



Faculty of Engineering
University of Kragujevac



Ministry of Science, Technological
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Motor Vehicles & Motors 2026
ECOLOGY -
VEHICLE AND ROAD SAFETY
- EFFICIENCY
Proceedings**



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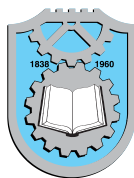
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Review paper

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ANALYSIS OF EXPERIMENTAL METHODOLOGIES FOR TESTING INNOVATIVE BRAKE SOLUTIONS

ABSTRACT: The development of the automotive industry, as well as the development of modern on-board systems, require detailed tests from the aspect of functionality and safety of the developed systems. The implementation of new materials, sensors and new braking systems requires advanced, reliable and highly accurate evaluation methods. This paper is dedicated to a comprehensive analysis of modern experimental methodologies used to test innovative brake solutions. The paper presents a detailed analysis of three types of experimental approaches to testing innovative brake solutions, i.e. the brake testing in laboratories, field tests and computer simulations. By analyzing the advantages and limitations of each of the mentioned approaches, the paper indicates the necessity of integrating hybrid testing methods (so-called Hardware-in-the-Loop - HiL systems), which successfully bridge the gap between isolated laboratory conditions and the complexity of real traffic.

KEYWORDS: experiment, methodology, brakes, system, innovations

ANALIZA EKSPERIMENTALNIH METODOLOGIJA PRI ISPITIVANJU INOVATIVNIH REŠENJA KOČNICA

REZIME: Razvoj automobilske industrije, kao i razvoj savremenih sistema na vozilu, zahtevaju detaljna ispitivanja sa aspekta funkcionalnosti i bezbednosti razvijenih sistema. Implementacija novih materijala, davača i novih načina rada sistema za kočenje zahteva napredne, pouzdane i visoko precizne metode evaluacije. Ovaj rad posvećen je sveobuhvatnoj analizi savremenih eksperimentalnih metodologija koje se koriste za ispitivanje inovativnih rešenja kočnica. U radu je prikazana detaljna analiza tri vrste eksperimentalnih pristupa ispitivanja inovativnih rešenja kočnica, odnosno ispitivanje kočnica u laboratorijama, terenska ispitivanja i računarske simulacije. Analizom prednosti i ograničenja svakog od navedenih pristupa, rad ukazuje na neophodnost integracije hibridnih metoda testiranja (tzv. Hardware-in-the-Loop - HiL sistemi), koje uspešno premošćuju jaz između izolovanih laboratorijskih uslova i kompleksnosti realnog saobraćaja.

KLJUČNE REČI: eksperiment, metodologija, kočioni sistem, inovacije

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INTRODUCTION

The braking system is one of the most important systems when it comes to traffic and vehicle safety. Any failure of the braking system can have a significant impact on the occurrence of a traffic accident with consequences that can be fatal for humans (Haq, M. T. et al. 2023). According to data from LookupAPlate (2023), brake failures directly cause 0.44% of all traffic accidents, or about 264,000 accidents per year in the USA. Brake problems are the most common technical cause of accidents, accounting for 22% of all crashes caused by critical vehicle failures, while the risk of fatal accidents is significantly higher in older vehicles and heavy trucks. Similar data is presented in the report Arrive Alive (2026), which indicates that the braking system has an impact on a total of 25.05% of traffic accidents, considering only the vehicle factor, while in the total factors that influence the occurrence of a traffic accident, it has an impact of 2.29%.

