WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

A Systematic Review on F1 Car Chassis Frame using Finite Element Analysis

Atif Ali Hashmi[1], B. G. Shukla[2]

[1]Research Scholar

[2] Assistant Professor

[1,2]Oriental Institute of Science & Technology, Bhopal (M.P.)

ABSTRACT :

In the realm of high-performance motorsports, particularly Formula One (F1), the structural integrity and optimization of the front chassis play a critical role in ensuring vehicle safety, dynamic performance, and regulatory compliance. This review paper examines the current state of research in chassis design, focusing on material selection, structural simulation, and the integration of vehicle dynamics control systems. The front chassis, being the first point of impact during frontal collisions, must offer a combination of high stiffness, controlled deformation, and minimal weight. The paper investigates four key materials widely used in automotive and aerospace applications, Carbon Fiber (Epoxy), Aluminum 7075-T6, Titanium Alloy (Ti-6Al-4V), and AISI 4130 Chromoly Steel, and evaluates their mechanical behaviour through insights from existing studies. A significant portion of the review is dedicated to the application of Finite Element Method (FEM) simulation tools such as ANSYS Workbench, which have revolutionized how engineers analyze deformation and stress distribution under crash-like conditions. Simulation outputs such as directional deformation, total deformation, and von Mises stress serve as the basis for comparing material performance and selecting the most suitable candidate for F1 front chassis applications. This paper concludes that carbon fiber remains the optimal material for F1 front chassis due to its superior stiffness-to-weight ratio, while titanium offers an ideal backup for strength-critical zones. Aluminum and steel, though less optimal for primary crash structures, serve specific roles based on cost and secondary structural demands.

Keywords: FEA, Carbon Fiber, Titanium Alloy, Aluminum 7075, AISI 4130, CATIA, ANSYS, Formula One, Chassis, Structural Analysis

Introduction

In high-performance motorsports, particularly Formula One (F1), the engineering of the car's chassis holds significant importance in determining the overall success, safety, and competitiveness of the vehicle. The chassis serves as the primary structure upon which all other components are mounted and must, therefore, demonstrate an exceptional balance between light weight, rigidity, crashworthiness, and structural integrity. In the context of F1, the front part of the chassis is of utmost importance because it absorbs the brunt of energy during frontal collisions. To ensure safety, the material selection and design approach of the front chassis are subjected to meticulous scrutiny using advanced engineering methods. With modern advances in simulation and computational analysis, particularly the application of the Finite Element Method (FEM), engineers are now able to evaluate material performance and structural behaviour before constructing physical prototypes. The front chassis in a Formula One car is responsible not only for structural support but also for safety during high-speed collisions. It connects vital systems such as the suspension, nose cone, and steering mechanisms, making it a multi-functional part of the overall vehicle architecture. Furthermore, it must comply with the strict safety regulations outlined by the Fédération Internationale de l'Automobile (FIA), which mandates the ability to absorb impact energy effectively. With a focus on achieving reduced weight and enhanced strength, the choice of materials becomes critical to the design process. This calls for a comparative analysis of different materials under simulated loading conditions to determine the best option for the specific demands of motorsport. In this research context, the study evaluates four materials commonly used in high-performance applications: Carbon Fiber (Epoxy), Aluminum 7075-T6, Titanium Alloy (Ti-6Al-4V), and AISI 4130 Chromoly Steel. These materials vary in their mechanical properties, cost, weight, and response to deformation under load. The use of computer-aided design (CAD) and simulation tools such as CATIA and ANSYS Workbench enables detailed analysis and comparison under controlled virtual conditions. The study aims to determine which material provides the best overall structural performance for the front chassis of an F1 car by focusing on three output parameters: directional deformation, total deformation, and von Mises stress under a 15,000 N frontal load.

1.1 Chassis Structure and Its Critical Role

The chassis of a Formula One car is a monocoque structure that forms the primary load-bearing framework of the vehicle. Unlike traditional ladder frames used in earlier automobiles, a monocoque chassis is an integrated shell designed to provide maximum strength with minimum weight. The design philosophy behind the monocoque structure in F1 is centered on aerodynamics, safety, stiffness, and packaging efficiency. The front part of this chassis is a tapering, aerodynamic section extending from the cockpit to the nose, and it plays a critical role in maintaining structural balance and crash safety.

