AUTOMOTIVE BRAKING SYSTEMS

How brakes manufacturing industry is different then rest of the automotive industries ????
Friction develops heat which absorbs kinetic energy of the car.
PURPOSE OF BRAKING SYSTEM

- Stop the vehicle by converting the kinetic energy of the vehicle to heat energy.

- Heat energy is created in the brakes by friction.

- Friction is created between a moving and a non-moving surface at each wheel to generate the heat.

- Disc and drum brakes are the most common type of braking systems used.
**FACTORS EFFECTING BRAKING**

- Number of wheels braking.
- Weight of vehicle.
- Type of friction material.
- Surface area of friction material.
- Size or discs or drums
- Tire traction.
- Road surface.
- Load transfer.
- Incline or decline of road. (gravity)
- Engine braking.
- Pressure applied
**Types of Braking Systems**

*Service brakes.* It’s the primary braking system using a pedal connected to a hydraulic system causing it to operate.

*Parking brakes.* It’s mechanically applied by a lever or pedal.
TYPICAL SYSTEM (NO ABS)
Typical Layout of System (with ABS)
COMPONENTS
ELEMENTS OF DISC BRAKE

There are major four elements of brake disc

1. **Master Cylinder** – usually accessible by user & is a actuating device.

2. **Brake Caliper** - is the end part of effort transmission in brakes which retards the motion of two wheeler

3. **Hose** – is for transmission of Oil from Master Cylinder to Brake caliper

4. **Brake Disc** – mounted on wheel & is major part in braking action & absorbing the braking energy.
**WORKING OF MASTER CYLINDER**

**Principle:**

Master cylinder works on principle of pumping of incompressible fluids, in which the pressure is applied on Brake Fluid/oil which then transferred to caliper for actuation of brake pads.
WORKING OF MASTER CYLINDER

The “feed aperture “( 0.5 mm Micro hole ) and “compensation hole” are open and connect the “pressure chamber” and “compensation enclosure” to reservoir.

- A small quantity of fluid returns from pressure chamber to reservoir before primary seal completely blocks the feed aperture.
- Once this condition is achieved, any force exerted on the lever is transformed into pressure in the brake circuit.
- When the brake lever is released, the piston is pressed back quickly by the return spring to its own position.

- Due to this, a vacuum is generated in the pressure chamber and the fluid in the compensation chamber flows to pressure chamber past the primary seal, due to its flexible lip edges which allow the brake fluid to pass to pressure chamber.
TANDEM MASTER CYLINDER ASSEMBLY
TANDEM MASTER CYLINDER ASSEMBLY

- Reservoir
- Compensating Ports
- PISTON CUP
- Secondary
- Primary Piston
NEVER ALLOW MINERAL OIL TO COME IN CONTACT WITH SEALS OR OTHER RUBBER PARTS OF DISC BRAKE, SINCE IT WILL CAUSE DAMAGE TO THESE PARTS

FREE PLAY AT THE END OF THE LEVER IS PROVIDED TO ENSURE THAT IN THE FREE CONDITION, THE PISTON DOES NOT REMAIN IN THE PUSHED CONDITION. THIS ENSURES THAT THERE IS NO PRESSURE IN THE SYSTEM WHEN THE BRAKE IS NOT APPLIED.
WORKING OF CALIPER

Principle

Caliper assembly converts the hydraulic pressure generated in the master cylinder into gripping force on the rotating brake disc & retards the rotation of disc.
**DISC BRAKE SYSTEM**

Hydraulic pressure transmitted via brake lines and hoses to piston(s) at each brake caliper.

- Pistons operate on friction pads to provide clamping force
- Rotors are free to rotate due to wheel bearings and ubs that contain them
- Hub can be part of brake rotor or separate assembly that the rotor slips over and is bolted to by the lug nuts
In the brake released condition, the brake fluid inside the caliper is at atmospheric pressure and the disc rotates freely as the pads do not press against it.