In addition to all the consequences that can be caused by brake failure, an additional problem can arise when applying some of the modern innovative solutions to the braking system. The application of innovative solutions in the case of brakes represents a very big problem if the solutions are not sufficiently tested, so this can lead to greater unreliability in the application or some unforeseen failures. Today, the problem is perhaps even more complex than before, considering that modern vehicles generally combine mechanics and electronics. Therefore, tests must be conducted from the aspect of mechanical elements and the reliability of such parts of the braking system, and on the other hand, tests of the operation of electronics and algorithms according to which the operation of the system itself functions. Thus, today a large number of research on braking systems relates to the analysis of the validity of the algorithm according to which the electronic part of the braking system is activated and functions. According to Pfister et al. (2025), the development of braking technologies is particularly complex due to the interdisciplinary nature of the systems involved, which include multiple software and hardware subsystems interacting in different physics. These complexities are intensified when the systems must meet stringent performance, safety, and regulatory testing requirements on different platforms. The integration of these disparate components often leads to long product development timelines and an increased risk of costly late-stage failures.

Advanced experimental methods and techniques are used to test braking systems and innovations related to the braking system today. Tests are performed at different levels and by applying various combined test methods. The goal of such tests is to analyze the reliability of the system itself and of individual system components. In addition to testing the braking system itself, the analysis of the validity of the functioning is often also tested for the quality of integration of electronic and mechanical components of the system. Experimental methodologies described in the scientific literature rely on a structured testing hierarchy to validate braking innovations. These methods evaluate new brake-by-wire mechanics, sustainable friction materials, regenerative energy mixing and environmental impact profiles.

Considering the complexity of innovative solutions related to the braking system and, on the other hand, the importance of the braking system, the paper analyzes the experimental methods that have been and are used in researching innovations related to braking systems. In addition to the innovative solutions themselves, an analysis of the requirements placed on experimental technologies was performed. The aim of this paper is precisely to introduce modern experimental systems that are used in the analysis and verification of innovations related to the braking process and braking system.

REQUIREMENTS FOR MODERN EXPERIMENTAL BRAKE INSTALLATIONS

Brake innovation testing procedures combine advanced laboratory setups, inertial dynamometers, and real-world testing to evaluate mechatronic components, brake-by-wire systems, and friction materials. The procedure for testing innovative technical solutions in motor vehicle braking systems is a complex scientific and professional process aimed at verifying safety performance, functional stability, and reliability before their serial application. Depending on the nature of the innovation itself — whether it is new composite brake element materials, advanced stability control algorithms, or Brake-by-Wire systems — the tests are strictly codified (CITA, 2025). Scientific papers classify experimental testing for innovative vehicle brakes into four progressive levels, as shown in Figure 1, (Kumbhar, N. et al. 2016).

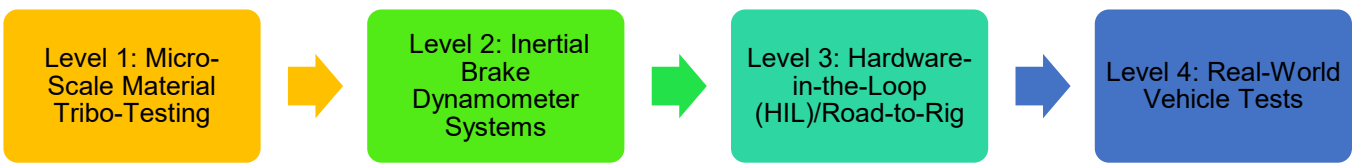


Figure 1 Levels of experimental testing of innovations in the case of braking systems

The primary regulatory framework in Europe and associated countries consists of the international regulations of the Economic Commission of the United Nations for Europe, more precisely UN ECE R13 for heavy commercial vehicles and UN ECE R13-H for passenger vehicles, while in the Republic of Serbia the processes of homologation and controlled attestation are carried out under the supervision of the Traffic Safety Agency (ABS) (DTC, 2026; United Nations Economic Commission for Europe, 2014; United Nations Economic Commission for Europe, 2021).

The experimental development of the innovation begins in laboratory conditions through the phases of numerical simulations (finite element method, modeling in environments like MATLAB/Simulink) and static tests of subsystems. A key step in this phase is Hardware-in-the-Loop (HIL) testing, where the actual Electronic Control Unit (ECU) is integrated with a computer model of vehicle dynamics to analyze the response time and transient characteristics of the system in milliseconds. After successful laboratory verification, the brake system prototype is installed in a dedicated test vehicle and subjected to rigorous testing on closed training grounds with dedicated tracks.