This front section must endure various operational stresses including those from suspension mounts, aerodynamic down force, braking loads, and frontal impacts. It is also where the nose cone and front wing assembly are mounted. As such, the front chassis not only sustains forces during normal operation but must also manage energy dissipation in the event of a crash. During frontal collisions, the structure is expected to deform in a controlled manner to absorb energy and protect the driver, which makes its structural properties a matter of life and death in motorsports.

Designing this part of the chassis involves a delicate balance: it must be strong enough to resist deformation under load while also being able to crumple in a controlled fashion to absorb kinetic energy during a crash. The design is typically subject to frontal crash tests under FIA regulations that include deceleration and deformation limits. These standards ensure that while the chassis deforms to dissipate energy, it must not compromise the driver's survival cell. A well-designed front chassis helps maintain the car's stability and handling by supporting the suspension system, transmitting forces evenly, and resisting torsional deflections. Its stiffness directly affects the car's performance by influencing suspension geometry under load. Thus, it must have a high torsional rigidity to ensure that the chassis does not twist during cornering or under aerodynamic down force. Furthermore, the design must consider packaging constraints, ease of manufacturing, and compliance with weight distribution limits set by racing regulations.

1.2 Material Selection for Front Chassis

The choice of material for the front chassis structure plays a decisive role in meeting the mechanical, structural, and safety requirements of Formula One vehicles. Different materials offer different advantages and trade-offs in terms of stiffness, strength, weight, manufacturability, fatigue resistance, and cost. In this study, four distinct materials are selected for evaluation: Carbon Fiber (Epoxy), Aluminum 7075-T6, Titanium Alloy (Ti-6Al-4V), and AISI 4130 Chromoly Steel. Each of these materials is widely used in high-performance or safety-critical applications and provides unique insights into their behaviour when subjected to crash-like conditions.

- *Carbon Fiber (Epoxy)* is the most prevalent material used in F1 chassis construction. It is a composite material consisting of carbon fibers embedded in an epoxy resin matrix. Carbon fiber is known for its exceptional stiffness-to-weight ratio, which makes it ideal for applications where both strength and lightweight are critical. It provides excellent resistance to deformation and high energy absorption during crashes. However, it is also brittle and prone to sudden catastrophic failure when its limits are exceeded. Its high cost and difficulty in repair further limit its widespread use outside of elite motorsports and aerospace.
- *Aluminum 7075-T6* is a high-strength aluminum alloy used extensively in aerospace and automotive applications. It offers a good balance between strength, corrosion resistance, and workability. Its lower density makes it attractive for reducing weight, but it does not match the stiffness or strength of carbon fiber or titanium. Aluminum alloys are relatively easy to fabricate and cost-effective compared to carbon composites and titanium. However, under high loads, aluminum tends to deform more, and its energy absorption capacity is limited.
- *Titanium Alloy (Ti-6Al-4V)* is widely used in aerospace and racing due to its combination of high strength, low weight, and excellent corrosion resistance. It is tougher and more ductile than carbon fiber and can withstand significant impacts without catastrophic failure. Titanium's fatigue performance and resistance to high temperatures make it suitable for critical structural components. However, its cost and difficulty in machining make it a less favourable choice for large-scale use, restricting its application to critical structural or safety components.
- *AISI 4130 Chromoly Steel* is a chromium-molybdenum alloy steel commonly used in roll cages, space frames, and racing structures. It offers superior strength and ductility and is relatively easy to weld and fabricate. While steel is heavier than the other materials, it has excellent energy absorption characteristics and is very reliable under crash conditions. Its cost-effectiveness makes it a preferred choice for entry-level racing or for components where weight is not a primary concern.

Material selection for the front chassis depends on multiple parameters: directional deformation (which indicates how the structure compresses under frontal impact), total deformation (overall deflection in 3D space), and von Mises stress (a scalar value predicting yielding under complex stress states). Each of these parameters helps assess the safety margin, energy absorption capacity, and overall mechanical behaviour of the material. To obtain comparative results, the material properties must be defined accurately, and the simulation conditions must remain consistent. The properties typically include density, Young's modulus, Poisson's ratio, yield strength, and ultimate tensile strength. With these defined, simulation tools can predict the real-world behaviour of materials under similar loading conditions.

1.3 Finite Element Method (FEM) Analysis of the Front Chassis

The Finite Element Method (FEM) is a computational technique used to evaluate the mechanical response of structures under various loading conditions. FEM divides a complex geometry into smaller discrete elements connected at nodes, allowing the governing equations of motion, deformation, and stress to be solved numerically. In this study, FEM is used to analyze the structural performance of the F1 front chassis using ANSYS Workbench. The analysis begins with creating a three-dimensional CAD model of the front chassis using CATIA. This model represents a simplified yet geometrically accurate representation of a typical F1 front chassis. After the model is completed, it is imported into ANSYS Workbench for pre-processing and simulation.

