PS 1: Design, Finite Element Analysis, and Optimisation of an Automotive Suspension System using Python

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In this report, we present the design of a double wishbone suspension system which includes a push rod mechanism. Firstly, we learnt some basics of Vehicle Dynamics. Secondly, we made some rough designs based on references. Then we made several changes based on our requirements. In future, we will try optimisation using Python.

1 INTRODUCTION

A suspension system in vehicles connects wheels to the chassis, using springs and shock absorbers to absorb shocks, maintain stability, and enhance ride comfort.

2 DESIGN

2.1 ADVANTAGE OF DOUBLE WISHBONE SUSPENSION SYSTEM OVER OTHERS

- **Camber Control:** Maintains consistent tire contact through better camber angle control, enhancing grip and handling.
- **Independent Wheel Movement:** Each wheel moves independently, improving response to bumps and uneven surfaces.

2.2 DESIGN PROCEDURE

We started with a double wishbone suspension design taking reference from GrabCad but identified an unrealistic knuckle, leading us to redesign it and modify several joints. Following discussions with mentors, we replaced the standard shock absorber with a pushrod mechanism to enhance the suspension system's performance.

2.3 Advantages of Pushrod Mechanism

- **Reduced Unsprung Mass:** It reduces unsprung mass by centralizing heavier components like springs and dampers.
- **Better Weight Distribution:** It improves weight distribution by relocating components closer to the vehicle's center of gravity.
- **Increased Suspension Travel:** The design allows for increased suspension travel without requiring additional space, improving bump absorption.
- **Structural Efficiency:** It enhances structural efficiency by transferring forces to a central location, resulting in a lighter and more rigid chassis, ideal for high-performance applications.