According to the requirements of the homologation protocols, the innovation must successfully pass three standardized groups of efficiency and thermal endurance tests, known as the Type 0, Type I and Type II cycles. Test Type 0 (testing of cold brakes) defines the measurement of the minimum stopping distance and the mean fully developed deceleration (MFDD) at defined initial speeds, with the initial temperature of the brake discs below 100 °C. Test Type I (test of loss of efficiency or Fade Test) implies a series of successive braking and acceleration in short time intervals with the aim of causing extreme thermal load of the brake pairs, whereby the innovative system must not show a drop in efficiency below the law prescribed percentage. The Type II test evaluates the long-term durability of the system when simulating long downhills under constant braking load.

Vehicle stability and distribution of braking force in critical situations represent an elimination criterion for any technical innovation. For this purpose, dynamic tests are carried out on so-called "split" surfaces, where one side of the vehicle brakes on a surface with a high coefficient of adhesion (dry asphalt), while the other side is on a surface with a low coefficient (ice or wet film). Innovative systems for managing the dynamics of braking must, in these asymmetric conditions, ensure that the direction of movement of the vehicle is maintained without the intervention of the driver on the steering wheel beyond the permitted limits, minimizing the risk of drifting or rotation of the vehicle.

When the innovation includes electronic components, microcontrollers or software algorithms (such as electro-mechanical brakes - EMB), the validation process extends to functional safety and cyber security standards. According to the international standard ISO 26262 (Road vehicles - Functional safety) (International Organization for Standardization, 2018), braking systems are categorized under the strictest level of safety integrity - ASIL D (PatSnap, 2026). This requires designers to implement hardware and software redundancy (e.g. backup subsystems of power supply and signal transmission) that guarantee that the system, in the event of a primary failure of the electronics, will go into a safe state and enable the vehicle to stop safely. Additionally, in accordance with the latest UN ECE R155 and R156 regulations, system resistance tests against unauthorized external intrusions and cyber threats are performed if the brake system supports wireless software updates (Over-the-Air).

DYNAMOMETER TESTS OF BRAKE INNOVATIONS

Dynamometer tests (dyno testing), which is shown in Figure 2, represent a key step in the development of brake innovations. They enable laboratory simulation of real driving conditions and extreme loads without the need for expensive and risky tests on the track. In the modern auto industry, tests are performed on sophisticated brake inertial dynamometers (Sporysz, B. 2024). They simulate the mass and inertia of the vehicle using heavy rotating flywheels or advanced electric motors with load simulation.

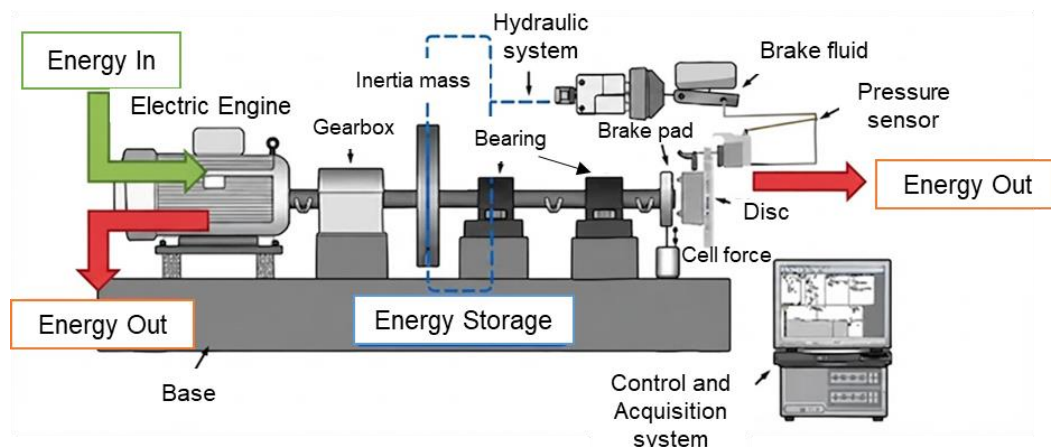


Figure 2 Inertial brake dynamometer for testing regenerative braking (Mendoza & Squadrani 2021)

