DESIGN AND DEVELOPMENT OF ELECTROMECHANICAL BRAKE TEST RIG (TÜBİTAK 2209-A)

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Abstract

Brake systems are mechanisms used to reduce the speed of vehicles in general or to stop vehicles completely. Hydraulic brake systems are used in most of the passenger cars. However, with the widespread use of L-class electric micro-cars and/or electric vehicles designed for special purposes, the brake systems used in these vehicles will evolve into electromechanical systems.In this study, it is aimed to design and manufacture an electromechanical brake system that can be used in light electric vehicles with hardware-in-the-loop simulation method and a test setup for evaluating the capacity of this system. In the calculations, a vehicle model was created in the simulation environment, considering the vehicle dynamics, tire model and wheel-road relations. By using this vehicle model created in accordance with real conditions, the braking force and braking time required by the braking system was determined to obtain the stopping distance in accordance with the braking demands, and the electromechanical braking system were operated under these conditions. The braking force obtained as the output of the electromechanical brake system and the braking time related to it was transferred to the vehicle model and it were evaluated whether the performance of the system is in accordance with the demands.

Keywords: Electro-mechanical brake, mechatronic system, hardware in the loop, vehicle dynamics, tire model

1. Introduction

The main purpose of the current project is to be able to model and test the performance of the electromechanical braking system, which may be more efficient and more suitable for electric vehicles. It is to create a system that can test the vehicle model, wheel dynamics and brake dynamics with hardware simulation in the loop.Hardware-in-the-loop simulation is a technique that enables real-time simulation and is widely used in both academia and industrial product research and development.[1]

The aim in this process is not just to test vehicle dynamics and road conditions in a simulation environment. In this context, the data used as input to the test system were taken from the simulation model created to take into account the vehicle system dynamics. Using this method, mechanism designs are tested in loop with hardware simulation before being used in real life. In this way, it is made applicable in the laboratory environment instead of experimenting on the vehicle in order not to damage the physical parts.

2. Method and Theoretical Calculations

Other vehicle subsystems (vehicle model,wheel dynamics, road conditions etc.) outside the electromechanical brake system, the mathematical models of the general vehicle dynamics will be transferred to the simulation environment and the simulation cycle will be completed. [2][3]

