International Journal of Advances in Scientific Research and Engineering (ijasre)

E-ISSN : 2454-8006

DOI: 10.31695/IJASRE.2023.9.6.3

Volume 9, Issue 6
June - 2023

Design and Fabrication of Electro-Mechanical Active Suspension System Test Rig

Anil Kumar P R[1], Raghav Ramesh[2], Rasika Rukmini Rajesh[3]

Assistant professor[1], Students [2 3]

Department of Mechanical Engineering

Sapthagiri College of Engineering Bengaluru, Karnataka

India

ABSTRACT

This abstract discusses the design and fabrication of an active suspension system. The goal is to enhance ride comfort, stability, and vehicle dynamics. The research focuses on analyzing the quarter car model dynamics and employing advanced control algorithms and actuators for adaptive suspension adjustment. Integration of sensors, control units, and actuators is crucial for real-time monitoring and control of the suspension. With the help of this rig, we are analyzing the linear acceleration in passive suspension and active suspension. By doing so we can determine the load acting on the chassis. The active suspension system test rig is a valuable tool for automotive engineers and designers. It allows them to evaluate the performance of different suspension systems in a controlled environment, under various operating conditions.

Key Words: Accelerometer, Battery, Gyroscope, Rack and pinion.

---

1. INTRODUCTION

Electromechanical active suspension systems have become increasingly popular in recent years due to their ability to provide better ride comfort and handling compared to traditional passive suspension systems. These systems use a combination of mechanical and electronic components, including actuators, sensors, and controllers, to adjust the suspension in real-time and respond to changing road conditions. The design and fabrication of a test rig are critical in evaluating the performance of active suspension systems and validating their effectiveness.

The design of an electromechanical active suspension system begins with selecting the appropriate actuator. The actuator is responsible for adjusting the suspension in real time based on the road conditions. Electromechanical actuators are the most common type of actuator used in active suspension systems due to their high energy efficiency, precision control, and faster response time.

The selection of the appropriate actuator depends on the required force, displacement, and speed of the system. Once the actuator is selected, the next step is to design the control system. The control system consists of sensors, a controller, and a power supply. The sensors are used to measure the displacement, velocity, and acceleration of the suspension and chassis. The controller processes the sensor data and sends commands to the actuator to adjust the suspension. The power supply provides the necessary power to the actuator and control system. The fabrication of a test rig for an electromechanical active suspension system involves the construction of a physical model that simulates real-world road conditions. The test rig consists of a frame, a suspension system, an actuator, and a control system. The frame provides a stable platform for the suspension system, actuator, and control system.

The actuator is mounted to the frame and connected to the suspension system. The actuator is responsible for adjusting the suspension in real time based on the road conditions. The control system is mounted on the frame and includes the sensors, controller, and power supply required to operate the actuator. The construction of the test rig requires the use of various materials and fabrication techniques. The frame is typically constructed from Mild steel and welded together to form a stable platform.

The actuator is typically a rack and pinion mechanism, which is mounted to the frame and connected to the suspension system. The control system includes sensors, such as accelerometers and position sensors, which are mounted to the suspension system to measure the displacement, velocity, and acceleration of the suspension. The controller processes the sensor data and sends commands to the actuator to adjust the suspension. The validation of the electromechanical active suspension system test rig involves testing the system under various road conditions and evaluating its performance. The test rig is typically programmed to simulate various road conditions, such as smooth roads, rough roads, and potholes, to evaluate the performance of the suspension system. The performance of the system is evaluated based on various metrics, such as ride comfort, handling, and road holding.

