Chapter 29
Braking Fundamentals
Introduction

• After vehicle has stopped, braking system of heavy trucks—not drive train—is used to keep vehicle parked.
• Braking systems integral to stability control, collision avoidance, rollover protection, traction control systems.
• Braking system has large element of electronic control operating braking system with virtually no driver input.
Introduction

• Brakes convert vehicle’s kinetic energy into heat energy using friction.
• Heat in brake components dissipated to atmosphere through brake design factors.
• Unless build-up of heat in brake parts is minimized, heat accumulations will lead to loss of braking efficiency and damage to brake components.
Introduction
How Brakes Work

- Braking system takes vehicle power stored as kinetic energy (energy of body in motion) and converts it back into heat through friction.

- Using brake drums or discs attached to wheels, friction is produced by forcefully applying heat-resistant braking material against these rotating components.

- Friction’s by-product—heat—is dissipated into the air.
How Brakes Work

• With the heavier weight and the speed commercial vehicles travel, power generated by brakes must be several times that of the engine.
• Many times more power is required to slow and stop a vehicle than required to accelerate a vehicle.
How Brakes Work

It takes more power to slow down than it does to accelerate

**Accelerating**

<table>
<thead>
<tr>
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<th>Horse</th>
<th>Truck</th>
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<tr>
<td>60 mph</td>
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+ 100 Hp  + 75 kW

**Slowing Down**

<table>
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<tr>
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<th>Horse</th>
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<td>60 mph</td>
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+ 1000 Hp  + 745 kW

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How Brakes Work

• Influence of Vehicle Weight and Speed
  – As the weight of vehicle is doubled, kinetic energy converted into heat energy is doubled.
  – Doubling vehicle weight or speed needs twice the braking power for same deceleration rate.
  – When weight and speed both doubled, braking force must increase by factor of eight.
  – Heavy-duty brakes specified not by type of vehicle but by weight carried by an axle and its location on the vehicle.
How Brakes Work

• Influence of Vehicle Weight and Speed
  – Increasing vehicle speed has greater effect than vehicle weight on braking system power.
  – Increased vehicle weight and speed need greater braking system pressure, larger friction surfaces, and greater capacity to absorb as well as dissipate heat.
How Brakes Work

- Brakes Applied
  - 20 mph (32 km/h) to 30 ft (9 m)
  - 40 mph (64 km/h) to 120 ft (36 m)
  - 60 mph (96 km/h) to 270 ft (82 m)
How Brakes Work

• Brake Torque and Inertia Shift
  – Components used to attach brake mechanism capable of repeated torque transfer from brake to axle.
  – Deceleration during braking produces shift in vehicle weight from rear to front of vehicle.
  – The effect (inertia shift) moves weight from rear axles and transfers it forward.
How Brakes Work

• Brake Torque and Inertia Shift
  – Wheel lock-up: tires skid; driver loses ability to steer vehicle
  – Too much braking by front axle can cause jackknifing.
  – Too much braking by rear axles can cause trailer or rear axles to swing out.
Types of Braking Systems

• Another term for brake application force is actuation pressure.
  – Force multiplication needed by braking system: multiply brake pedal input force enough to effectively apply brakes.
  – Hydraulic multiplication of driver input force: multiply brake pedal force and supply pressure to multiple wheel cylinders or brake caliper pistons.
Types of Braking Systems

• Air Systems
  – Best choice; large amount of air instead of liquid needed to actuate all brake chambers at each axle end.
  – Supply of air limitless; allows for minor leaks without loss of braking.
  – Connecting tractor and trailer braking systems easier using air lines than hydraulic hoses.
  – Not sensitive to altitude changes.
Types of Braking Systems

• Air Systems
  – Simpler foundation brakes (shoes, drums, components at wheel ends) simpler and fewer
  – Air can be compressed and store energy like a coil.
  – Air must be pressurized, filtered, and stored in large, multiple reservoirs.
  – Speed of air pressure transmission much slower than hydraulic system.
  – Control of air pressure through brake circuits requires more valves and components.
Types of Braking Systems

• Air Systems Disadvantages
  – Driver dissatisfaction with delay: air system empty and needs to build up pressure after engine started.
  – Little to no feedback from brake pedal about braking effort.
  – Larger brake system components and diameter lines required.
  – Air brake system complexity requires technicians have more knowledge and skill when servicing.
Types of Braking Systems

• Hydraulic Systems
  – Higher line pressures; use of smaller components
  – Faster force transmission through smaller lines
  – Improved feedback during braking application
  – Lower initial cost due to fewer and smaller components
Types of Braking Systems

- Power Steering Pump
- Power Steering Gear
- Hydromax Booster
- Disc Brake
- Disc Brake
Types of Braking Systems

• Brake System Components
  – Brake foundations: braking components found at wheel ends.
  – Dual brake circuits: two separate brake circuits control front and rear axle braking systems.
  – Parking brakes: with exception of trucks using drive line park brake, all vehicles use foundation brakes for keeping vehicle stationary when parked.
Air Brake Foundation Systems