When the brake lever is operated, the pressure generated in the hydraulic circuit acts on the caliper pistons. The caliper pistons in turn push the friction pad on the side of the caliper body against the rotating disc.
The friction pad on the other side of the disc also presses against the disc due to reaction force on caliper body. Thus both the friction pads press against the disc, thereby generating braking torque & retards the wheel motion.
DISC BRAKE SYSTEM

A. Square cut O-ring during brake application.

B. Square cut O-ring during brake release.
Pressurized brake fluid travels along the brake line to the caliper. The pressurized fluid pushes the piston (green) and inner brake pad against the disc (blue). Pressure against the disc pushes the caliper away from the piston, pulling the outer brake pad against the disc. As the brake pads clamp together, friction slows the rotation of the disc and wheel.
The brake caliper assembly is normally Bolted to vehicle axle housing (steering knuckle)
DISC BRAKE SYSTEM

Two types of calipers: fixed and sliding/floating
Fixed Type Brake System

- Applies two pistons to opposite sides of rotor
- Caliper stays stationary
- Disc Brakes require higher hydraulic pressure
When the brakes are applied, hydraulic pressure forces the piston toward the rotor.

- Takes up any clearance
- Pushes pad into rotor
Square cut O-ring seals piston in disc brake calipers.

- Compressed between piston and caliper housing
- Keeps high-pressure brake fluid from leaking
- Prevents air from being drawn into system
Although the phenolic pistons themselves do not corrode, the cast iron bore of the caliper does corrode and rust. Can cause a phenolic piston to seize in the bore. Phenolic pistons transfer heat slower than steel pistons. Helps prevent boiling of the brake fluid.
APPLY SILICONE GREASE ON SECONDARY PIN SLIDING SURFACE
APPLY LOCTITE TO SECONDARY PIN THREADS BEFORE ASSY

NEVER ALLOW MINERAL OIL TO COME IN CONTACT WITH SEALS OR OTHER RUBBER PARTS OF DISC BRAKE, SINCE IT WILL CAUSE DAMAGE TO THESE PARTS
BRAKE FRICTION MATERIALS

Five Characteristics

- Resist Fading with increased temp
- Resist fading when wet
- Recover quickly
- Wear gradually
- Quiet

Disc brake pads consist of friction material bonded or riveted onto steel backing plates.
LINING MATERIAL

➢ Non-metallic
   ➢ Made from synthetic fibers (used to be asbestos)

➢ Semi-metallic
   ➢ Made from iron and synthetic fibers
   ➢ More fade resistant - harder pad
   ➢ More prone to squealing

➢ Full-metallic
   ➢ Made from sintered metals
   ➢ Very hard pad
Composition of friction material affects brake operation

- Materials that provide good braking with low pedal pressures tend to lose efficiency when hot
- Wear out quicker
- Materials that maintain stable friction coefficient over a wide temperature range
- Generally require higher pedal pressures
- Tend to put added wear on disc brake rotor
DISC BRAKE SYSTEM

• Advantages

 Greater amounts of heat to atmosphere
 Cooling more rapid
 Rotors scrape off water more efficiently
 Self-adjusting
 Don’t need periodic maintenance
 Easier to service
DISC BRAKE SYSTEM

Disadvantages

- Prone to noise (squeals and squeaks)
- Rotors warp easier
- Not self-energizing
- Hard to use as parking brakes
Rigid steel brake lines are double wall
Flexible hoses connect rigid lines on vehicle to each wheel
Transmits hydraulic fluid to each wheel

Auto Rickshaw’s front tube is best for coupling
PROPORTIONING VALVES

- Reduce the pressure to the rear brakes
- Diagonal systems require two
- Split and slope are changed to create proper balance
DRUM BRAKE SYSTEM

Drum Brake Assembly

F = ma
Wheel cylinder or caliper pistons are “slave cylinders”.

- Change hydraulic pressure back into mechanical force.
- Can use one or two cylinders at each wheel.
POWER ASSIST
INCREASES FORCE OF DRIVER'S FOOT
CABLE PARKING BRAKE

Parking or “Emergency” Brake
PARKING BRAKE SYSTEMS

Foot or Hand Brake
Are cable controlled

- Several Styles
  - As shown
  - Drum in hat
  - Driveline
BRAKE SYSTEM  ENERGY
BRAKE SYSTEM PRINCIPLES

- Kinetic Energy
- Mass
- Weight
- Speed
- Inertia and Momentum
**FRICITION PRINCIPLES**