2.4 Design Dimensions

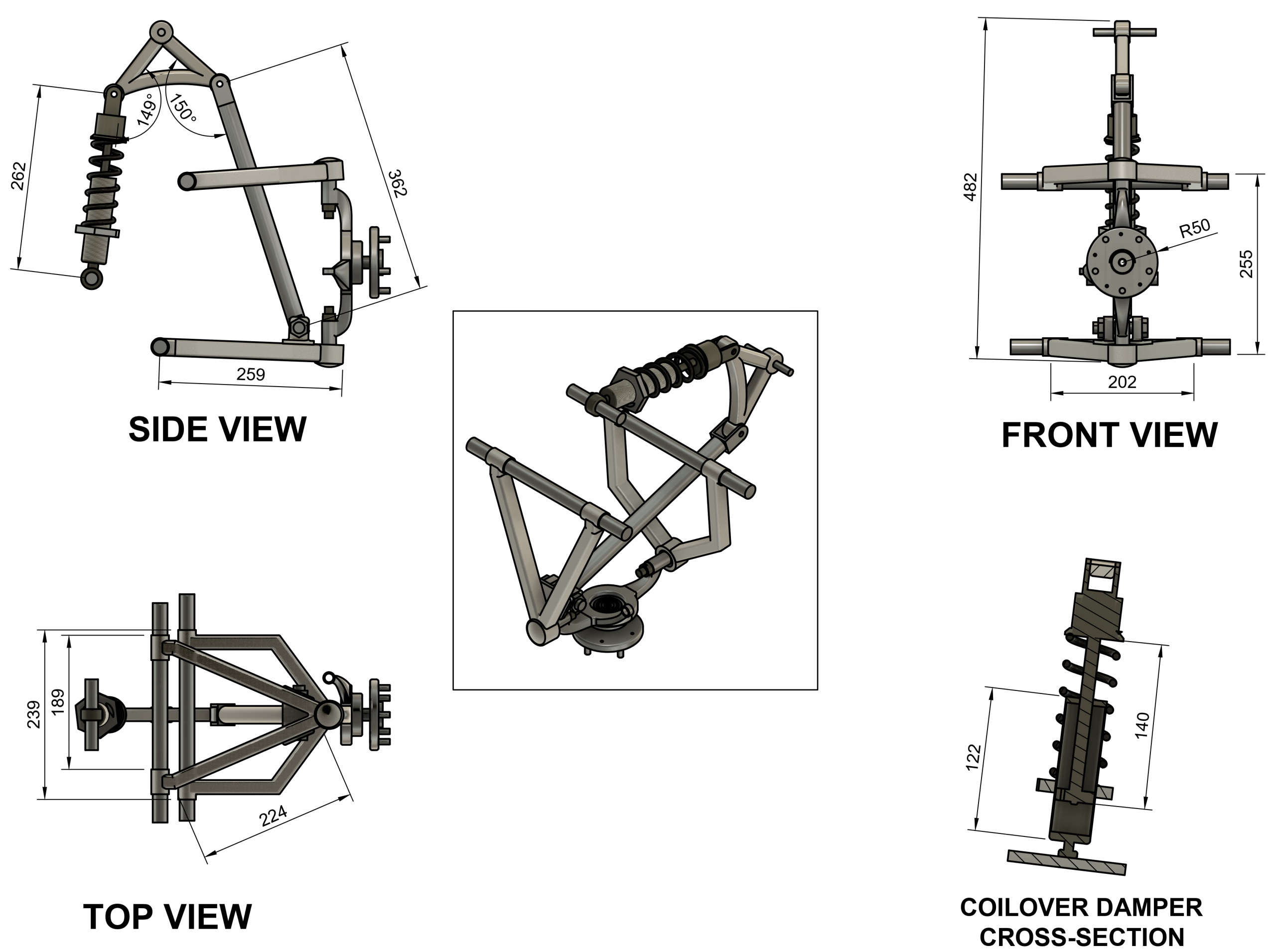

Figure 2.1: Design Dimensions

3 Analysis

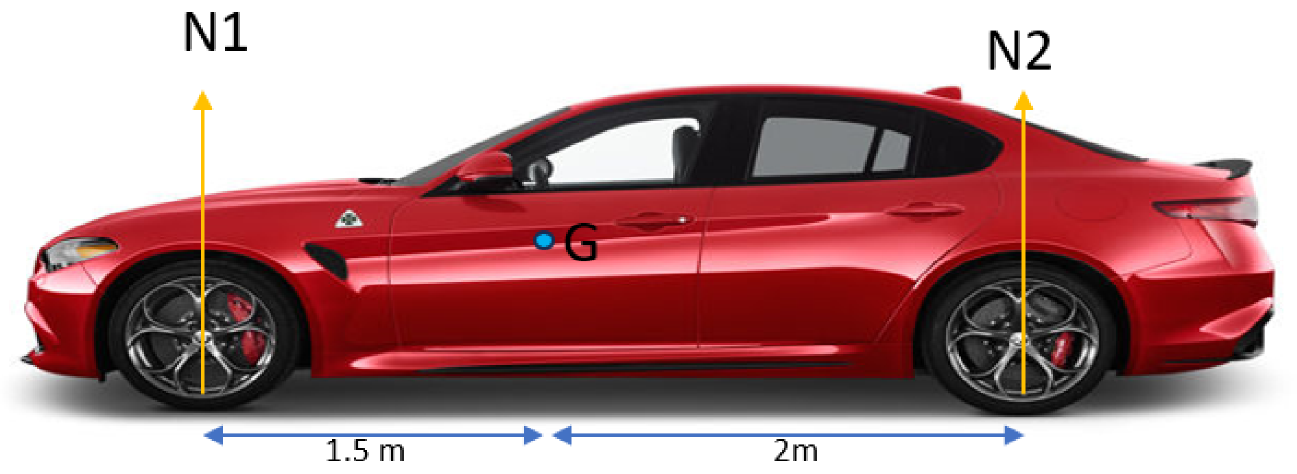

Figure 3.1: FBD

For $\sum F_y = 0$:

$$N_1 + N_2 = 1400 \times 10 \text{ N} \quad (\text{Considering } g = 10 \text{ m/s}^2)$$
$$N_1 + N_2 = 14000 \text{ N}$$

For $\sum M_G = 0$:

$$-1.5 \times N_1 + 2 \times N_2 = 0$$
$$1.5 \times N_1 = 2 \times N_2$$

After solving the above equations:

$$N_1 = 8000 \text{ N}$$
$$N_2 = 6000 \text{ N}$$
$$\text{Normal force at the front wheel} = \frac{N_1}{2} = 4000 \text{ N}$$
$$\text{Normal force at the rear wheel} = \frac{N_2}{2} = 3000 \text{ N}$$

We know that,

$$K = \frac{G \cdot d^4}{64 \cdot n \cdot R^3} \tag{3.1}$$

For our model,

$$G = 7.57 \times 10^{10} \text{ N/m}^2$$
$$d = 0.012 \text{ m}$$
$$n = 5$$
$$R = 0.021 \text{ m}$$

$$K = \frac{7.57 \times 10^{10} \times (0.012)^4}{64 \times 5 \times (0.021)^3} = 5.29 \times 10^5 \text{ N/m} \tag{3.2}$$

Using Hooke's law,

$$F = k \cdot x \tag{3.3}$$

$$x = \frac{F}{k} = \frac{4000}{5.29 \times 10^5} = 0.0075 \text{ m} = 7.5 \text{ mm (Max Displacement)} \tag{3.4}$$

4 Errors

- **Meshing Error:** Attempting to achieve quadrilateral meshing led to several errors, which we addressed by implementing local meshing and specific sizing.
- **Contact Error:** The initial use of contacts in the simulation produced incorrect outputs, which we resolved by replacing some contacts with joints.
- **Output Error:** The simulation showed a maximum displacement of 6.9 mm, while the analytical result was 7.5 mm, resulting in a percentage error of 8%.
- **Factor of Safety (FOS):** After adjusting the bracket dimensions and switching to steel, the simulation yielded a minimum FOS of 1.68, which is still below the ideal value of 2.

References

- Vehicle Dynamic Course
- Reference model for design
- Initial Design
- Initial Design Simulation
- Final Design Reference Research paper
- Final Suspensions
- Final Suspension Simulation
- Final Suspensions Assembly