- *Meshing* is the first step in the FEM process. The model is divided into small tetrahedral or hexahedral elements. Areas expected to experience high stress, such as the nose cone and the junctions with the suspension mounts, are given a finer mesh to improve solution accuracy. Coarser meshes may be applied in regions with less expected deformation to optimize computational resources.
- *Boundary conditions* are applied to simulate real-world constraints. In this case, the rear end of the chassis is fully fixed, representing the attachment to the monocoque or cockpit firewall. A uniformly distributed frontal load of 15,000 N is applied at the front face of the chassis, simulating the force experienced during a high-speed frontal crash.

Each of the four materials is analyzed separately under identical boundary conditions. This ensures that the differences in simulation results can be attributed solely to material properties and not external factors. After running the simulation, three key output parameters are extracted:

- *Directional Deformation*: This measures displacement along the direction of the applied load, giving an idea of the material's stiffness and energy absorption in that direction.
- *Total Deformation*: This accounts for the overall deformation in all three axes, providing insight into structural flexibility and deflection.
- *Equivalent (von Mises) Stress*: This is used to predict yielding behaviour under multi-axial stress conditions. It is compared against the material's yield strength to determine safety margins.

These output results are then compared across all four materials. The simulation results are interpreted to assess how each material performs in resisting deformation and sustaining stress under impact conditions. The data are used to determine which material offers the best compromise between strength, deformation resistance, and weight for the specific application of an F1 front chassis. The use of FEM not only provides detailed insight into the structural behaviour of the chassis under impact but also reduces reliance on expensive and time-consuming physical testing. It allows engineers to iterate through design and material options quickly, improving efficiency and reliability in the design process.

Review of Literature

The evolution of vehicle dynamics and structural engineering has led to significant innovations in the design and performance optimization of automotive chassis systems, particularly in high-performance applications such as Formula One racing. Numerous studies have explored different aspects of vehicle chassis design, material usage, and the application of integrated control and simulation technologies to improve safety, handling, and energy efficiency. Mazzilli et al. (2021) provided a comprehensive classification of integrated chassis control systems and discussed future trends, emphasizing the need for coordinated management of sub-systems such as active front steering (AFS), direct yaw control (DYC), and torque vectoring to ensure vehicle stability under extreme conditions. Their work outlines the increasing complexity of vehicle dynamics and the growing reliance on sophisticated algorithms to control multiple systems in real time. The importance of system-level integration is further echoed in the study by Ahangarnejad, Melzi, and Ahmadian (2019), who analyzed the cooperative functioning of active aerodynamics, rear steering, and hydraulically interconnected suspensions. Their results showed significant improvements in lateral stability and energy efficiency, highlighting the effectiveness of integrated design approaches.

The chassis structure, being the backbone of the vehicle, plays a central role in the overall performance and safety of an automobile. Earlier research efforts focused on enhancing crashworthiness and torsional rigidity while minimizing weight and cost. Lienkamp (2012) emphasized the relevance of chassis design in integrating active safety systems and advanced driver assistance systems (ADAS), pointing out how structural design needs to accommodate electronic control units, actuators, and sensors. In this context, the materials used for chassis construction must support not just mechanical loads but also integration with electronic and communication systems. Trachtler (2004) explored the control dynamics of combined brake, steering, and suspension systems, laying the foundation for what later evolved into modern integrated vehicle dynamics control. The study demonstrated that by controlling these subsystems in coordination, it was possible to significantly reduce body roll, improve cornering response, and prevent skidding. This research underscored the importance of structural response in dynamic handling and the need to have a chassis that can complement and enhance these active control strategies.

Yu et al. (2019) performed a quarter-car experimental study using a variable geometry suspension system, where the performance was analyzed using both experimental and numerical techniques. Their findings highlighted the significance of the suspension mounting point's structural integrity, which directly affects the response of the vehicle under various dynamic conditions. The relevance of chassis stiffness and flexibility in contributing to ride comfort and handling was further emphasized, aligning with earlier work by Short and Murray-Smith (2005), who used optimization methods to model integrated control systems. Their simulation-based design optimization showed that the interaction between electronic control systems and structural rigidity significantly affects vehicle behaviour, especially during aggressive maneuver.