Modern test benches, like advanced systems, consist of several subsystems:

- Drive electric motors are powerful AC motors (often over 400 kW) that accelerate the assembly to precisely defined speeds (and over 3500 rpm),
- Mechanical flywheels (Inertia), which is a combination of massive discs that store kinetic energy. Modern systems combine physical inertia with electrical simulation,
- Climatic chamber and environment simulation where there are closed systems that allow testing in the range from -40 °C to +50 °C, with sprinklers for water, salt water or snow.

Dynamometer tests of innovations follow strict global standards (eg SAE J2522 for brake material performance or SAE J3211 for vehicles with regenerative braking). During multi-day cycles, the following phases are executed:

- Burnishing/Bedding, which represents a series of 100 to 200 lighter braking operations so that the new pads fit perfectly on the disc and stabilize the friction.
- Maximum performance, which is performed by braking at speeds over 150 km/h with a pressure of up to 200 bar, which checks the maximum power and durability of the system.
- Thermal weakening (Fade & Recovery) which includes successive, aggressive braking that raises the disc temperature above 600 °C. The loss of braking power due to overheating is monitored, as well as the speed of recovery during cooling.
- Noise and vibration testing (NVH). Braking at different angles and pressures (mostly at lower speeds) inside the sound chamber to detect screeching or shaking.
- Particle emission measurement where it is necessary to close the assembly in a special chamber for the collection and measurement of microparticles (PM₁₀ and PM_{2.5}) that are produced by material wear, which is key to the new Euro 7 environmental standards.

The use of an inertial brake dynamometer (Inertial Brake Dynamometer) is crucial for testing innovations for several reasons that cannot be replicated with classic laboratory tests:

- Realistic vehicle mass simulation: Instead of simply spinning a disc, this device uses massive, adjustable flywheels that physically store the exact kinetic energy of the vehicle in motion. When the brake is applied, it must stop the "real" weight of the car.
- Total safety during destructive tests: Innovations are often tested to the point of complete failure (eg bursting a disc or melting a wafer at 800 °C). On the dynamometer you do it without any risk to the life of the test driver or the destruction of the prototype vehicle.
- Perfect repeatability of the cycle (Reproducibility): On the track, the wind, air temperature and asphalt condition are constantly changing. A dynamometer in the laboratory allows the exact same test (e.g. 100 consecutive braking from 120 km/h to 0 km/h) to be repeated to millisecond and degree Celsius accuracy, which is necessary for a scientific comparison of old and new technology.
- Isolation and micron measurements: Because the assembly is fixed, engineers can place ultra-sensitive thermal imaging cameras, laser sensors to measure disc micro-wear, and highly sensitive noise (NVH) microphones, which is impossible to do in the wheel of a car speeding down a track.
- Simulation of extreme climatic conditions: Dynamometers enclosed in climate chambers can change conditions from Siberian -40 °C with salt spray (corrosion testing of innovative coatings) to desert +50 °C within minutes, speeding up the testing process by several months.

Although it brings enormous advantages, the use of an inertial brake dynamometer has two key drawbacks: the extremely high cost and the laboratory isolation of the hardware. The devices themselves, accompanying software and air-conditioned chambers cost hundreds of thousands of euros, and the complex assembly and calibration of each new prototype requires a lot of time and highly educated engineers. In addition, the consumption of electricity to drive massive flywheels and simulate high speeds drastically raises the operating costs of testing. Another big minus is the impossibility of perfect replication of the real world, primarily in terms of cooling and vehicle mechanics. On the dynamometer, the air cooling of the brake is simulated with artificial fans, which can never completely accurately convey the complex aerodynamics and the swirling of air around the wheel in motion. Also, the fixed laboratory assembly completely ignores the influence of the suspension, chassis vibrations and the real weight change of the vehicle during braking, which is why the final confirmation of the innovation must still be carried out on a real track.

