Chapter 33
Fundamentals of Hydraulic and Air-Over-Hydraulic Braking Systems
Introduction

• Vehicle’s braking system must meet the following requirements:
  – To adequately and safely reduce a vehicle’s speed, when required to do so
  – To maintain vehicle speed on downhill gradients
  – To be able to hold vehicle stationary, even when on gradient and driver is away from the vehicle
Fundamental Configurations for Hydraulic Braking Systems

• Hydraulic brake systems: same basic components augmented by one of two power assist or boost methods.
  – Vacuum booster: medium-duty commercial vehicles; lower cost factor for vehicle range; engine of choice is diesel engine.
  – Hydroboost: Class 4 to Class 6 commercial vehicles; uses pressurized hydraulic fluid to provide brake power assist.
Fundamental Configurations for Hydraulic Braking Systems

• Air-Over-Hydraulic Braking Systems
  – Use air compressor to provide power assistance over hydraulic components to braking system
  – Hydraulically controlled system: compressor, air dryer reservoir tanks, lines
  – Air treadle (foot) valve: sends air pressure directly or indirectly to air boosters that actuate hydraulic master cylinders to apply the brakes
Fundamental Configurations for Hydraulic Braking Systems

- Hydraulic Braking Systems
  - Brake pedal or lever
  - Pushrod (actuating rod)
  - Master cylinder assembly containing piston assembly (one or two pistons, series of seals, O-rings, fluid reservoir)
  - Reinforced hydraulic lines
  - Disc brake assemblies
  - Filled with glycol-ether-based brake fluid
Fundamental Configurations for Hydraulic Braking Systems

- Master cylinder
- Brake pedal
- Brake lines
- Front calipers
- Wheel cylinders
Fundamental Configurations for Hydraulic Braking Systems

- Hydraulic Braking Systems
  - When brake pedal pressed, pushrod exerts force on piston(s) in master cylinder, causing fluid from brake fluid reservoir to flow into pressure chamber through compensating port.
  - Results in increase in pressure of entire system
  - Forces fluid through hydraulic lines toward disc brake calipers and drum brake wheel cylinders, where fluid force acts upon pistons

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Fundamental Configurations for Hydraulic Braking Systems

- Hydraulic Braking Systems
  - Brake caliper pistons apply force to brake pads and brake shoes to push them against spinning rotor or drum.
  - Friction between pads/shoes and rotating surfaces generates braking torque to slow vehicle.
  - Release of brake pedal/lever allows spring(s) to return master piston(s) back into position.
  - Designed as closed system
Foundation Components of Hydraulic Braking Systems

• Drum Brakes
  – Drum arrangements used on rear wheels, with disc brakes on front in disc/drum configuration.
  – Drum brake has two brake shoes with attached lining made of friction material.
  – Main advantage: shoe mountings designed to assist their own operation (self-energizing)
Foundation Components of Hydraulic Braking Systems

• Drum Brakes
  – Main disadvantage: friction area almost entirely covered by lining; heat conducted through drum to reach outside air to cool.
  – Brake fade: gradual loss of brake stopping power during prolonged or strenuous use.
  – Very high temperatures occur at brake drum; causes deterioration in frictional value of lining or pad material.
Foundation Components of Hydraulic Braking Systems

• Brake Shoe Configurations and Actuation Mechanisms
  – Single-leading-shoe drum brake (SLS): leading/trailing shoe drum brake arrangement; basic drum brake design
  – Found on rear wheels of vehicles
  – Term “leading/trailing”: one shoe “leading,” that is, moving with direction of drum’s rotation and exhibiting self-applying, or self-servo, effect.
Foundation Components of Hydraulic Braking Systems

• Brake Shoe Configurations and Actuation Mechanisms
  – Other shoe is “trailing”: moving against direction of rotation, and being thrown off drum’s friction surface and not retarding drum effectively.
  – Self-servo effect arises in two-leading-shoe arrangement because leading shoes are dragged into brake drum’s friction surface and achieve maximum braking force.
Foundation Components of Hydraulic Braking Systems
Foundation Components of Hydraulic Braking Systems

- Types of Adjusters Used with Drum Brakes
  - Important to maintain specified drum-to-lining clearance at all times.
  - Star adjusting screw: threaded bolt and two nuts; each end of adjusting in contact with a brake shoe, clearance decreases as screws are turned.
  - Wedge-type adjuster: conical wedge screwed in or out from back of backing plate between tappets that adjust brake lining to brake drum clearance.
Foundation Components of Hydraulic Braking Systems

