SoS 2024
Automotive Design
Final Report

Design and Analysis of Electric Go-Kart

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Contents

1. What is Automotive Design?

Automotive design is a multidisciplinary field that combines art, engineering, and technology to create vehicles that are both functional and aesthetically pleasing. It encompasses various aspects, including exterior and interior styling, aerodynamics, ergonomics, and manufacturing feasibility. The process begins with conceptualization, where designers sketch initial ideas based on market research, brand identity, and customer preferences. These sketches are then refined into detailed drawings and 3D models using advanced computer-aided design (CAD) software.

Exterior Design

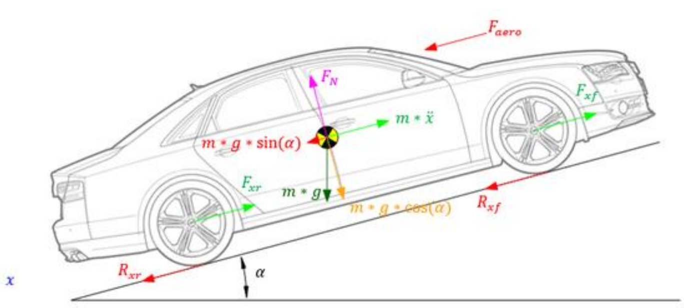
The exterior design of a vehicle focuses on its shape, size, and overall aesthetic appeal. Designers must balance form and function, ensuring the vehicle is visually appealing while also meeting aerodynamic and safety requirements. Aerodynamics play a crucial role in improving fuel efficiency and reducing wind noise, so features like the car's silhouette, grille, and spoiler are meticulously crafted.

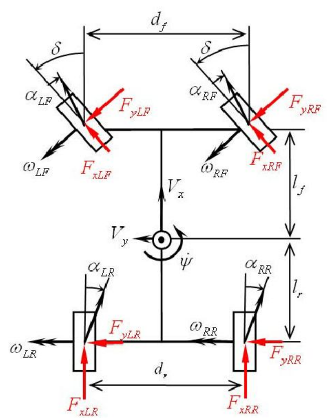
Interior Design

The interior design of a vehicle aims to provide comfort, convenience, and a pleasant driving experience. This includes the layout of the dashboard, seating arrangements, and the selection of materials and finishes. Ergonomics is a key consideration, ensuring that controls are easily accessible and that seats offer adequate support for long drives. Designers also integrate advanced technologies such as infotainment systems, climate control, and driver assistance features, enhancing the overall user experience

Design and modelling of mechanisms (Vehicle Kinematics and Dynamics)

Automobiles use various engineering mechanisms to operate. The powertrain converts fuel into motion, while suspension systems ensure a smooth ride. Steering mechanisms provide control, and braking systems ensure reliable stopping power. Advanced systems like electronic stability control (ESC) and traction control (TCS) maintain stability and prevent skidding, ensuring modern vehicles are efficient, safe, and high-performing





2. What's my Project about?

My project, "Design of Electric Go-Kart," encompasses the comprehensive design and simulation of an electric go-kart. This endeavor involved the creation of the chassis, steering system, braking mechanism, and other critical components that are computer aided and designed using ***SOLIDWORKS 2023*** ensuring a fully functional and efficient vehicle. Each part of the go-kart was meticulously designed and validated using advanced simulation tools like ***MSC ADAMS and ANSYS***.

An electric go-kart is a type of go-kart powered by electric motors and batteries, as opposed to a traditional petrol engine. In this project, we want to design from scratch a car chassis, couple it to an electric motor through a chain drive system, and propel the car forward. It is ***Real Wheel Drive Car (RWD)***

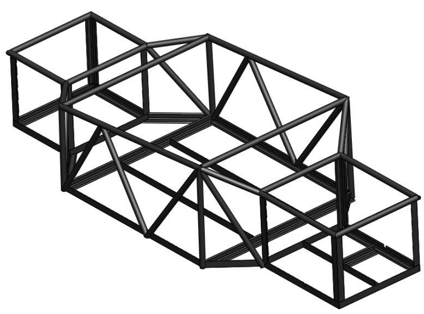
A controller can be used to vary the speed and change the direction of rotation of the motor. We want to show the numerous advantages of using an electric go-kart in motorsport as opposed to the traditional internal combustion go-kart available on the market.

Main Highlights of the project are:

- The Truss Design of the chassis
- Individual Part modelling and whole assembly
- The Drum braking Mechanism
- The Parallel steering Mechanism

Overall, the "Design of Electric Go-Kart" project showcases a thorough approach to vehicle design, combining innovative engineering with advanced simulation techniques. The project highlights my skills in CAD modeling, mechanical design, and simulation, demonstrating my ability to take a concept from initial design through to a validated and optimized final product.

Through the project I was able to get well versed with the CAD software SOLIDOWORKS 2023, especially in the areas of weldments, sheet metals, part modelling and assembly. Also, I learned the dynamic mechanical simulation software MSC ADAMS for the project for kinematic simulation of mechanisms

