International Journal of Analytical, Experimental and Finite Element Analysis
Volume 10, Issue 2, June 2023, pp 62 - 67
https://doi.org/10.26706/ijaefea.icramen202315

Design Optimization of Adaptive MacPherson Strut using ANSYS Simulation: A Study

Robin Babu[1,*], Radheshyam H. Gajghat[2], Amit Sarda[3], P. S. Rao[4]

Department of Mechanical Engineering, Christian College of Engineering and Technology, Bhilai, India

[1]r4ccet@gmail.com, [2]radhegaj@gmail.com, [3]amitsarda3@gmail.com, [4]srinivas.indore@gmail.com

[*]Corresponding Author: r4ccet@gmail.com

Abstract: The MacPherson strut is a widely used suspension system in the automotive industry due to its simplicity and effectiveness. In recent years, the development of adaptive MacPherson struts has gained significant attention to improve handling, stability, and ride comfort. The optimization of the design parameters of adaptive MacPherson struts is crucial to achieve the desired performance characteristics. In this study, we present a comprehensive review of the design optimization of adaptive MacPherson struts using ANSYS simulation software. We discuss the various design parameters, simulation techniques, and optimization algorithms used in recent studies. The study aims to provide insights into the design and optimization of adaptive MacPherson struts using ANSYS simulation software.

Keywords: MacPherson strut, ANSYS, Adaptive suspension, Optimization, Simulation.

Mini Review – Peer Reviewed
Received: 20 April 2023
Accepted: 5 June 2023
Published: 30 June 2023

Cite this article: Robin Babu, Radheshyam H. Gajghat, Amit Sarda, P. S. Rao, "Design Optimization of Adaptive MacPherson Strut using ANSYS Simulation: A Study", International Journal of Analytical, Experimental and Finite Element Analysis, RAME Publishers, vol. 10, issue 2, pp. 62-67, 2023.
https://doi.org/10.26706/ijaefea.icramen202315

1. Introduction

The MacPherson strut is a suspension system that has been used in millions of vehicles worldwide due to its simplicity and effectiveness. However, with the increasing demand for higher performance, safety, and comfort, there is a need for more advanced suspension systems. The development of adaptive suspension systems, such as adaptive MacPherson struts, has gained significant attention in recent years. These struts use advanced technologies, such as electronic controls and variable damping, to adjust the suspension characteristics in real-time to improve handling, stability, and ride comfort.

The optimization of the design parameters of adaptive MacPherson struts is crucial to achieve the desired performance characteristics. ANSYS simulation software offers advanced tools for designing and optimizing the performance of adaptive MacPherson struts. In this study, we present a comprehensive review of the design optimization of adaptive MacPherson struts using ANSYS simulation software.

2. Literature Review

Su Z. et al. [1] presented a study on improving the performance of a minivan's MacPherson-strut suspension system. The authors proposed a novel approach that combines a weighting combination method with a neighborhood cultivation genetic algorithm for the optimization process. By considering various design parameters, such as spring stiffness, damping coefficient, and anti-roll bar parameters, the authors aim to enhance ride comfort and handling stability. Through simulations and analysis, they demonstrated the effectiveness of their approach in achieving significant improvements in the optimized suspension system design compared to the initial design.

R. K. Singh and S. Singh [2] discussed the design optimization of a MacPherson strut suspension system using ANSYS simulation software. The authors investigated the effect of various design parameters, such as the length and diameter of the strut, on the performance of the suspension system. ANSYS simulation was used to model the suspension system and perform various simulations to optimize its design. The results showed that the proposed design leads to improved performance in terms of ride comfort and handling. The study highlights the importance of simulation software in optimizing the design of suspension systems and provides valuable insights into the design parameters that affect the performance of MacPherson strut suspension systems.

N. K. Jain and A. Kumar [3] discussed the design and analysis of a MacPherson strut for an ATV suspension system. The authors aim to improve the ride comfort and handling of an ATV by designing an optimized MacPherson strut. ANSYS simulation software was used to model and simulate the strut and optimize its design. The results shows that the proposed design leads to improved ride comfort and handling of the ATV. The study highlights the importance of suspension system design in achieving optimal performance and demonstrates the effectiveness of simulation software in achieving the desired performance improvements. Overall, the paper provides valuable insights into the design and analysis of MacPherson struts for suspension systems and highlights the importance of simulation software in achieving optimal performance.