EXPERIMENTAL TESTS OF BRAKES IN LABORATORY CONDITIONS

Experimental tests of brake system innovations in laboratory conditions (Figure 3) represent the first phase of physical validation of new solutions. Before the system is installed in an actual vehicle, the components are tested in a strictly controlled environment. The laboratory provides ideal conditions for the isolation of specific phenomena without the influence of external factors such as wind, weather or human error of the driver. In laboratory conditions, it is possible to test complete real vehicles, as well as individual parts of brake systems or specific brake innovations. Modern research centers are designed as modular systems, which allows engineers to adjust the level of testing depending on the stage of development in which the project is located. In this way, maximum flexibility is ensured, because the

technology can be checked from the level of raw material all the way to its full integration into the finished car (Markel, A. 2005).



Figure 3 An example of experimenting with a vehicle in laboratory conditions (HORIBA, (n.d.))

For indoor testing of complete real vehicles, massive dynamometers with rollers (Chassis Dynamometers) are used, which are often located inside advanced climatic wind tunnels. The real vehicle is fixed with wheels on metal rollers that faithfully simulate road resistance, mass and inertia of the car in motion. A driver or robot-automator controls the vehicle inside the laboratory, while simulated winds of over 150 km/h and extreme temperatures from -40 °C to +50 °C enable safe monitoring of brake operation, ABS/ESP electronics and heat distribution throughout the chassis.

When developing a completely new concept or individual component, there is no need to spend resources on the entire vehicle, but only the targeted parts of the system are mounted on the laboratory benches. On inertial dynamometers for components, only one wheel assembly is isolated to analyze in detail innovative pad friction materials, anti-rust coatings or environmental particulate emissions. In addition, special robotic actuators perform material fatigue tests by pressing the brake calipers or master cylinder hundreds of thousands of times without stopping, checking the durability of the seals under extreme pressures.

This approach is particularly important for the development of modern Brake-by-Wire systems, where only electronics and mechatronics can be tested in the laboratory, completely separated from mechanical discs. Engineers place only an electronic brake pedal, sensors and a drag simulator on the test bench to calibrate software algorithms and check fail-safe modes in case of failure. Only when the individual part of the braking system proves its reliability and safety in these isolated laboratory cycles, it moves to the stage of its integration and testing at the level of the complete vehicle.

Testing of brake system innovations brings key benefits that directly affect the safety, ecology, performance and economic viability of new technologies before they reach the market. Here are the main benefits and reasons why conducting these rigorous tests is necessary:

- Brakes are the most important safety system on a vehicle. Detailed tests ensure that innovations (such as new alloys or software) function flawlessly in critical situations, reducing the risk of brake failure,
- New environmental standards for the first time limit the emission of particles that are caused by brake wear. Testing of innovative hard disc coatings (e.g. tungsten carbide) and new disc compounds directly proves a reduction of harmful PM₁₀ and PM_{2.5} particles by over 60%,
- In the case of electric and hybrid vehicles, the tests enable the perfect blending of electric motor braking and classic brakes. This maximizes the return of energy to the battery and extends the range of the vehicle, while maintaining a natural feel on the pedal,
- Electronic brake tests allow engineers to create faster response systems (under 100 milliseconds). This drastically shortens the stopping distance and enables better integration with ADAS systems for autonomous emergency braking,
- Through a combination of virtual simulations, HiL systems and laboratory tests, engineers can eliminate errors at an early stage. This prevents expensive recalls of production vehicles and accelerates the entry of new technology into the market,
- Tests enable the isolation and elimination of unpleasant sounds, screeching and vibrations. This ensures that the innovative brake system provides superior comfort for the driver and passengers, without irritating noises in the cabin.