• Disc Brakes
  – Slows rotation of wheel by friction caused by pushing brake pads against brake disc with set of calipers.
  – Made of cast iron or composites
  – Disc connected to wheel and/or axle.
Foundation Components of Hydraulic Braking Systems

• Disc Brakes
  – To stop wheel, friction material (brake pads mounted on device called brake caliper) forced mechanically, hydraulically, pneumatically, or electromagnetically against both sides of disc.
  – Friction causes disc and attached wheel to slow or stop.
  – Compared with drum brakes, disc brakes offer better stopping performance because disc more readily cooled.
Foundation Components of Hydraulic Braking Systems

• Disc Brakes
  – Less prone to brake fade and recover more quickly from immersion.
  – Has no self-servo effect.
  – Disc brake performance improves as components heat up; drum brake performance deteriorates.
  – Disc brakes can be retrofitted.
Emergency/Hand Brakes

- Mechanical Hand Brake
  - Primary function: hold vehicle in stationary position when parked.
  - Secondary function: act as emergency stopping brake if primary brake malfunctions.
  - Drive shaft brakes not designed to act as emergency brake.
Emergency/Hand Brakes

- Electrically Activated Hand Brake
  - Found in light-duty commercial vehicles.
  - Cable-pulling type: electric motor pulls emergency brake cable rather than mechanical handle in cabin.
  - More complex unit uses two computer-controlled motors attached to rear brake calipers to activate it.
Emergency/Hand Brakes

- Caliper Body
- Brake Pads
- Disc
- Self Adjuster
- Wedge
- From Master Cylinder
- Park Motor

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Emergency/Hand Brakes

• Spring Brake Park Brake
  – Air-over-hydraulic systems use vehicle’s air system to hold brake off when vehicle moving.
  – When actuation valve moved to apply brakes, air pressure is exhausted from spring brake chamber.
  – Power spring in unit mechanically moves brake components to apply brake.
Hydraulic Components of Hydraulic Brake Systems

- **Master Cylinder**
  - Primary function is that of a pump.
  - When activated by foot brake pedal, it forces hydraulic brake fluid through brake lines under pressure to activate wheel cylinders.
  - Develops pressure necessary to force wheels to expand and apply brakes.
  - Maintains equal pressure on brake shoes/disc pads.
Hydraulic Components of Hydraulic Brake Systems

• Master Cylinder
  – Keeps braking system full of fluid to reduce risk of possible air induction into system as well as keep other contaminants from entering system.
  – Compensates for wear in brake linings/pads as well as maintain a slight residual pressure in braking system
  – Converts non-hydraulic pressure from driver’s application of brake pedal into hydraulic pressure.
Hydraulic Components of Hydraulic Brake Systems

• Master Cylinder
  – Primary piston moved directly by pushrod or power booster; generates hydraulic pressure to move secondary piston.
  – Single bore
  – Separated into two chambers by primary and secondary piston.
  – Could contain residual pressure valve for drum-type brakes (not fitted to disc brakes).
Hydraulic Components of Hydraulic Brake Systems

- Lid
- Atmospheric Seal (prevents the brake fluid from absorbing moisture from the air)
- Reservoir
- Secondary Piston
- Primary Piston
- Housing
- Spring
- To rear brakes
- To front brakes
- Primary seal
- Secondary Seal
- O-ring
- Quad Seal
- Lip Seal
- Recuperation Grooves

Secondary Seal Types

Primary Seal

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Hydraulic Components of Hydraulic Brake Systems

• Master Cylinder
  – Reservoir above each master cylinder supplies master cylinder with enough brake fluid to avoid air from entering.
  – Medium-duty vehicles with hydraulic brakes will have one master cylinder for the brakes.
  – Actuating rod from brake pedal linked directly to primary piston (pushrod).
Hydraulic Components of Hydraulic Brake Systems

• Split Braking Systems
  – Divided system safer in event of partial failure.
  – Longitudinal split: brake system has one piston in master cylinder operating front braking circuit and other piston to operate rear braking circuit.
  – Diagonal split: brake system has each master cylinder piston controlling and operating braking system diagonally.
Hydraulic Components of Hydraulic Brake Systems