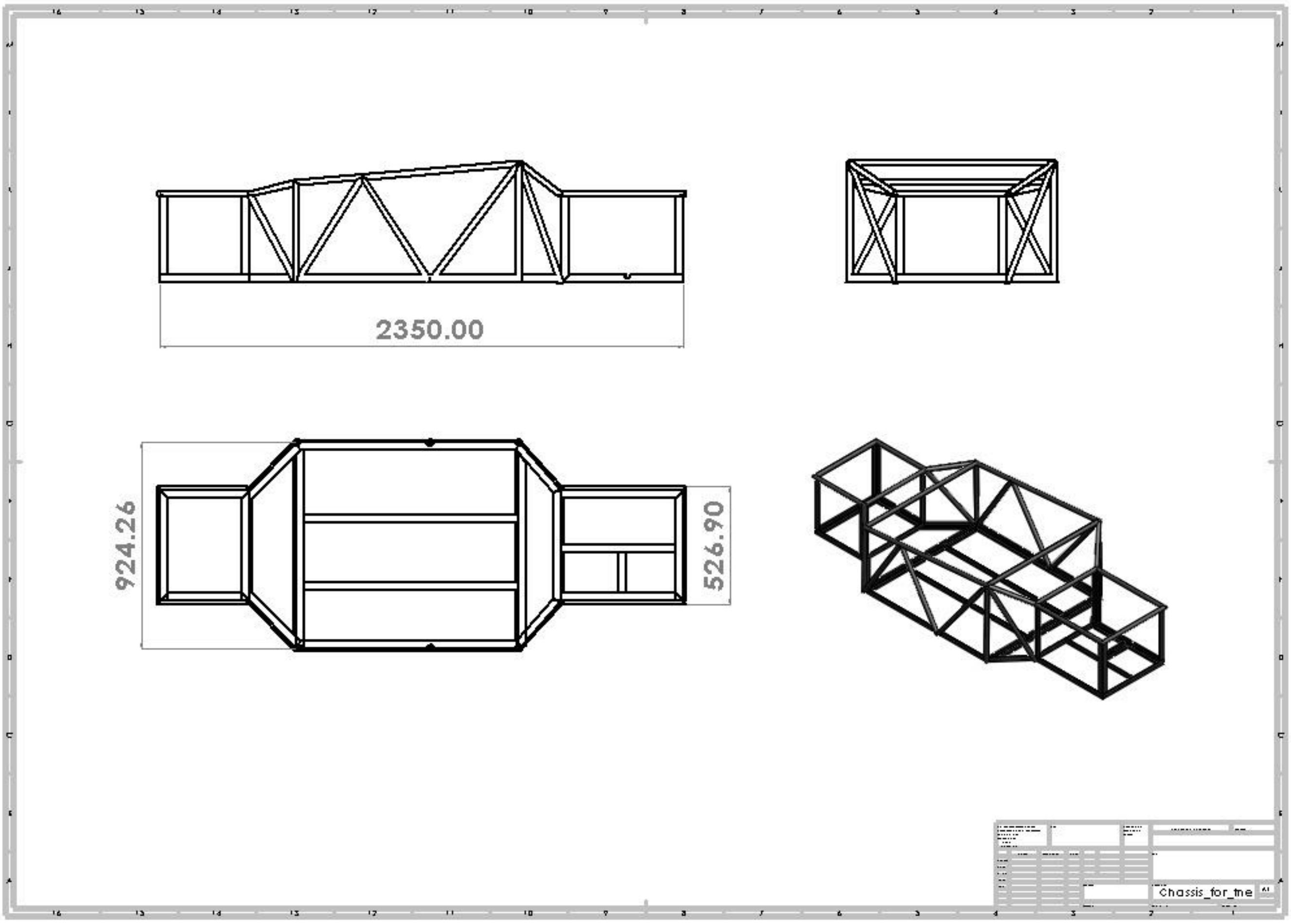


3

Components in the CAD Design of go-kart

3a. Chassis

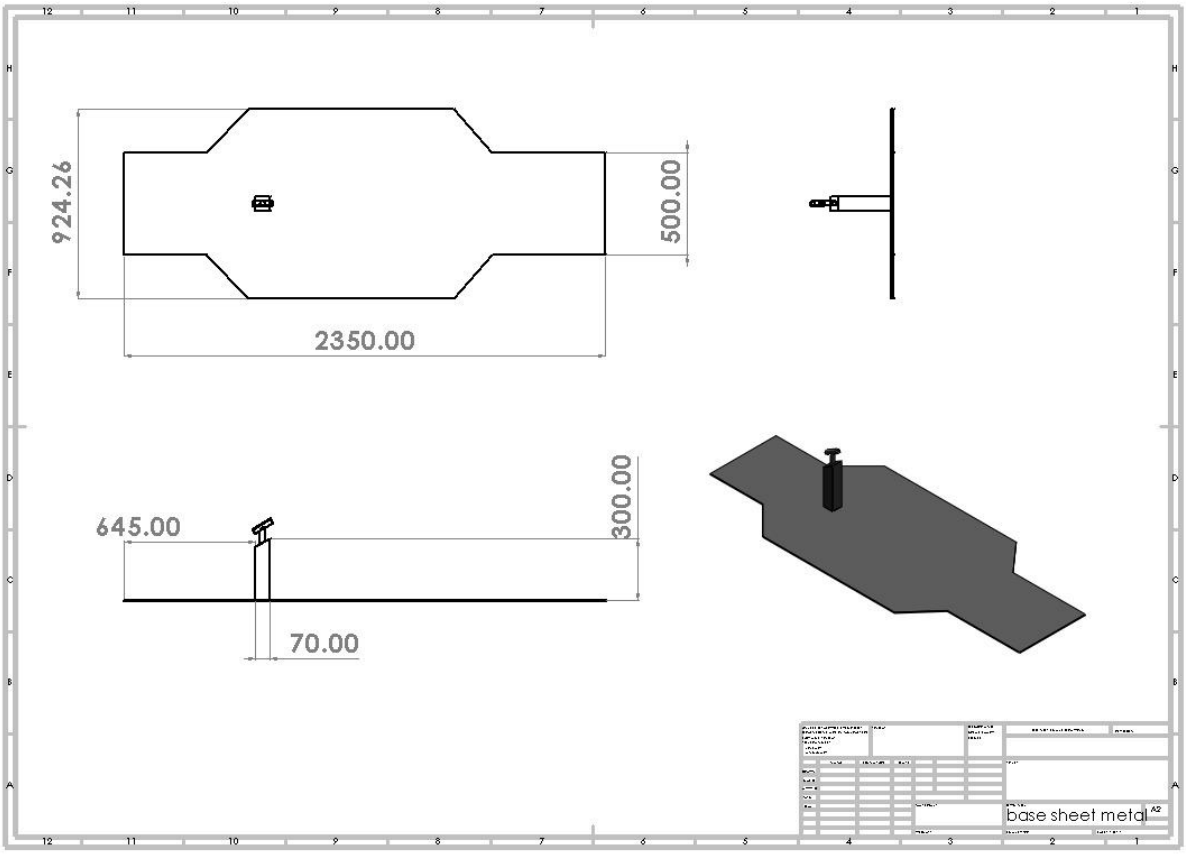
- Contains 58 structural members including L beam of dimension 35 x 35 and pipes of dimension 26.9 x 3.2, welded together to their nearest neighbors using weldments in SOLIDWORKS
- Chassis designed using 3D sketch in and aligned the members along the sketch lines
- ***Material Used:*** Alloy Steel (SS)
- ***Modulus of Elasticity:*** 210 GPa
- ***Density***: 7700 kg/cubic meter
- ***Mass:*** 65.134 kg



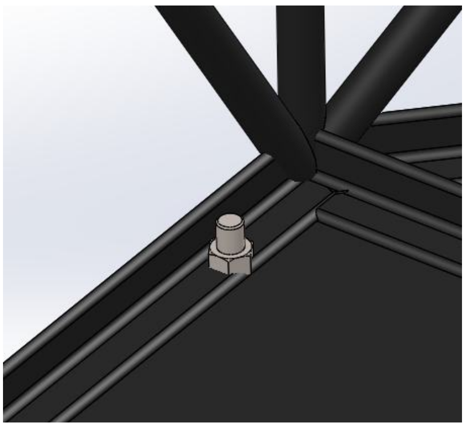
When designing a chassis, key considerations include structural integrity, weight optimization, and load distribution. A truss framework is often used for its strength and efficiency, incorporating zero-force members to maintain stability without adding excessive weight. These members help to distribute loads evenly and enhance the overall rigidity of the chassis, ensuring safety and performance

3b. Floorboard

- Made using SOLIDOWORKS sheet metal feature like base flange, edge flange by tracing top-view imager of chassis. The floor board is attached using nuts and bolts to the chassis (details are given below)
- It contains a beam attached that contains cylindrical hole which is a pivot for steering column. It is welded to the floor board
- ***Thickness of Sheet Metal:*** 7 mm
- ***Bend Radius:*** 1 mm with Rectangular relief
- ***Material Used:*** Aluminium Alloy
- ***Modulus of Elasticity:*** 370 GPa
- ***Density***: 3960 kg/cubic meter
- ***Mass:*** 52.33 kg

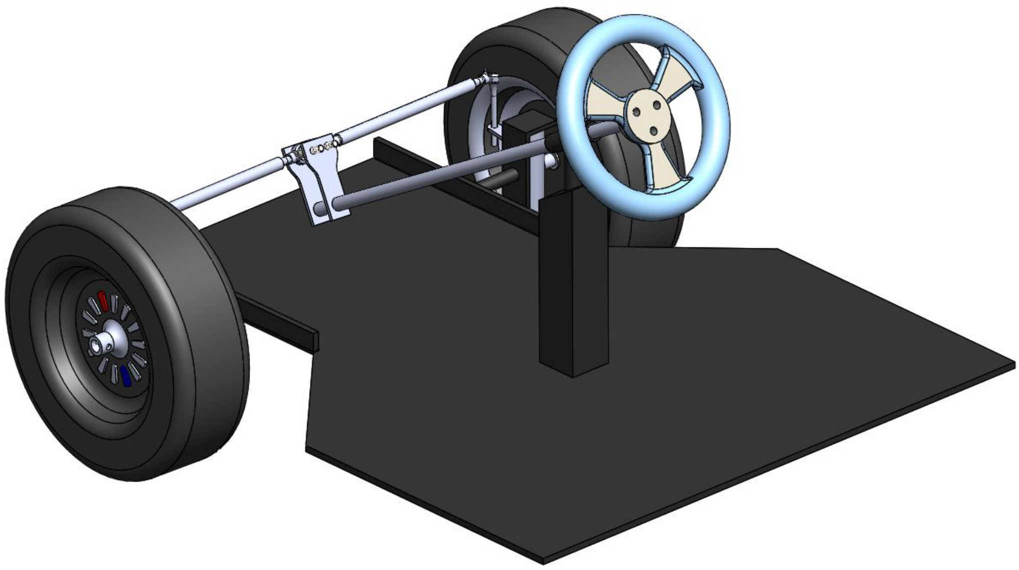


The chassis is attached to floor board as shown in the figure. Used Hexagonal flanged M16 Bolt of length 45 mm and M16 Hex nut to tighten it to the L member of the chassis