2. LITERATURE SURVEY

“Design and analysis of an electromechanical active suspension system" by Jianwei Zhang et al.,(2018) published paper which presents a design and analysis of an EMASS based on linear quadratic regulator control theory. The authors designed a mathematical model of the suspension system and used simulation software to evaluate the performance of the system. The results showed that the EMASS was able to reduce the vibration of the vehicle and improve ride comfort [1].
An electromechanical active suspension system based on sliding mode control" by Zhenyu Li and Huifang Li (2020), paper presents an EMASS based on sliding mode control theory. The authors designed a mathematical model of the suspension system and used simulation software to evaluate the performance of the system. The results showed that the EMASS was able to reduce the vibration of the vehicle and improve ride comfort [2].
Experimental validation of an electromechanical active suspension system by Haojie Xiao, Guoping Tang, and Jihong Chen (2019) paper presents an experimental validation of an EMASS. The authors designed a prototype suspension system and conducted experiments to evaluate the performance of the system. The results showed that the EMASS was able to reduce the vibration of the vehicle and improve ride comfort [3].

Design and analysis of an electromechanical active suspension system for an electric vehicle" by Xinyu Wang, Weiwei Sun, and Xiangyu Yang (2019) paper presents a design and analysis of an EMASS for an electric vehicle. The authors designed a mathematical model of the suspension system and used simulation software to evaluate the performance of the system. The results showed that the EMASS was able to improve the ride comfort of the electric vehicle and reduce energy consumption [4].

Design of Experiments for Optimization of Automotive Suspension System Using Quarter test rig, This paper is about the suspension system of a vehicle plays a critical role in providing ride comfort, stability, and handling. Therefore, optimizing the suspension system is crucial for improving the overall performance of the vehicle. The authors propose the use of a quarter test rig, which is a laboratory-based testing facility that replicates the behavior of the suspension system when the vehicle is in motion p[5].

3. MATERIALS and METHODOLOGY

A. NEMA 17 STEPPER MOTOR

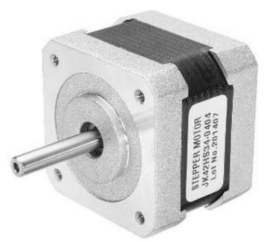

Fig 1: STEPPER MOTOR

Dimension NEMA 17 (42mm x 42mm)
Step Angle: 1.8 degrees/step
Rated Voltage: 3.3V
Rated Current: 1.5A
Holding Torque: 0.45 Nm (64 oz-in)
Weight: 0.28 kg (9.9 oz)
Two motors were used in this project a DC power supply is given to run the motor.

DOI: 10.31695/IJASRE.2023.9.6.3

B. Rack and pinion

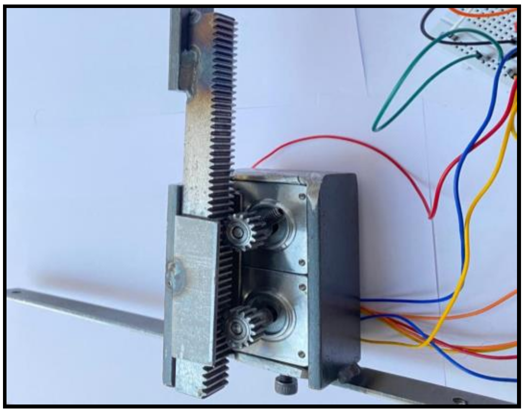

Fig 2: Rack and pinion mechanism

Outer Diameter of the pinion:16.5mm
Inner Diameter of the Pinion: 4mm
Length of the Rack:180mm
Width of the Rack:15mm
The pinion is attached to the motor shaft which is laid on the rack, hence the pinion is driven by the motor. Therefore creating the require lift.

C. Wish bone suspension

Fig 3: Suspension

This suspension is assembled with the help of bushes, metal strips, and wheel housing. A double wishbone suspension, It is designed to provide precise control over wheel motion and improve handling, ride comfort, and stability.

D. SQUARE PIPES

Fig 4: Mild steel square pipes

Mild steel square pipes are hollow tubes made from low-carbon steel, which is an affordable and durable material. They provide high stability and structural support, therefore helpful in projects where load-bearing capacity is a requirement. Here two different

DOI: 10.31695/IJASRE.2023.9.6.3

sizes of pipes are used one for the L- frame and the other for the chassis

E. Linear Bearings

Fig 5: Linear bearing

Here we are using a linear bearing of 16mm inner diameter so that the chassis can move through the guideway without any friction.