• Wheel Cylinders
  – Component in drum brake system
  – Located in each wheel at top, above shoes
  – Responsibility: exert force onto shoes so they can contact drum and stop vehicle with friction.
  – Single piston/single action
  – Dual action/double cylinder with piston at each end
Hydraulic Components of Hydraulic Brake Systems
Hydraulic Components of Hydraulic Brake Systems

• Hydraulic Brake Valves
  – Proportioning valves: reduce brake pressure to rear wheels when their load is reduced during moderate to severe braking.
  – Metering valves: hold off application of front brakes on vehicles with disc brakes on front wheels and drum brakes on rear wheels.
  – Pressure differential valve: monitors pressure difference between two separate hydraulic brake circuits.
Hydraulic Components of Hydraulic Brake Systems

• Hydraulic Brake Valves
  – Combination valve: can combine pressure differential valve, metering valve, and proportioning valve(s) in one unit.
  – Not serviceable; if they become faulty, they must be replaced.
Hydraulic Brake Power-Assist Systems

• Vacuum Brake Booster or Servo
  – Vacuum power-assist system: uses vacuum booster to provide assistance to driver by increasing braking force created by brake pedal effort.
  – Vacuum boosters or servos use differential in pressure principle to increase braking force applied to brake master cylinder.
Hydraulic Brake Power-Assist Systems

To Engine Intake Manifold
- Vacuum Check Valve
- Diaphragm
- Atmospheric Valve
- Brake Pedal Pushrod
- Brake Lamp Switch
- Pedal Height Adjustment
- Master Cylinder Pushrod
- Reaction Disc
- Seal
- Air Filter
- Pushrod Adjustment
Hydraulic Brake Power-Assist Systems

• Vacuum Brake Booster or Servo
  – Booster between brake and master cylinder
  – Stage 1: driver’s foot off pedal; vacuum valve open to both sides of diaphragm; equalizes pressure so there is no power assist, and system is released.
  – Stage 2: driver pushes foot on pedal. Atmospheric pressure enters rear side of diaphragm and starts to push towards master cylinder creating power assist.
Hydraulic Brake Power-Assist Systems

• Vacuum Brake Booster or Servo
  – Stage 3: driver holds pedal at a certain point. Allows vacuum valve to move to position that maintains pressure differential between two sides; assist pressure holds at steady level.
  – Boosters designed with reserve capacity to allow two to three full brake applications before entire vacuum is lost.
Hydraulic Brake Power-Assist Systems

• Hydroboost Systems
  – Use pressurized hydraulic fluid to provide brake power assist.
  – Booster unit bolted to flywheel; master cylinder bolted to booster.
  – Hydraulic pressure used for power assist supplied by vehicle’s power steering pump.
  – Equipped with electrical back-up motor
Hydraulic Brake Power-Assist Systems

• Hydroboost Systems
  – First mode: engine running and no brake application, hydraulic pressure delivered to inlet of booster and travels through unit unrestricted.
  – Second mode (braking mode): driver pushes brake pedal.
  – Third mode: driver holds brake pedal depressed at any point.
  – Fourth mode: electrical backup motor.
Hydraulic Brake Power-Assist Systems

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Air-Over-Hydraulic Braking Systems

- Air Booster Units
  - Convert control line air pressure from foot brake valve into hydraulic pressure to operate wheel cylinders or calipers and apply brakes.
  - Indirect-acting type and direct-acting type.
Air-Over-Hydraulic Braking Systems

• Indirect Air Booster Operation
  – Pneumatic [air] section and hydraulic section [master cylinder] separated by seals.
  – Relay valve part of the assembly.

• Direct Air Booster/Stroke Detector Operation
  – Foot brake valve supplies control line pressure directly to pneumatic piston.
  – Atmospheric pressure on non-pressure side of pneumatic piston exhausts through breathe.
Air-Over-Hydraulic Braking Systems

• Piston Stroke Detector
  – If brakes too far out of adjustment or fault occurs in hydraulic circuit, pneumatic piston will have to stroke excessively to operate wheel cylinders.
  – All types of boosters have a piston stroke detector to warn of this condition.
Park Brake and Emergency Circuits

• All vehicles required to have park brake system that can act as emergency brake should there be failure of service brakes.
  – Tandem arrangements: either one or the other part of tandem system designated as emergency brake, depending on which service system fails.
  – Hydraulic braking systems: park or emergency brake mechanically operated hand brake
  – Air-over-hydraulic systems: spring brakes often used as parking brakes.
• Spring Brake Chamber/Wheel Cylinder
  – In brake-type wheel cylinder, design enables it to actuate brakes when activated by spring brake chamber providing a parking brake.
Park Brake and Emergency Circuits