3c. CAD of Steering Mechanism

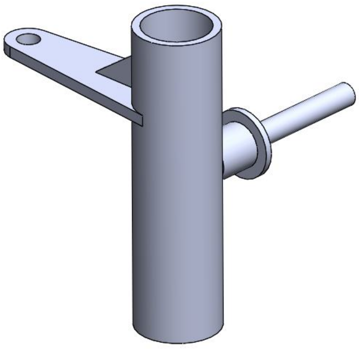
- The go-kart uses ***parallel steering mechanism***. Parallel steering mechanism is a type of steering system in which the front wheels turn at the same angle. This design ensures that both wheels remain parallel to each other during turns, simplifying the steering geometry.
- It contains following parts:
  - ***Steering Wheel:*** The primary control interface for the driver, it converts rotational motion into steering commands to guide the vehicle's direction
  - ***Steering Column:*** Connects the steering wheel to the steering mechanism, transferring the driver's input to the steering gear while often incorporating features like tilt and telescoping adjustments
  - ***Tie rods:*** Connect the steering gear to the steering knuckles, transmitting steering force to the wheels and ensuring precise control and alignment
  - ***Left and Right Spindle:*** Components that attach to the vehicle's wheels and pivot to allow steering motion, supporting the wheel assembly and enabling smooth directional changes
  - ***Spindle Holders:*** (Can be attached to the floor board or chassis) Gives the axis about which spindles/knuckles rotate



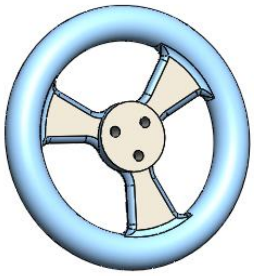
How does the mechanism Work?

- When the steering wheel is rotated by the driver, the ankle of the steering column also rotates. The tie rods are concentrically connected to the hex bolt of the ankle where it rotates about
- Then the tie rod pulls the spindle, where the wheel is perpendicularly attached. By this way, the wheels are rotated through specific angles

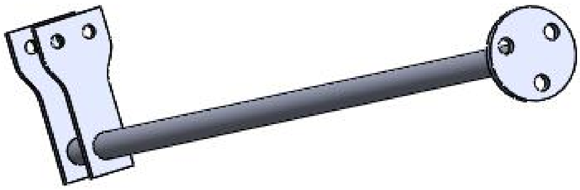
Individual Parts of steering mechanism



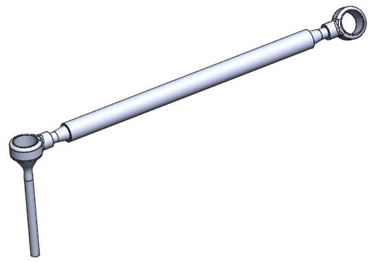
Left Spindle



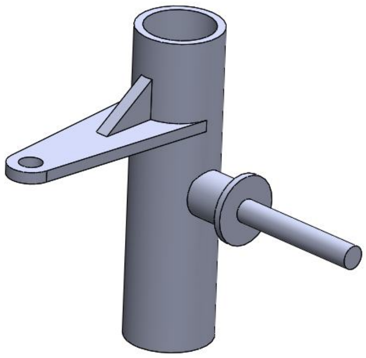
Steering Wheel



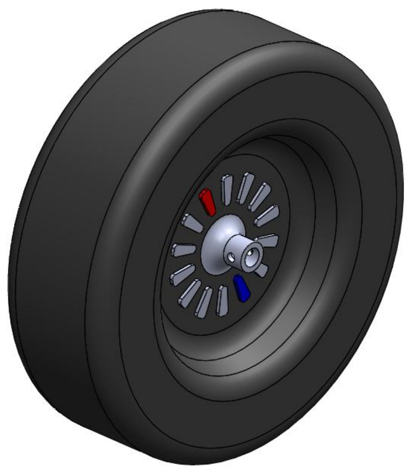
Steering Column



Tie Rod



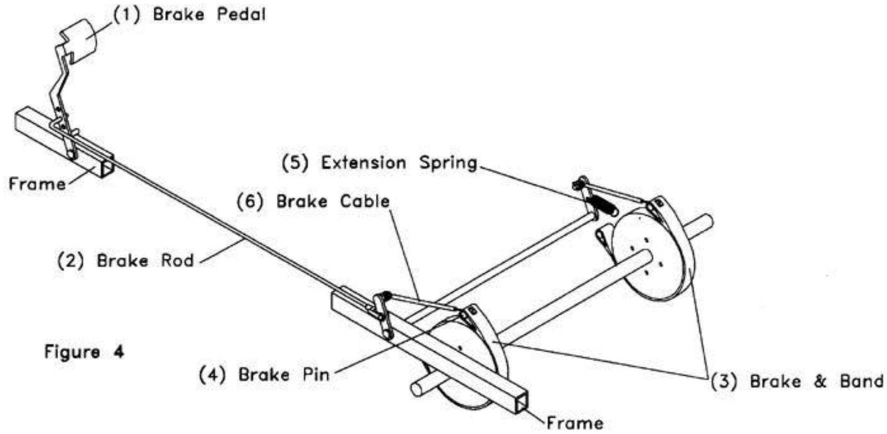
Right Spindle



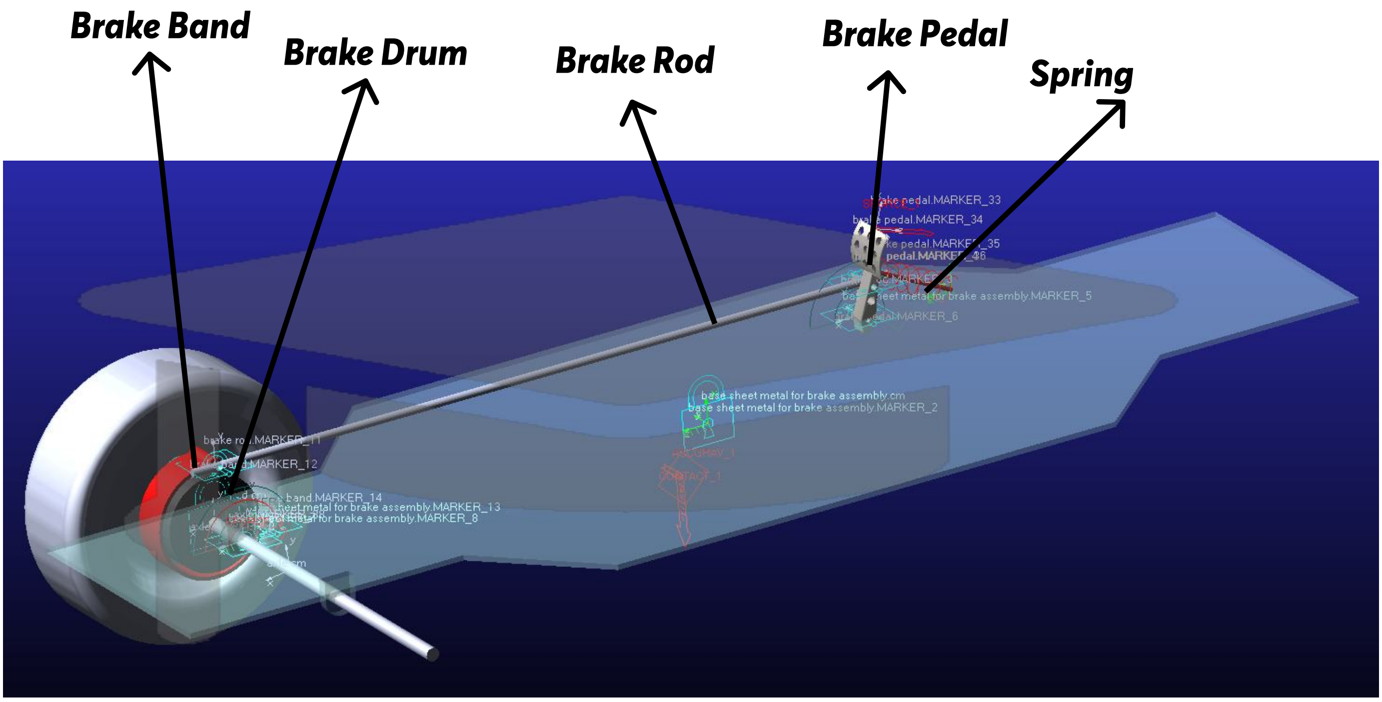
Wheel

3d. CAD of Braking Mechanism

- This particular go-kart uses the ***Drum Brakes System.*** The drum brake systems use a cylindrical drum mounted on the wheel's hub and brake band that expand inside the drum to create friction. When the brake pedal is applied, mechanical force pushes the brake band inward, pressing against the drum's outer surface to slow down or stop the vehicle
- It contains following parts:
  - ***Brake Pedal:*** The driver-operated component that initiates braking by applying force to the brake system comfortably
    - Material: AISI 4340 Normalized Steel
    - Weight: 0.95 kg
  - ***Brake Rod:*** Connects the brake pedal to the brake mechanism, transferring the pedal's force to engage the braking system
    - Material: AISI 1045 cold drawn steel
    - Weight: 1 kg
  - ***Brake Band:*** A frictional component that wraps around the brake drum to create braking force through friction when tightened
    - Material: Aluminium Alloy
    - Weight: 1.2 kg
  - ***Brake Drum:*** A cylindrical component that rotates with the wheel; the brake band presses against its outer surface to slow down or stop the wheel
    - Material: Gray Cast Iron
    - Weight: 2.35 kg
  - ***Spring:*** To retract the pressed brake pedal to its original position and ensuring comfortable press and release of brake pedal
    - Material: Stainless steel
    - Weight: 513 g



