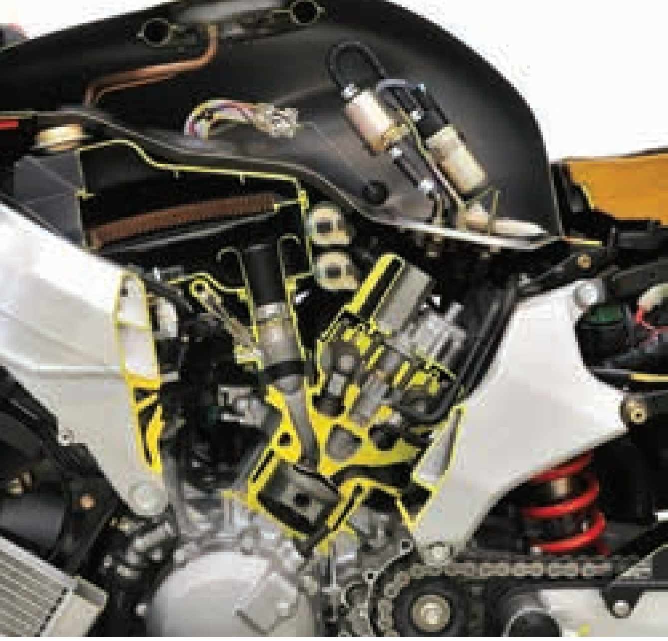

Chapter 18
Frame, Chassis, and Suspension Systems

Learning Outcomes

After studying this chapter, you will be able to:

- ✓ Describe the types of frames used on today's powersports vehicles.
- ✓ Identify the types and explain the operation of motorcycle telescopic front suspension systems.
- ✓ Define rake, trail, and offset angles in reference to motorcycle steering geometry.
- ✓ Perform maintenance and service on motorcycle front suspension system components.
- ✓ Explain rear swingarm and shock absorber construction and operation as part of a motorcycle rear suspension.
- ✓ Recall the importance of suspension balance.
- ✓ Summarize the inspection process for front and rear motorcycle suspension systems.
- ✓ Define the alignment angles measured during an ATV and UTV four-wheel alignment.
- ✓ Troubleshoot frame and suspension system problems.

Technical Terms

backbone frame
camber
caster
chassis
delta-box frame
diamond frame
double cradle frame
dual-shock rear suspension
frame
offset
oil damper
pentagonal frame
pivoting link front suspension
progressive link rear suspension
rake
rear suspension
shock absorber
shock absorber spring
single cradle frame
single-shock rear suspension
spindle
stamped frame
steering damper
steering geometry
suspension system
telescopic front suspension
telescoping fork
thrust angle
toe-in
toe-out
trail
triple clamp

Motorcycles, ATVs, UTVs, and scooters must handle properly at all times. Proper handling is critical to both rider safety and comfort. It is particularly important when accelerating, stopping, turning, and going over bumps. The design of the ***chassis***, which includes the frame and suspension system, is a major factor determining the handling characteristics of a motorcycle. This chapter discusses frame and suspension designs and how they affect performance and dependability. The chapter also covers fundamental inspection, service, troubleshooting, and repair procedures for frames and suspension systems.

Frame

The ***frame*** is the backbone of any powersports vehicle. It serves as the skeleton on which virtually all other parts are attached. A critical function of any frame is to provide a non-flexing mount for the engine, suspension, and wheels, **Figure 18-1**. The frame also provides

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Figure 18-1. The primary function of the frame is to provide a non-flexing platform for the engine, suspension, and wheels.

a rigid structure between the front suspension assembly, including the steering head and steering stem, and the rear suspension assembly, including the rear swingarm or A-arms. Cornering and accelerating tend to twist or misalign these assemblies.

The frame absorbs vibration from the engine, and to some degree, the road surface. To prevent excessive vibration to the rider and premature fatigue of structural members, the appropriate frame structure is determined by the engine type and the intended use of the motorcycle. Two slightly different frame designs can have significantly different vibration-absorbing or vibration-generating characteristics. One design may be more suitable than another, even with the same engine installed.

Frames can be made of aluminum or steel. The frame's material is chosen to match the machine's function. Aluminum frames are used for on-road sport motorcycles with medium- and large-displacement engines and for motocross motorcycles. Aluminum alloys are lighter than steel, but the frames made from aluminum alloys must be bulkier to provide the same strength and are more expensive to produce. Steel frames, (usually mild steel) are used in most other motorcycles, ATVs, UTVs, and scooters. They are very economical and easy to manufacture while providing adequate strength.

A wide variety of tubing and pressed steel shapes, as well as castings and forgings, are combined to form the optimal frame for a particular model. Some of today's frames are made almost entirely of round steel tubing of various sizes and thicknesses. Others are made of square steel tubing or a combination of extruded aluminum alloys. Round tubing has the same strength in all directions. Square and rectangular tubing, as well as other variants, have different strength characteristics in different directions. When maximum strength is required in a vertical direction, and strength in a horizontal direction is less important, rectangular tubing is used. Most aluminum frame members use some form of rectangular tubing, although a few pieces may be square. See **Figure 18-2**.

A frame can be lightened by changing the types of tubing used to build the frame. Thin wall rectangular aluminum tubing is given greater strength by adding internal ribs and producing it by extrusion, the process of forcing semi-soft metal through a die. Some

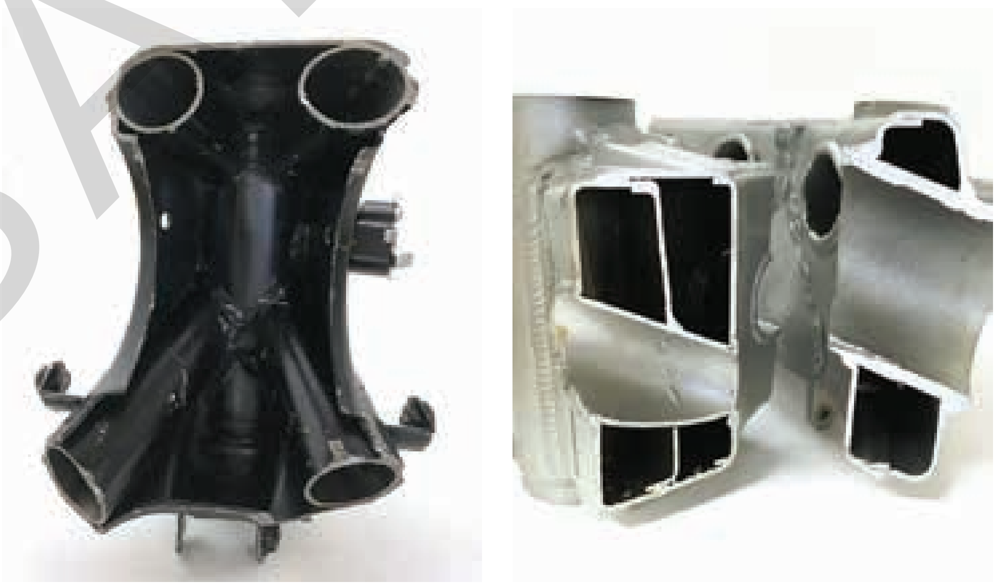

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Figure 18-2. Frame cross sections. A—Cross section of a steel frame made up largely of round tubing. B—Cross section of an aluminum frame.

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models use a specially modified pentagonal or hexagonal aluminum tubing to improve the frame's strength-to-weight ratio and rigidity in one or more directions. In some cases, this tubing allows for a more compact and unobstructed riding position. Most aluminum and steel frames include some castings or pressed steel sections to form strong and compact tube joints and to form pivot points and major attachment points.

Subframes are an important part of all chassis frame assemblies. The subframe may be fixed or it may be removable to improve service access on some models. Removable subframes are used on sport, on-road, and motocross motorcycles. Some chassis subframes (the removable rear portion of the frame that supports the seat and rear fender) are made of titanium alloys. In addition to titanium's excellent weight advantage over most metals, including aluminum, it is resistant to corrosion.

The frames of most ATVs and UTVs are made of steel and are ruggedly constructed, **Figure 18-3**. Their function, like that of motorcycle frames, is to provide support for all the vehicle's components. Scooter frames are simple in design, usually using the engine as part of the rear suspension.

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Figure 18-3. An ATV frame serves the same function as a motorcycle frame.

Frame Designs

Frame designs can be classified into a few categories. Frames are chosen for a particular model according to the engine's displacement, the designed use of the machine, ease of service, cost, and visual appeal. The following is a description of the more popular designs. Motorcycle frame designs are constantly being upgraded. It is not uncommon to find frames that use combinations of more than one design.

Cradle Frame

Cradle frames derive strength from the triangulation of support tubing. Almost anywhere you look on a cradle frame, triangles are formed at major stress areas. Cradle frames are relatively lightweight and extremely strong.

There are two cradle frame designs: single cradle and double cradle. The ***single cradle frame*** has one down tube and one main pipe at the front of the engine, **Figure 18-4**. The frame structure surrounds the engine. This frame is mainly used on off-road motorcycles and light and midsize on-road sport motorcycles because of its weight, strength, and ease of service.

The ***double cradle frame*** is similar to the single cradle frame, but it has two down tubes and two main pipes, resulting in increased rigidity. See **Figure 18-5**. On some models, part of the down tube may be removable to facilitate engine removal. The double cradle frame is mainly used on large-displacement, multi-cylinder, on-road motorcycles. On some large, high-powered motorcycles, additional support may be provided by gussets, **Figure 18-6**.

Backbone Frame

On the ***backbone frame***, the engine hangs from the top of the frame at the rear and acts as a structural part of the rear suspension, **Figure 18-7**. Because the engine is not enclosed by lower frame tubes, engine service is simplified. This type of construction allows freedom in the overall

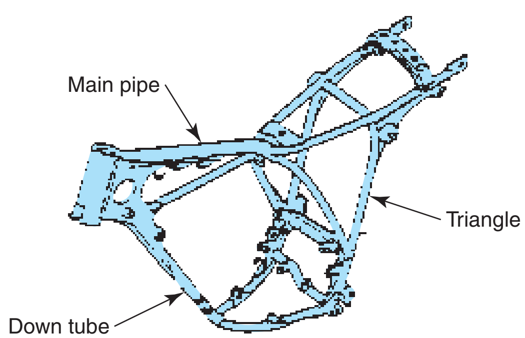

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Figure 18-4. Single cradle frame.