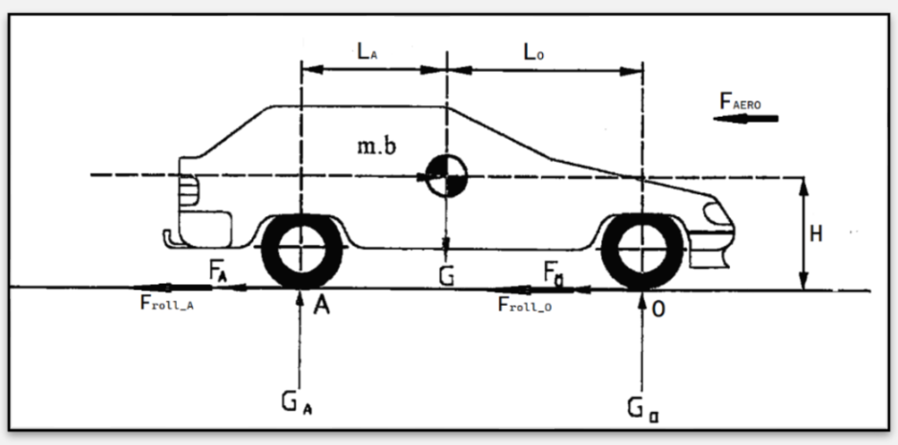

Figure 1: Axle Loads Acting on The Vehicle

- **Dynamic Equations of the Vehicle**

$$F_A + F_O + F_{aero} + F_{roll\_A} + F_{roll\_O} = -mb$$

$$\sum \overrightarrow{M_A} = -G.L_A + G_B(L_A + L_B) - m.b.H = 0$$

$$\sum \overrightarrow{M_O} = -G.L_O + G_O(L_A + L_O) - m.b.H = 0$$

$$F_{roll\_A} + F_{roll\_O} = c(G_A + G_O)$$

- **Braking Distance**

$$S = -\frac{V^2}{2}(b - g.\tan(\beta))$$

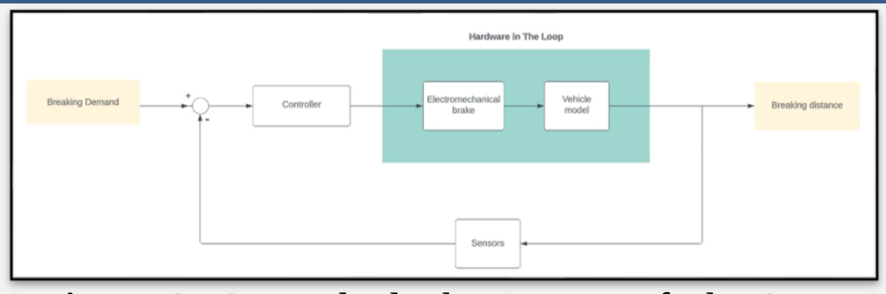

Figure 2: General Block Diagram of The System

3. System Modeling and Prototyping

Based on the mathematical model, we created a Simulink model of the brake system and vehicle dynamics. In the model, simulation blocks have been created for the vehicle's wheel dynamics, slip condition and vehicle braking dynamics.

In our study, we planned to perform our simulation operations on the Matlab/Simulink platform.

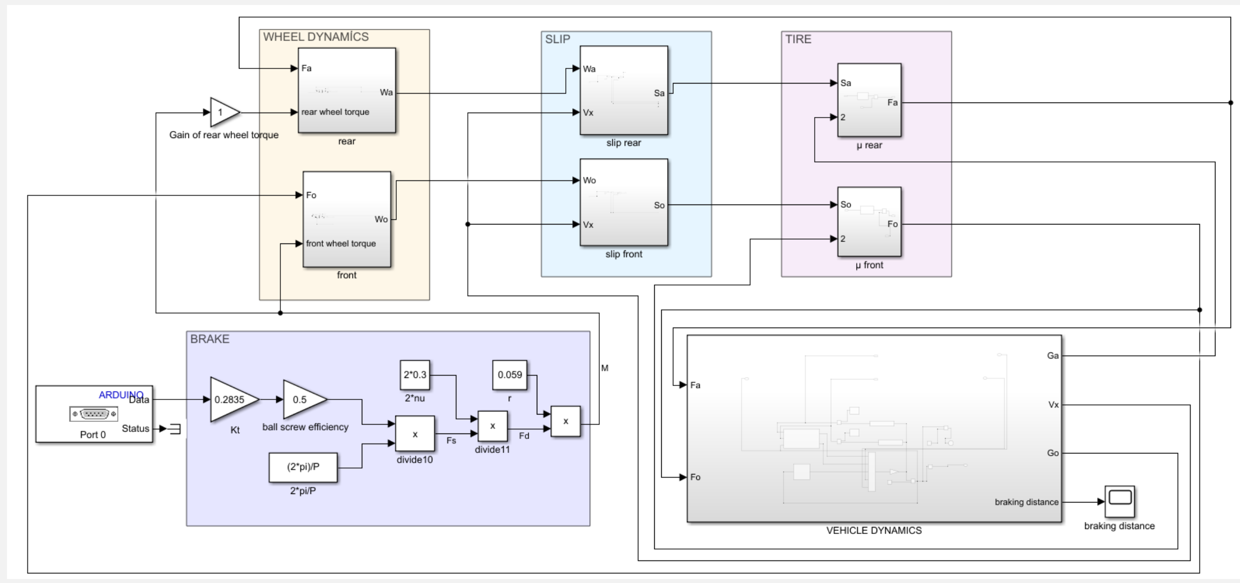

Figure 3: SIMULINK modal of The System

Our physical braking mechanism will also help us measure the performance of the vehicle under study. The ball screw will move clockwise, the calipers will start to move away from the disc, and the ball screw will start to go clockwise, and the calipers will move closer to the disc. Thus, the disc will be slowed down, and braking will be realized.

