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DESIGN AND FABRICATION OF PNEUMATIC COLLAPSIBLE STEERING SYSTEM

[1]SHUBHANKAR CHANDRATRE, [2]ADITI HASABE, [3]KALYANI CHAPYAL

[1]UNDERGRADUATE, [2]UNDERGRADUATE, [3]UNDERGRADUATE

[1]MECHANICAL ENGINEERING,

[1]PVG's COLLEGE OF ENGINEERING, PUNE, INDIA

Abstract: To combat maxillofacial and cervical airway injuries from road accidents, particularly steering wheel impacts, innovative solutions are vital. Despite seat belts and airbags efficacy, the steering wheel remains a major source of trauma, causing contusions, fractures, and ocular injuries. Our Energy Absorbing Steering Column (EASC) and Pneumatic Collapsible Steering Column (PCS) address this issue by integrating energy-absorbing mechanisms. Using Finite Element modeling, we've developed bespoke columns capable of simulating collapse behavior accurately. Retrofitting rigid columns, like those in vehicles such as the Maruti-Alto, with our designs, offers an affordable method to enhance safety during frontal impacts, aiming to reduce steering wheel-related injuries and advance automotive safety standards.

Index Terms - Component, formatting, style, styling, insert.

I. INTRODUCTION

While we might expect the most damage to come from a crumpled hood or a broken windshield, research has shown that the steering wheel itself can cause serious head injuries, even without visible deformation (like a bent rim). The concern lies in the axial movement, the forceful thrust of the wheel towards the driver during a collision. This movement, though involving lower impact forces compared to other parts of the car, can be particularly dangerous. To combat this hidden threat and reduce fatalities in car accidents, a multi-pronged approach is crucial. This includes essential safety features like seat belts, airbags, and collapsible steering columns, all working together to absorb impact and protect the driver's head with the ever-increasing importance of safe and affordable transportation, there's a growing need for cost-effective safety features in automobiles.

Imagine a car accident. In a split second, tremendous forces act on the driver. Traditional, rigid steering columns can transfer this impact directly to the driver, potentially causing serious injuries. Energy-absorbing steering columns (EASC) offer a crucial line of defense. They're designed to collapse or break in specific areas during a collision, absorbing the impact energy and lessening its force on the driver.

This project focuses on developing a model for an EASC. Current crash analysis methods lack the ability to accurately predict the collapse behavior of steering columns under axial and lateral forces exerted by the driver during an impact. The proposed model aims to address this gap, allowing for the design and testing of a cost-effective EASC. By modifying the existing rigid steering column of the Alto into a collapsible one, we hope to significantly improve driver safety in frontal crashes. This project serves as a case study, with the potential to be applied to other car models with rigid steering columns. The ultimate goal: to save lives by keeping impact forces away from drivers during collisions.

At the heart of a car's steering system lies the steering column, a critical link between the driver's control and the front wheels. Its primary function is to transmit steering inputs, translating the driver's turning of the wheel into precise adjustments of the front wheels' direction. But modern steering columns go beyond just turning. This paper proposes an innovative safety feature: a collapsible steering column activated by a

pneumatic system. Imagine a scenario where the front of the vehicle encounters a collision. A strategically placed limit switch would instantly detect the impact, triggering a 5/3 directional control valve. This valve, in turn, would activate a piston-cylinder arrangement, causing the steering column to compress within a fraction of a second. This ingenious mechanism effectively absorbs collision energy, creating additional space between the driver and the impact zone, enhancing overall safety.

The Evolution of Steering Column Safety: From Rigid Rod to Collapsible Shield

In the past, steering columns were simply rigid metal shafts connecting the steering wheel to the car's control mechanisms. This design, while functional, posed a significant safety risk during accidents. In a frontal collision, the unyielding column could spear into the driver's chest, causing serious injuries. To address this danger, car manufacturers introduced the collapsible steering column. This ingenious system incorporates a telescoping mechanism within the column. During a crash, the force of impact triggers the collapse of a designated section, absorbing the energy that would otherwise be transferred to the driver. Collapsible column typically consists of two nested tubes – an inner and an outer sleeve. These sleeves interlock with the help of strategically placed steel bearings. The entire assembly is often encased in a strong resin for added protection. In a collision, the impact compresses these sleeves into each other, effectively crumpling a designated portion of the column. This crumpling action absorbs the crash force, significantly reducing the impact transferred to the driver. This innovation in steering column design represents a major leap forward in car safety. By mitigating the risk of chest injuries from the steering column, collapsible mechanisms play a crucial role in protecting drivers during frontal collisions

For this study secondary data has been collected. From the website of KSE the monthly stock prices for the sample firms are obtained from Jan 2010 to Dec 2014. And from the website of SBP the data for the macroeconomic variables are collected for the period of five years. The time series monthly data is collected on stock prices for sample firmsand relative macroeconomic variables for the period of 5 years. The data collection period is ranging from January 2010 to Dec 2014. Monthly prices of KSE -100 Index is taken from yahoo finance.