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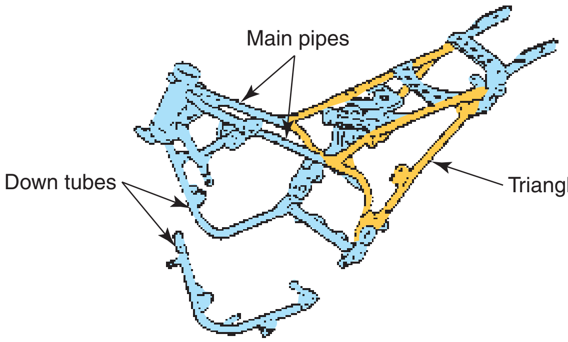

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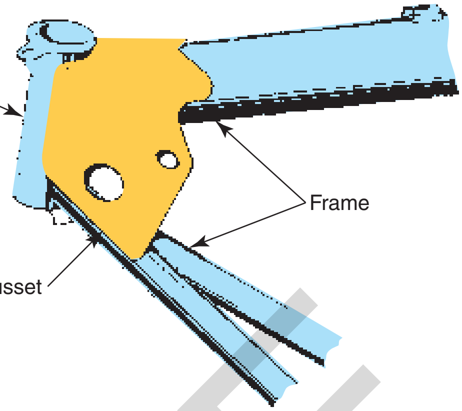
Figure 18-5. Double cradle frame. A—Note how triangles are often formed at junctions of cradle frame tubes. B—Down tube removed from frame. Note the holes that allow the down tube to be bolted and unbolted from the frame.



Triumph Motorcycles, Ltd.

Figure 18-6. Gussets reinforce the area where the steering head is welded to the frame.

Honda Motor Co., Ltd.

Figure 18-7. Backbone frame.

vehicle design, including seating and rider mounting and dismounting. The backbone frame is relatively heavy to provide adequate strength. It is economical to produce and is used mainly on scooters.

Diamond Frame

The ***diamond frame*** is similar to the single cradle frame, but the lower section of the down tube is not connected to the other frame tubes, **Figure 18-8**. The engine forms the final portion of the frame structure. Mounting the engine gives the frame strength. The diamond frame is a simple design that is lightweight and provides excellent serviceability. It is used on small and medium motorcycles.

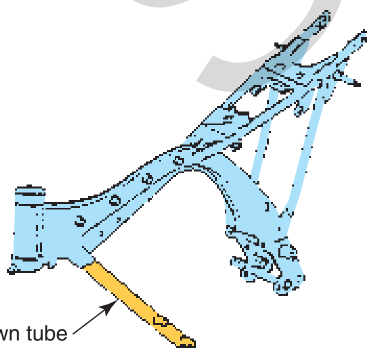


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Figure 18-8. Diamond frame.

Delta-Box Frame

The ***delta-box frame***, shown in **Figure 18-9**, features a strong steel or aluminum triangle between the steering head and the swingarm pivot. This design provides responsive handling characteristics and is used on sport motorcycles and off-road motorcycles. It may also be referred to as a perimeter frame.

Pentagonal Frame

The ***pentagonal frame*** is a five-sided frame similar to the delta-box frame. It is made of cast and extruded aluminum and has good torsional rigidity, **Figure 18-10**. Its rails extend from the steering head section to the swingarm pivot. The seat of the subframe is bolted on and can be easily removed for maintenance. This frame is also called a perimeter frame.

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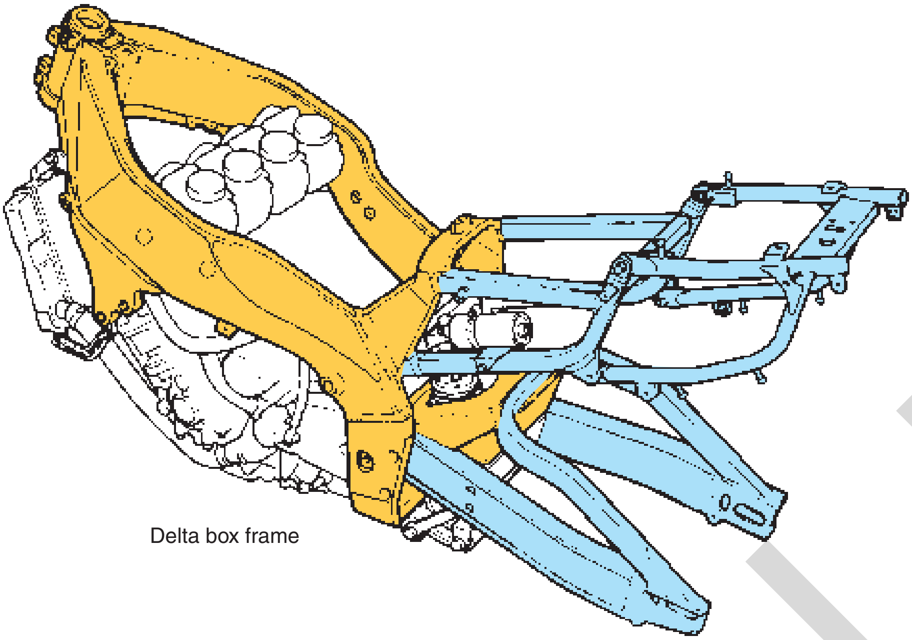
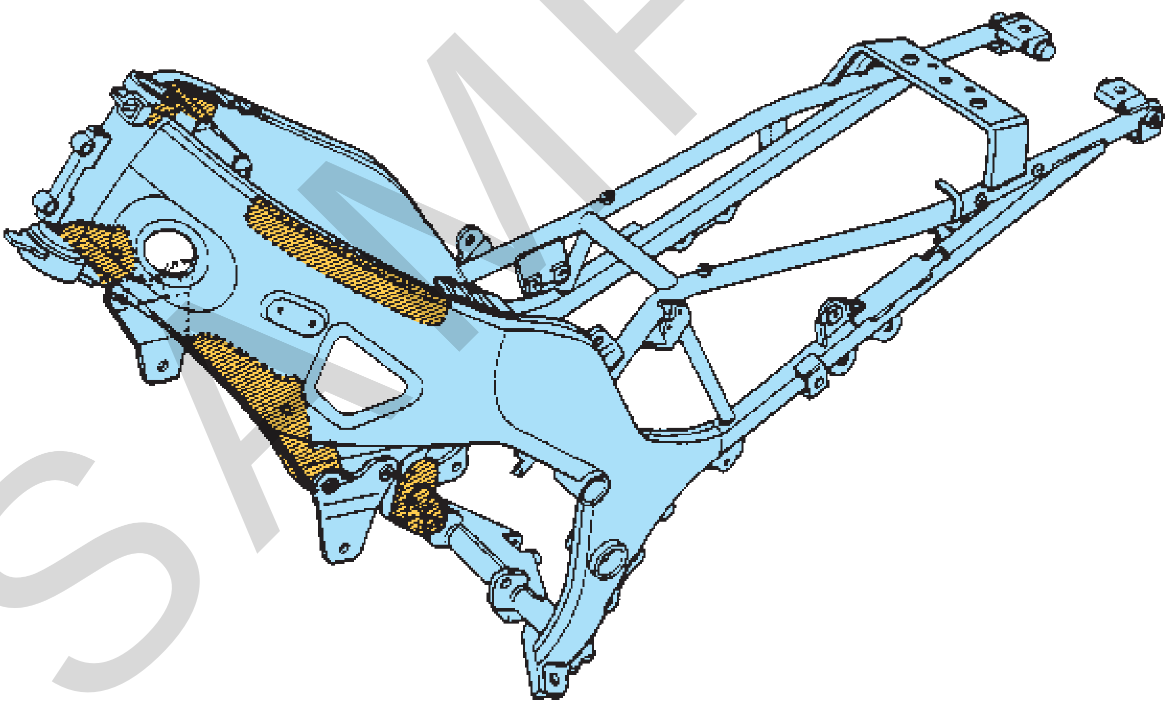


Yamaha Motor Corporation U.S.A.

Figure 18-9. Delta-box frame.



American Suzuki Motor Corporation

Figure 18-10. Pentagonal, or five-sided, frame. The yellow areas show the locations of gussets.

Stamped Frame

The ***stamped frame*** consists of two pieces of stamped sheet metal welded together. Frame strength is achieved by the stamping's shape. A stamped frame is the least expensive to produce and is normally used on inexpensive small-displacement motorcycles and ATVs. The frame was common in the 1960s and 70s. It is not as common today, but it is an economical choice that may still be found in the field.

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Frame Inspection

Visually check the frame for damage or bent tubes and components. If paint cracks appear on the frame, inspect the affected areas closely to determine whether the frame itself is cracked. Apply a spray penetrant to closely inspect and verify any suspected cracks. Although it is possible to weld some cracked frames and straighten frames that are slightly bent, it is best for safety and liability purposes to replace damaged frames.

The mid-frame, the center section of the chassis, must be inspected. Check this area for chipped paint, corrosion, damage, and straightness, and make repairs or replace as needed. Check the fasteners on the engine mounts, side stand, center stand, brake pedal, and foot pegs. Replace any damaged fasteners. Lubricate the brake pedal, foot pegs, center stand, and side stand pivots.

Straighten the handlebar and check the alignment between the front and rear wheels. If the rear wheel does not align with the front wheel, ensure the drive chain and belt adjusters are adjusted correctly. If the rear wheel leans to either side when viewed from above, **Figure 18-11**, check whether the right or left arm or rear shock absorber mounts (on dual-shock models) are twisted or bent. Proper wheel alignment for ATVs is discussed later in this chapter.