J. J. Kim et al. [4] discussed the optimal design of a MacPherson strut suspension system for improving ride comfort and handling stability. The authors used a combination of simulation and experimental methods to determine the optimal design parameters for the strut, such as the spring stiffness and damping coefficient. ANSYS simulation software was used to model and simulate the suspension system, and a full-scale vehicle test was performed to validate the results. The study shows that the proposed design leads to improved ride comfort and handling stability of the vehicle. The paper provides valuable insights into the design optimization of MacPherson strut suspension systems and highlights the importance of combining simulation and experimental methods in achieving optimal performance.

M. R. Azadi et al. [5] presented a multi-objective genetic algorithm-based approach to optimize the design of a MacPherson strut suspension system. The authors aim to improve both the ride comfort and handling performance of the suspension system. The study employed a multi-objective optimization technique to simultaneously optimize the design parameters of the suspension system, such as the spring rate and damping coefficient. The results show that the proposed method leads to a Pareto front of optimal solutions that trade-off between ride comfort and handling performance. The paper provides valuable insights into the design optimization of MacPherson strut suspension systems and demonstrates the effectiveness of multi-objective optimization techniques in achieving optimal performance.

S. K. Singh et al. [6] presented a particle swarm optimization (PSO) based approach for the design optimization of a MacPherson strut suspension system. The authors aim to optimize the suspension system parameters to improve both ride comfort and handling performance. The study employs PSO to optimize the design parameters, such as the spring stiffness and damping coefficient, and validates the results using simulation techniques. The results show that the proposed method leads to improved performance of the suspension system compared to the original design. The paper provides valuable insights into the design optimization of MacPherson strut suspension systems and highlights the effectiveness of PSO as a design optimization tool.

Li and Li [7] proposed an optimization method for the adaptive McPherson strut suspension system using a genetic algorithm. They optimized the adaptive control algorithm for better ride comfort, handling stability, and road handling capability. The results of the study showed that the optimized adaptive control algorithm significantly improved the performance of the suspension system compared to the original algorithm.

Guo et al. [8] aimed to optimize the MacPherson strut suspension system for a hybrid electric vehicle using ANSYS simulation. The study used a multi-objective optimization approach to simultaneously consider ride comfort and handling stability, and evaluated the performance of the strut under different road conditions. The results showed that the optimized strut design achieved better performance in both ride comfort and handling stability compared to the original design. The authors concluded that ANSYS simulation was an effective tool for evaluating and optimizing the MacPherson strut suspension system for hybrid electric vehicles.

Zhu et al. [9], an adaptive control strategy based on a fuzzy logic controller (FLC) was proposed for the McPherson strut suspension system. They optimized the FLC parameters using a particle swarm optimization algorithm. The simulation results showed that the optimized FLC strategy improved the ride comfort and handling stability of the vehicle compared to the original control strategy.

Ali et al. [10] proposed a multi-objective optimization approach for the adaptive McPherson strut suspension system using the NSGA-II algorithm. They optimized the control parameters for minimizing the suspension deflection and tire deflection while maximizing the handling stability. The simulation results showed that the optimized control parameters significantly improved the performance of the suspension system.

Liu et al. [11] proposed an optimization design approach for the MacPherson suspension system using a multi-objective genetic algorithm. The study aimed to find the optimal parameters of the suspension system that would improve the handling stability, ride comfort, and road holding capability of the vehicle. They modeled the suspension system using ADAMS and ANSYS software and applied the multi-objective genetic algorithm to optimize the design parameters. The results of the study showed that the optimized suspension system had better handling stability, ride comfort, and road holding capability compared to the original system. They also conducted sensitivity analysis to determine the influence of the design parameters on the performance of the suspension system. Overall, the study provides insights into the optimization design of the MacPherson suspension system using a multi-objective genetic algorithm.

Chen, H., and Liu, Z. [12] introduced a novel approach for optimizing the design of a suspension system. The authors proposed the utilization of the Response Surface Method (RSM) in conjunction with the Neighborhood Cultivation Genetic Algorithm (NCGA) to achieve optimal suspension system performance. The RSM is employed to construct a mathematical model of the suspension system, which is then used to analyze and predict its response. The NCGA algorithm is applied to efficiently search for the optimal design parameters of the suspension system. The paper highlights the effectiveness of this combined approach in enhancing the performance and reliability of the suspension system, offering potential improvements for future design optimization endeavors in the field of automotive engineering.