F. Arduino UNO

Fig 6: Arduino uno

- Arduino which is a microcontroller is being used. This board is best suitable because it offers expansion possibilities through its various input/output pins and communication interfaces (such as I2C, SPI, and UART). This enables you to integrate additional sensors, motors.

G. MPU6050

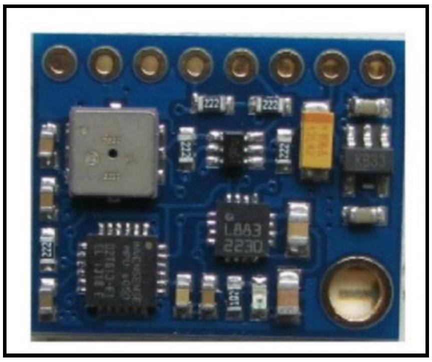

Fig 7: MPU6050

MPU6050 is a gyroscope, and accelerometer sensor it is a two-in-one sensor the sensor plays an important role in giving us the out from the test rig

DOI: 10.31695/IJASRE.2023.9.6.3

4. METHODOLOGY

The methodology is a process of project planning wherein all the major and minor steps of the project whether it may be logical creative fabrication application steps are neatly explained. The electromechanical active suspension system test rig is a specialized device used to test and optimize the performance of active suspension systems. This type of suspension system utilizes advanced sensors and actuators to actively adjust the stiffness and damping of the suspension in response to changing road conditions and driver inputs. The construction of an electromechanical active suspension system test rig typically involves several key components, including the actuator, sensor, control system, and power supply. The actuator is responsible for applying forces to the suspension system, while the sensor measures the displacement and velocity of the suspension. The control system processes this data and generates the appropriate signals to adjust the actuator and optimize the suspension performance. The power supply provides the necessary energy to drive the actuators and power the control system. One of the key advantages of an electromechanical active suspension system test rig is its ability to simulate a wide range of road conditions and driving scenarios. By adjusting the test rig parameters, it is possible to simulate everything from smooth highways to rough dirt roads, and from high-speed driving to stop-and-go traffic. The operation of an electromechanical active suspension system test rig begins with the selection of a test scenario. This may involve specifying the type of road surface, the speed and acceleration profile, and other parameters that affect the suspension performance. The test rig is then programmed to simulate these conditions, using a combination of sensors, actuators, and control algorithms. During the test, the sensor measures the displacement and velocity of the suspension, and transmits this data to the control system. The control system then processes this data, calculates the appropriate actuator forces, and sends signals to the actuator to adjust the suspension stiffness and damping. This process is repeated continuously, with the control system adjusting the suspension in real-time to optimize the performance under changing conditions.

One of the key challenges in the design and operation of an electromechanical active suspension system test rig is achieving a high degree of accuracy and repeatability. This requires careful calibration of the sensors, actuators, and control algorithms to ensure that the test rig accurately simulates real-world conditions. It also requires careful monitoring and maintenance of the test rig, to ensure that it remains in optimal working condition and delivers reliable results. In terms of the construction of the electromechanical active suspension system test rig, there are several key considerations that need to be taken into account. These include the selection of appropriate sensors and actuators, the design of the control system, and the integration of these components into a robust and reliable test rig.

For example, the selection of appropriate sensors is critical to achieving accurate and reliable measurement of suspension displacement and velocity. This may involve the use of high-precision linear position sensors, or accelerometers that can measure both translational and rotational motion. Similarly, the selection of appropriate actuators is critical to achieving the necessary range and precision of motion required to simulate a wide range of road conditions. This may involve the use of high-performance electric motors, hydraulic actuators, or other types of actuators that can deliver the necessary forces and motion profiles.