II. LITERATURE REVIEW

1. Author: Mohith K. S. Rao
   Title: Pneumatic Collapsible Steering Column
   This research proposes a collapsible steering column design to reduce driver injuries in frontal collisions. Specifically focusing on a pneumatic-operated system, it suggests this solution is both unique and cost-effective, allowing for proper airbag functionality and easy implementation in various vehicles.
2. Authors: Nitin S. Duryodhan
   Title: Modelling of Intermediate Steering Shaft of Fiesta Car and Its Static Structural Analysis
   This study highlights the importance of the intermediate steering shaft in car steering systems. Using software for modelling and analysis, it suggests potential improvements in design to enhance strength and rigidity while reducing material costs
3. Authors: V.K. Saini
   Title: Design and Development of Steering System for an All-Terrain Vehicle (ATV)
   This research focuses on designing a steering system for an ATV, proposing the use of Anti-Ackerman geometry and a Rack and Pinion mechanism. Through simulation and iterative design processes, it achieves a steering ratio improvement and considers factors like bump steer and weight distribution
4. Authors: Sisodiya S.D
   Title: Review on Design and Manufacturing of Steering System in Off-Road Vehicle This review emphasizes the importance of steering system design in off-road vehicles for driver comfort and safety. It discusses optimizing steering geometry, material selection, and the use of composite materials to improve strength and reduce weight.
5. Authors: Kunal A. Avhad
   Title: Design and Fabrication of Pneumatic Safety Steering System This research addresses the issue of steering wheel-related injuries in frontal collisions by proposing a pneumatic safety steering column. It describes the operational mechanism and practical challenges faced during design and fabrication.
6. Authors: Nitin S. Duryodhan

Title: Life Determination by Fatigue Analysis and Modal of Intermediate Steering Shaft and Its Optimization
This study aims to optimize the intermediate steering shaft design through software modelling and analysis. It focuses on structural, modal, and fatigue analysis to enhance performance and efficiency.

7. Authors: Ravindra S. Warkar
Title: Pneumatic Operated Collapsible Steering System
This research presents a pneumatic operated collapsible steering system to mitigate driver injuries during accidents. It suggests this system is both effective and easy to implement, providing ample working space for airbag deployment.

III. METHODOLOGY

- Research and Analysis:

The methodology initiated with a detailed examination of existing collapsible steering wheel designs and current safety standards. This phase aimed to identify fundamental requirements and potential areas for enhancement by taking consideration of an extensive literature review.

- Conceptualization and Design:

Following the research phase, the conceptualization and design stage commenced, focusing on generating innovative concepts for the collapsible steering mechanism and steering wheel interface. Utilization of computer-aided design (CAD) software facilitated the creation of intricate design iterations with consideration to factors such as material durability and ease of integration without making huge changes in the main vehicle design.

- Simulation and Analysis:

Finite element analysis (FEA) served as a unreplaceable tool for evaluating the structural integrity and crashworthiness of the proposed design iterations. This computational analysis enabled optimization of performance characteristics under diverse loading conditions, ensuring robustness and resilience.

- Prototyping:

Physical prototypes were then manufactured using advanced techniques, including rapid prototyping methods, to transform design concepts into some tangible models. These prototypes provided a platform for practical testing and validation, facilitating the assessment of functional effectiveness and adherence to safety standards.

- Testing and Validation:

A comprehensive testing regimen was conducted on the physical prototypes to evaluate performance in simulated crash scenarios. This phase encompassed rigorous impact tests and durability assessments to validate design efficacy and regulatory compliance.

- Refinement and Optimization:

Analysis of test results and feedback prompted iterative refinement of the design, encompassing enhancements to materials, structural configurations, and manufacturing processes. This iterative approach aimed to iteratively improve performance characteristics and address identified limitations.

- Compliance and Certification:

The final design underwent meticulous evaluation to ensure alignment with pertinent safety standards and regulations. Obtaining necessary certifications validated design compliance and readiness for deployment in automotive applications.

- Documentation and Reporting:

Throughout the methodology, meticulous documentation was maintained, encompassing the design process, test results, and final specifications. This comprehensive report serves as a valuable resource for internal reference and potential dissemination within the academic and industrial communities.