Schematic of a Drum Brake System



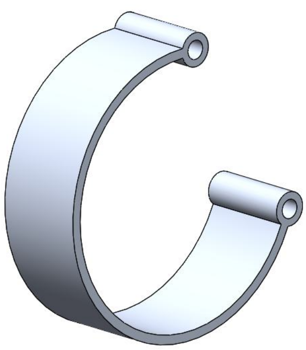
Actual Design of Brake Assembly

(Designed in SOLIDWORKS, Imported in ADAMS)

Individual Parts of the Assembly

Brake Pedal

Brake Rod

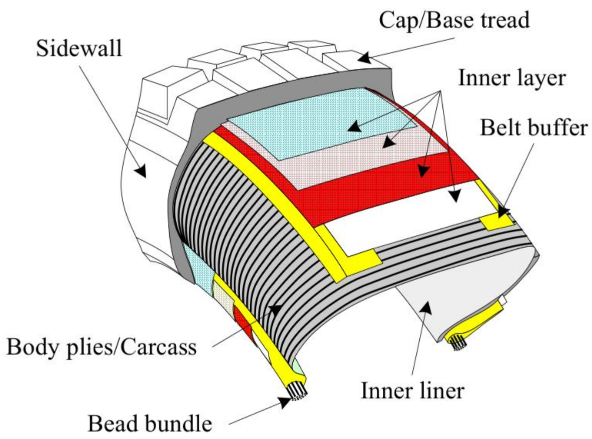


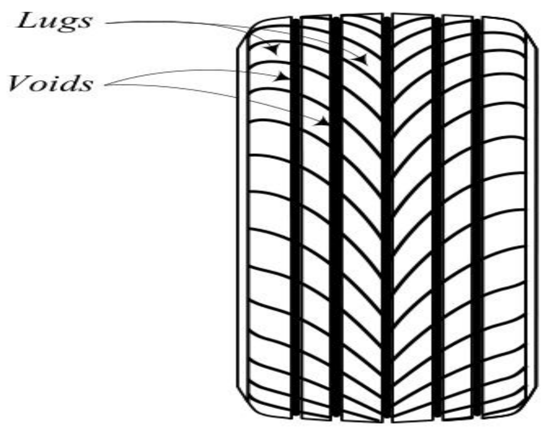
Brake Band

Brake Drum

3e. Vehicle Seat and Treaded Tyre

- The Vehicle seat is placed to ensure comfortable position of the driver while being seated. This will ensure best handling and stability of the vehicle
- The wheel is a treaded tire, with specific tread patterns to ensure good contact area and generate sufficient traction to the ground
- Both the models was download and used from the website https://www.mcmaster.com/

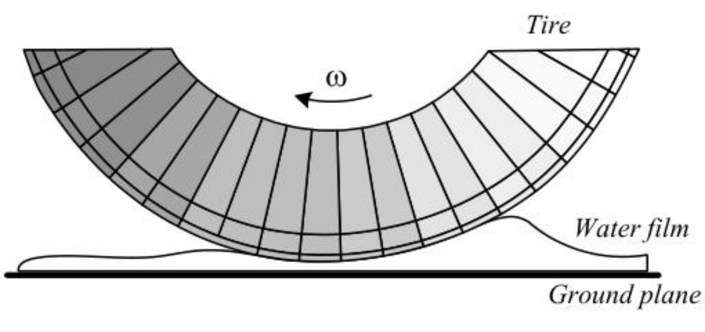




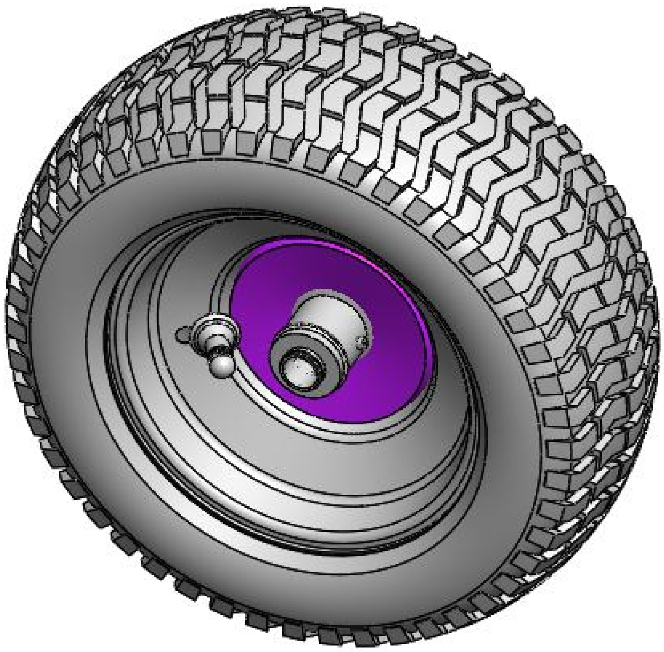
Hydroplaning: Hydroplaning is sliding of a tire on a film of water. Hydroplaning can occur when a car drives through standing water and the water cannot totally escape out from under the tire. This causes the tire to lift off the ground and slide on the water. The hydroplaning tire will have little traction and therefore, the car will not obey the driver's command

Treads: The tread pattern is made up of tread lugs and tread voids. The lugs are the sections of rubber that make contact with the road and voids are the spaces that are located between the lugs. Lugs are also called slots or blocks, and voids are also called grooves. The tire tread pattern of block-groove configurations affect the tire's traction and noise level. Wide and straight grooves running circumferentially have a lower noise level and high lateral friction

Tire print: The contact area between a tire and the road is called the tire print . At any point of a tire print, the normal and friction forces are transmitted between the road and tire. The effect of the contact forces can be described by a resulting force system including force and torque vectors applied at the center of tire print



CAD images of Seat and Wheel

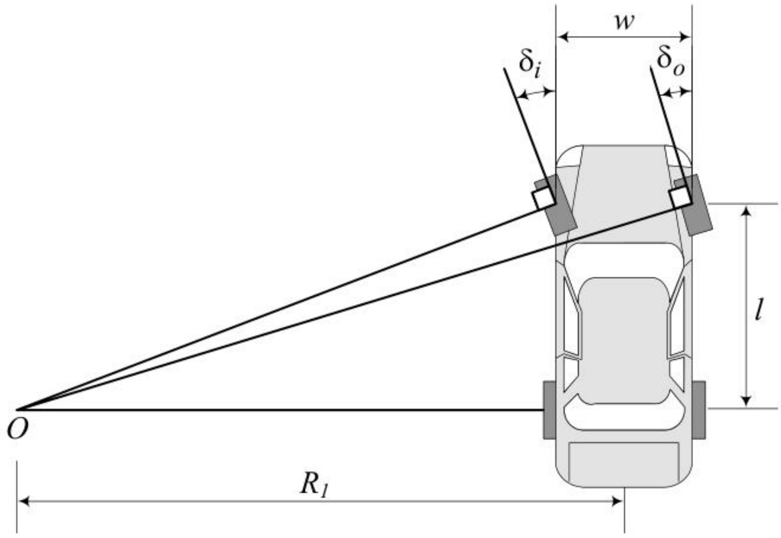


4. The Steering Mechanism

What is Ackermann Steering?