The design of the control system is also critical to achieving the necessary performance and reliability of the test rig. This may involve the use of advanced control algorithms, such as model-based predictive control or adaptive control, to optimize the suspension performance under changing conditions. Finally, the integration of these components into a robust and reliable test rig requires careful consideration of factors such as mechanical stability, electrical safety, and environmental conditions. This may involve the use of specialized materials, such as high-strength steel or advanced polymers, to ensure the rig can withstand the forces and stresses of testing, as well as the use of advanced environmental control systems to maintain optimal operating conditions

The fabrication of a quarter-car test rig involves the construction and assembly of a scaled-down model of a vehicle's suspension system. This rig is designed to simulate and evaluate the performance of the suspension system under various conditions. Here are a few key steps involved in fabricating a quarter-car test rig:

- The Frame construction: The test rig's frame serves as the structural backbone and supports the various components. It is typically constructed using sturdy materials such as mild steel to ensure stability and durability. The length and breadth of the L frame is 710mm. The fabrication process starts with cutting and shaping the selected material into the desired L-shaped structure. This may involve using tools like saws, drills, and welding equipment to create the necessary joints and connections. To enhance the structural integrity reinforcements, such as additional beams or gussets are added
- Wheel Assembly: The wheels and tires of the test rig are attached to the suspension components. These wheels replicate the rolling motion of a vehicle and are often equipped with sensors to measure parameters like wheel acceleration, displacement, and forces.
- Suspension Arms: The double wishbone suspension consists of upper and lower control arms, also known as A-arms, on each side of the test rig. These arms are typically fabricated from materials such as steel, chosen for their strength and stiffness. Bushs are used to connect the suspension arms to the chassis, allowing for the articulation and movement of the suspension

DOI: 10.31695/IJASRE.2023.9.6.3

system. Additionally, bushings are incorporated at various connection points to provide vibration isolation and improve the overall motion

- Hard Chrome Rod Selection: A hard chrome rod is chosen based on its material properties, including high hardness, corrosion resistance, and smooth surface finish. The rod is typically made of steel and undergoes a chrome plating process to achieve the desired characteristics.

  The hard chrome rod is securely mounted to the L-frame and the chassis. Bearing and Bushes are Integrated To facilitate smooth motion and reduce friction, these bearings or bushings are incorporated into the connection points between the hard chrome rod and the L-frame and chassis. These components provide support and allow the chassis to move vertically while maintaining stability.
- CAM: The fabrication of a 15 mm offset CAM wheel involves creating a specialized wheel with an intentional offset to simulate a bumpy or uneven road surface. This offset CAM wheel is designed to induce specific vibrations and perturbations in the test rig, allowing researchers to evaluate the suspension system's response to such conditionsThe design phase involves determining the required dimensions and specifications for the offset CAM wheel. This includes the desired offset distance (in this case, 15 mm) and the wheel's overall diameter, width, and mounting configuration. The diameter of the wheel is 170mm and the thickness is 45mm.
- Linear actuator-The rack and pinion components are typically made of durable materials with low friction properties, such as hardened alloys. The selection of materials should ensure smooth and reliable operation over an extended period a rack is a long, toothed bar that facilitates linear motion. It is fabricated by cutting or shaping a piece of material to form a straight bar with evenly spaced teeth along its length. Precision machining or casting techniques may be used to create the rack. The pinion is a small gear that engages with the teeth on the rack, converting rotational motion into linear motion. The pinion is usually a small, cylindrical gear with teeth that mesh with the rack. The rack along with the motor housing is securely mounted to the L-frame, while the pinion is attached to a motor shaft. The pinion is positioned in a way that allows it to mesh with the teeth of the rack, ensuring proper engagement during operation.

5. RESULTS

Fig 9: Fabricated Test Rig

The results and discussions of the study comparing linear acceleration in passive suspension (0.97 m/s²) and active suspension (0.71 m/s²) revealed important insights into the effectiveness of active suspension systems. The passive suspension, without any active control intervention, exhibited a linear acceleration of 0.97 m/s², indicating the magnitude of the vertical vibrations experienced by the vehicle's chassis and occupants. However, when the active suspension system was engaged, the linear acceleration was significantly reduced to 0.71 m/s².