Front Suspension

The ***suspension system*** allows the wheels to follow an irregular road surface with a minimum amount of shock transmitted to the frame. Some vintage motorcycles used an early front suspension system with spring-loaded swingarms mounted on stationary tubes. The arms would simply swing up and down to absorb bumps in the road surface. Today's motorcycle suspensions are a great deal more sophisticated. Three of the most common types are shown in **Figure 18-12**. The front suspension systems on ATVs and UTVs, with the exception of three-wheelers, are more closely related to rear motorcycle suspension systems. Some four-wheelers use automotive style struts. See **Figure 18-13**.

Telescopic Front Suspension

Telescopic front suspensions are made of a pair of inner fork tubes and outer fork sliders that telescope into one another. Within the set of tubes on either side are a spring and an

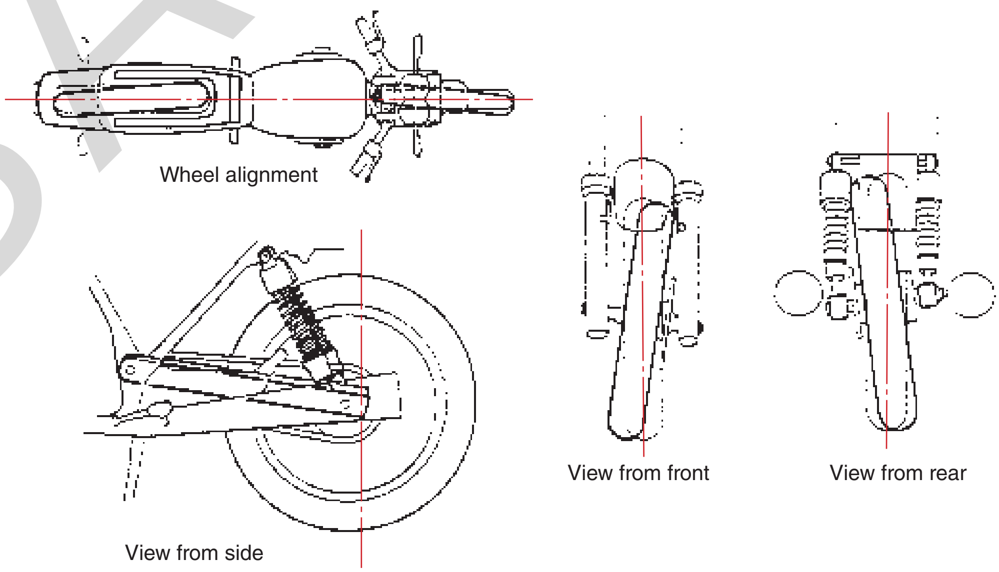

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Figure 18-11. Common frame problems often result in wheel misalignment.

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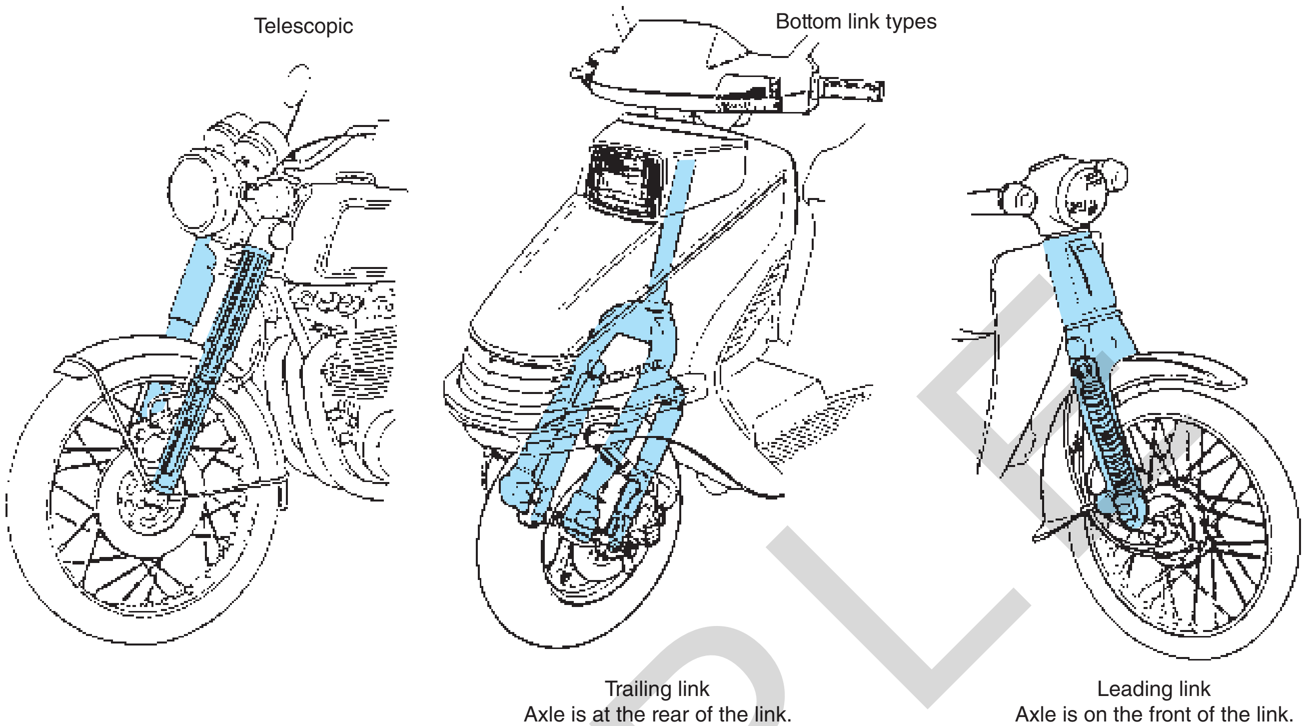

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Figure 18-12. Three of the most common front suspension systems. A—Telescopic. B—Trailing link. C—Leading link.

oil damping system. Some systems use a cartridge damper within the fork sliders. The oil controls the spring's natural tendency to rebound in ever decreasing amounts in both directions. Forcing the oil in each fork leg through a series of small holes or shims and valves separates the rider and motorcycle combination from spring oscillation.

Conventional Telescoping Fork

A ***telescoping fork*** assembly consists of an inner fork tube, an outer fork slider, two triple clamps, a spindle, and related fasteners. The parts are shown in **Figure 18-14**. The fork tubes assemblies are shock-absorbing devices that hold the front wheel in place. They are attached to the motorcycle by the triple clamps and spindle. The ***triple clamps*** secure the fork tubes to the frame and hold them in alignment. The lower triple clamp is an integral part of the spindle. The ***spindle***, or steering stem, on the lower triple clamp passes through the steering head, or hole in the frame. This allows the fork to be turned to the right or left.

In the conventional configuration, the outer fork sliders provide a mounting place for the front wheel axle. They slip over the bottom of the inner fork tubes. Damper rods, or cylinders, are attached to the outer fork sliders and project into the inner fork tubes. This is shown in **Figure 18-15**.

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Figure 18-13. ATV and UTV front suspension systems are similar to automotive front suspension systems. Note the upper and lower control arms and strut.

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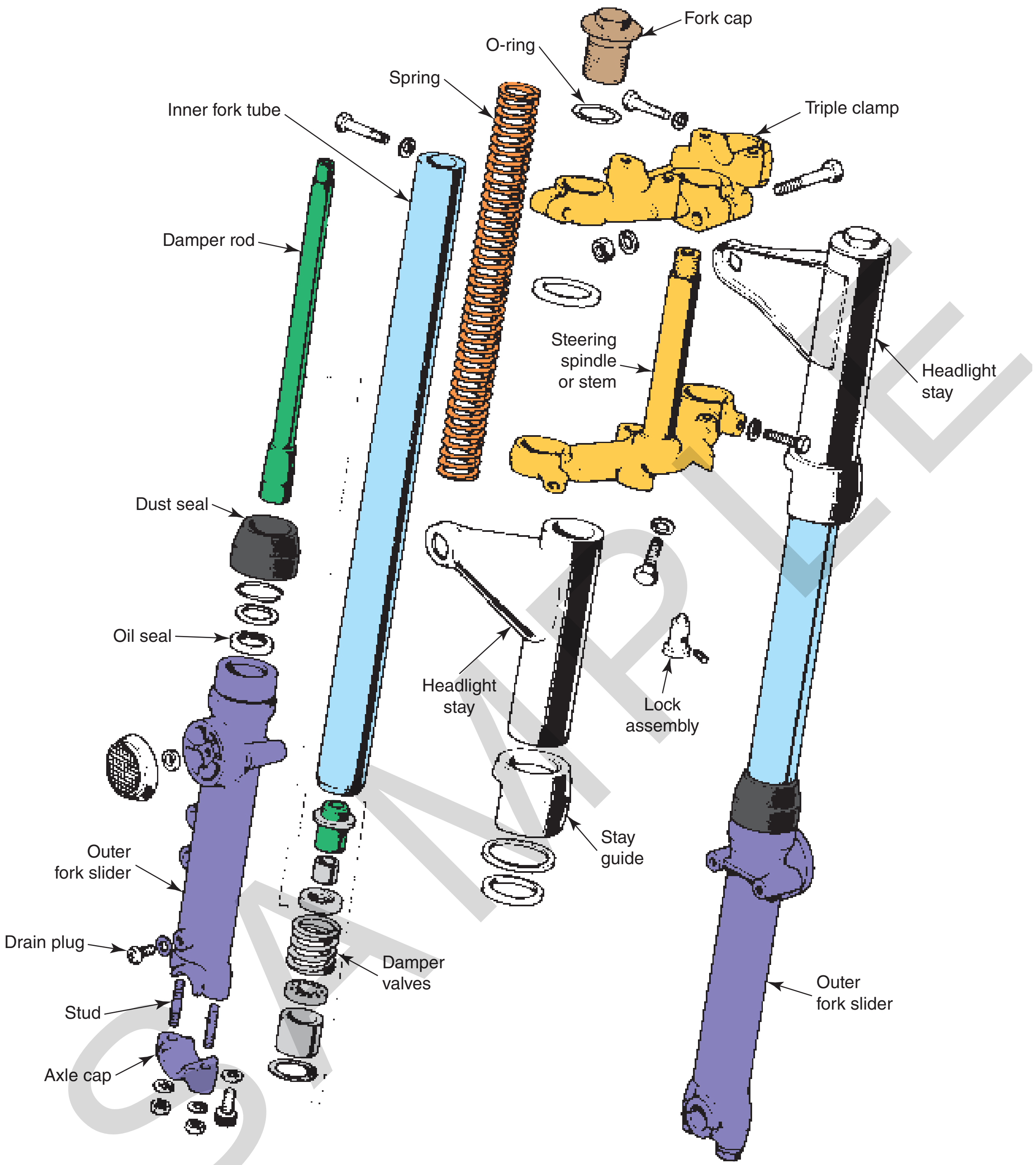

Kawasaki Motors Corporation U.S.A.