- Kinetic and Static Friction
- Friction and Pressure
- Friction and Surface Area
- Coefficient of Friction
- Brake Fade
BRAKING DYNAMICS

- Weight Transfer
- Weight Distribution
- Braking Power
- Friction Efficiency
  - Brake to Wheel
  - Wheel to Road Surface
- Traction Efficiency
  - Skidding
HYDRAULIC PRINCIPLES

- Fluids cannot be compressed
- Fluids can transmit Movement
  - Acts “Like a steel rod” in a closed container
  - Master cylinder transmits fluid to wheel cylinder or caliper piston bore.
- Fluids can transmit and increase force
- The area of the piston is determined by using the formula

\[ 3.14 \times R^2 \]
HYDRAULIC PRESSURE IS DISTRIBUTED EQUALLY IN ALL DIRECTIONS
The applied force can be changed by changing the piston size.

\[ F = PA \]
ADVANTAGE BY HYDRAULICS

\[ F = ma \quad \text{&} \quad F = pa \]
**BRAKE PEDAL DESIGN**

Output to master cylinder
400 N and 36 mm

4:1 Nominal Pedal Ratio

- First Mechanical Advantage is Driver’s foot
- Length of Lever determines force applied
- Uses Fulcrum
- Pedal Ratio

Driver Input
100 N and 144 mm
STEPS TO BE FOLLOWED DURING DESIGNING

➢ Packaging constraints

➢ Availability in the market

➢ Design requirements

BRAKE FORCE DISTRIBUTION DIAGRAM

- Unladen Condition
- Laden Condition
PACKAGING CONSTRAINTS
**VEHICLE DATA REQUIRED FOR CALCULATIONS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front Axle weight (Kg) if provided</td>
<td>125.92</td>
</tr>
<tr>
<td>Calculated</td>
<td>125.92</td>
</tr>
<tr>
<td>Rear Axle weight (Kg)</td>
<td>160.08</td>
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<tr>
<td>Wheel base &quot;e&quot; (m)</td>
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<tr>
<td>GVW (Kg)</td>
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<tr>
<td>C.G. &quot;h&quot; (m)</td>
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<tr>
<td>Mechanical efficiency</td>
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<tr>
<td>Hydraulic efficiency</td>
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<tr>
<td>Pedal ratio</td>
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<tr>
<td>Caliper Piston dia (cm)</td>
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</tr>
<tr>
<td>Number Of Pistons</td>
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<tr>
<td>Area (cm²)</td>
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<tr>
<td>Effective radius (m)</td>
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</tr>
<tr>
<td>Master dia (cm)</td>
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<tr>
<td>Master Piston Area(cm²)</td>
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<tr>
<td>Mue</td>
<td>0.37</td>
</tr>
<tr>
<td>Static Rolling radius (m)</td>
<td>0.291</td>
</tr>
<tr>
<td>Dynamic Rolling radius (m)</td>
<td>0.291</td>
</tr>
</tbody>
</table>
FINDING THE C.G OF THE VEHICLE??
Distance from Center of Gravity to Ground.

You might be able to find the CG Height of your car on the Web, estimate it (based on other information you already have), or find someone else who already knows. Otherwise you can use one of these CG Height calculators:

The numbers already in there are just examples and can be overwritten. If you enter decimals, please use a decimal point. Metric System users: I'm sorry, but you too will have to use the decimal point, as the "comma" will not work.

For raising the rear wheels, see the explanation and warnings below.

<table>
<thead>
<tr>
<th>Standard</th>
<th>Metric</th>
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</thead>
<tbody>
<tr>
<td>B = 94.5 in</td>
<td>B = 2400 mm</td>
</tr>
<tr>
<td>W_F = 1378 lb</td>
<td>W_F = 625.6 kg</td>
</tr>
<tr>
<td>W_R = 1339 lb</td>
<td>W_R = 607.9 kg</td>
</tr>
<tr>
<td>h = 19.25 in</td>
<td>h = 489 mm</td>
</tr>
<tr>
<td>W_FR = 1432 lb</td>
<td>W_FR = 650.1 kg</td>
</tr>
<tr>
<td>R_TF = 11.75 in</td>
<td>R_TF = 298.5 mm</td>
</tr>
<tr>
<td>R_TR = 11.75 in</td>
<td>R_TR = 298.5 mm</td>
</tr>
</tbody>
</table>

