEW

This section reviews existing literature on LVPH locomotives, covering topics such as their design principles, advantages, and challenges. It explores previous optimization studies and identifies gaps in the current knowledge, laying the foundation for the research presented in this paper.

Agastya Gaurav researchers worked towards railway track and worked on FEA part of railway track, and they performed static test for this. Srihar Pall, Ramji Koona investaged towards Eigenvalue analysis of Railway coach using FEM. In this research work they have taken complete CAD mode l of Rail Coach and they have used UG-NX Software for this. They have used HYPERMESH for FEA. With this research they shown both unladen and laden conditions the coach attains similar predominant values of natural frequencies and mode shapes. Prashant, Simant worked towards Topology optimization, in this research work they worked towards reduce the weight of bottom center pivot, for this they used FEA in Ansys software, they performed structural analysis and did design optimization.

J. Kalivoda and L. O. Neduzha, in their research, primarily focused on the mechanical behavior of locomotives, particularly considering non-linear aspects. M. A. Zulkifli et al. conducted studies centered on wheel dynamics simulations.

Dr. Sanjay Shukla and Manish Pandey concentrated their research on the design of freight rolling stock with higher axle loads suitable for high-speed, dedicated freight tracks. They conducted transient analyses on CAD models and, based on the outcomes, suggested various improvements.

Xiufang Jia and Zhe Liu explored the rise of electrified railways and the increased use of AC-DC locomotives, which led to harmonic problems in power systems. Their research simplified the structural design, analyzed the working principles, and developed a PSCAD/EMTDC simulation model to address these issues. The model's accuracy was confirmed by comparing simulation results with theoretical calculations and real-world data.

Yali Song and Yaru Li developed a new method for assessing railway locomotive stability using Virtual Reality (VR) and dynamic simulations. Their paper introduced a VR-based system for testing running stability, alongside MATLAB and Simulink for numerical simulations. This approach enhanced stability analysis, maintenance simulations, and improved the inspection and repair of locomotive components.

Maksym Spiryagin, Qing Wu, Oldrich Polach, and their co-authors focused on the key components needed for locomotive studies, such as developing realistic locomotive design models, validating them, and applying them to train studies. Their research incorporated advanced simulation techniques, including AC, DC, and hybrid locomotive designs, wheel-rail dynamics, and co-simulation approaches, all validated through field testing to enhance locomotive designs.

Stanislav Špirk and Miloslav Kepka addressed the interior passive safety of rail vehicles by comparing theoretical assumptions with real-world railway accidents. Due to limited accident data from the Czech Ministry of Transport, the study used diverse information sources to compare simulation outcomes with actual accidents, offering valuable insights for safety legislation.

Maciej Witek explored the hardware implementation of a train simulator driver stand using custom electronic devices and the MaSzyna open software platform. The main controller was based on the Atmel ATMega2560 microcontroller. The simulator was tested and validated by train drivers and instructors, and its communication protocol was used in various locomotive projects.

Deepak Sehgal's research documented the operation of locomotives through motion transfer mechanisms. It traced the evolution of steam locomotives in both appearance and function, while emphasizing the transition to diesel engines for both passenger and freight trains. Despite the ongoing importance of electric locomotives, rapid advancements in transportation engineering were highlighted.

After reviewing numerous research projects, it was observed that limited research has been conducted on the locomotive rack side. This presents a notable research gap that warrants further exploration.

III. METHODOLOGY

The methodology section outlines the approach taken to achieve the optimization objectives. This may include the use of simulation tools, computational modeling, and experimental validation. The research may involve parametric studies, sensitivity analyses, and multi-objective optimization techniques. Firstly, we developed CAD model and in second phase we worked on FEA part with Simcentere 3D software.