The reduction in linear acceleration demonstrates the ability of active suspension systems to mitigate the impact of road disturbances and improve ride comfort. By actively adjusting the suspension parameters and damping characteristics in real time, the active suspension system effectively counteracts the vertical movements induced by the road surface irregularities. This reduction in linear acceleration translates into a smoother ride experience for the vehicle occupants, minimizing discomfort and fatigue

DOI: 10.31695/IJASRE.2023.9.6.3

- The formula used for passive

  The linear acceleration formula is = $\text{sqrt}((ax - gx)^2 + (ay - gy)^2 + (az - gz)^2)$

- Accelerometer data: ax= 0.01, ay= 0.01, az= 0.93.
- Gyroscope data: gx= 0.06, gy= -0.10, gz= -0.03.

  Upon further substituting the values of ax, ay, az and gx, gy, gz in the above formula

  Linear acceleration = $\text{sqrt}\ (0.01+0.06)^2+(0.01+0.10)^2+(0.93+0.02)^2$

  = sqrt (0.0649+0.0121+0.9025)

  = sqrt (0.9795)

  Linear acceleration = **0.98 m/s^2**

- The formula used for active

- Accelerometer data: ax= 0.01, ay= 0.01, az= 0.7009
- Gyroscope data: gx= 0.06, gy= -0.10, gz= -0.03.

Linear acceleration = $\text{sqrt}\ (0.01-0.06)^2+(0.01+0.10)^2+(0.7009+0.03)^2$

= sqrt (0.51)

= **0.714 m/s^2**

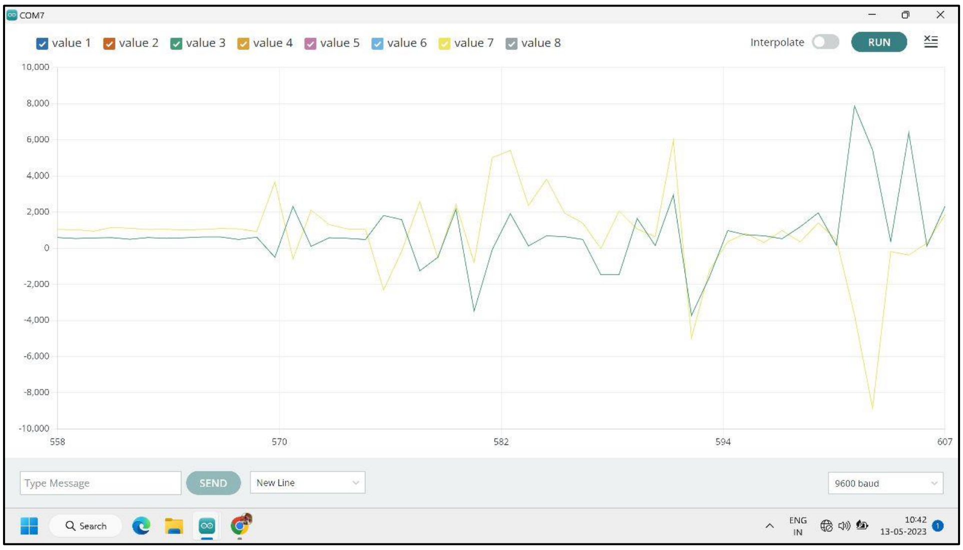

Fig 10: Chassis Linear Acceleration

6. CONCLUSIONS

In conclusion, the design and fabrication of the electromechanical active suspension system test rig is an important step forward in the field of automotive engineering. This test rig offers a comprehensive platform for testing and evaluating the performance of active suspension systems, which are becoming increasingly popular in modern cars.