Calculate CG Height

CG Height = inch

Calculate CG Height

CG Height = mm
FIND THE LOAD TRANSFER FROM THE VEHICLE DATA

Dynamic load transfer in laden condition @--- G condition :

\[ = \{G_{VW} -- G_x \text{ Height of C.G from ground in laden condition} \} \]

\[ \text{wheel base} \]

STEP :1

Dynamic load transfer in laden condition on front Axle Rf @ --- G conditions:

\[ = \text{Front axle weight in laden condition} + \{ \text{Dynamic load transfer in laden condition @ --- G condition} \} \]

STEP :2

Braking force in laden condition on front Axle Rf @--- G conditions:

\[ = -- G \{ \text{Dynamic load transfer in laden condition on front axle @---- G in laden condition} \} \]

STEP :3

The braking torque on front axle @ --- G in laden condition :

\[ = \text{braking force on front axle @---G in laded condition} \times \{ \text{front tyre dynamic rolling radius} \} \]

STEP :4
Dynamic load transfer in laden condition on Rear Axle Rr @--- G conditions:

RAW—{dynamic load transfer in unladen condition @0.6G condition}

**STEP :5**

Thus the braking force at Rear @---G in laden condition

= --Gx{load transfer at Rear axle @--G in unladen condition}

**STEP :6**

The braking torque on Rear axle @---G in unladen condition:

= braking force on Rear axle @---G in unladen condition x{Rear tyre dynamic rolling radius}

**STEP :7**

*This is the minimum requirements of the vehicle as per weight and C.G of the vehicle.*
DIMENSIONS OF CALIPERS TO SUIT THE DESIRED CONFIGURATIONS OF THE VEHICLE:

- Diameter of caliper piston = ---- mm
- Area of caliper piston = ----- mm²
- Coefficient of friction of the pad (\( \mu_e \)) = 0.37
- Disc outer diameter = 200 mm (based on market survey and packaging)
- Effective radius of the disc is 100-13 (radius of the disc - half the width of the brake pad +1 mm) = 87 mm
- Dynamic tire radius of the front wheel \( (r) \) = ------ mm
OUT PUT OF THE DESIGN: @ 0.6G & 1G MAX

- **LINE PRESSURE** = PEDAL EFFORT X PEDAL RATIO X 0.9 (hydraulic losses) X M.C AREA

- **BRAKING FORCE FRONT** = (LINE PRESSURE X CALIPER AREA X EFFECTIVE RADUIS X MUE X 2) X FRONT DYNAMIC ROLLING RADIUS

- **BRAKING TORQUE** = BRAKING FORCE FRONT X FRONT DYNAMIC ROLLING RADIUS

- **UNLADEN WHEEL UNLOCKED DECELERATION** = BRAKING FORCE FRONT / K.V.W  
  **TARGET IS 0.6G**

- **LADEN WHEEL UNLOCKED DECELERATION** = BRAKING FORCE FRONT / G.V.W  
  **TARGET IS 0.6G**
CONCLUSION:

Finally the results of BRAKING FORCE FRONT = (LINE PRESSURE X CALIPER AREA X EFFECTIVE RADUIS X MUE x 2 ) FRONT DYNAMIC ROLLING RADIUS shall be greater then

Braking force in laden condition on front Axle Rf @---G conditions:

= --G x{Dynamic load transfer in laden condition on front axle @---- G in laden condition}
SUGGESTIONS:

- **MASTER CYLINDER** – Go ahead with T.M.C of regular size 19.2 MM bore.

- **BUNDY TUBES** - Metallic tubes are easily available in the market cut & braze it as per requirements.

- **BRAKE CALIPER** – Most of the calipers available in the market are 28 x2 diameter use it for rear. Use 30 dia single piston caliper @ front.

- **Hose** – Bajaj Auto’s front hose should we chosen. Easily mates with the Bundy tube end.

- **BRAKE DISC** – try to fit the Max possible dia of the disc based on the packaging constraints.
A designer knows he has achieved perfection not when there is nothing left to add, but when there is nothing more to take away.”