EXPERIMENTAL TESTS IN REAL CONDITIONS

Real-World Vehicle Tests represent the final and most important stage in the development of brake innovations. While laboratories and dynamometers provide a theoretical basis, only on a real vehicle do engineers get an insight into how the brakes work in interaction with the entire mechanics, aerodynamics and electronics of the car. These tests are conducted through strictly defined protocols on closed proving grounds and public roads, and are focused on key aspects. Experimental tests of brake innovations in real conditions are the most important validation phase before serial production. Although simulations and dynamometers provide excellent initial data, it is only on the real track and in real traffic that the braking system faces the complex interplay of aerodynamics, suspension, vibrations and unpredictable environmental factors. Tests in field conditions (Off-road/Terrain testing) represent a special, extreme segment of experimental testing of brake innovations. Unlike flat asphalt on race tracks, off-road conditions (mud, sand, rock, deep water, sharp slopes) expose the brake system to unpredictable mechanical, thermal and environmental loads (The Brake Report, 2024). These tests are crucial for innovations intended for SUVs, pickup trucks, military, construction and agricultural machines, as well as for the calibration of modern electronic stability control systems.



Figure 4 Vehicle testing in real conditions (Robert Bosch GmbH, 2026)

The main mechanical challenge in off-road conditions is protection against accelerated wear and extreme thermal shocks. Sand and small gravel easily penetrate between the brake pad and disc, acting as an abrasive that can destroy the material, so innovative protective coatings and harder compounds of brake elements are tested in these conditions. In addition, when the vehicle descends a steep mountain pass, the brakes heat up to several hundred degrees, and a sudden entry into a deep puddle or river causes a dangerous thermal shock that can lead to cracking or warping of the discs.

In addition to mechanical durability, the field is the only place where innovative electronic systems and Brake-by-Wire algorithms can be precisely calibrated. On loose surfaces like gravel or sand, classic ABS would lengthen the stopping distance, so engineers here are testing specific "Off-road ABS" programs that deliberately allow short-term wheel locking so that the tire in front creates a wedge of gravel and stops faster. Also, systems for automatic hill descent control (Hill Descent Control) rely on millisecond reactions of the brakes, which on slippery and uneven ground must work in perfect synchronization so that the vehicle does not slide into the abyss.

In order to successfully carry out these tests, the prototype vehicle is equipped with robust, waterproof measuring equipment and high-resolution cameras that record the behavior of the jaws in the mud. After the tests are completed, the brake assembly is completely disassembled in the laboratory and analyzed under a microscope. Engineers measure micron damage on the surface of the disc and check whether the internal seals and rubbers have maintained 100% tightness, which is the final confirmation that the innovation is ready for serial production and the most difficult work tasks. Testing braking innovations under real road conditions brings key benefits that cannot be fully replicated in the lab or on simulators. Here are the main advantages of this method of testing:

- Actual aerodynamics and cooling. A vehicle in motion on the open road generates a natural vortex of air around the wheel. This enables a 100% accurate check of how the innovative discs are cooled under the influence of the actual aerodynamics of the car,
- Interaction with suspension and chassis. Braking on the right track involves realistic vehicle weight transfer, shock absorber operation and chassis vibrations. These factors directly affect the operation of the ABS/ESP electronics and cannot be faithfully simulated on a fixed laboratory bench,
- During fleet-tests (driving entire fleets of vehicles), the brakes cross tens of thousands of kilometers. It is the only way to check how the new materials react to a combination of moisture, dust, industrial road salt and small stones over time,

- Precise calibration for real drivers (Pedal Feel). Test drivers on public roads and training grounds provide subjective and objective insight into "pedal feel". That's key to fine-tuning the Brake-by-Wire system to make braking feel natural and predictable for the average driver,
- Validation with ADAS systems (Autonomous Braking). On the road, it is tested how the innovative brake actuators cooperate with the vehicle's radars and cameras. The exact reaction speed of the system is measured in moments when the car has to brake independently in emergency traffic situations.