Figure 18-14. Exploded view showing typical major front fork components.

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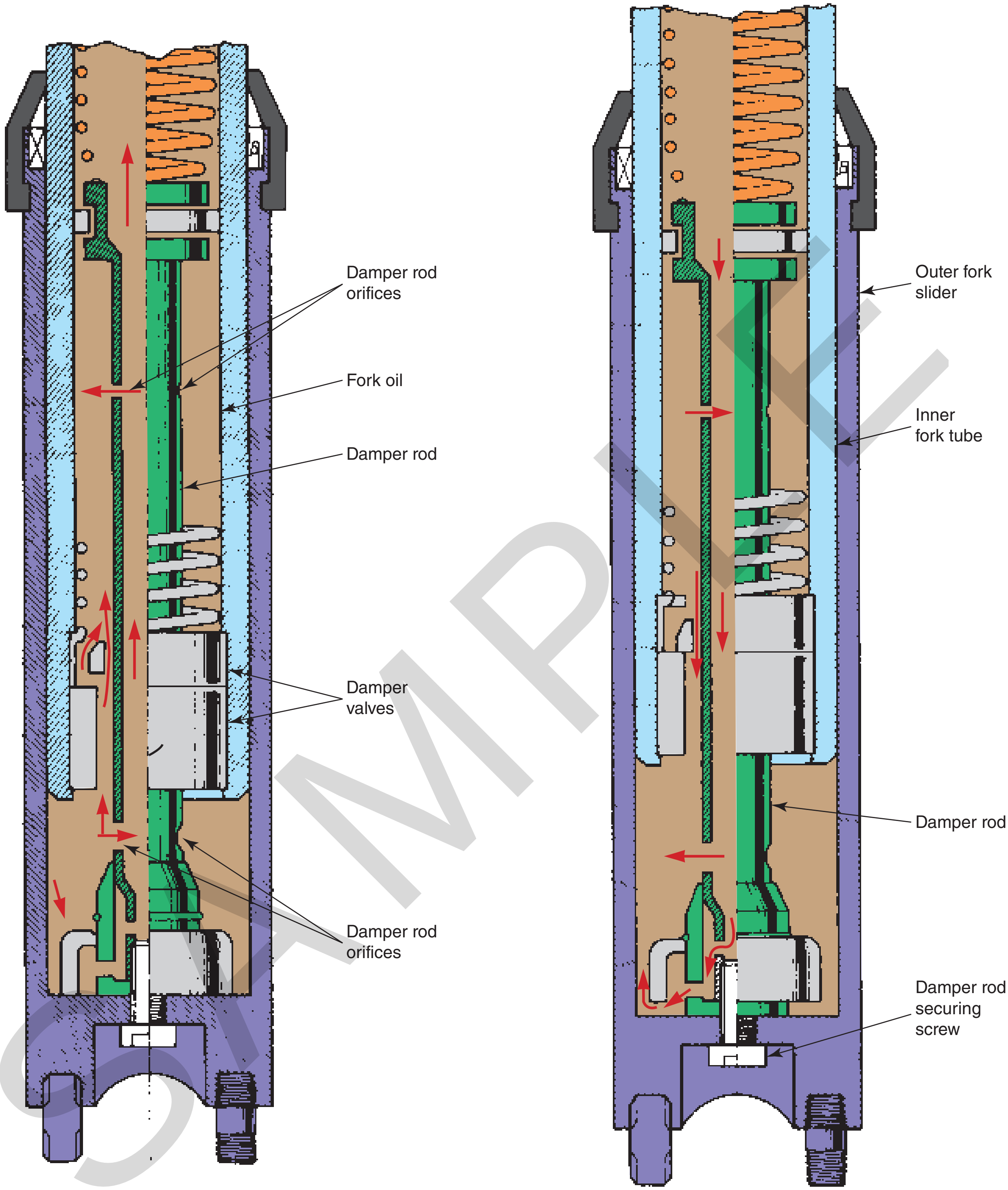

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Figure 18-15. Fork action is controlled by metering the oil flow through valves and orifices in the damper rod. The damper rod is attached to the outer fork slider and protrudes into the inner fork tube.

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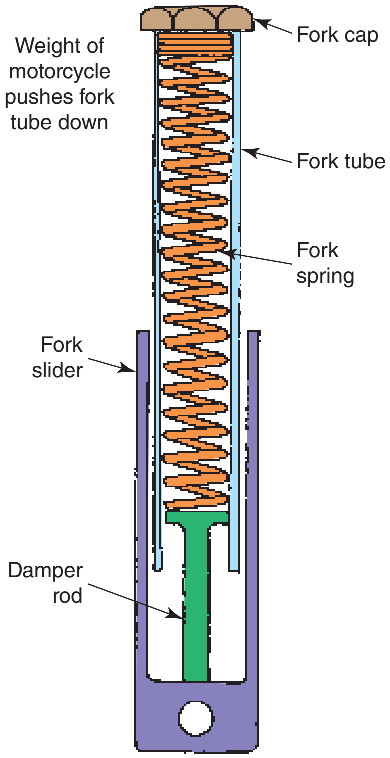

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Figure 18-16. A coil spring, which rests on the damper rod, exerts pressure on the fork cap to support the motorcycle.

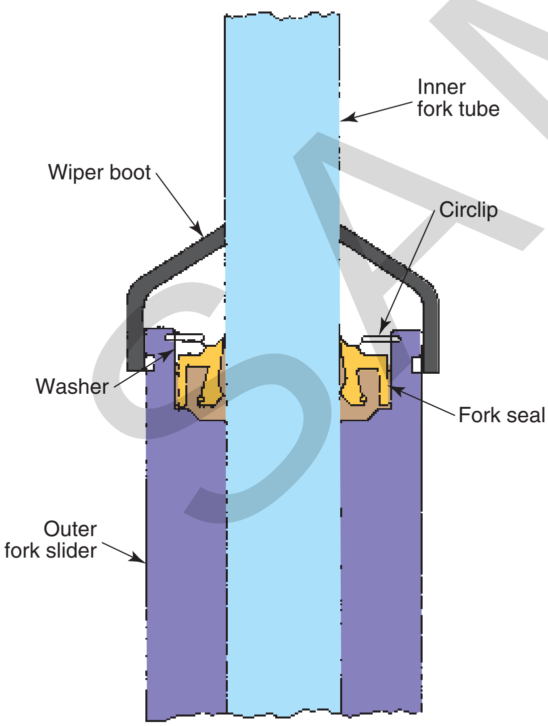

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Figure 18-17. A fork seal mounted at the top of the outer fork slider wipes the inner fork tube, keeping oil in the fork and preventing contaminants from entering the fork.

Damper rods work in conjunction with the fork oil and damper valves and prevent the outer fork sliders from falling off the inner fork tubes at full extension. Coil springs inside the inner fork tubes provide spring pressure to support the motorcycle, **Figure 18-16**. Seals at the top of the outer fork sliders keep oil in and contaminants out, **Figure 18-17**.

While all telescoping forks work on the same principle, there are many design variations. Internal or external springs may be used. In the case of modern air forks, no springs are used. In these types of forks, air or air bladders are used in place of springs to provide ride height and serve the same other purposes as coil springs. Air forks are considerably lighter in weight. On all forks, the axle may be mounted at the bottom or on the front side of the outer fork slider. Damping may be controlled by damper rods or orifices in the inner fork tubes. To provide suspension system adjustment, adjustable dampers and air-assisted springs are also common.

Inverted Telescoping Forks

The inverted, or upside-down, telescoping fork is the opposite of the conventional telescoping fork. The outer fork slider is attached to the triple clamps, and the inner fork tube connects to the front wheel axle. See **Figure 18-18**. Motorcycle forks need to be as ridged as possible and yet remain as light as possible. The major advantages of inverted forks are their strength and reduced weight due to the inner fork tube being shorter and using thinner wall tubing. This results in less steering effort and more responsive handling, as well as better compression and rebound dampening. Forks equipped with adjustable components such as compression and rebound settings allow for fine tuning of the fork action.

Cartridge Forks

Cartridge forks may be used in conventional or inverted telescoping forks. Non-cartridge forks use a damper rod that has orifices through which oil is forced. Under extreme uses hydraulic lock can occur. Cartridge forks eliminate this concern. Most cartridge forks use an inner cartridge and damper rod attached to a valve. The rod is attached to the valve using thin, wafer-like shims that bend and deflect creating resistance to oil flow through the valve. This improves suspension travel over all obstacles and gives the rider the ability to tune the suspension action by "re-valving", which is a process of re-shimming with individually tuned high-speed and low-speed valve stacks. The high and low speeds refer to fork travel, which enables suspension dampening to better match riding conditions.

Twin Chamber Forks

One type of inverted telescoping forks is the twin chamber, or closed chamber, forks. This fork design uses an inner tube that is closed off from the outer chamber. The major difference in this type and the open chamber forks is the cartridge is inverted and a spring or bladder

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is used to keep oil in the inner chamber pressurized. This minimizes oil cavitation (air bubbles) in the inner tube. Oil is used in both the inner and outer chambers of the tube assembly. The main spring is at the bottom of the fork slider submerged in the outer tube's oil. The advantages of this design are constant dampening travel with no lag, which creates a smooth ride.

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Figure 18-18. In an inverted fork, the outer fork slider is attached to the triple clamps, and the inner fork tube is connected to the front wheel axle.

