

DESIGN AND ANALYSIS OF BRAKE CALIPERS FOR FSEV

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1. Introduction

The braking system of a Formula Student Electric Vehicle (FSEV) is a critical safety component that enables the controlled deceleration and stopping of the car. This report focuses on the selection and analysis of the brake calipers, which convert hydraulic pressure into clamping force during braking.

The FSEV under consideration has the following characteristics:

- Total weight (including driver): 305 kg
- Maximum speed: 110 -125 km/h
- Brake system: Hydraulic with 2 master cylinders and 4 calipers

2. Brake system overview

2.1 System Description

The hydraulic brake system includes:

- 2 master cylinders (front and rear circuits)
- 4 brake calipers (2 front, 2 rear)
- Brake discs fitted inside 11-inch rims (limited rotor diameter)

2.2 Flow of Braking Force

When the driver applies force on the brake pedal, the master cylinder responds by displacing brake fluid through the system. This hydraulic pressure causes the caliper pistons to push the brake pads against the rotating discs (rotors). The resulting friction between the pads and rotors generates a braking force that slows down or stops the vehicle.

3. Caliper selection

3.1 Selected Caliper

- **Model:** Wilwood GP200
- **Type:** 2-piston floating caliper
- **Material:** Billet Aluminium

- **Reason for Selection:**

- ❖ Compact and lightweight, weighs only **0.9 lbs**(Other calipers weigh more than 1.8 lbs)
- ❖ Sufficient piston area for required braking torque – **1.23 sq.in**
- ❖ Widely used in FSAE applications

3.2 Selection Criteria

- Number of pistons
- Piston area
- Weight
- Availability

Company/Manufacturer	Make/Model	Body Material	Piston Material	Weight (lbs)	Disk OD (in)	Disk Thickness (in)	Piston Diam (in)	Piston Area (in ²)	# of Pistons
AP Racing	Aluminium - Lug Mount - CP2576	Aluminum	Aluminum	2.4	10.5118	0.38189	1.625984	2.08	2
AP Racing	Aluminium - Lug Mount - CP2577	Aluminum	Aluminum	2.4	10.5118	0.38189	1.751969	2.41	2
AP Racing	Aluminium - Lug Mount - CP3176	Aluminum	Aluminum	2.4	10.5118	0.38189	1.5	1.77	2
AP Racing	Aluminium - Lug Mount - CP3177	Aluminum	Aluminum	2.4	10.5118	0.38189	1.41732	1.58	2
AP Racing	Aluminium - Lug Mount - CP3178	Aluminum	Aluminum	2.4	10.5118	0.38189	1.251969	1.23	2
Wilwood	Dynapro Single IIIA	Aluminium	Stainless	1.8	13	0.38	-	2.4	2
Wilwood	Billet GP 200	Billet Aluminium	Stainless	0.9	11	0.25	-	1.23	2
Wilwood	Dynapro Single	Aluminum	Stainless	2.3	13	0.19	-	2.4	2
Wilwood	Dynapro Lugmount	Aluminum	Stainless	3.8	13	0.25	-	4.8	4

Figure – 1: Comparative Caliper Matrix

4. Brake force calculations

4.1 Basic Parameters

- Coefficient of friction (μ): 0.7
- Height of CG: 300 mm
- Wheelbase: 1590 mm
- Front axle distance (L_f): 923.5 mm
- Rear axle distance (L_r): 666.5 mm
- Piston area (Wilwood GP200): $1.23 \text{ in}^2 = 793.547 \text{ mm}^2$

4.2 Braking Force Formula

$$W_f = w \cdot \frac{l_2}{L} + w \cdot \mu \cdot \frac{h}{L}$$

$$W_f = 2992.05 \cdot \frac{0.6665}{1.59} + 2992.05 \cdot 0.7 \cdot \frac{0.30}{1.59} = \mathbf{1646.56 \text{ N}}$$

$$W_r = w \cdot \frac{l_1}{L} - w \cdot \mu \cdot \frac{h}{L}$$

$$W_r = 2992.05 \cdot \frac{0.9235}{1.59} - 2992.05 \cdot 0.7 \cdot \frac{0.30}{1.59} = \mathbf{1342.65 \text{ N}}$$

$$F_b = \mu \cdot w$$

$$F_b = 0.7 \cdot 2992.05 = 2094.435 \text{ N}$$

4.3 Caliper Force Requirements

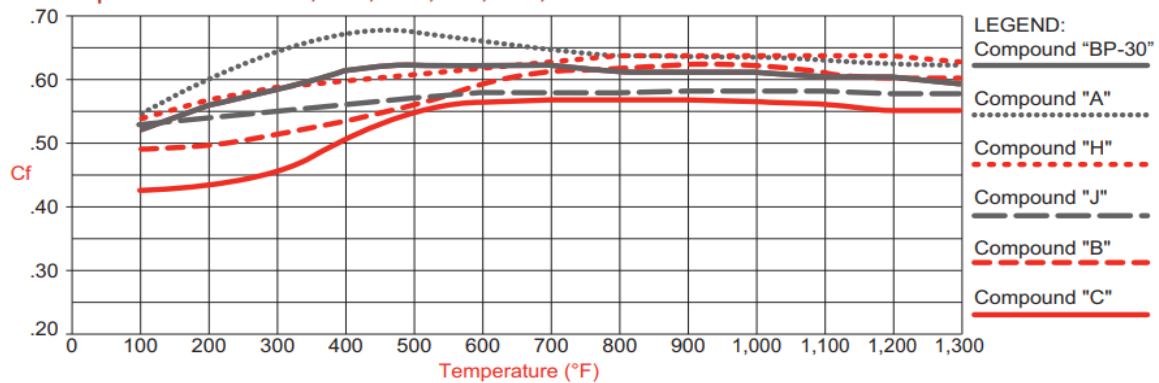
$$F_{FCP} \cdot R_{FCP} - \mu_b \cdot W_f \cdot R_{FT} = 0$$

