Technion FSAE Racing

Wheel & Brake Team

Original Product Design Course# 034353/4

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Abstract

The **FormulaSAE** teaches university students to design and manufacture a marketable vehicle for racing. The Technion Formula consists of 7 subgroups whom, together, designed and built this vehicle.

The **Brake Team** of the Technion Formula conducted comprehensive research of braking systems and vehicle dynamics for preliminary modeling. Simplicity, manufacturability, maintenance, ease of use, safety, and system integration were essential elements in design. A final design was produced and manufactured.

Project Objectives and Requirements

The **Technion Formula Teams'** objective is to design, manufacture, market and race a vehicle according to the FormulaSAE guidelines.

The **Brake Teams'** objective is to design and manufacture optimal pedal system, brake system, and brake lines that will work seamlessly, provide driver safety, and integrate with all the vehicle components.

Product Description

HOW THE SYSTEM WORKS

Hydraulics

The vehicle has two independent hydraulic systems (see Figure 1) which act as a fail-safe for the system.

Another fail-safe for the system is a limit switch located behind the brake pedal which disables the engine.

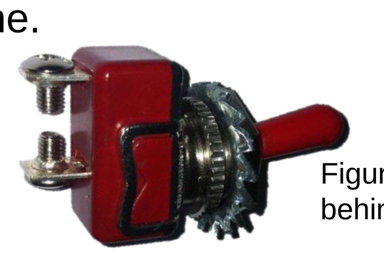


Figure 2: Limit switch behind brake pedal

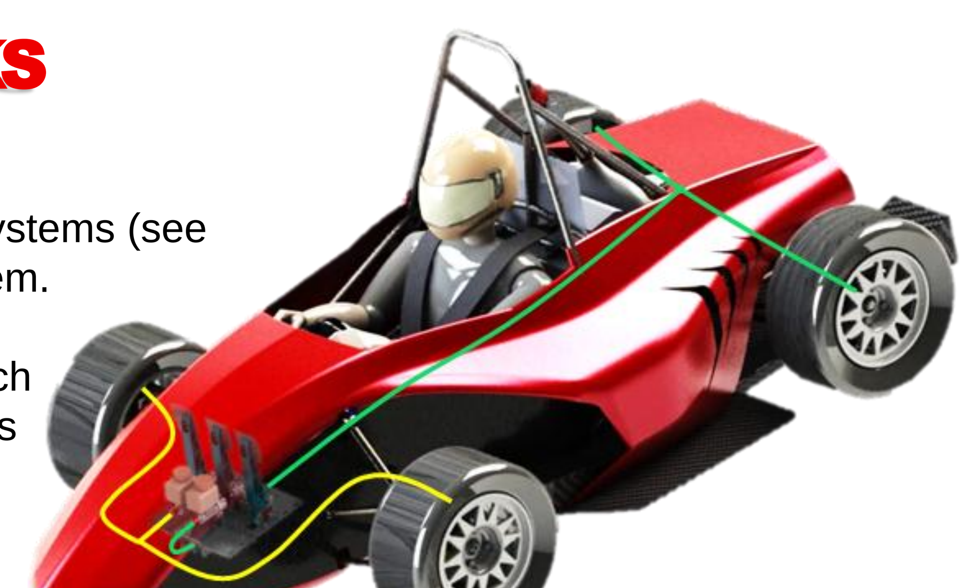
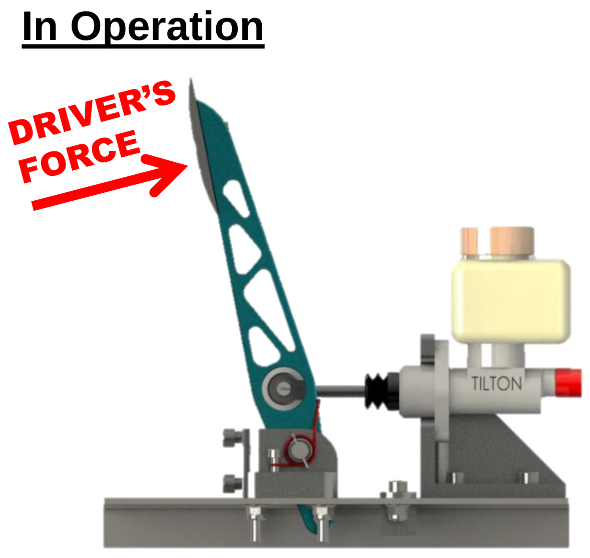
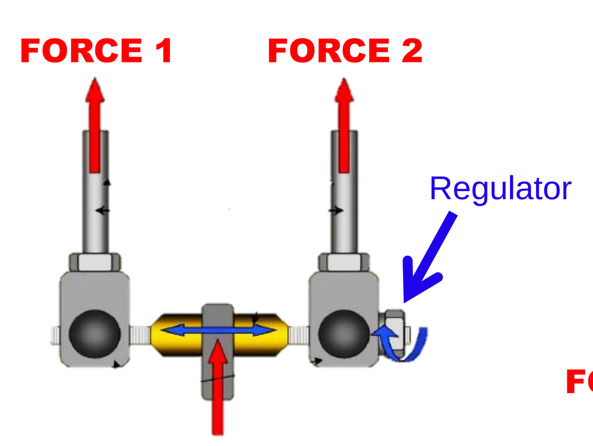