Fig 1.3: Discretized model of locomotive

S.No.	Description	Numbers
1	Total No. of Elements	529241
2	Number of nodes in the mesh	726525

Table 1.1: Boundary conditions of locomotive

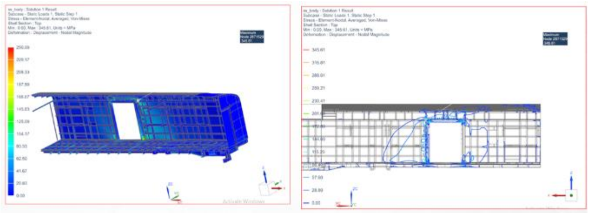

Fig 1.4: Post processing scenario 1

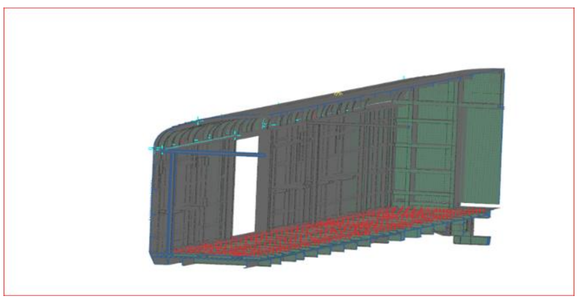

Fig 1.5: Boundary condition and constraints

IV. RESULTS AND DISCUSSION

This section presents the results of the optimization process and discusses their implications. It highlights the improvements achieved in energy efficiency, performance, and environmental sustainability, providing insights into the practical implications of the research.

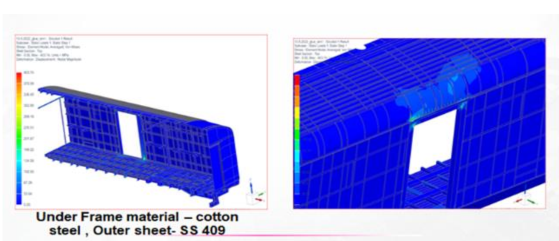

Fig 1.6: Post processing scenario 2 and result

5.1 Optimization:
For Optimization we identified the various are in locomotive including side wall, end wall under Rame, z channels, roof vents and changed the thickness and e l simulated the whole locomotives.

5.2 Parameter Optimization:
This section focuses on the optimization of key parameters, such as gear ratios, wheel diameters, and traction motor characteristics. It explores how these optimizations contribute to achieving the defined objectives and improving overall locomotive performance.

5.3 Control System Optimization:
Optimizing the control system is crucial for achieving efficiency and dynamic performance. This section discusses strategies for optimizing the locomotive's control algorithms, regenerative braking, and energy management systems.

S.No.	NAME	Weight Reduction (In Kg)
1	Side Wall (2 mm to 1.4 mm)	274
2	End Wall Thickness (2 mm to 1.24)	101
3	Sol Bar (8 mm to 7 mm)	127
4	Under Frame Weight (2mm to 1.4)	299
5	End Wall Removed	156
6	Roof Trough Sheet (3 mm to 1.1 mm)	475
7	Extended Roof Sheet (2 mm to 1.4 mm)	66
8	Window Frame Area (aluminium)	341
9	Z channel at side wall and roof interaction area (4 mm to 2.5 mm)	125
10	Roof Vent (while changing material to aluminium)	11
11	Roof support Z member	7
12	Weight Reduction due to New Rack pivoting mechanism	165
	Total Weight Reduction	**2140 Kg**

Table 1.2: Weight reduction table

Presentation and analysis of FEA results, identifying critical areas for improvement and validation of the design modifications to ensure optimal performance and durability.

CONCLUSION

The conclusion summarizes the key findings, discusses the significance of the research, and suggests avenues for future work in the field of LVPH Coach Locomotive design optimization. It emphasizes the potential impact of these optimizations on the rail transportation industry, promoting a more sustainable and efficient future.

Keywords: LVPH Coach Locomotive, Design Optimization, Energy Efficiency, Environmental Impact, Railway Transportation, Hybrid Locomotives.

We have reduced the weight by 2139 kg and strength is also good. For achieving this goal, we have changed the thickness and material and material and found this reduction gives superior design optimization resulting cost cutting and economic manufacturing environment for locomotives.

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