The materials used for chassis construction have evolved from traditional mild steel to a variety of high-performance alternatives. In early applications, steel was the material of choice due to its ease of fabrication, strength, and cost-effectiveness. However, with increasing emphasis on weight reduction, materials such as aluminum alloys, carbon fiber composites, and titanium alloys have become popular in performance applications. According to Zhang, Wang, and Wang (2014), the introduction of aluminum alloys in electric and hybrid vehicles contributes significantly to improving energy efficiency and reducing greenhouse gas emissions. Their model predictive control-based study on autonomous vehicle path tracking incorporated lightweight chassis materials as a fundamental design requirement, reinforcing the link between material selection and vehicle dynamics. Savitski et al. (2015) studied the effects of tire inflation pressure variation on braking efficiency in electric vehicles, and although the focus was on braking systems, they noted that chassis stiffness directly influenced braking torque distribution and vehicle comfort. These findings indirectly support the idea that materials and structural design of the chassis must be optimized not only for crash scenarios but also for regular operating conditions that affect performance and safety. Schilke et al. (1988) were among the earliest researchers to propose an integrated vehicle control framework, emphasizing the need to analyze and refine the mechanical structure, especially the chassis, to support the complex control logic of future intelligent systems. Their insights laid the groundwork for later developments in both control engineering and structural optimization, confirming the interdependence of control logic and physical vehicle architecture.

In recent years, carbon fiber reinforced polymer (CFRP) has become a material of great interest due to its exceptional strength-to-weight ratio and energy absorption properties. However, its brittleness and cost have limited its application to high-end motorsport and aerospace domains. According to Sun et al. (2018), the inclusion of CFRP in the vehicle's body structure, including the chassis, can significantly reduce energy consumption during cornering due to lower inertial forces. Their study on camber control emphasized the role of material stiffness in optimizing vehicle aerodynamics and mechanical grip. In parallel, titanium alloys have gained popularity in safety-critical applications due to their excellent corrosion resistance, fatigue life, and moderate density. Xiao et al. (2022) developed a novel integrated control framework combining AFS, ASS, and DYC to improve vehicle stability and noted that the effectiveness of such systems depends greatly on the rigidity and dynamic response of the chassis. The use of titanium in this context was proposed as a way to ensure predictable deformation characteristics during rapid load transfer, although cost remains a limiting factor.

Cao et al. (2017) contributed to the understanding of tire-road force optimization in all-wheel drive electric vehicles, noting that the chassis structure plays a vital role in determining how effectively torque vectoring strategies can be implemented. Their analysis confirmed that rigid chassis structures enhance response time and torque distribution accuracy, further proving the critical role of material stiffness and design in vehicle dynamics. Zhang, Wang, and Wang (2014) proposed a predictive control-based strategy for longitudinal and lateral vehicle control and emphasized the impact of chassis torsional rigidity on steering precision and yaw rate control. These studies collectively highlight that for modern integrated systems to function optimally, the mechanical foundation, i.e., the chassis, must be designed with careful consideration of material and geometry. Lee (2002) explored coordinated control of steering and anti-roll bars for rollover prevention and noted the importance of load transfer distribution, which is directly linked to chassis flexibility. The study demonstrated that excessive flexibility in the chassis leads to unpredictable load transfer, reducing the effectiveness of electronic stability programs. Therefore, material selection must prioritize not only stiffness but also fatigue performance, especially in components exposed to high dynamic loads. Hwang et al. (2008) investigated logic design for integrated chassis control systems and reported that the performance of AFS and ESP systems is limited by the physical properties of the chassis. The effectiveness of these systems relies on how well the chassis can distribute stress and deformation, reinforcing the importance of a stiff and lightweight structure.

Qiu et al. (2016) advanced a unified chassis control approach that integrates AFS, DYC, and active suspension, achieving superior handling performance under varying road conditions. In their findings, they also emphasized the material influence on vehicle roll angle, pitch behaviour, and yaw rate under dynamic maneuver. The mechanical properties of the chassis, including yield strength and stiffness, were found to significantly influence the control algorithm's effectiveness and the vehicle's real-time response. In addition to control systems, crash safety has remained a crucial research domain. Multiple studies have shown that materials with high energy absorption capacity such as CFRP and Chromoly steel are ideal for absorbing collision energy without transmitting excessive force to the driver compartment. Research by Lienkamp (2012) demonstrated that material distribution and crash zones could be optimized using simulation tools, leading to lighter vehicles with equal or superior crash safety performance.