Figure 1: Digital render of Technion Formula vehicle with two independent hydraulic systems (shown in green and yellow).

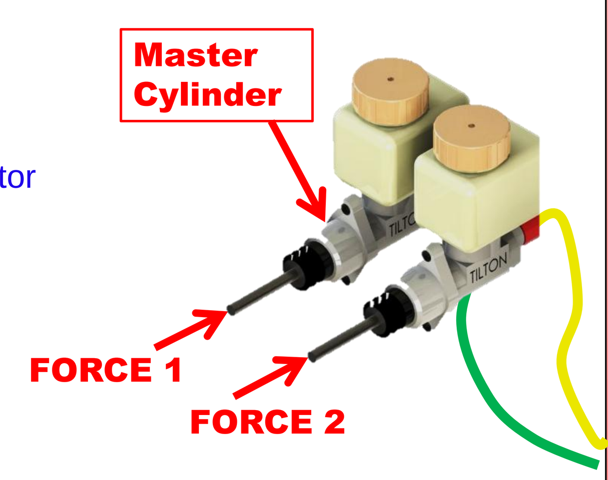
In Operation



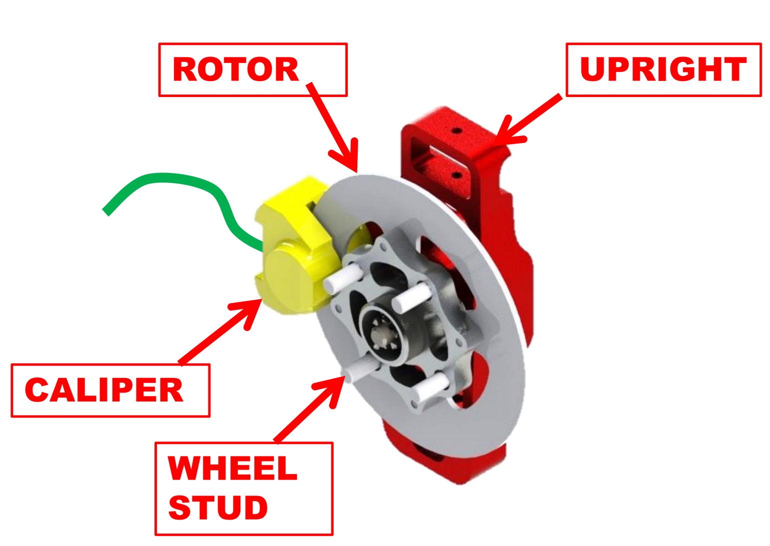
(1) Driver depresses brake pedal.