Conventional Telescoping Fork Operation

The fork operates in two phases called strokes:

- Compression stroke.
- Rebound stroke.

During the compression stroke, the inner fork tube moves into the outer fork slider when the front wheel encounters a bump or other abnormality in the road. Oil trapped below the inner fork tube and check valve is forced to flow through the check valve and compression damping holes, **Figure 18-19A**.

The amount of damping is determined by the size of the compression damping holes, the clearance between the check valve and check valve body, and, to a limited extent, the springs. Compression damping can be relatively light since the fork spring provides some of the resistance to compression.

As the inner fork tube nears full compression, the fork tube collar blocks the compression damping holes. This causes a partial hydraulic lock that prevents mechanical bottoming (metal-to-metal contact), **Figure 18-19B**.

During the inner fork tube's rebound stroke, the fork spring causes the outer fork slider to extend, or move out to the outer fork slider. The spring pushes against the top of the damper rod. Oil above the damper rod piston flows freely through the damper rod into the bottom of the outer fork slider, **Figure 18-19C**. Oil trapped between the damper rod piston and check valve is metered through the rebound damping holes before it can flow back into the outer fork slider. This restriction provides the necessary rebound damping.

As the inner fork tube nears full rebound, the lower rebound damping hole is blocked off. This causes firmer damping. When the remaining damping hole is blocked off, a hydraulic lock is formed. A top-out spring provides final cushioning, **Figure 18-19D**. In the cartridge and inverted fork, compression and rebound are more sophisticated. The fork uses a series of shims that bend during oil flow through the valve.

There are many variations in fork design. The size and location of damper holes determines fork action. Suspension adjustment is accomplished by changing spring rates, oil viscosity, adjustable damping valves, and air pressure. Typical front fork adjustment points are shown in **Figure 18-20**.

A test ride will indicate how the front suspension reacts on various types of road surfaces. According to the symptom noticed, adjust the front fork to obtain the best setting for the rider and the motorcycle's typical road conditions. Follow the instructions in the service manual or in **Figure 18-21**.

Pivoting Link Front Suspension

On many scooters, a ***pivoting link front suspension*** connects the axle to the fork by a pivoting link that extends from the axle ends to the upper portion of the fork. The spring and damper units are attached to eyelets between the pivot points on the fork and the axle. The top of each shock absorber is attached to the fork, near the lower steering head bearing.

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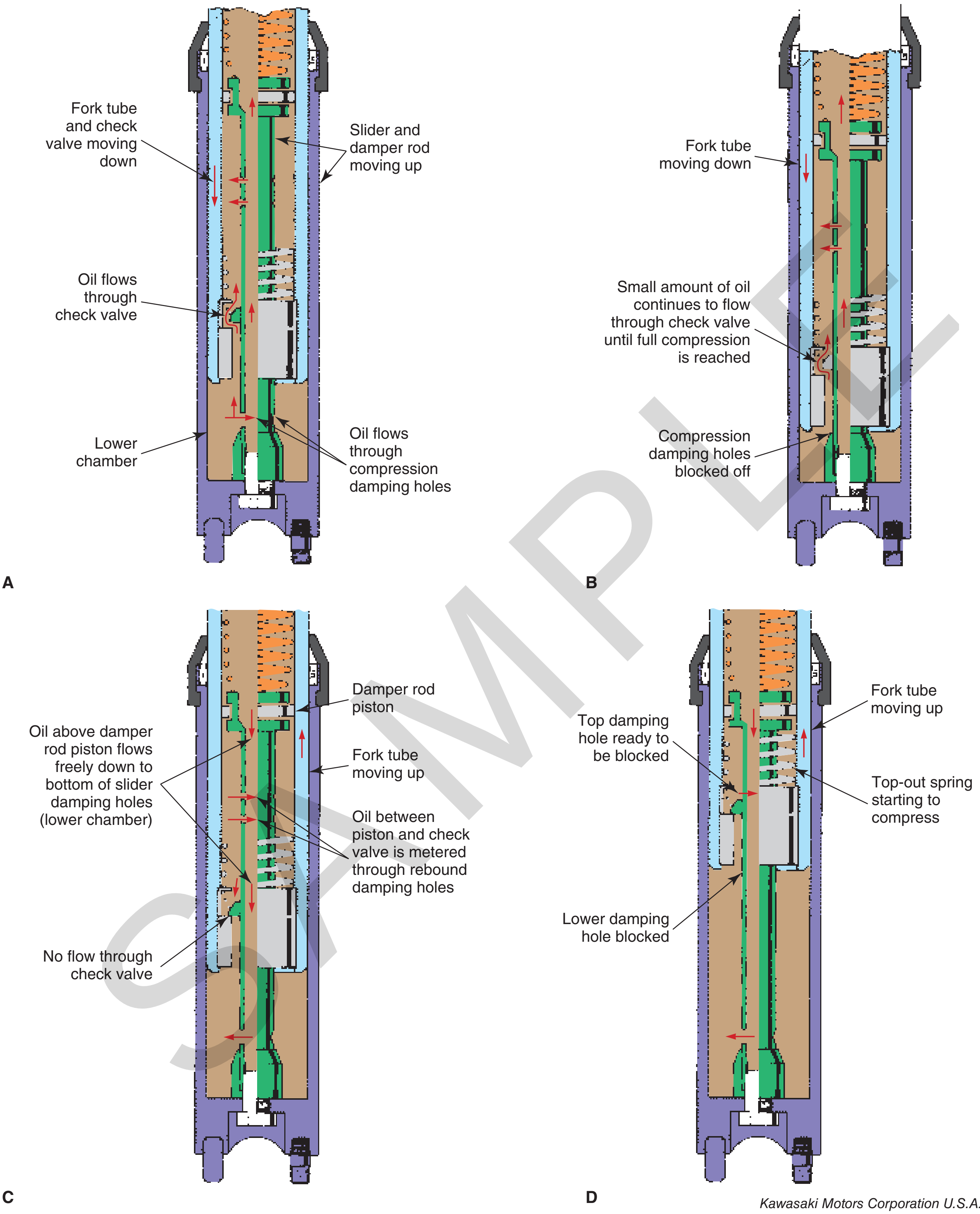

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Figure 18-19. A—During fork compression, oil trapped in the lower chamber flows through compression damping holes and a check valve. B—Hard fork bottoming is prevented by blocking off the damping holes before full compression is reached. C—Fork rebound damping is controlled by rebound damping holes. D—Cushioning at end of rebound stroke is controlled by blocking off rebound damping holes and by use of a top-out spring.

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Figure 18-20. This fork cap includes adjustment screws for compression and tension.

Front Suspension Fork Adjustments	
Symptom	**Adjustment Procedure**
Feels too hard overall	Adjust the compression and rebound damping to a softer setting. Decrease fork oil capacity.
Feels too soft overall and bottoms	Adjust the compression damping to a stiffer setting. Increase fork oil capacity.
Feels too hard near end of travel	Decrease fork oil capacity.
Feels too soft near end of travel and bottoms harshly	Adjust the compression damping to a stiffer setting. Increase fork oil capacity.
Feels too hard in beginning of stroke	Adjust the compression damping to a softer setting.
Feels too soft and unstable	Adjust the rebound damping to a stiffer setting.
Bounces	Adjust the rebound damping to a softer setting.

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Figure 18-21. A ride symptom and suspension adjustment chart.

This design is divided into two categories: trailing link and leading link. In the trailing link design, the axle is supported by links and shock absorbers that trail from the leading edge of the lower fork. In the leading link design, the links pivot toward the front and the shock absorbers are mounted to the fork's leading edge. There have been many different link front suspensions used throughout the history of motorcycles.

Oil Damper

One of the major components of the pivoting link front suspension is the ***oil damper***. Similar to a rear shock damper unit, its primary function is to control the spring's natural rebound energy so that traction and ride comfort are maintained. An oil damper controls the spring action by forcing oil to flow through a specific set of holes in the damper piston as the spring and damper unit compresses and extends. The resistance to damper piston movement created by the oil within the damper controls the spring force. By varying the path the oil is forced to take on the compression and rebound strokes, the desired damping rates can be achieved. Shock damper units will be covered in detail with rear suspension systems.

Steering Geometry

Steering geometry refers to the angles formed by the various steering and front suspension components on a motorcycle or scooter. Factors that determine steering geometry are rake, trail, and offset. Rake, trail, and offset work together to affect a certain feel and steering response. Other factors, such as weight, center of gravity, and intended use, also determine the steering geometry for a given motorcycle. The steering geometry principles used in ATVs and UTVs will be discussed later in this chapter.

Rake

Rake is the angle of the frame's steering head from true vertical, **Figure 18-22**. Rake may vary depending on the motorcycle's intended use. More rake, meaning there is a larger angle between the steering head centerline and vertical, results in slower steering response and greater high-speed stability. Lesser rake, meaning there is a smaller angle between the steering head centerline and vertical, quickens the steering but increases the chance of high-speed wobble.

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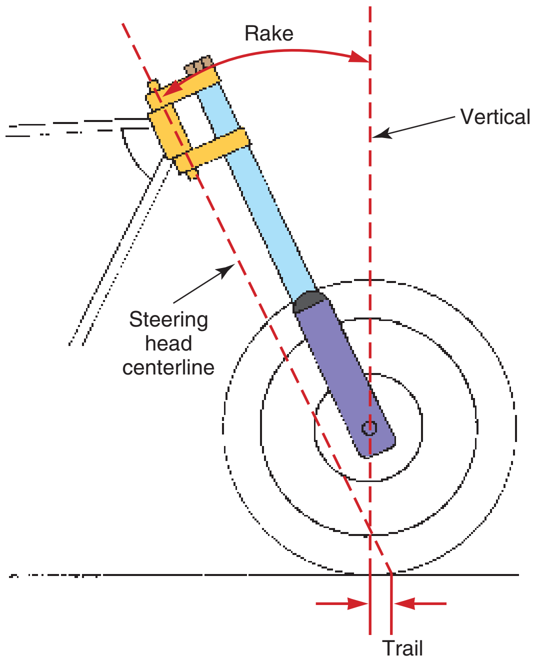

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Figure 18-22. The angle of the frame's steering head from vertical is called rake. The distance between the steering head centerline and the vertical line through the center of the axle is called trail.