Fang et al. [13] proposed a hybrid approach based on fuzzy logic and genetic algorithm for the multi-objective optimization of the MacPherson suspension system. The fuzzy logic controller was used to control the damping force of the suspension system, while the genetic algorithm was used to optimize the design parameters of the suspension system. The study considered ride comfort, handling stability, and tire wear as the optimization objectives. The simulation results showed that the proposed hybrid approach significantly improved the performance of the suspension system, achieving a good balance between ride comfort, handling stability, and tire wear.

Rao et al. [14] proposed an optimization approach for the MacPherson strut suspension system using grey relational analysis (GRA) and the Taguchi method. They considered five control factors, including the spring rate, damping coefficient, pre-load, spindle length, and ball joint length, and three performance factors, such as ride comfort, road holding capability, and handling stability. The results showed that the proposed approach significantly improved the performance of the suspension system in terms of the selected factors compared to the original design. The study demonstrated the effectiveness of the GRA and Taguchi method in the optimization of the suspension system.

Sun and Lin [15] proposed an optimization design approach for the MacPherson suspension system of an electric vehicle using a multi-objective genetic algorithm. The objective was to improve the handling stability, ride comfort, and tire wear of the vehicle while reducing the energy consumption. The optimization results showed that the proposed approach significantly improved the performance of the suspension system, especially in terms of handling stability and ride comfort. Another important finding was that the optimized suspension system could effectively reduce the energy consumption of the electric vehicle. The results of this study provide useful insights into the design optimization of the MacPherson suspension system for electric vehicles.

3. Design Parameters Identified

The design parameters of adaptive MacPherson struts identified from the various studies are the strut length, strut angle, spring rate, damping coefficient, and various geometrical parameters. The optimization of these parameters is critical to achieve the desired performance characteristics, such as ride comfort, stability, and handling. ANSYS simulation software provides a comprehensive set of tools for designing and optimizing these parameters. Following Table 1 shows the list of parameters identified with their references.

Table 1. Design Parameters Identified

S.N.	**Design Parameters Identified**	**References**
1	Toe Angle	[1],[12]
2	Camber Angle	[1],[12]
3	Length of the Strut	[2],[3]
4	Diameter of the Strut	[2],[3]
5	Spring Stiffness	[3],[4],[6]
6	Damping Coefficient	[3],[4],[5],[6],[14]
7	Spring Rate	[5],[14]
8	Ride Comfort	[7],[8],[11],[13],[15]
9	Handling Stability	[7],[8],[10],[11],[13],[15]
10	Road Handling Capability	[7]
11	Fuzzy Logic Controller Parameters	[9]
12	Suspension Deflection	[10]
13	Tire Deflection	[10]
14	Road Holding Capability	[11]
15	Kingpin Caster Angle	[12]
16	Kingpin Inclination Angle	[12]
17	Tire Wear	[13],[15]
18	Pre-Load	[14]
19	Spindle Length	[14]
20	Ball Joint Length	[14]
21	Energy Consumption of Electric Vehicle	[15]

4. Simulation Techniques and Optimization Algorithms Used

ANSYS simulation software offers various simulation techniques for the analysis of adaptive MacPherson struts, such as finite element analysis, multibody dynamics analysis, and fluid-structure interaction analysis. These techniques can be used to simulate various operating conditions, such as cornering, braking, and acceleration, and evaluate the performance of the strut.

The optimization of adaptive MacPherson struts using ANSYS simulation software involves the use of various optimization algorithms, such as genetic algorithms, particle swarm optimization, and response surface methodology. These algorithms can be used to optimize various parameters, such as stiffness, damping, and spring rate, to achieve the desired performance characteristics.

The optimization of adaptive MacPherson struts using ANSYS simulation software has been applied in various studies to improve the performance of the suspension system. These studies include the optimization of the strut design for different operating conditions, such as ride comfort, stability, and handling. The optimization of the strut design has also been used to reduce the weight of the strut and improve fuel efficiency. Following Table 2 shows the list of Simulation Techniques and Optimization Algorithms Used with their references.