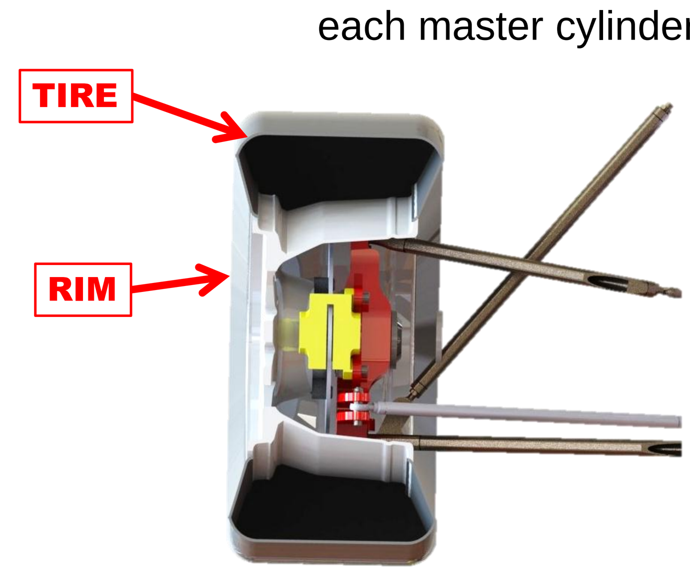


(2) Force of pedal transfers to balance bar.



(3) Balance bar regulates amount of force provided to each master cylinder.



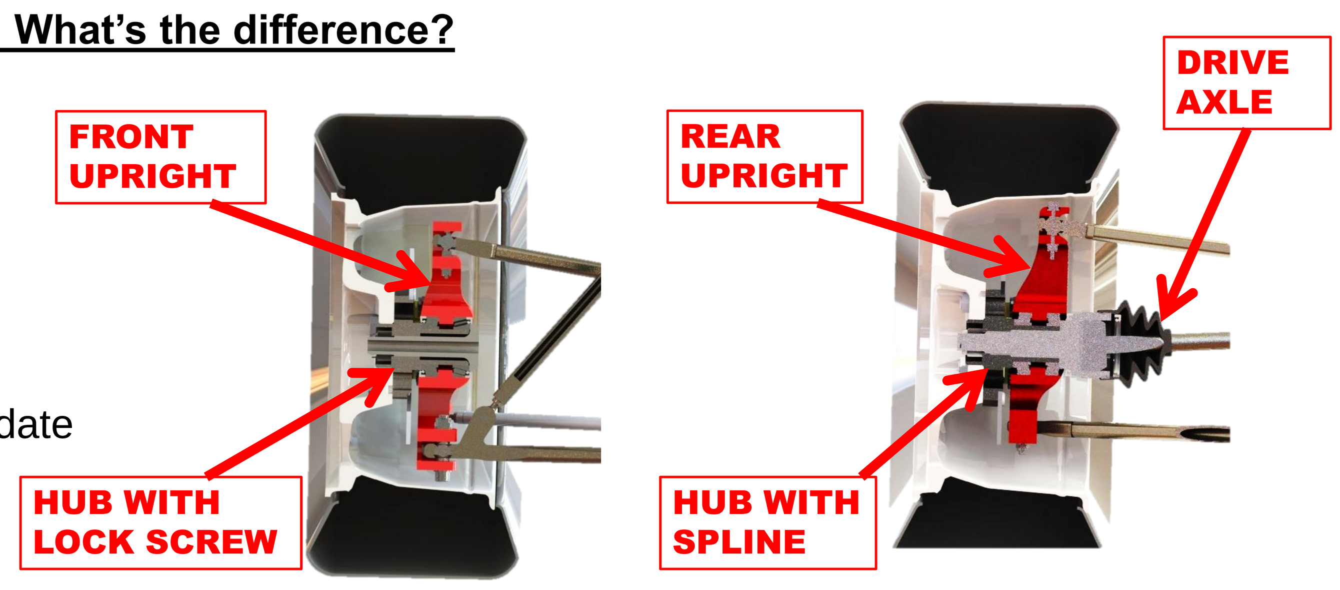


(4) Hydraulic forces transfer to calipers which slows the rotor discs thereby slowing the wheels.