Trail

Trail is the distance along the ground between the centerline of the steering head and a vertical line through the axle center. Trail gives the steering a self-centering effect. As trail is increased, the self-centering effect improves stability. Rake and trail are interrelated. As rake is increased, trail is increased.

As the motorcycle moves, rake and trail change. This is shown in **Figure 18-23**. Today's off-road, long-travel suspensions exhibit extreme rake and trail changes during suspension movement.

Offset

Offset provides the proper steering arc. Offset may be achieved by changing triple clamps. The location of the centerline of the fork tube in relation to the centerline of the steering stem, or offset, determines the effort required in steering the motorcycle. See **Figure 18-24**. An off-road motorcycle will likely have the centerlines closer together, quickening the steering response, whereas an on-road motorcycle will have a greater distance between centerlines to slow the steering response.

Steering Damper

A ***steering damper*** is a device that helps to eliminate unwanted steering oscillation and wobble. The two types of steering dampers are:

- Hydraulic—An oil-filled cylinder places drag on steering.
- Friction—An adjustable spring-loaded disc places drag on steering.

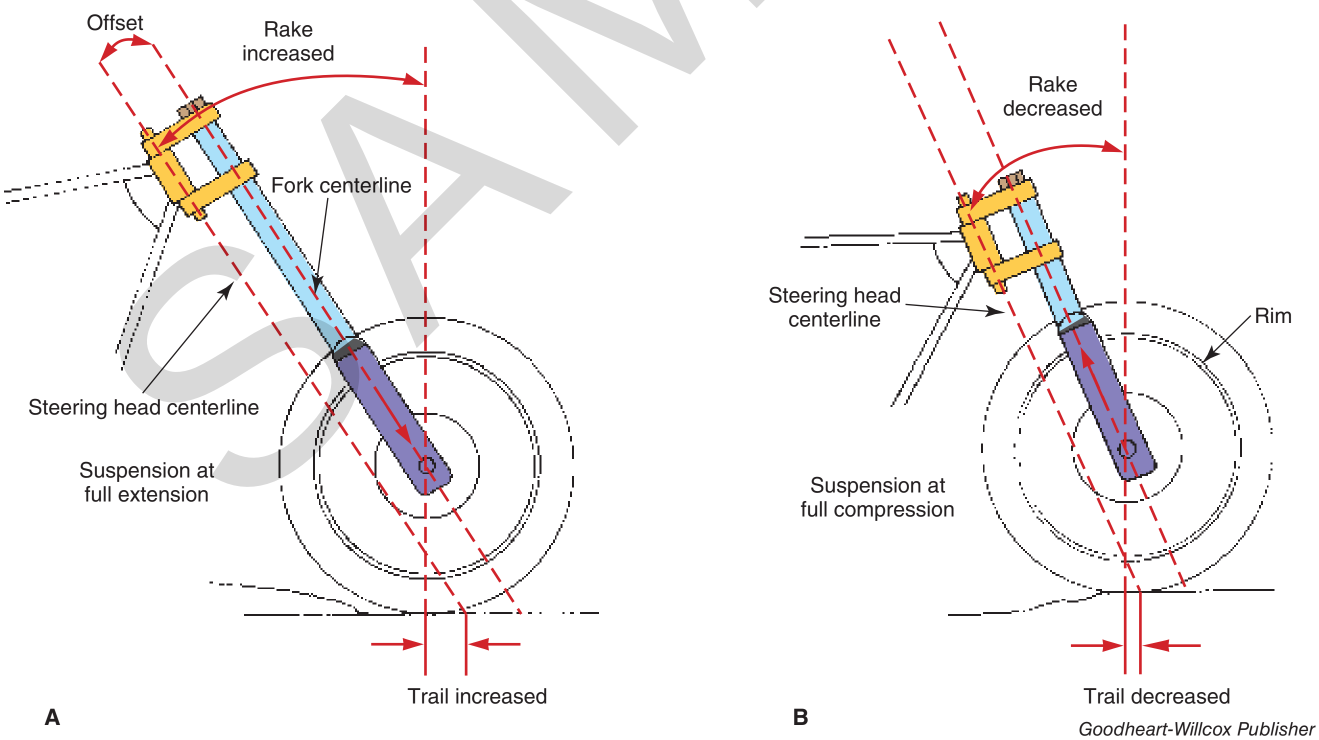

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Figure 18-23. Trail and rake change as the motorcycle moves down the road. A—Trail and rake increase with fork extension. B—Trail and rake decrease with fork compression.

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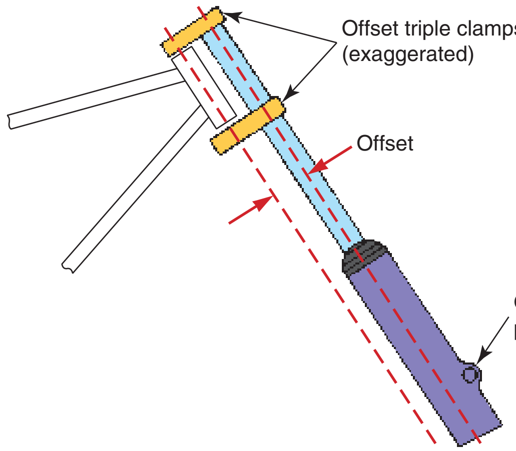

Figure 18-24. Offset fork clamps or offset axles are used in conjunction with rake and trail to provide the desired steering characteristics.

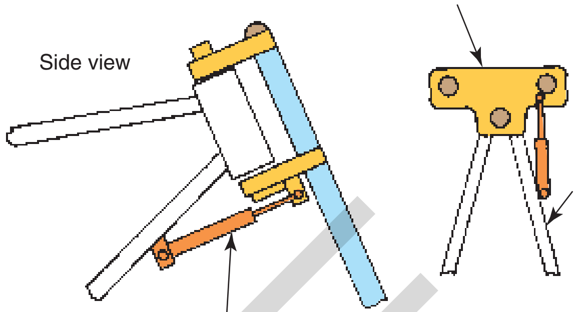

Figure 18-25. A hydraulic steering damper is attached between the frame and lower triple clamp to help control steering oscillations.

Modern hydraulic dampers have replaced friction steering dampers. See **Figure 18-25**. The cylinder connects the frame and either fork clamp. Some are fully adjustable and can be rebuilt. Many modern street bikes use electronically assisted units.

Servicing Front Suspension Components

Typical front suspension service consists of changing fork oil, lubricating and adjusting steering head bearings, and rebuilding forks.

Changing Conventional Fork Oil

Fork oil must be changed because the oil can break down. Also, the oil can become contaminated with dirt, metal particles, and moisture. Riding conditions and manufacturer recommendations determine how often fork oil should be changed. A motorcycle that is ridden in dirt, sand, rain, or mud requires more frequent fork oil changes than one that is not exposed to these conditions. Even under ideal conditions, the fork oil should be changed at least once a year.

To change fork oil, drain the old oil by either removing the drain plug (if equipped) or, after removing the fork cap bolt, dump the oil out the top of the fork, **Figure 18-26**. After reinstalling the drain plug (if equipped), fill the fork with the proper weight and volume of fresh oil and reinstall the fork cap, **Figure 18-27**. Inverted and cartridge forks require a more extensive procedure. Follow the service manual for specific instructions, specifications, and oil change intervals.

Lubrication and Adjustments of Steering Head Bearings

Two types of steering head bearings are used: ball bearings and tapered roller bearings. Ball bearings are the most common type of steering head bearings since they are inexpensive. Tapered roller bearings have the advantage of extremely long service life and ease of assembly and disassembly.

Repacking, or lubricating, steering head bearings requires disassembling the triple clamps and spindle. Periodically lubricate and adjust the steering head bearings as follows:

1. Completely disassemble the triple clamp. After cleaning and inspecting the bearings and races, repack them with the recommended grease.
2. Adjust the steering head preload by tightening the slotted steering stem nut. Follow service manual specifications.

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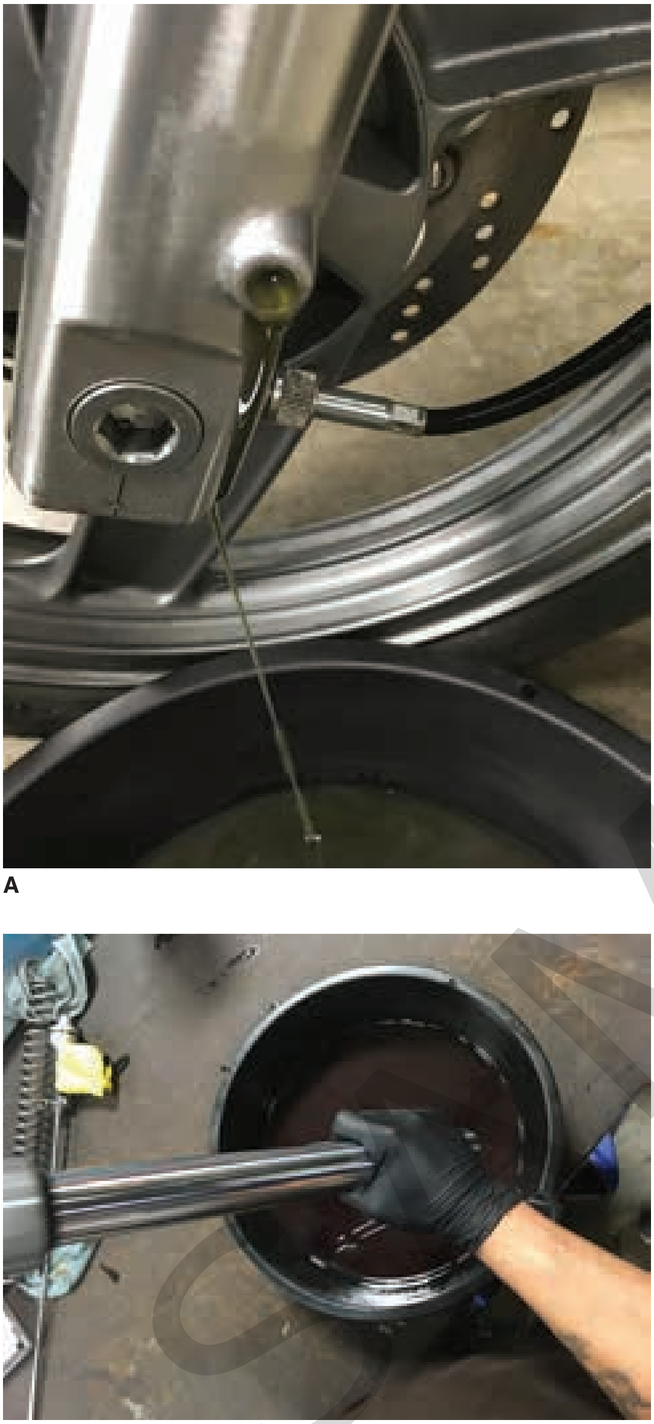

A

B

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Figure 18-26. Draining fork oil. A—If the fork is equipped with a drain screw, remove the drain screw and fork cap to drain the oil. B—If the fork does not have a drain screw, remove the fork assembly. Remove the fork cap, and tilt the fork over a drain pan to drain the oil.