Table 2. Simulation Techniques and Optimization Algorithms used

S.N.	**Simulation Techniques and Optimization Algorithms Used**	**References**
1	Neighborhood Cultivation Genetic Algorithm	[1],[12]
2	Multi-Objective Optimization Approach	[2],[3],[8]
3	Combination of Simulation and Experimental Methods	[4]
4	Multi-Objective Genetic Algorithm	[5],[11],[15]
5	Particle Swarm Optimization	[6]
6	Genetic Algorithm	[7],[13]
7	Fuzzy Logic Controller	[9],[13]
8	Non-Dominated Sorting Genetic Algorithm II (NSGA-II)	[10]
9	Grey Relational Analysis and Taguchi Method	[14]

5. Conclusion

In conclusion, the design optimization of adaptive MacPherson struts using ANSYS simulation software is crucial to achieve the desired performance characteristics, such as ride comfort, stability, and handling. ANSYS simulation software provides advanced tools for designing and optimizing the performance of adaptive MacPherson struts. The optimization of the strut design has been applied in various studies to improve the performance of the suspension system. Future research directions may include the optimization of the strut design for electric and hybrid vehicles, as well as the development of new optimization algorithms for adaptive MacPherson struts.

References

[1] Su Z, Xu F, Hua L, Chen H, Wu K, Zhang S. Design optimization of minivan MacPherson-strut suspension system based on weighting combination method and neighborhood cultivation genetic algorithm. Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering. 2019;233(3):650-660. doi:10.1177/0954407018789303.

[2] R. K. Singh and S. Singh, "Design optimization of MacPherson strut suspension system using ANSYS," International Journal of Engineering Research and Applications, vol. 6, no. 4, pp. 12-19, 2016.

[3] Jain, N. K., & Kumar, A. (2015). Design and analysis of MacPherson strut for an ATV suspension system. Journal of Mechanical Engineering and Automation, 5(1), 1-5.

[4] Kim, J. J., Kim, S. J., & Lee, S. S. (2014). Optimal design of MacPherson strut suspension system for ride comfort and handling stability. Journal of Mechanical Science and Technology, 28(7), 2611-2618.

[5] Azadi, M. R., Taheri, A. M., & Tavakoli, A. H. (2014). Optimization of MacPherson strut suspension system using multi-objective genetic algorithm. Journal of Vibration and Control, 20(13), 1991-2006.

[6] Singh, S. K., Singh, R. K., & Singh, R. (2014). Design optimization of MacPherson strut suspension system using particle swarm optimization. Journal of Engineering Science and Technology Review, 7(3), 43-50.

[7] Li, X., & Li, K. (2014). Optimization of adaptive control algorithm for McPherson strut suspension system based on genetic algorithm. Applied Mechanics and Materials, 556, 1529-1532.

[8] Guo, Y., Liu, Y., & Huang, Y. (2020). Optimization of MacPherson Strut Suspension System for Hybrid Electric Vehicle Using ANSYS Simulation. Journal of Physics: Conference Series, 1548(1), 012073.

[9] Zhu, J., Li, J., Wu, S., Liu, J., & Jiang, H. (2020). Design and optimization of an adaptive fuzzy control strategy for a McPherson suspension system. IEEE Access, 8, 209,057-209,068.

[10] Ali, M., Mahmood, N. H., Li, Y., & Almeshal, A. M. (2021). Multi-objective optimization of an adaptive MacPherson strut suspension system using NSGA-II algorithm. International Journal of Automotive Technology, 22(1), 19-30.

[11] Liu, Y., Wang, X., & Yang, L. (2018). Optimization design of MacPherson suspension system based on multi-objective genetic algorithm. Journal of Mechanical Science and Technology, 32(3), 1383-1393.

[12] Chen, H., & Liu, Z. (2022). Optimization Design for Suspension System Based on Response Surface Method and NCGA Algorithm. Highlights in Science, Engineering and Technology, 1, 336–345. https://doi.org/10.54097/hset.v1i.484.

[13] Fang, H., Liu, Y., & Xu, H. (2017). Multi-objective optimization of MacPherson suspension system using hybrid approach based on fuzzy logic and genetic algorithm. Advances in Mechanical Engineering, 9(11), 1687814017736255.

[14] Rao, B. S., Prasad, K. S., & Srinivas, J. (2017). Optimization of MacPherson strut suspension system using grey relational analysis and Taguchi method. Journal of Mechanical Engineering and Sciences, 11(3), 2779-2795.

[15] Sun, J., & Lin, H. (2018). Design optimization of MacPherson suspension system for electric vehicle. Journal of Vibroengineering, 20(1), 353-366.