The Ackermann steering geometry is a design principle used in the steering systems of vehicles to ensure that all wheels correctly align and roll through the desired arc during a turn, minimizing tire wear and increasing efficiency. Named after German carriage builder Rudolph Ackermann, this geometry focuses on the relationship between the steering arms, tie rods, and the pivot points of the front wheels. In an ideal Ackermann steering system, the inner and outer wheels turn at different angles, with the inner wheel turning more sharply than the outer wheel. This configuration aligns the wheels' paths to intersect at a common point, the center of the turning circle, allowing for smoother and more controlled cornering

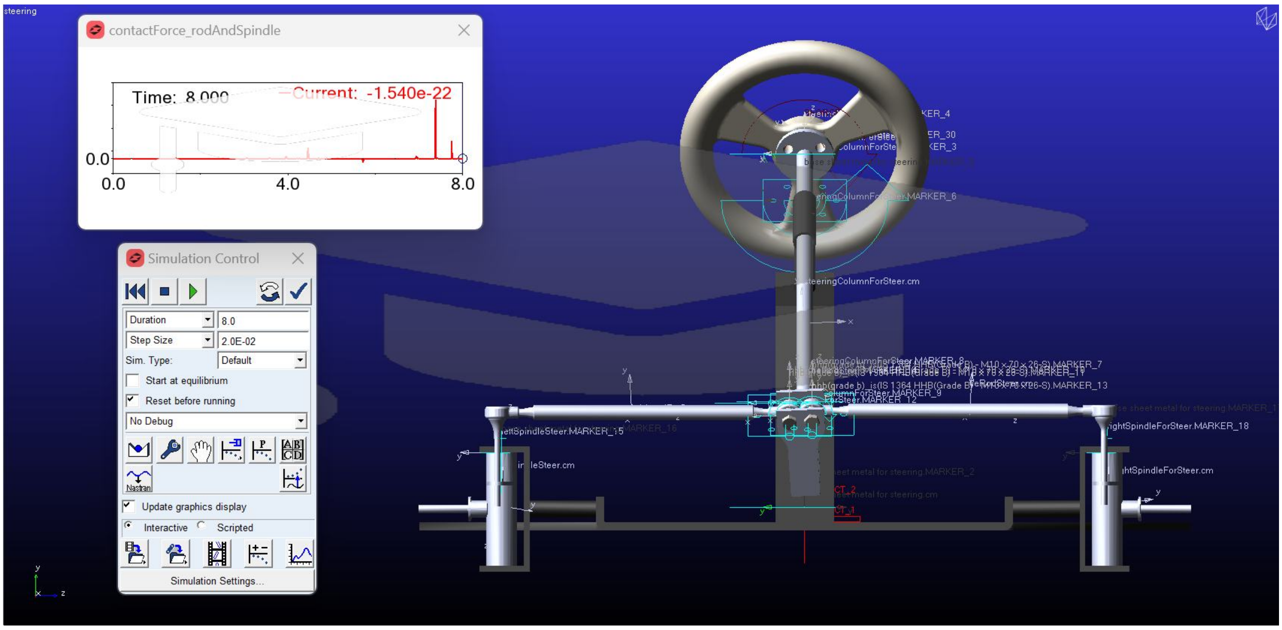
$$\cot \delta_o - \cot \delta_i = \frac{w}{l}$$



A device that provides steering according to the Ackerman condition is called Ackerman steering, Ackerman mechanism, or Ackerman geometry. There is no four-bar linkage steering mechanism that can provide the Ackerman condition perfectly. However, we may design a multi-bar linkages to work close to the condition and be exact at a few angles.

The trapezoidal steering mechanism is a steering geometry design used in vehicles to improve handling and stability. It features a trapezoidal arrangement of the steering arms and tie rods, ensuring that the wheels turn at different angles during a turn, similar to the Ackermann steering principle. This design allows for more precise control of the steering angles, reducing tire wear and enhancing maneuverability. The trapezoidal steering mechanism is particularly effective in minimizing the slip angles of the tires, ensuring better traction and stability, especially in tight corners and low-speed maneuvers. By optimizing the steering angles, this mechanism contributes to a smoother and more controlled driving experience.

4a. Simulation and Validation of Steering Mechanism

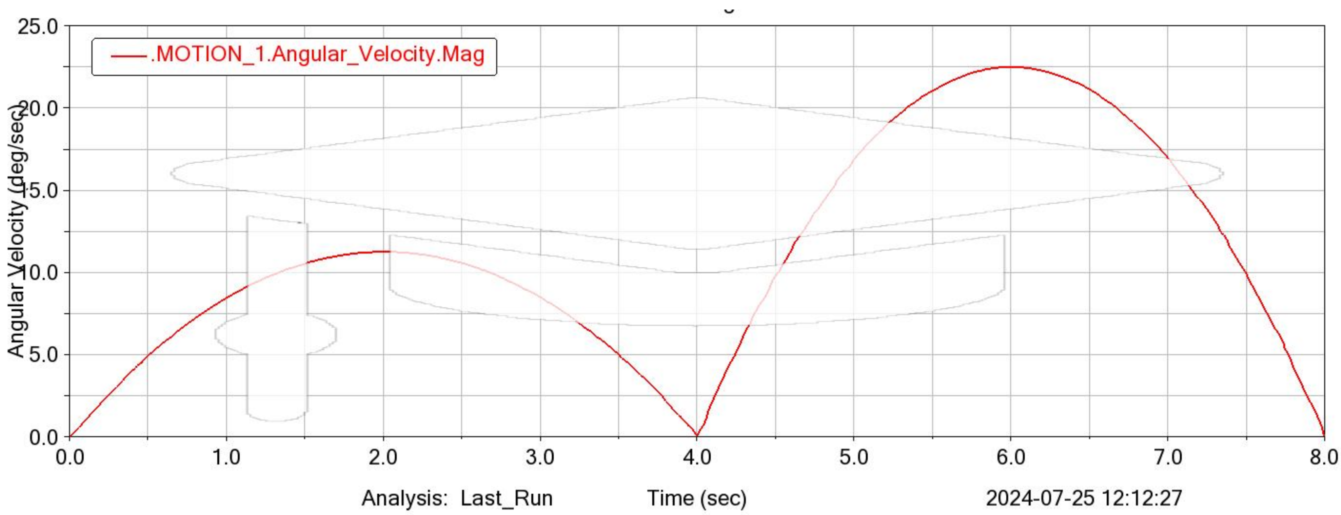


MSC ADAMS VIEW Workspace Image of Steering Simulation

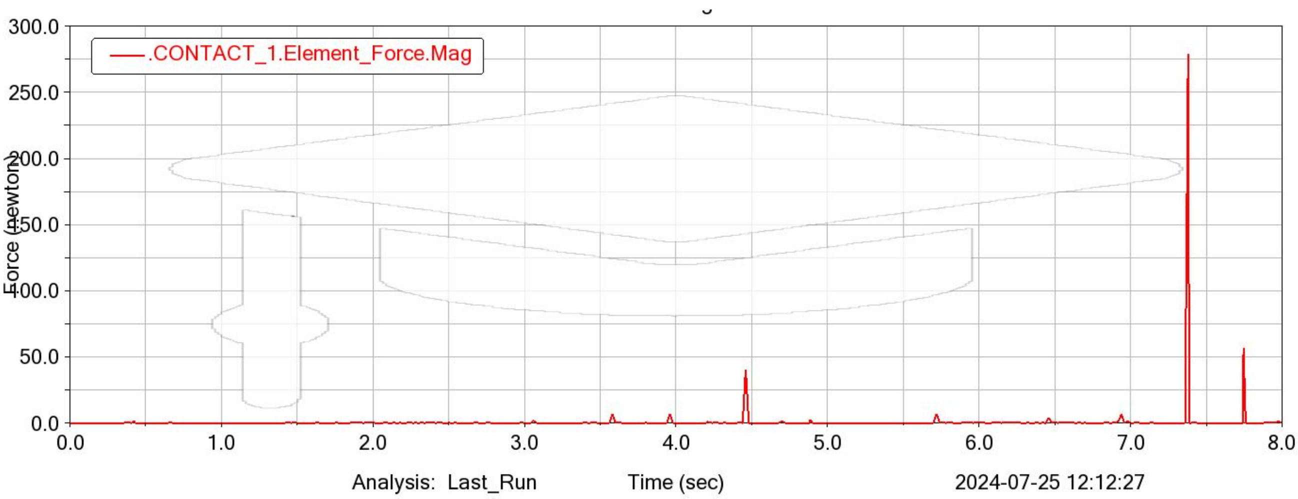
Simulation Video: https://drive.google.com/file/d/1HvSRgnz-Xka1PZp15yIsZ5OGWLGZ_9Km/view?usp=sharing