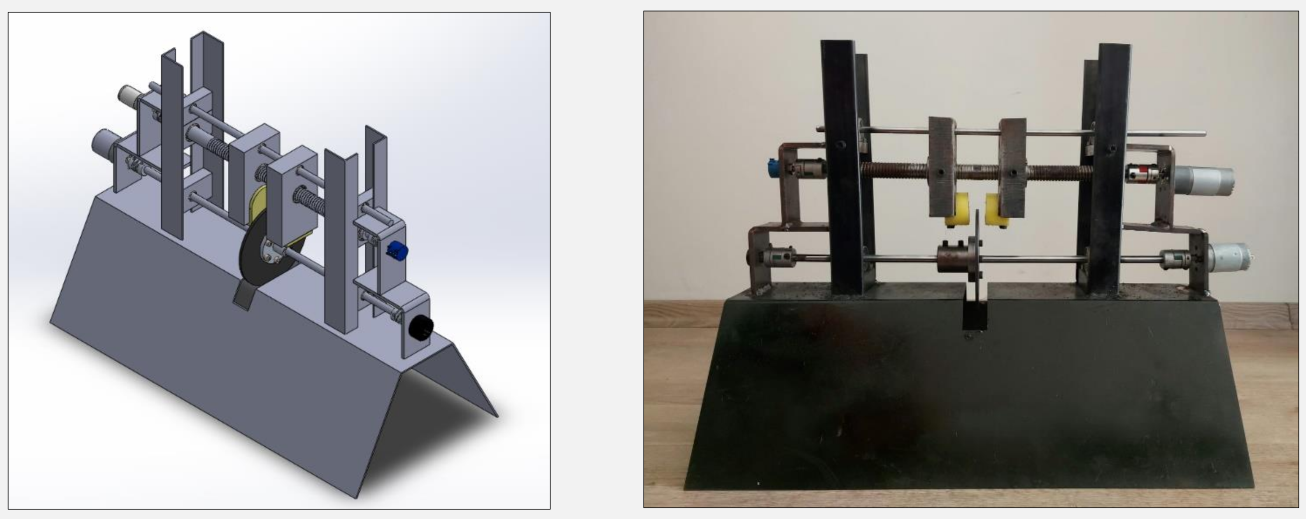

Figure 4: Design and Prototype of The Mechanism

4. Conclusions

As a result, the system was manufactured as a desktop stand to prove the operability and applicability of the electromechanical brake. It is aimed to give the results of the model analysis to the MATLAB/Simulink model for dynamic simulations later on. With the parameters to be used, the response time and brake performance will be controlled in the simulation environment.The research is important for the principle reason; A useful technique for the design and development of electromechanical braking systems is the hardware-in-the-loop (HIL) approach. This technique allows for real-time evaluation and improvement of system performance. It also allows engineers to simulate different scenarios to learn how the system will react in different situations.

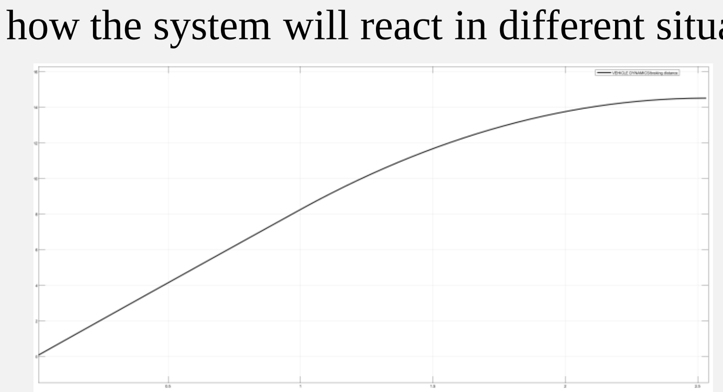

Figure 5: *Simulation Result for braking distance and braking time at T=3.5 N/m and Vx= 8.33 m/s (30 km/h)*

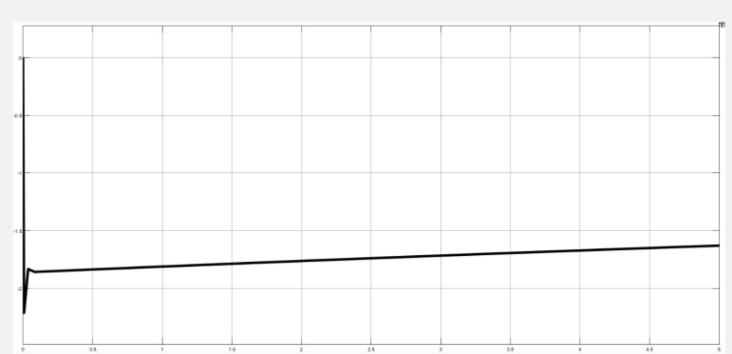

Figure 6: *Simulation Result for Acceleration (30 km/h)*

References

[1] Banu Arıkan (15 Temmuz 1999) "Otomobil ve Kamyonet Fren Sistemlerinin Bilinen Taşıt Verilerine Bağlı Tasarımı".

[2] GÜLERYÜZ I.C. ve BASER Ö.(10 Şubat 2021) " Modelling the longitudinal braking dynamics for heavy-duty vehicles".

[3] Banu Arıkan (15 Temmuz 1999) "Otomobil ve Kamyonet Fren Sistemlerinin Bilinen Taşıt Verilerine Bağlı Tasarımı