• Types of Brake Foundation Configurations
  – Cam brakes: most common foundation brake found on heavy trucks today.
  – Air disc systems squeeze brake pads against rotor attached to wheel to produce braking action.
  – Wedge brakes use leverage to multiply braking force.
  – Air pressure proportional to brake pedal travel supplied primary and secondary air systems.
Air Brake Foundation Systems
Air Brake Foundation Systems

• Cam Brake System
  – Air brake chamber, automatic slack adjuster, S-camshaft, brake hardware, shoes and linings, spider, brake drum
  – Cam brake: “S”-shaped camshaft, or S-cam, used to force brake shoes onto brake drum.
  – When torque applied to camshaft through S-shaped cam ramps, rollers on brake shoes ride up cam, causing shoes to contact brake drum.
  – Shoe-to-drum friction slows and stops vehicle.
Air Brake Foundation Systems

Diagram showing components of an air brake system:
- Cam Rollers
- S-Cam
- S-Cam Bushing
- Slack Adjuster
- Actuator Chamber
- Anchor Pins
- Spider
- Shoes
Air Brake Foundation Systems

• Cam Brake System
  – Primary-secondary shoe design with fixed anchor points for each shoe opposite camshaft end of shoe.
  – Self-energizing causes shoe-drum friction to rotate brake shoe into drum with more force.
  – Effect is brake will apply “harder” or “bite” into drum with greater force increasing friction.
  – Self-energization can cause uneven brake shoe wear.
Air Brake Foundation Systems

- Cam Brake System
  - Depending on direction camshaft rotates to force primary shoe against drum, cam referred to as left- or right-hand camshaft.
  - Left-hand cams rotate counterclockwise; right-hand cams turn clockwise.
  - Cam-same camshaft rotates in same direction as drum to energize brakes.
  - Cam-opposite camshaft rotates opposite drum’s rotation to energize brakes.
Air Brake Foundation Systems

• Cam Brake System
  – To support camshaft between brake chamber and brake spider at wheel end, a support bracket is used to enclose camshaft.
  – S-cams shimmed with washers to prevent any excessive end play in cam bracket.
Air Brake Foundation Systems

• Cam Brake System
  – Cam brakes use brake shoes made in different sizes to match an axle weight rating.
  – One or two pieces of friction material attached to brake shoe table (brake block/brake lining)
  – Coefficient of friction (CoF): amount of force required to move an object while in contact with another.
  – Two categories for friction material: non-asbestos organic (NAO) lining and semi-metallic linings
Air Brake Foundation Systems

• Cam Brake System
  – Selection of brake block material: taking in axle weight, service condition—severe, heavy, and moderate
  – AL factor: size or surface area of brake chamber multiplied by length of slack adjuster in inches.
  – All brake block friction material identified by a stencil on its edge called an edge code.
Air Brake Foundation Systems

• Cam Brake System
  – Brake fade: inability of brakes to maintain their effectiveness
  – Types of brake fade: heat, water, mechanical, and chemical fade; glazing of lining
  – Heat fade: loss or reduction in coefficient of friction as brake temperature increases
  – Anti-fade: opposite condition of heat fade, where coefficient of friction increases as brakes get hotter
Air Brake Foundation Systems

• **Cam Brake System**
  
  – Water fade: water gets between friction surfaces and drum and acts as lubricant, reducing braking efficiency.
  
  – Mechanical fade: drums expand due to heat.
  
  – Chemical fade: steam or gases from vaporized lining materials form between hot lining and drum, reducing coefficient of friction.
  
  – Glazing: characterized by hard, glassy burnt appearance to lining surface.
Air Brake Foundation Systems

• Cam Brake System
  – Brake torque: force applied to foundation brakes during braking
  – Brake drums must:
    • Resist distortion and brake fade
    • Resist wear, scoring, and heat damage
    • Absorb heat and transfer it to outer surface
  – Two types of brake drums:
    • Cast drums made from cast iron
    • Centrifuge drums made with cast iron core surrounded by steel band
Air Brake Foundation Systems

- Dust Shield Recess
- Open End
- Squealer Band
- Barrel
- Balance Weight
- Mounting Bolt Holes
- Hat Section
- Drum Back / Closed End
- Pilot Chamfer Inboard
- Pilot Diameter
- Pilot Chamfer Outboard
- Mounting Flange
- Friction Surface Width
- Braking Surface Width
- Open End Chamfer
- Brake Drum Diameter

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Air Brake Foundation Systems

• Cam Brake System
  – Two types of brake drums: inboard or outboard—mounted on disc type wheels.
  – Type of wheel end a drum is mounted to will change the features of a drum.
Air Brake Foundation Systems

• Cam Brake System
  – Applying the brakes supplies air pressure to actuator chambers proportional to brake pedal travel.
  – Brake chambers then take air pressure and convert it to mechanical force to apply brakes.
  – Actuators are like brake chambers except they have additional components such as power springs used to apply park brakes or internal pushrod lock mechanisms.
Air Brake Foundation Systems