Highlights of Defining the System Dynamics:

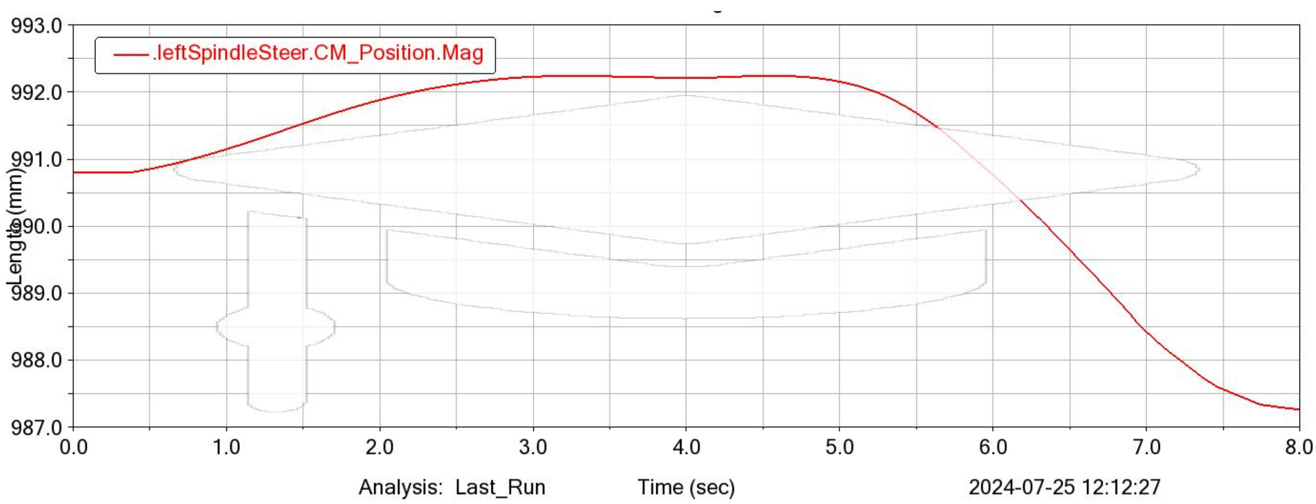
- 6 moving parts
- 5 revolute joints
- 4 fixed joints (to prevent relative motion wherever necessary)
- Rotational Motion is applied for the joint associated with steering wheel as an expression: ***STEP(time, 0.0, 0.0d, 4, 30.0d)+STEP(time, 4.0, 0.0d, 8.0, -60.0d).*** Angular velocity of associated motion in deg/sec vs time is shown below
- Simulation runs for 8 seconds with a step size of 0.02



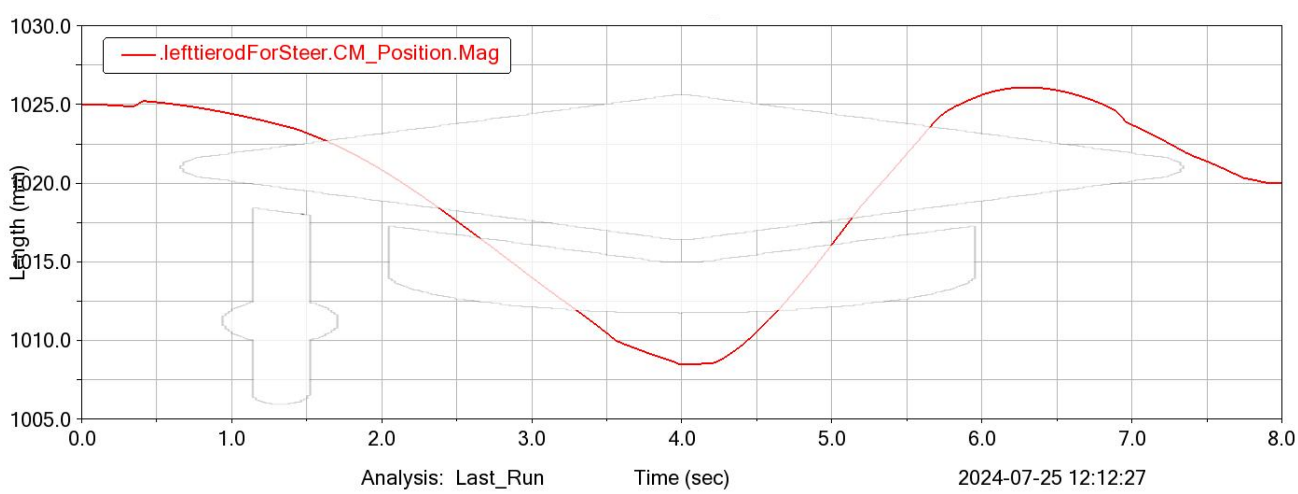
4b. Some Graphs



Contact Force (N) vs time (s)



CoM Position of Spindle (mm) vs time (s)

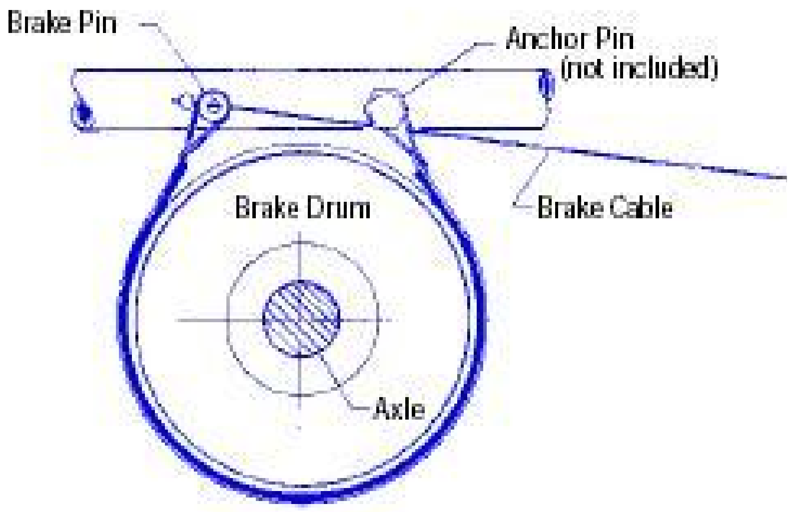


CoM Position of Tie Rod (mm) vs time (s)

5. The Braking Mechanism

What are Drum Brakes?

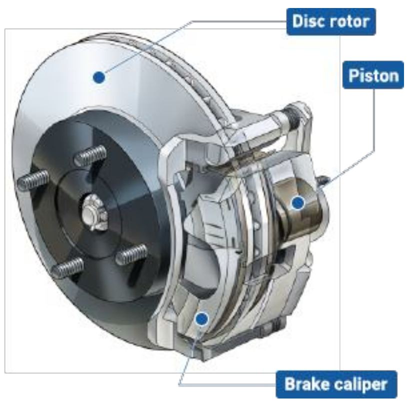
In go-karts, mechanical drum brakes are a common choice due to their simplicity and reliability. Unlike hydraulic systems, these brakes operate through a mechanical linkage, where the driver applies force to a brake pedal connected to a brake rod. This rod actuates a brake band that wraps around the outer surface of the drum attached to the wheel. When the brake pedal is pressed, the brake band tightens around the drum, creating friction that slows down or stops the go-kart. This type of braking system is particularly effective for the lightweight and lower-speed nature of go-karts, offering straightforward maintenance and robust performance without the complexity of hydraulic components.