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Figure 18-27. Replace the drain plugs before refilling the forks. Use a graduated cylinder or measuring cup to add the proper amount of fork oil to each fork tube assembly. Refer to the service manual for the proper weight and amount of oil.

3. Make the steering head bearing final adjustment with the front suspension completely assembled. Double-check the steering action after adjustment.

Bearing preload adjustment is a simple task that does not require removing the steering head assembly. The adjustment must not be too tight or too loose. Some manufacturers use a "fall away" specification. This adjustment is determined by the distance from the center of the wheel or fender to the point where the wheel free-falls. Improper steering head bearing adjustment will make the motorcycle dangerous to ride. Refer to the shop manual for specific instructions on steering head bearing disassembly, lubrication, replacement, reassembly, and adjustment. The handlebars should be adjusted to the rider's preference, as directed in the service manual.

Rebuilding Conventional Forks

The most frequent reason for fork disassembly is leaking seals. Seal replacement may only require partial fork disassembly. However, if fork seals are leaking, other parts, such as wear bushings, are likely to be damaged or worn. **Figure 18-28** shows worn wear bushings. A complete fork rebuild is recommended during seal replacement. After disassembling the fork, clean and inspect all parts for wear, scratches, and other problems. See **Figure 18-29**.

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To rebuild a fork, follow the instructions in the service manual. They will describe important disassembly, inspection, and reassembly methods for the particular motorcycle. When servicing a motorcycle fork, remember the following:

- Check outer fork slider and inner fork tube bearings or bushing surfaces for wear.
- Make sure all components are straight, and check for galling and nicks.
- Replace all sealing rings and washers.
- Replace all snap rings or circlips.
- Use proper torque values on all fasteners.
- Lubricate all parts liberally during reassembly.

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Figure 18-28. Worn wear bushings.

Warning

Use extreme care when servicing front-end components. Faulty service or repair methods can result in suspension failure and rider injury or death. Always refer to the vehicle's service manual when working on the front end.

Rear Suspension

A typical motorcycle ***rear suspension*** consists of a swingarm and one or more shock damper units, also known as shock absorbers. Using the front of the swingarm as the fulcrum and mounting the rear axle at the trailing end allows the wheel to respond quickly to variations in the road or travel surface. On some scooters, the entire engine and drive unit pivots at the swingarm.

Rear suspension design can be broken down into a few categories, depending on the number of shocks and the swingarm design. A ***single-shock rear suspension*** uses only one shock absorber. It may be mounted in front of the rear wheel or on one side of the swingarm, **Figure 18-30A**. The single-shock rear suspension uses an adjustable shock absorber and may use levers and links to provide rising rate operation. This type of rear suspension is popular on dirt bikes.

A ***dual-shock rear suspension*** has a shock absorber on each side of the frame, **Figure 18-30B**. With both single- and dual-shock suspensions, the shock connects the swingarm and the frame to provide the spring and damping action for the rear wheel. Dual-shock rear suspensions are found on motorcycles with all sizes of displacement. The system is simple to install, with few components and low cost.

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Figure 18-29. Disassemble the fork and clean and inspect all parts for wear, scratches, and other problems.

An increasing number of motorcycles use a ***progressive link rear suspension***, **Figure 18-30C**. The progressive rising rate delivers ideal damping over a wide range of riding conditions. Initial rates are soft for handling small bumps and ripples. Should the riding surface become rougher, increasingly stiffer rates provide the control necessary to prevent bottoming and to keep the rear wheel in contact with the road.

The swingarm and shock unit are connected by linkage. The damper unit travel, in relation to the rear wheel movement, can be changed with relative freedom during the design stage in accordance with the combination of the cushion arm and connecting rod. As the axle stroke distance increases, the piston speed damper and shock absorbing force increase progressively.

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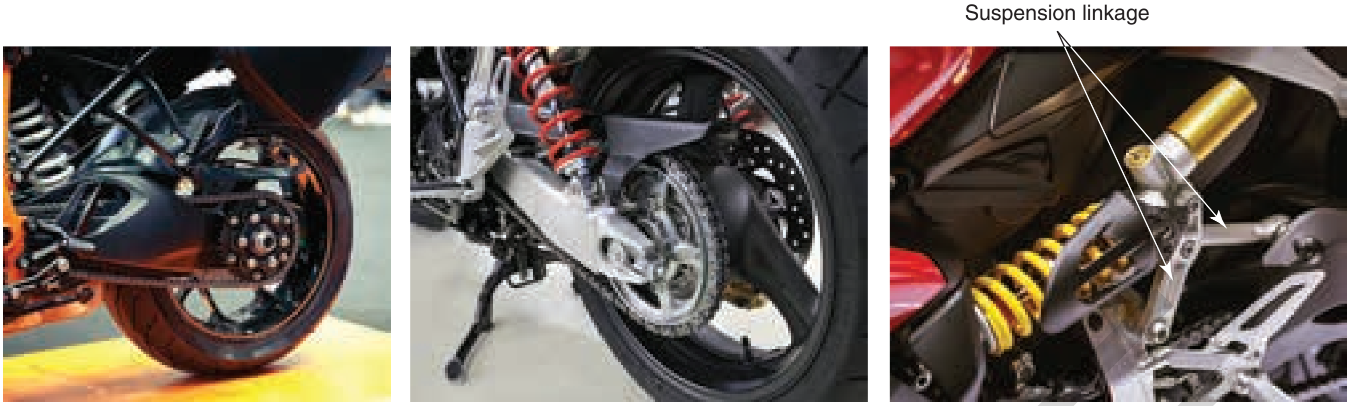

A socrates471/Shutterstock.com B dreamnikon/Shutterstock.com C socrates471/Shutterstock.com

Figure 18-30. Three types of common swingarm rear suspension systems: A—Single-shock rear suspension. B—Dual-shock rear suspension. C—Progressive link rear suspension.

Some motorcycle styles have specially designed rear suspension systems. Long-travel rear suspension systems, for example, provide a softer swingarm travel (suspension travel). This is ideal for competition and off-road motorcycles since it helps the wheel stay in contact with the ground, **Figure 18-31**.

Swingarm

The swingarm is attached to the frame with a pivot bolt, shaft, or link, **Figure 18-32**. The arm itself may be made of steel or aluminum, either stamped or fabricated from tubing. Bushings, needle bearings, or tapered roller bearings are used to provide smooth operation and accurate alignment. Some designs require periodic adjustment and lubrication. Refer

A Oleksandr Kostiuchenko/Shutterstock.com B Rattanapon Ninlapoom/Shutterstock.com

Figure 18-31. Typical long-travel rear suspension systems. A—Long-travel single-shock suspension. B—Long-travel dual shock suspension.

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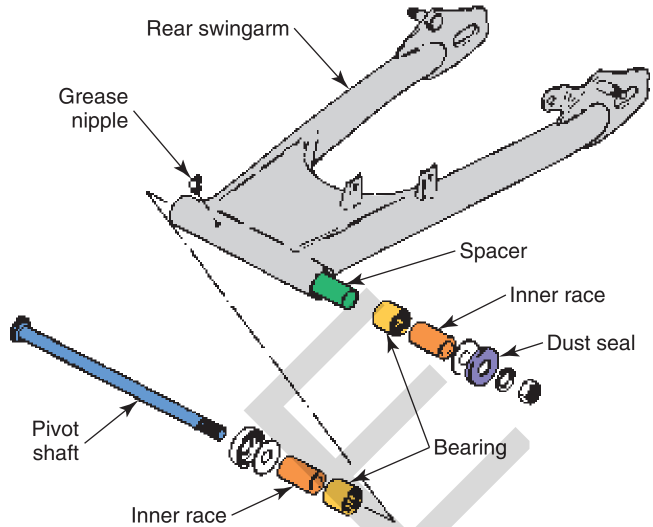
to the service manual for details. On shaft drive motorcycles, one leg of the swingarm houses the driveshaft.

Shock Dampers (Shock Absorbers)

Shock absorbers work much like a front-suspension telescoping fork. There are different types of shock absorbers available for various riding conditions. Some absorbers have external damping adjustments, but the most conventional type is the unpressurized, oil-damped shock absorber shown in **Figure 18-33**.

For severe applications, including competition and off-road motorcycles, conventional shock absorbers can overheat and provide inadequate damping. This is due in part to the small amount of oil in the shock that provides damping. Large oil capacity, gas-charged, rebuildable shocks have been designed to solve this problem and are standard on most competition and off-road motorcycles, as well as on a few on-road motorcycles. See **Figure 18-34**.



American Suzuki Motor Corporation

Figure 18-32. This swingarm uses needle bearings for positive location and smooth operation of the rear suspension.

apiguide/Shutterstock.com

Figure 18-33. A typical oil-damped rear shock absorber. Note that the swingarm leg shown houses a driveshaft.