HARDWARE-IN-THE-LOOP TEST BENCH

Hardware-in-the-loop (HIL) testing is an advanced cyber-physical testing methodology where real physical hardware components are connected in real time to a computer-simulated virtual environment, as shown in Figure 5. Instead of installing a new component in a physical test vehicle and driving it on a test track, the component is connected to a high-speed simulator that tricks the hardware into "thinking" that it is operating inside a real car moving under real-world road conditions. HIL testing involves simulating vehicle and environmental inputs to the electronic control unit (ECU) under test, leading it to believe that it is responding to real-world driving conditions on the open road. The HIL bench contains all relevant vehicle components. The simulator displays the inputs to real-world cameras and radar systems, which in turn send signals to the system under test to see if it is responding correctly to the inputs. For example, test scripts can create a scenario in which a vehicle traveling at 100 km/h around a curve in the rain encounters an unknown object on the road or an oncoming car swerving across the centerline. Cameras and radars connected to the HIL test bench send images to the ECU, and the system under test must process this data in real time and decide what to do (Aptiv,2026).

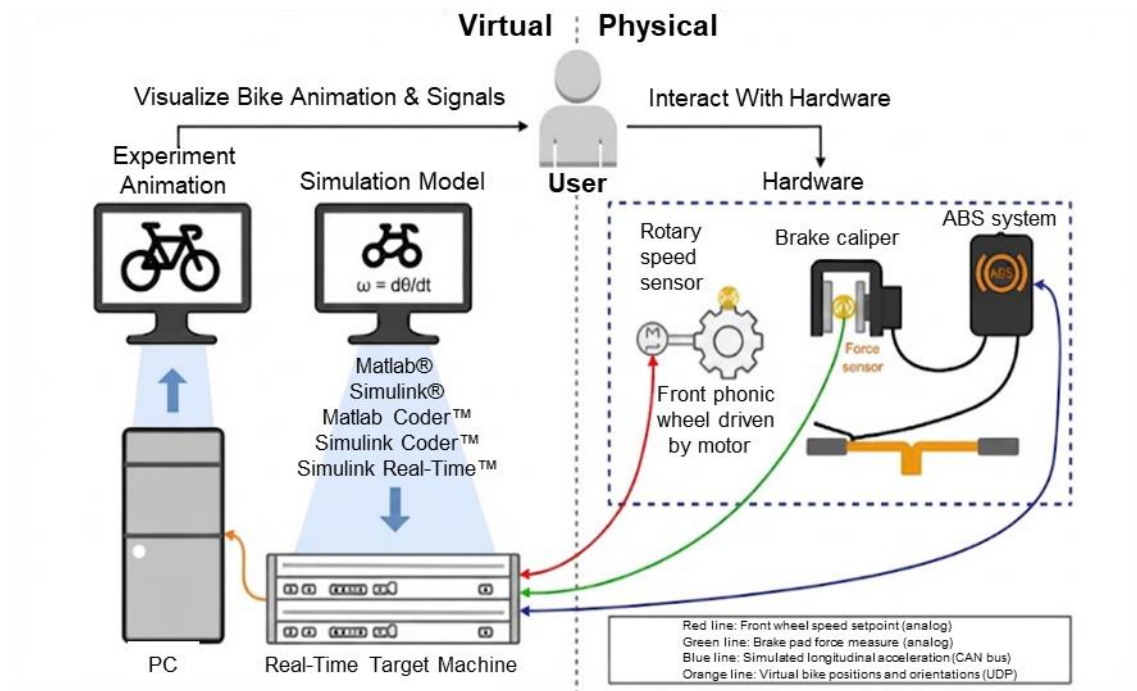


Figure 5 HIL testing scheme (Ramosaj, N. et al. 2023)

In a typical automotive brake speed control application, the setup balances physical hardware and virtual data. The physical objects are typically an electronic control unit (ECU) that runs control algorithms, actual hydraulic or pneumatic valves, and sometimes physical brake calipers, brake pipes, and pedals. A real-time computer simulator runs complex mathematical equations that model the mass of the vehicle, the dynamics of multiple tires, the coefficients of tire-road friction (μ), aerodynamics, and even the speeds of individual wheels (Pfister, F. et al. 2025). When the physical brake ECU commands the hydraulic valve to close, the virtual environment immediately registers the pressure change. The simulation model calculates the resulting vehicle deceleration and tire slip and sends simulated wheel speed sensor data back to the physical ECU in milliseconds (latency < 1 ms).