Front vs. Rear Wheels: What's the difference?

Two major dissimilarities:

1. Uprights are variant due to vehicle frame geometry.
2. Hubs are variant since rear wheels accommodate drive axle.



Analysis

During the design process, extensive calculations of the vehicle braking dynamics and the hydraulic systems were calculated. A parametric subroutine was developed where parameters of the pedal and wheel systems were inputted and a comparison analysis was outputted. Using this, an optimal braking system and braking components were chosen.

Calculations

A free body diagram of the vehicle braking with locked wheelswas constructed (see Figure 2). Using this, dynamic equations of the system were developed.

$$(1)\, a_v = \mu \cdot g$$

$$(2)\, \frac{R_r}{W_t \cdot g} = 1 - \frac{[WB - X_{CG} + \frac{a_v}{g} \cdot h_{CG}]}{WB}$$

$$(3)\, R_r + R_f = W_t \cdot g$$

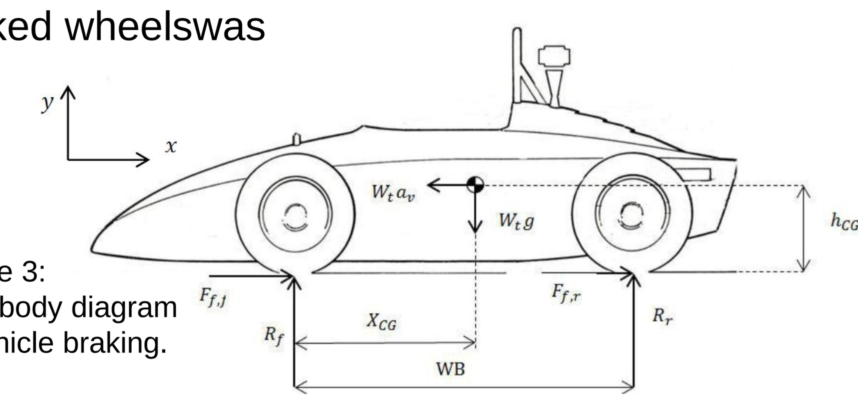


Figure 3: Free body diagram of vehicle braking.

Graphs

Figure 4 shows the ratio of the weight applied to the rear axle out of the total weight of the vehicle as a function of the deceleration. The brake torque ratios (BTR) of the vehicle were determined in order to obtain the best stopping distance – while all 4 wheels locked simultaneously. The weight ratio applied to the rear axle out of the total weight of the car is 0.33.