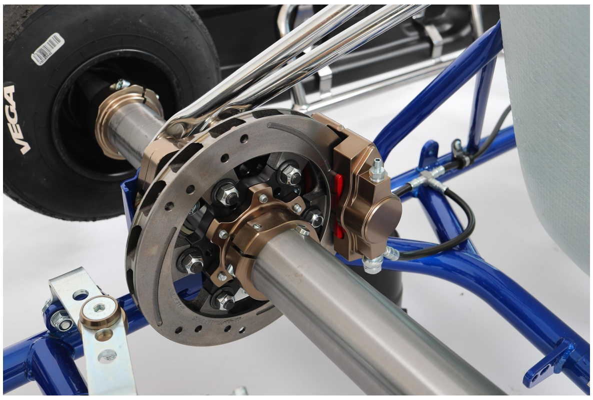


Disc Braking Mechanism

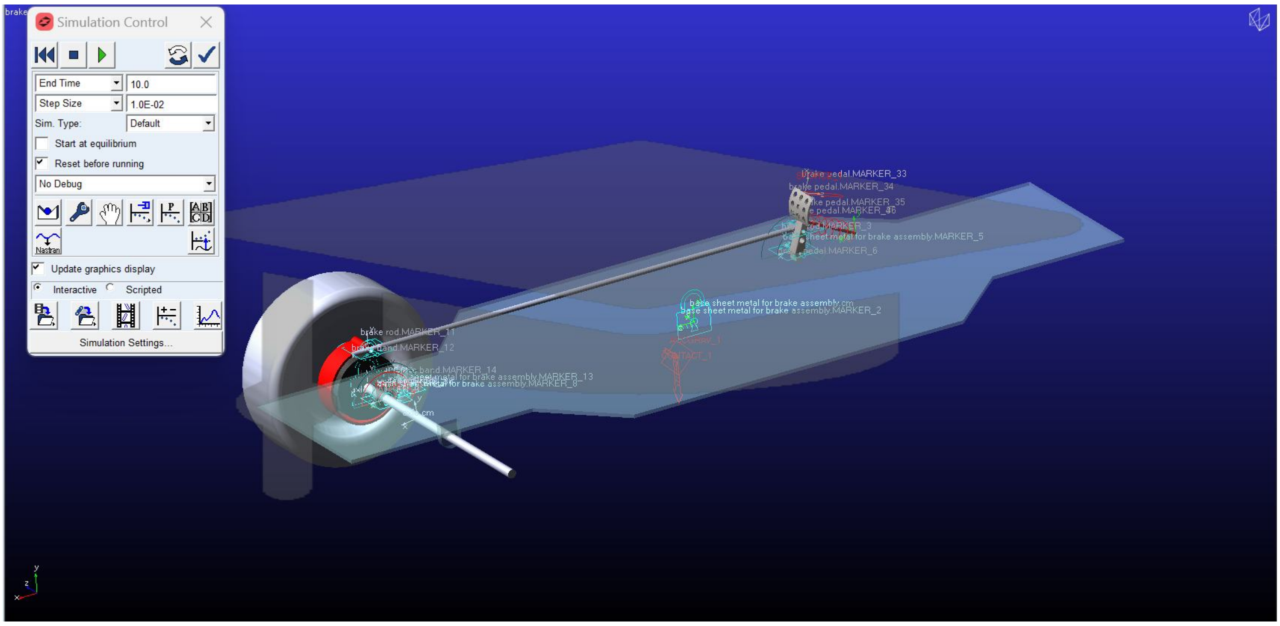
Disc brakes in go-karts use a caliper to squeeze pads against a rotating disc, creating friction to slow or stop the wheel. They provide superior heat dissipation and quicker response times.

However, disc brakes are more expensive than drum brakes in initial cost and maintenance. They are also more vulnerable to damage from debris and environmental conditions.





5a. Simulation and Validation of Braking Mechanism

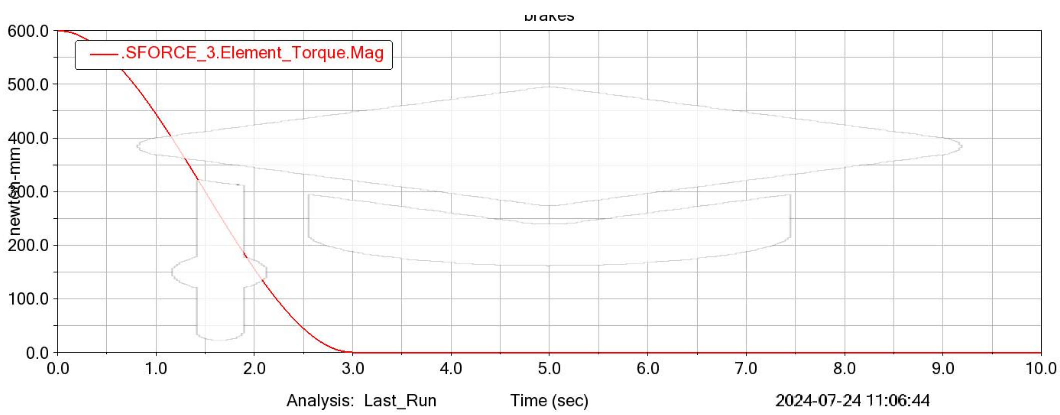


MSC ADAMS VIEW Workspace Image of Braking Simulation

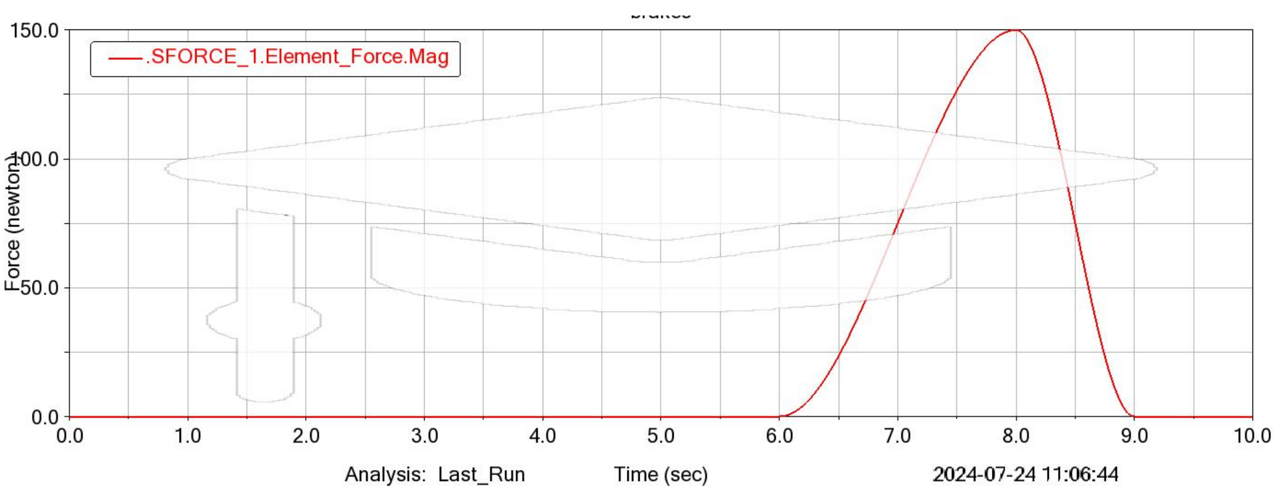
Simulation Video: https://drive.google.com/file/d/1HvSRgnz-Xka1PZp15yIsZ5OGWLGZ_9Km/view?usp=sharing

Highlights of Defining the System Dynamics:

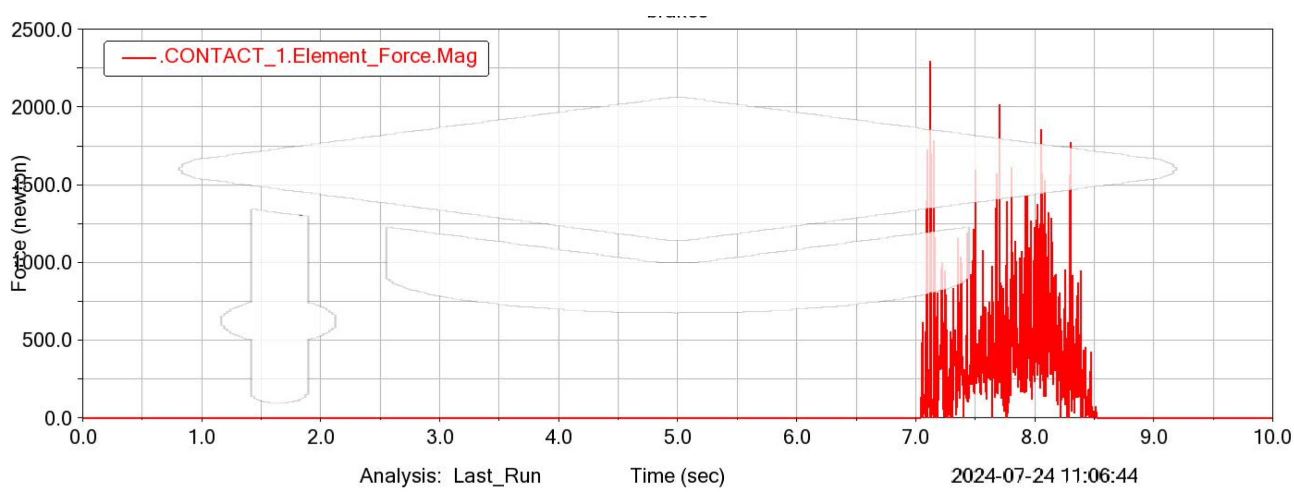
- 6 moving parts, 5 revolute joints and 3 fixed joints
- Torque is applied to the wheel to observe inertial effects of wheel motion given by expression: ***STEP(time, 0.0, 600, 3, 0.0). Graph is shown below***
- Force is applied to brake pedal given by expression: ***STEP(time, 6, 0, 8, 150.0)+STEP(time, 8, 0, 9, -150.0)***
- Spring is attached between brake pedal and floor board, with stiffness of around 8 N/mm and damping coefficient 0.16 N/mm
- Simulation runs for 10 seconds with a step size of 0.03
- Frictional Contact is defined between brake band and drum with stiction coefficient of 0.4 and dynamic coefficient of 0.3