• Cam Brake System
  – Standard brake chamber: 2.5" stroke travel
  – Some 3" stroke chambers called long stroke chambers.
  – Service chamber: when brake chamber uses only a single chamber.
  – Dual brake chambers contain spring brake actuator and two separate air and mechanical actuators in a single housing.
Air Brake Foundation Systems

• Cam Brake System
  – Service chamber requires air pressure to apply brakes.
  – Park/emergency spring brake needs air pressure to release brakes.
  – In event of a loss of vehicle air pressure and ability of air system to build pressure, power spring will apply brakes.
Air Brake Foundation Systems

• Cam Brake System
  – Power spring can be released by inserting a release bolt into spring and tightening the bolt.
  – Release or caging bolt attached to every dual chamber brake actuator.
  – Roto-chambers: actuators with unique diaphragm construction; delivers consistent output force regardless of pushrod position.
Air Brake Foundation Systems

- Inner Diaphragm Clamp
- Outer Diaphragm Clamp
- Diaphragm
- Return Spring
- Push Rod Assembly
- Boot
- Lock Nut
- Yoke
- Mounting Stud
- Cover
- Body
Air Brake Foundation Systems

• Cam Brake System
  – Slack Adjuster
    • Mechanical lever between brake chamber and foundation brake assembly
    • Multiply force from brake chamber to camshaft of foundation brakes.
    • Remove excessive chamber pushrod travel to maintain minimal clearance between brake shoe and drum on a cam brake system.
    • Two types: manual and automatic.
Air Brake Foundation Systems

• Cam Brake System
  – Automatic Slack Adjusters (ASA)
    • Stroke sensing ASAs: makes adjustments to slack based on measured rotation between a brake application and release.
    • Clearance sensing ASAs: reduce pushrod travel based on torque input to ASA.
Air Brake Foundation Systems
Air Brake Foundation Systems

• Air Disc Brakes (ADB) Advantages
  – Lower side-to-side consistency in braking torque
  – Lower potential for heat- and mechanical-related brake fade
  – Better cooling with air disc brakes
  – Consistent actuation force
  – Shorter service time
Air Brake Foundation Systems

• Air Disc Brakes (ADB)
  – Disc brakes use rotors instead of drums.
  – Floating caliper design (caliper floats on two pins); two major parts: caliper and carrier
  – Bendix ADB system: air chamber as actuator
  – When brake actuation has finished, brake caliper will return to its initial position.
  – Internal automatic clearance sensing adjusting mechanism is used.
Air Brake Foundation Systems
Air Brake Foundation Systems

• Wedge Brakes
  – Ramp-and-roller design inside wheel cylinder to multiply force supplied by an air chamber.
  – Simplex system: single actuator
  – Duplex systems: dual actuators
  – Due to greater complexity, cost, unpredictable release, wedge brakes not popular.
  – Adjusting mechanism incorporated into housing of brake itself
Air Brake Foundation Systems

Simplex Wedge

Duplex Wedge
Summary

• Moving vehicle has tremendous amount of kinetic energy.
• To stop vehicle, kinetic energy must be converted into heat energy through braking system.
• Weight and speed have different effects on braking requirements.
• Doubling the weight requires double the braking force, but doubling the weight and the speed requires eight times the braking force.
Summary

• To operate, brakes must turn kinetic energy into heat and be capable of dissipating heat quickly, or they will lose their effectiveness.
• As a vehicle brakes, its weight shifts from back to front. Brakes must be designed to be able to handle this inertia shift.
• All brake systems use some force to multiply braking effort applied to brake pedal by driver.
• This force can be compressed air, hydraulic pressure, or a combination of the two.
Summary

• Compressed air is primary method of choice to multiply brake force for on highway trucks.
• Air brake systems are very versatile and can be easily hooked up and disconnected; there is no worry of leaks or spills, as in hydraulic systems.
• Air brake systems can handle small system leaks without adverse effects.
• All brake systems are dual brake systems; if one system fails the other can still stop the vehicle.
Summary

• Because of their simplicity, cam brakes most popular air brake foundation brake system in on-highway trucks.

• Air brake systems are subject to federal regulation under Federal Motor Vehicle Safety Standard (FMVSS) 121.

• S-cam used in cam brakes can be left- or right-handed.

• Brake friction material is edge coded to ensure material used is matched to vehicle.
Summary

• Brake chamber size and slack adjuster lever length combine to deliver a twisting force to the brake camshafts.

• Brake chambers are air operated diaphragm chambers used to apply pressure to the brakes.

• Actuators have dual chambers with one containing a power spring to operate emergency or parking brake system.
Summary

• Spring brake chambers must be disarmed before they are discarded by cutting the power spring with an acetylene torch.
• Slack adjusters used to keep brake chamber stroke adjusted.
• All modern vehicles are equipped with automatic slack adjusters.