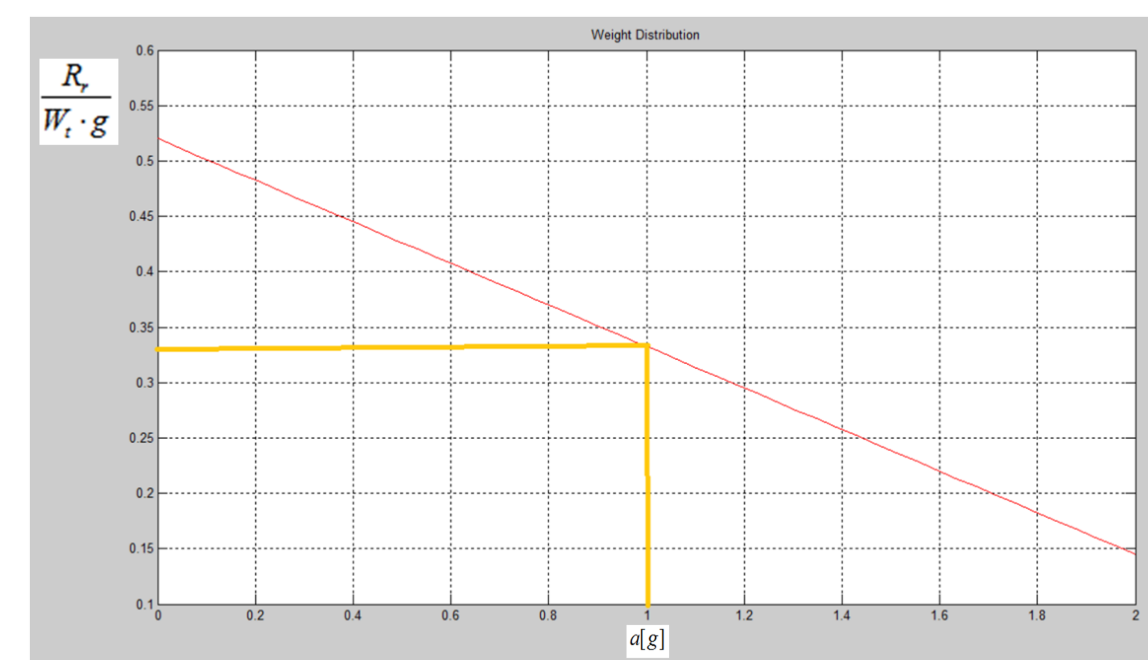
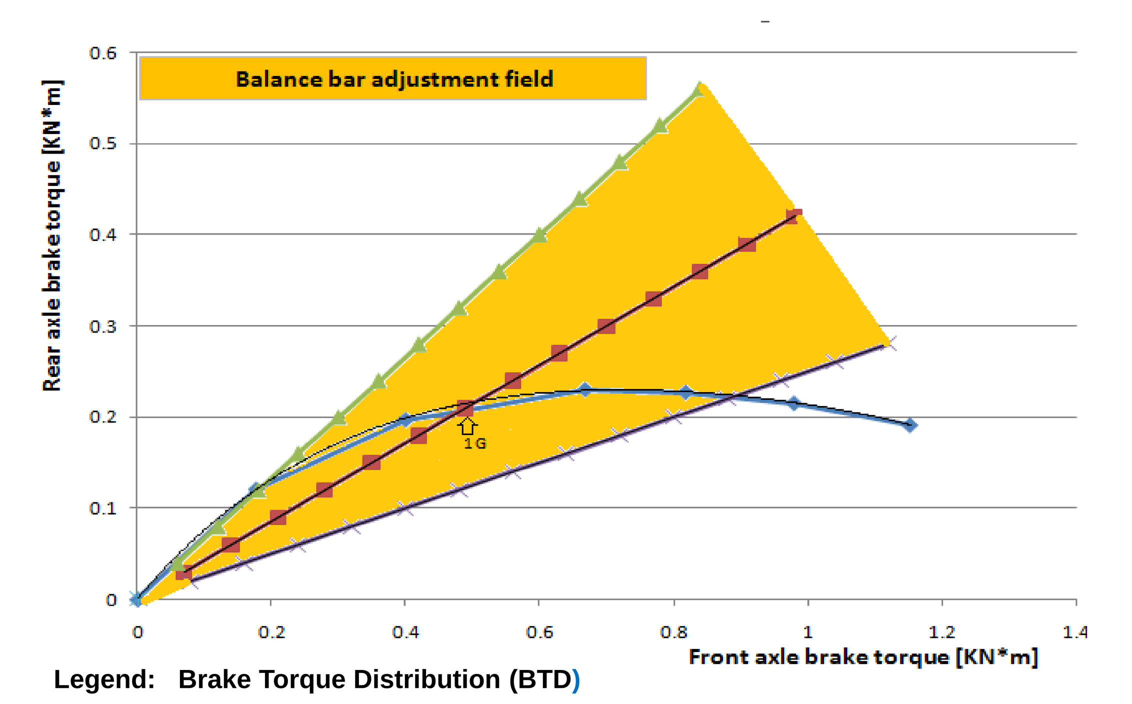


Figure 4: Ratio of weight on rear axle out of total weight as a function of vehicle deceleration.

The balance bar enables control of the BTR between the front and rear axles. For simplicity and convenience, the initial position of the BTR was chosen to be 70%-30%. This enables the BTR to reach a 60%-40% on the one hand and 80%-20% on the other.