Hardware-in-the-Loop (HiL) test benches provide a bridge between pure computer software and physical on-track testing. When testing brake innovations, their application brings the following key advantages:

- Modern brakes are not just mechanics, but complex mechatronic systems driven by algorithms. HiL allows real brake electronics (ECU) and sensors to be connected to a virtual vehicle simulator. Engineers can test thousands of software scenarios in minutes, change parameters on the fly and calibrate system performance (such as brake force distribution) without waiting for a physical prototype of the entire car to be built.

- Testing braking innovations in extreme conditions on a straight track carries a huge risk of accidents. On the HiL table, you can simulate a burst brake hose, failure of a pressure sensor at a speed of 200 km/h, or a sudden transition from dry asphalt to ice (Split-Mu) in the middle of a bend. The system is tested to the absolute limits of safety, observing how the electronics react to critical failures (fail-safe modes) without any risk to the test driver.
- In electric vehicles, the coordination of the electrical (engine braking) and hydraulic (disc braking) systems is extremely complex. HiL stands allow simulation of electric drive, battery and torque operation in real time. Engineers can thus perfectly "iron" the transition between these two modes of braking on the pedals, ensuring maximum energy return (regeneration) with a natural feeling on the pedal for the driver,
- Unlike track tests that depend on weather conditions and availability, HiL systems operate 24/7. Tests are fully automated through scripts – the computer can independently, overnight, perform thousands of consecutive braking, simulating different vehicle weights, pad's wear levels and driving styles, generating complete fault reports ready for analysis.

CONCLUSIONS

Innovation is one of the key challenges in modern engineering. The application of certain innovations in mass production or the change of some systems, such as braking systems on motor vehicles, can lead to very negative effects if, before mass application or production, innovative solutions are not tested or their effectiveness and operation is not validated. That is why the process of testing the validity and functionality of the system must undergo rigorous experiments that give the exact answers as to whether the innovation is applicable, justified and above all safe for mass application. The importance of experimentation is especially important today when the mechanical and electronic parts of the system are integrated. The application of experiments in the testing of modern braking systems is very important for the reason of not only checking the integrated operation of the system, but also the operation of the activation algorithms and the operation of modern systems.

In order to successfully test modern braking systems and innovations that are being researched, there are certain procedures and regulations that the system must satisfy and function according to. Thus, today there are different levels of brake system testing, depending on the level at which the system is tested and how much of the system is tested, but on the other hand, what innovation in the brake system is tested. Nowadays, different levels and types of systems are mainly used, starting from the lowest level, where systems are tested on an inertial brake dynamometer, and on the other hand, real vehicles can also be tested. Experiments where real vehicles are used are experiments that can be applied in laboratory conditions as well as in a real environment, that is, on specialized tracks in a real traffic environment, that is, on roads. Each type of experiment that examines innovations related to the braking system has its advantages and disadvantages. When it comes to experimenting with brake systems, the importance of detailed testing is very important for reasons of importance to vehicle and traffic safety. Bearing in mind the mentioned importance, the braking system passes all levels of testing with the aim of detailed analysis and verification. If there are certain negative results of the innovation test, there may be a correction of the proposed engineering solution or its rejection. Today, hybrid experimental methods are increasingly being applied, combining real systems and simulations, that is, computer systems. In this way, more favorable tests are possible where different variants of the innovation can be tested. In the future, it will surely be improved even more and new experimental test methods will be developed that will eliminate existing shortcomings and speed up the very process of experimentation of braking system innovations.

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