• Park Brake Off and Applied
  – When park brake and service brake at rest, spring brake chamber charged with air pressure from hand brake valve.
  – When park brake applied, air pressure exhausted from spring brake chamber.
  – When park brake is released while service brake is applied, air pressure from park brake valve holds park brake off.
Park Brake and Emergency Circuits
Hydraulic Brake Anti-lock Braking System (ABS)

- Configurations of Hydraulic ABS
  - Single-channel ABS
  - Two-channel ABS
  - Three-channel ABS
  - Four-channel ABS
  - Four-channel ABS most commonly found today.
Hydraulic Brake Anti-lock Braking System (ABS)

- ABS Module
  - ABS electronic control module is brain behind ABS system.
  - Contains powerful computer that controls all functions of ABS system.
  - ABS system can be designed to provide stability control for vehicle.
Maintenance of Hydraulic Brake Systems

• Hydraulic brake systems components: brake master cylinder, wheel cylinders, brake shoes, drums/discs.
  – System inspected in two ways: foot-pressure applied and conduct a system test.
  – Whenever hydraulic brake circuits are opened to replace components, air can enter the system.
  – Air must be removed because, unlike hydraulic fluid, air is compressible.
  – If it remains in system, brake operation will be poor or non-existent.
Summary

• Medium- to heavy-duty vehicle hydraulic braking systems need power assist to operate satisfactorily.
• The power assist can be supplied by vacuum, hydraulic pressure, or air pressure.
• Hydraulic braking with vacuum assist typical for lighter-duty vehicles.
• Hydroboost systems and air-over-hydraulic systems used on medium- and heavy-duty vehicles.
Summary

• In all hydraulic braking systems, pushrod exerts force on piston(s) in master cylinder, causing increase in fluid pressure that results in force being applied to brake pads and shoes.
• Vacuum-assisted braking systems use atmospheric pressure to intensify braking effort.
• Hydroboost systems use hydraulic pressure supplied by power steering pump or a dedicated pump to intensify braking effort.
Summary

• Air-over-hydraulic brake systems use conventional hydraulic brake system.
• Drum brakes most common; some vehicles may have disc brakes on the front axle.
• Air-over-hydraulic systems use compressed air to intensify braking effort.
• Braking systems complex; components depend on whether system uses drum or disc brakes.
• Drum brakes use brake shoes in various configurations and adjusters; disc brakes use pads.
Summary

• Today, drum brakes generally found only on vehicle’s rear wheels.
• Drum brake has two brake shoes, with a friction material called a lining attached.
• These shoes expand against brake drum’s inside surface and slow wheel down.
• Even though drum brakes self-energizing, they commonly overheat and cause brake fade.
• Disc brakes slow rotation of wheels by friction caused by pushing brake pads against a brake disc with a set of calipers.
Summary

• Disc brakes offer better stopping performance than drum brakes and provide much higher braking force per lb (kg) of brake weight.
• Disc brake performance improves as components heat up.
• Drum brake performance deteriorates as components heat up.
• In addition to foot brakes, vehicles use hand brakes mechanical or electrically activated.
Summary

• Common components in hydraulic braking and air-over-hydraulic brake systems: master cylinder, wheel cylinder, and brake booster.
• Hydraulic brake systems use variety of valves to control system operation.
• These include proportioning valves, metering valves, pressure differential valves, and/or combination valves.
• Air-over-hydraulic systems include systems for air supply, foot brake valve, air booster units, and fail safe systems.
Summary

• Air boosters can be indirect or direct.
• Indirect are found on heavier trucks; direct found on lighter trucks.
• Boosters positions: released, applied, balanced
• As a fail safe, air-over-hydraulic braking systems required by regulation to use tandem system design so that one system can compensate if the other fails.
• All vehicles are required to have park brake system that can act as emergency brake should there be a failure of the service brakes.
Summary

• Spring brake actuators critical components of park and service brake operation.
• Most hydraulic brake systems equipped with four-channel ABS; each of four wheel brakes controlled individually.
• Vehicles with ABS system can use ABS system to operate electronic stability system to enhance vehicle safety.
• ABS components can be used to provide traction control on lighter vehicles.