Since the friction coefficient may vary due to the pavement conditions and tire selections, the BTR should be adjusted before driving. For safety, the front wheels are to lock prior to the rear wheels.



Legend: Brake Torque Distribution (BTD)

BTD of front to rear axle for varied decelerations that developed on car during braking.

BTD of 70%-30% of front to rear axle as applied by brake system (balance bar in default position).

Full range of BTD as applied by brake system and regulated by balance bar.

Figure 5: Rear axle brake torque (BT) as a function of front axle BT.

Material Strength

Using Solidworks, a stress analysis of the manufactured parts was conducted (see Figure 6).

A **safety factor of 2** was taken into account.

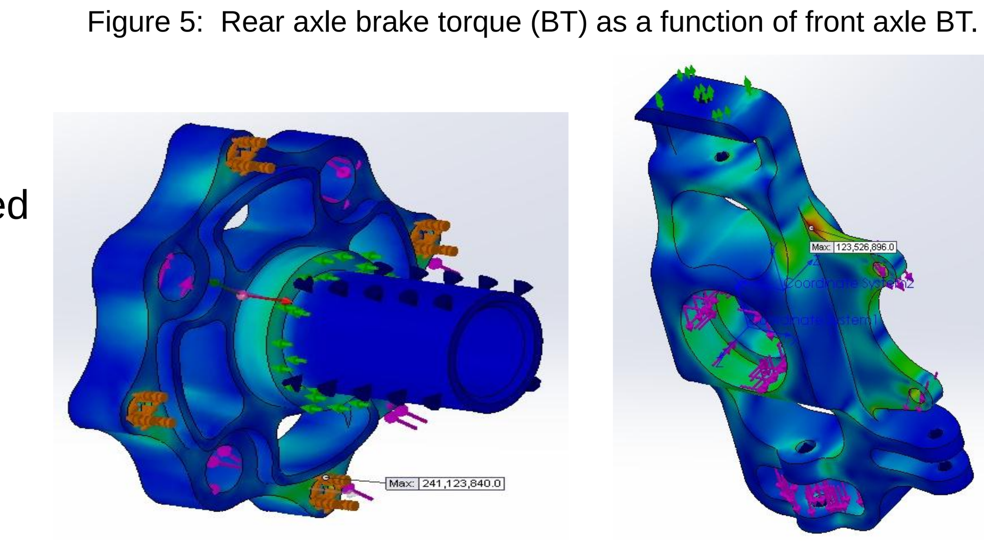
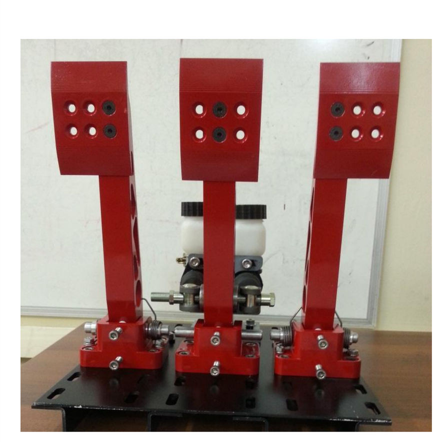


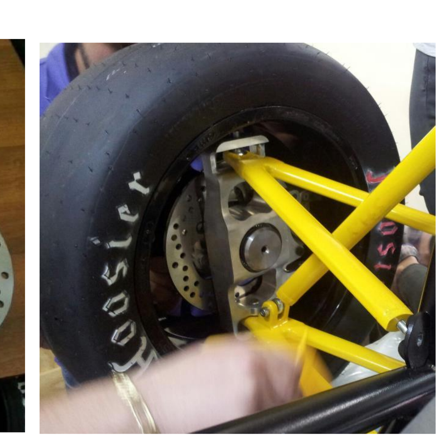
Figure 6: Material analysis of wheel hub and upright.

Final Product



Pedal System

Rotor with Hub



Wheel System

Disassembled Parts

Aknowledgements

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