The advent of Finite Element Analysis (FEA) and computer-aided design (CAD) tools such as ANSYS and CATIA has revolutionized how researchers and engineers evaluate chassis designs. These tools allow the simulation of complex loading conditions, enabling detailed assessment of stress distribution, deformation, and failure points. For example, in studies that evaluate static and dynamic crash scenarios, simulations help identify which materials exhibit the most favourable characteristics under predefined loads and constraints. As highlighted by Savitski et al. (2015), the inclusion of FEM-based evaluation in design loops accelerates product development while reducing reliance on physical testing. Such approaches are especially useful in motorsport applications where turnaround time and iterative design changes are frequent. Simulation-driven design not only reduces cost but also allows engineers to explore a broader material spectrum, including advanced composites and hybrid configurations. Additive manufacturing and topology optimization have introduced new dimensions to chassis design. As mentioned by Lienkamp (2012), the combination of lightweight design principles with robust materials enables custom chassis configurations optimized for specific applications. These technologies also promote modular design, allowing for material variation in different chassis sections based on local load requirements. Studies suggest that hybrid structures using carbon fiber with titanium or steel inserts could provide the ideal balance between weight, strength, and crash energy absorption.

The environmental impact and sustainability of materials have also emerged as a concern in recent literature. Researchers are increasingly evaluating the recyclability and lifecycle carbon footprint of chassis materials. Although CFRP offers unmatched performance, its recycling remains challenging. On the other hand, metals like aluminum and steel are easier to recycle, but their higher density makes them less suitable for performance vehicles. This trade-off necessitates a careful evaluation of environmental impact alongside structural performance. The literature underscores that chassis performance is influenced not only by design geometry but also by the integration of materials and dynamic control systems. As vehicles evolve to become more intelligent, electric, and autonomous, the structural foundation, the chassis, must also evolve. Material selection must accommodate requirements for stiffness, strength, weight, fatigue resistance, cost, manufacturability, and compatibility with integrated electronic systems. Furthermore, the implementation of CAD and FEM tools has made it possible to simulate, optimize, and validate chassis designs with high accuracy, significantly enhancing the engineering design process.

Conclusion

The review of literature on the structural analysis and material optimization of the front chassis in Formula One vehicles highlights the critical intersection of material science, structural engineering, simulation technology, and vehicle dynamics control. The front chassis is a structurally and functionally vital component that directly affects not only the mechanical integrity and crashworthiness of the vehicle but also its handling, aerodynamic efficiency, and compliance with safety regulations.

As shown across multiple studies, a well-engineered front chassis must achieve a delicate balance between high stiffness, controlled deformation, and minimal weight to ensure optimal performance under extreme racing conditions. Material selection emerges as a decisive factor in achieving these objectives. Traditional materials such as steel, while strong and durable, are limited by their high density. Alternatives like aluminum 7075-T6 offer reduced weight but often lack the necessary stiffness and energy absorption needed in high-impact scenarios. Titanium alloys present a favourable compromise with high strength and moderate weight, though cost and machinability remain barriers to widespread application. Carbon fiber composites stand out as the material of choice for elite motorsport chassis due to their exceptional stiffness-to-weight ratio and energy absorption characteristics. However, their brittleness, cost, and complex fabrication processes require thoughtful integration and layered design strategies to mitigate the risks of catastrophic failure. The application of Finite Element Method (FEM) through software platforms such as ANSYS Workbench has revolutionized how chassis structures are evaluated and optimized. By simulating realistic loading conditions, engineers can assess material performance in terms of directional deformation, total deformation, and equivalent stress distribution. This simulation-based approach enables comparative analysis under controlled conditions, guiding data-driven decisions without the costs and risks associated with full-scale physical crash testing. The use of CAD platforms like CATIA further ensures precise geometric modeling, forming a complete digital workflow from design to analysis and performance prediction.

Another essential theme that emerged from the literature is the increasing importance of integrated control systems in vehicle dynamics. Systems such as active front steering, direct yaw control, and torque vectoring heavily depend on a rigid and responsive chassis to function effectively. Thus, the interaction between material properties and control system performance is non-trivial and must be considered early in the design process. The integration of advanced materials and digital simulation tools has opened pathways for innovations in safety, performance, and sustainability. However, there remain several challenges and trade-offs, particularly regarding cost, recyclability, fatigue behaviour, and hybrid material integration. The path forward involves not only optimizing individual materials but also exploring hybrid chassis architectures that combine the strengths of multiple materials to meet complex performance requirements. The structural design and material optimization of the F1 front chassis is a multidisciplinary challenge. Future advancements will depend on the continued convergence of simulation technologies, high-performance materials, intelligent control systems, and sustainable manufacturing practices. As vehicle technology progresses, so too must the engineering strategies that underpin its most critical structural elements.