The design process involved a number of considerations, such as the choice of appropriate materials and components, the need for accurate measurement and control systems, and the requirement for a robust and reliable mechanical structure. Through careful planning and execution, the final product is a well-designed test rig that meets all the necessary specifications for reliable testing of active suspension systems.

The fabrication process was equally important, as it required precision and attention to detail. The various components and subsystems were carefully assembled to ensure proper alignment and function. The use of computer-aided design (CAD) and other advanced manufacturing techniques ensured that the final product was of high quality and met all the necessary performance requirements.

The active suspension system test rig is a valuable tool for automotive engineers and designers. It allows them to evaluate the performance of different suspension systems in a controlled environment, under various operating conditions. This can lead to improvements in suspension design, resulting in more comfortable and safer vehicles for drivers and passengers.

In addition, the test rig can be used for research purposes, such as the development of new active suspension technologies or the study of the dynamic behavior of suspension systems. This can lead to new insights into the physics of vehicle dynamics, which can be used to further improve suspension design.

Overall, the design and fabrication of the electromechanical active suspension system test rig is a significant achievement in the field of automotive engineering. It is a testament to the power of advanced design and manufacturing techniques, as well as the ingenuity and creativity of engineers and designers. The test rig will undoubtedly contribute to the ongoing evolution of active

DOI: 10.31695/IJASRE.2023.9.6.3

suspension systems, and will help pave the way for even more advanced technologies in the future.

ACKNOWLEDGMENT

We would like to express our sincere gratitude to the Management and Principal, Sapthagiri College ofEngineering Bangalore for the facilities provided and their support. Also, we would like to thank the Head of department Mechanical Engineering and faculties for their encouragement and support.

REFERENCES

[1] Shariati, A., & Rashidzadeh, M. (2015). Design and Development of an Active Suspension System Test Rig. In 2015 3rd International Conference on Control, Instrumentation, and Automation (ICCIA) (pp. 163-168). IEEE.

[2] Patil, S. B., & Chakravarthy, S. V. (2016). Review of Active Suspension System for Automotive Applications. International Journal of Engineering Research & Technology, 5(9), 146-150.

[3] Hossain, M. S., Ahmed, M. S., & Rahman, M. A. (2017). Design and Development of Active Suspension System for a Passenger Car. International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering, 11(5), 903-909.

[4] Guo, H., & Zhang, S. (2018). Development of an Electromechanical Active Suspension System for a Quarter Car Model. Shock and Vibration, 2018, Article ID 1561803.

[5] Shetty, N. S., & Joshi, S. V. (2019). Design and Fabrication of an Active Suspension System Test Rig for Formula SAE Vehicle. In 2019 International Conference on Smart Systems and Inventive Technology (ICSSIT) (pp. 77-82). IEEE

[6] Nair, P. S., & Rajesh, R. S. (2020). Performance Evaluation of Active Suspension Systems: A Review. International Journal of Vehicle Structures & Systems, 12(1), 13-19.

[7]Nair, S. N., Kannan, P., & Kumar, P. S. (2020). Design and Fabrication of an Electromechanical Active Suspension System for a Prototype All-Terrain Vehicle. Journal of Mechanical Engineering and Sciences, 14(2), 6675-6687.

[8]Elnaggar, M. A., Farag, A. S., & Elsayed, M. A. (2021). Design, Modeling, and Simulation of Active Suspension System with MRF Damper Using MATLAB/SIMULINK. Journal of Engineering and Applied Sciences, 16(7), 2222-2228.

[9]Cheng, X., Zhou, K., Li, Y., & Gong, W. (2021). Design and Testing of an Active Suspension System Based on Magnetorheological Damper. Journal of Mechanical Science and Technology, 35(1), 69-81.

[10]Elsaka, M. E., Elnady, A. M., Hassan, A. S., & El-Shafei, A. E. (2022). Design and Experimental Validation of an Active Suspension System Using Linear Actuators. International Journal of Vehicle Structures & Systems, 14(2), 165-173.

DOI: 10.31695/IJASRE.2023.9.6.3