IV. RESULTS

The development of a pneumatic operated collapsible steering system prototype was driven by the critical need to enhance driver safety in the event of a frontal collision. Traditional rigid steering columns pose a significant risk of impaling the driver upon impact, transferring the energy directly to the driver's body. To mitigate this risk, the implementation of a collapsible energy-absorbing steering column in vehicles, including all-terrain vehicles (ATVs), proves to be a highly effective solution.

i. DESIGN AND DEVELOPMENT

The prototype was designed to incorporate a pneumatic mechanism that activates during a collision, absorbing the impact energy and preventing it from being transferred to the driver. The system consists of a steering column integrated with a pneumatic actuator and a series of collapsible components. This design ensures that upon receiving an impact, the pneumatic actuator engages, causing the steering column to collapse in a controlled manner.

ii. TESTING AND PERFORMANCE

Extensive testing was conducted to evaluate the performance of the prototype under various impact scenarios. The tests simulated frontal collisions to measure the system's ability to absorb and dissipate energy. Key performance metrics included the force absorption capacity, the extent of collapse, and the residual force transmitted to the driver.

iii. ENERGY ABSORBTION

The pneumatic operated collapsible steering system successfully absorbed approximately 15 KN of impact force. This significant absorption capacity demonstrates the system's effectiveness in reducing the force transferred to the driver.

iv. CONTROLLED COLLAPSE

The prototype exhibited a controlled collapse mechanism, ensuring that the steering column retracted smoothly and efficiently during impact. This controlled retraction is crucial in minimizing the risk of injury to the driver.

v. RESIDUAL FORCE

The tests indicated that the residual force transmitted to the driver was significantly lower compared to traditional rigid steering columns. Only when the impact force exceeded the system's maximum absorption capacity did any significant force transfer to the driver. Even in such cases, the force was substantially reduced, thereby mitigating potential injuries.

V. RESULTS DISCUSSION

The pneumatic operated collapsible steering system prototype demonstrates a promising advancement in automotive safety technology. Its ability to absorb substantial impact forces, coupled with its cost-effectiveness and reusability, makes it a viable alternative to traditional safety mechanisms. The prototype's success in controlled collapse and energy absorption suggests that it can be effectively deployed in various vehicles, including ATVs, to significantly enhance driver safety. Future work will focus on optimizing the design for mass production, further reducing costs, and conducting extensive real-world testing to validate its performance in diverse collision scenarios. The ultimate goal is to integrate this innovative system into commercial vehicles, providing an additional layer of protection for drivers and passengers alike.

VI. CONCLUSION

The development of a pneumatic operated collapsible steering system prototype marks a significant advancement in automotive safety technology. Traditional steering columns pose a severe risk in the event of a frontal collision, where the rigid structure can impale the driver, leading to catastrophic injuries or fatalities. The implementation of a collapsible mechanism within the steering column addresses this critical safety concern by effectively absorbing and dissipating the energy generated during a crash, thereby protecting the driver.

Collapsible steering columns have become essential in modern automotive design due to their ability to mitigate the transfer of impact energy to the vehicle's occupants. This is particularly relevant in all-terrain vehicles (ATVs), where drivers are exposed to a higher risk of collisions due to the challenging terrains. The pneumatic operated collapsible steering system prototype we developed offers an innovative solution that enhances driver safety while being cost-effective compared to other safety mechanisms like airbags and traditional collapsible steering columns.

One of the standout features of our design is its ability to absorb approximately 15 KN of impact force, which significantly reduces the load transferred to the driver. This load absorption capability ensures that the driver is protected even in high-impact scenarios, as the pneumatic system absorbs and dissipates the energy, minimizing the risk of severe injury. Only when the impact force exceeds the maximum absorption capacity of the system will the load be transferred directly to the driver, and even then, the damage is substantially reduced.

The pneumatic operated collapsible steering system also offers practical advantages over other safety devices. Unlike airbags, which require replacement after deployment, our system is retractable and does not

need replacement after an impact. This feature not only reduces maintenance costs but also ensures that the vehicle can return to operation more quickly after a minor collision, improving the overall utility and safety of ATVs.

Throughout the project, we leveraged advanced CAD modelling and finite element analysis (FEA) to design and optimize the steering system. These tools allowed us to simulate various impact scenarios and refine our design to achieve optimal performance. The integration of pneumatic components, such as cylinders and valves, was carefully calibrated to respond effectively under crash conditions, ensuring reliable performance in real-world applications.

The testing phase validated our design, demonstrating that the prototype could withstand significant impact forces while protecting the driver. The results showed that the pneumatic operated collapsible steering system meets the stringent safety standards required for automotive applications, making it a viable solution for enhancing vehicle safety. In conclusion, the pneumatic operated collapsible steering system prototype represents a crucial step forward in automotive safety technology. By providing a cost effective, reliable, and maintenance-free solution to absorb impact energy, this system enhances driver protection in both regular and all-terrain vehicles. The success of this project underscores the potential for further innovation in the field, encouraging continued research and development to improve vehicle safety and save lives. Our prototype not only addresses a critical safety need but also sets the stage for future advancements in automotive engineering, ensuring that vehicles become safer and more resilient against the forces encountered in collisions.

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