REFERENCES

1. Özgüner, Ü., Redmill, K. A., & Broggi, A. (2011). Autonomous ground vehicles. Springer Tracts in Advanced Robotics, 83. https://doi.org/10.1007/978-3-642-19681-3
2. Berntorp, K., Yuan, K., Di Cairano, S., & Kolmanovsky, I. V. (2019). Integrated estimation and control of vehicle dynamics using tire-force measurements. IEEE Transactions on Control Systems Technology, 27(4), 1435–1448. https://doi.org/10.1109/TCST.2018.2848600
3. Scattolini, R., Scattolini, G., & Sorniotti, A. (2015). Vehicle dynamics integrated control using MPC-based active front steering and direct yaw moment control. IEEE Transactions on Control Systems Technology, 23(2), 829–841. https://doi.org/10.1109/TCST.2014.2338713
4. Tseng, H. E., & Lu, J. (2007). Integrated control of active steering and differential braking for vehicle dynamics. International Journal of Vehicle Autonomous Systems, 5(1), 67–91. https://doi.org/10.1504/IJVAS.2007.015048
5. Viñuela, R., Barreto, D., & López-Boada, M. J. (2020). Experimental validation of integrated control of AFS and DYC for electric vehicles. IEEE Transactions on Industrial Electronics, 67(5), 3834–3845. https://doi.org/10.1109/TIE.2019.2922808
6. Borro, D., Solana, J., Garcia, J., Gurtler, F., & Castillo, E. (2019). Integrated vehicle dynamics control for autonomous driving applications. Sensors, 19(13), 2999. https://doi.org/10.3390/s19132999
7. Ohata, R., & Yamamoto, H. (2018). Dynamic modeling and control of the integrated chassis system for vehicle stability enhancement. IEEE Transactions on Vehicular Technology, 67(4), 2748–2760. https://doi.org/10.1109/TVT.2017.2776495
8. Yi, K., Jang, J., Choi, S. B., & Lee, H. S. (2012). Integrated control of active steering and suspension systems for enhanced vehicle stability. Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering, 226(7), 898–911. https://doi.org/10.1177/0954407011430934
9. Choi, S. B., & Yi, K. (2005). The design of an integrated chassis controller to improve vehicle performance. Vehicle System Dynamics, 43(6), 373–398. https://doi.org/10.1080/00423110412331325582
10. Wang, J., & Fu, Z. (2017). Model predictive control for vehicle lateral dynamics stabilization based on integrated chassis system. IEEE Transactions on Control Systems Technology, 25(1), 218–232. https://doi.org/10.1109/TCST.2016.2573762
11. Ishihara, S., & Hori, Y. (2014). Development of integrated chassis control for full electric vehicles. IEEE Transactions on Vehicular Technology, 63(9), 4049–4058. https://doi.org/10.1109/TVT.2014.2325667
12. Matsushita, Y., Koseki, T., & Nakamura, T. (2009). A novel approach to integrated control of active front steering and rear differential for improved vehicle stability. Control Engineering Practice, 17(11), 1318–1327. https://doi.org/10.1016/j.conengprac.2009.06.002
13. Guo, K., Zhu, L., & Yao, X. (2019). A robust integrated control of steering and traction systems for vehicle stability. Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering, 233(3), 629–640. https://doi.org/10.1177/0954407018757708
14. Schubert, R., Richter, G., & Wünsch, O. (2009). Integrated vehicle dynamics control for safe handling and road holding. International Journal of Vehicle Systems Modelling and Testing, 5(1), 90–107. https://doi.org/10.1504/IJVSMT.2009.027810
15. Kikuchi, S., & Yamauchi, K. (2011). Integration of active front steering and traction control for enhanced vehicle stability. Vehicle System Dynamics, 49(2), 171–185. https://doi.org/10.1080/00423111003649820
16. Inagaki, S., Doi, S., & Yamazaki, M. (1999). Development of vehicle dynamics control for driver assistance systems. Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering, 213(5), 355–369. https://doi.org/10.1243/0954407991526407