$$F_{FCP} = 3650.107 \text{ N}$$

$$F_{RCP} \cdot R_{RCP} - \mu_b \cdot W_r \cdot R_{RT} = 0$$

$$F_{RCP} = 2479.53 \text{ N}$$

Compounds "BP-30", "A", "H", "J", "B", and "C"



Compounds "BP-10", "BP-20", "E", and "Q"

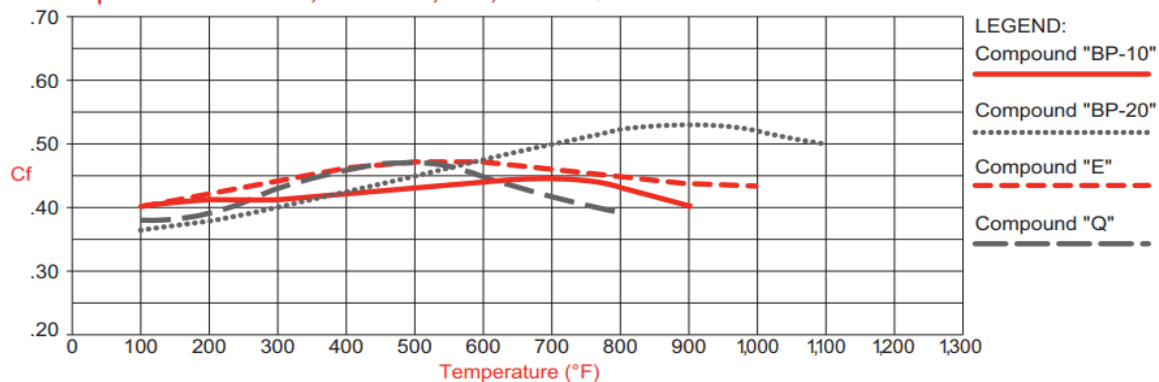


Figure – 2: Brake Performance Comparison Chart

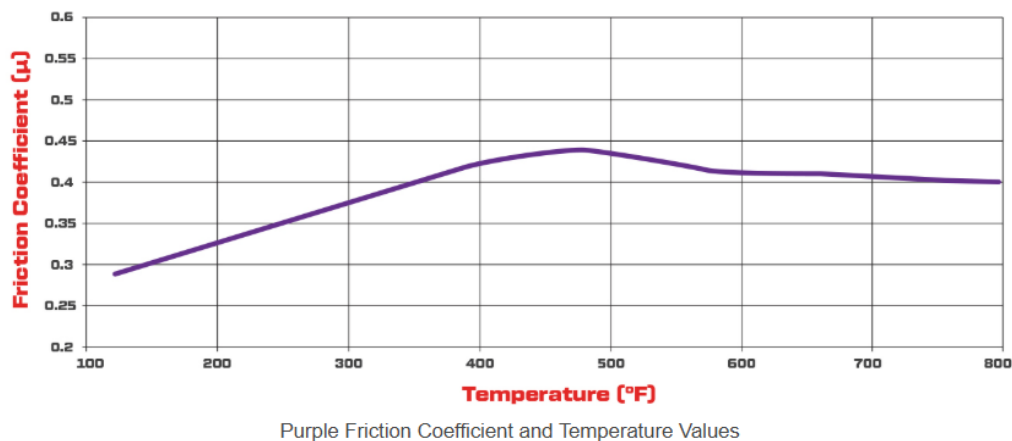


Figure – 3: Purple Brake Pad Performance Chart

5. Packaging considerations

- Rim OD: 279.4 mm
- Caliper clearance: ~ 30 - 40 mm
- Max rotor dia: 210 mm
- The selected caliper and disc combo fits within constraints and allows for optimal torque.

6. Material considerations

The caliper is made from **Billet Aluminium**, chosen for its combination of lightweight properties and high thermal conductivity, which helps dissipate heat generated during braking. Additionally, Billet Aluminium offers sufficient stiffness and strength to withstand braking loads without significant deformation, making it a suitable material for high-performance applications like FSEV.

7. Conclusion

In conclusion, the **Wilwood GP200 calipers** were selected as they meet the required braking torque, and weight criteria for the FSEV. They offer reliable, fade-resistant braking performance, and their significantly **lower weight** is a crucial advantage in a lightweight electric race vehicle. Additionally, the Wilwood brake pads have demonstrated consistent performance and reliability when compared to those from AP Racing, further justifying their selection for the braking system.

References

1. Prasanth Pujari, "Design and Analysis of Braking System of SAE Car", IJRET 2018
2. Wilwood Engineering – www.wilwood.com
3. Richard Gross – FSAE Braking System Design Notes