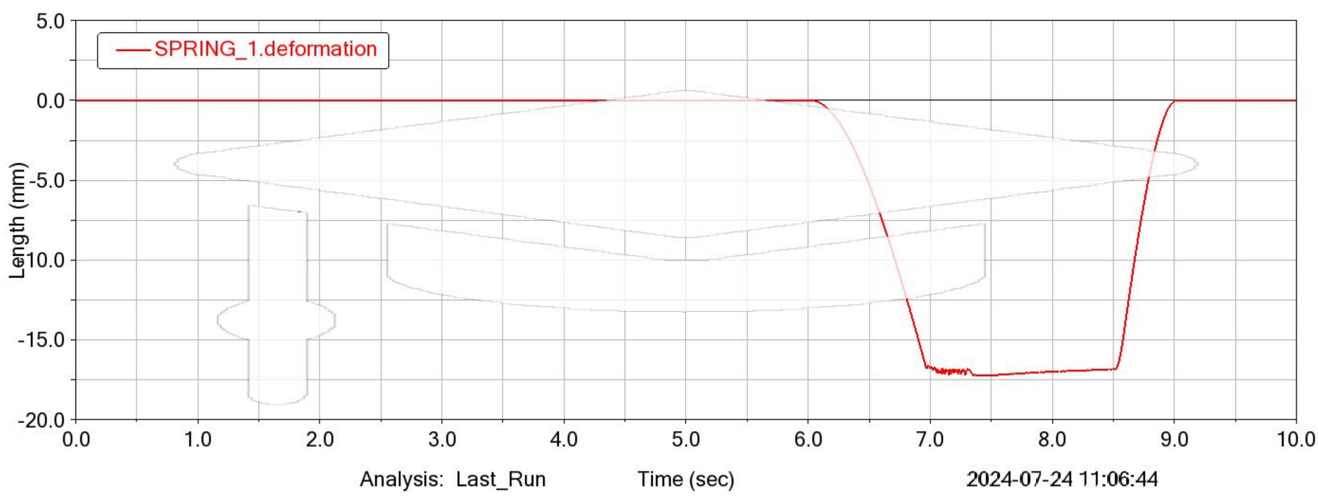
5b. Some Graphs



Force on Pedal (N) vs time (s)

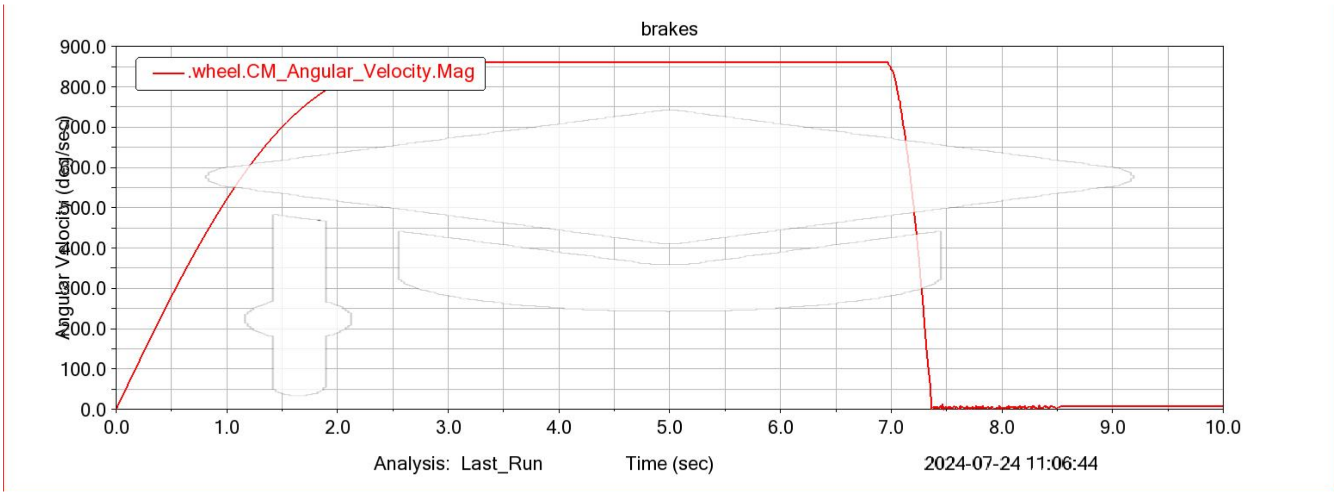


Contact Force b/w drum and band (N) vs time (s)

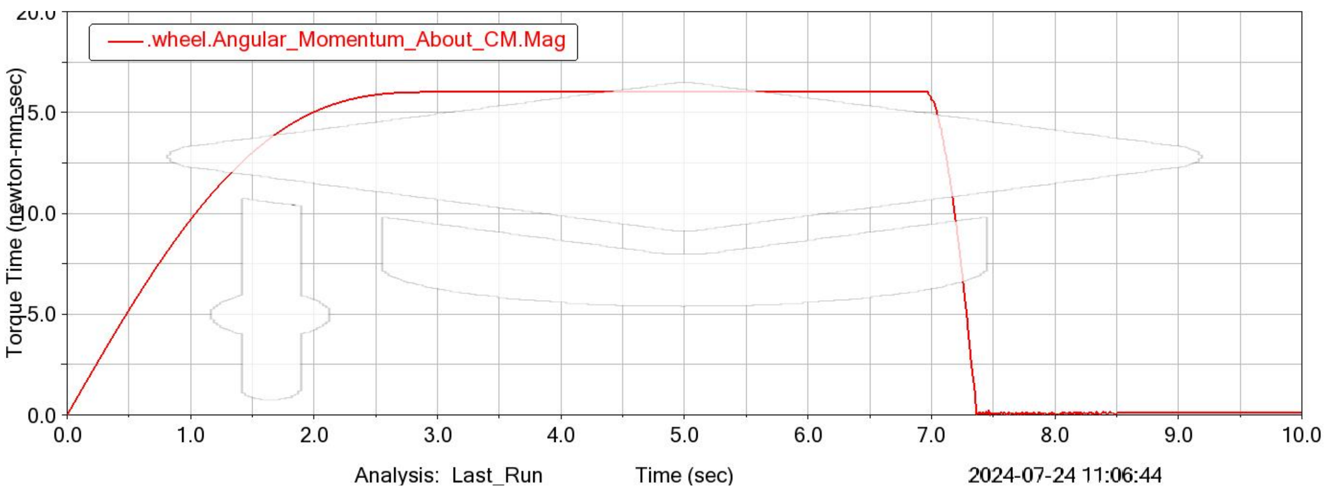


Spring Deformation length (mm) vs time (s)

Some Graphs



Angular velocity of CM of wheel (deg/sec) vs time (s)



Angular Momentum of Wheel about CM (N.mm.sec) vs time (s)

One can see from the graphs that, angular velocity and magnitude of angular momentum decreases as the brakes are applied. The observed value of angular deceleration of wheel is around 45000 deg/sec^2.

This tells and confirms that brakes or the contact between the brake band and drum are effective and when pressed harder (~150N of pedal force) it has very less stopping distance and time, even at 600 Nm of torque