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Figure 18-34. Gas-charged shock absorber.

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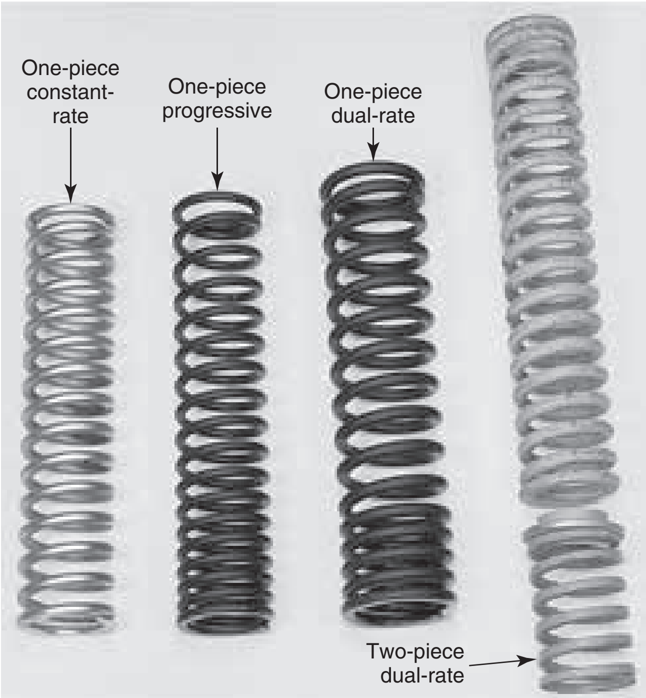

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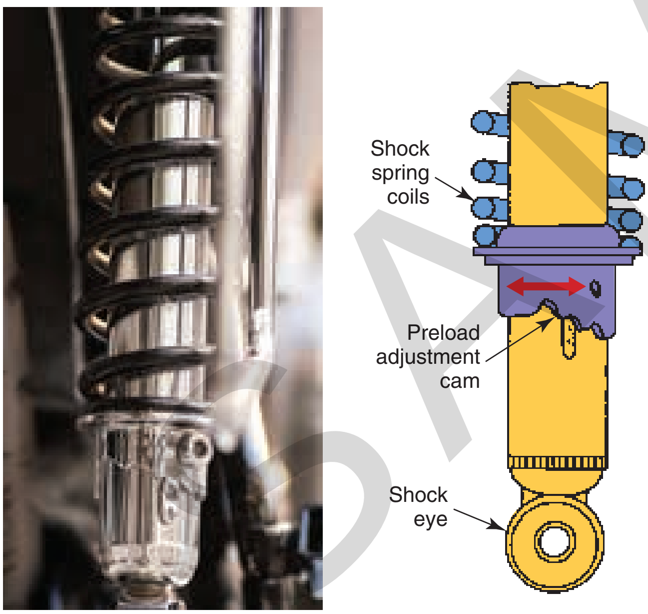
Figure 18-35. Variations of rear shock absorber springs. The springs are used to help control suspension action.



A *LifeisPixels/Shutterstock.com* B *American Suzuki Motor Corporation*

Figure 18-36. Shock with an adjustable lower spring platform. A—The lower spring platform on this shock is adjustable with a spanner wrench. B—More or less rear suspension spring preload is achieved by changing the adjustment cam. Twisting the preload cam changes the rear coil-spring compression rate.

Shock Absorber Springs

***Shock absorber springs,* Figure 18-35**, are mounted over the damper (shock) body. They are fastened to the shock absorber by collars or clips. The following types of springs may be used:

- One-piece constant-rate spring.
- One-piece dual-rate spring.
- One-piece progressive-wound spring.
- Two-piece dual-rate spring.
- Three-piece triple-rate spring.

Additional springing may be provided by internal pressure in gas-charged shocks. The lower spring platform on many shock absorbers also functions as a spring preload adjuster, **Figure 18-36**. It can be adjusted to modify ride height.

Warning

Gas-charged shocks are filled with high-pressure nitrogen gas. Property damage or personal injury may result from improper handling. Keep the following in mind:

- Do not tamper with or attempt to open the cylinder assembly without proper tools and procedural guides.
- Do not subject shock absorbers to an open flame or other high heat. This may cause the unit to explode.
- Do not deform or damage the shock in any way. Cylinder damage will result in poor damping performance or leakage.
- Gas pressure must be released from the shock absorber before disposal. Carefully follow the procedure in the vehicle's service manual.

Shock Absorber Mounting

Shock absorbers are bolted to the frame and swing-arm through rubber, bearings, or steel bushings. Look at **Figure 18-37**. Bushings allow the shock to swivel slightly on its mounting during suspension movement.

Suspension Balance

Properly balancing the suspension from front to rear is the most critical adjustment for a good ride and performance. Fork tubes will have a certain amount of stiction because of the rake of the assembly. If the front forks are adjusted harder than the rear suspension by changing to heavier fork oil, heavier springs, or stiffer compression and rebound settings, air pressure will build up and the front forks will collapse less on bumps. This transfers motorcycle and rider weight to the bottom of the fork.

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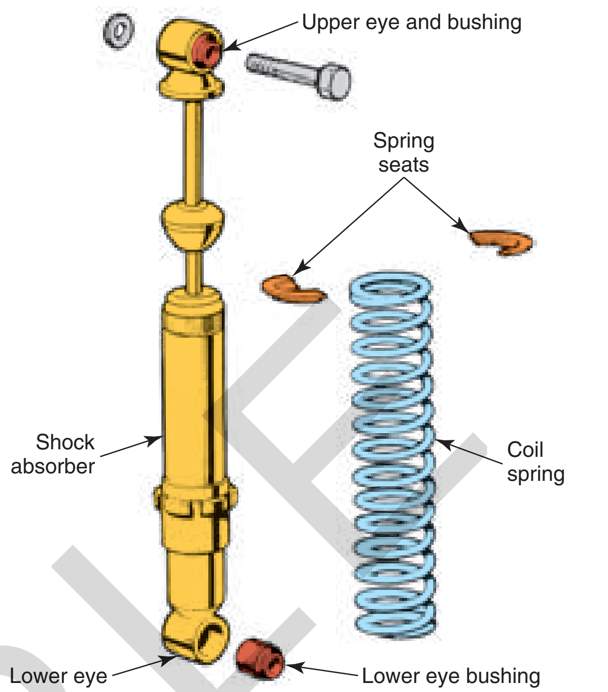
To check the balance, stand next to the motorcycle on level ground. Place one foot on the closest footrest. Sharply push down while holding the front brake. The front and rear suspension should both compress smoothly and equally. Here are some tips to keep in mind:

- Check for air pressure buildup in the front forks. Heat and altitude will increase air pressure in the front forks.
- Always stay within sag measurement (the amount of compression of the suspension with no load) limits when using spring preset to stiffen or soften the rear suspension. If this is not possible, the next stiffer or softer spring is needed.
- The rear-shock compression damping can be used to fine-tune suspension balance and is easy to access.



Triumph Motorcycles, Ltd.

Figure 18-37. A steel insert surrounded by a rubber bushing is used in the shock eye. It provides a vibration-resistant mounting for shock absorbers.

Suspension Inspection

The motorcycle's suspension system must be inspected periodically. Check the service manual for routine inspection intervals. It is a good idea to check for any problems that could affect rider safety. Look for worn pivots, worn shock absorber bushings, loose fasteners, unlubricated grease fittings, suspension misalignment, and similar problems.

The following summary and the service manual provide guidelines for a thorough suspension inspection. Because there are many designs, remember that the following is only a guide.

Front Suspension Inspection Summary

The following front suspension points must be carefully inspected:

1. Check steering head looseness and bearing condition.
2. Observe steering damper operation.
3. Check outer fork sliders or bushings for looseness.
4. Check wheel bearings for looseness.
5. Check trueness of wheels and tires.
6. Inspect tire for cuts, sidewall checking, and other damage.
7. Check spoke tension.
8. Measure tire pressure.
9. Check air forks for loss of air pressure.
10. Check tightness of fasteners at fender, brackets, brake plate brace, triple clamps, steering stem, steering damper, and axle.
11. Check alignment of forks and steering head.
12. Measure fork tube height in triple clamps.
13. Check fork tube straightness.
14. Inspect fork seals for leakage.
15. Check condition of fork wipers or accordion boots.
16. Check fork tubes for scratches, nicks, and dents.

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17. Inspect steering neck, triple clamps, and front chassis for chipped paint, cracks, and straightness.
18. Change fork oil. If the motorcycle has an air suspension, release pressure before draining. Pressurize after filling.
19. Observe fork operation.
20. Check handlebar tightness and straightness.

Rear Suspension Inspection

The following rear suspension points must be carefully inspected:

1. Check swingarm for looseness.
2. Inspect shock eye bushings or bearings for looseness.
3. Check wheel bearings and spokes for looseness.
4. Measure wheel and tire runout.
5. Check tire for cuts, cracks, and other damage.
6. Measure tire air pressure.
7. Check swingarm straightness and alignment.
8. Grease swingarm.
9. Inspect shock absorbers for oil and air leakage.
10. Check shock absorber rods for straightness.
11. Check shock absorber preload settings.
12. Observe shock absorber operation.
13. Check wheel and sprocket alignment.
14. Check tightness of fasteners at shock mounts, swingarm pivot, rear axle, brake plate brace, chain guard, passenger pegs, and fender brackets.
15. Inspect rear chassis, swingarm, and surrounding areas for chipped paint, corrosion, cracks, misalignment, and other signs of trouble.
16. If the motorcycle has saddlebags or a luggage rack, check for tightness, alignment, and cracked mounting brackets.

Note

Frame and suspension system inspection is imperative for powersports vehicles with handling problems or accident damage. Every problem must be located and corrected to ensure the vehicle is safe to ride.

SAMPLE

ATV and UTV Four-Wheel Alignment

Earlier in this chapter, motorcycle wheel alignment was discussed. Four-wheel alignments on ATVs and UTVs present different problems, **Figure 18-38**. In order to align an ATV or UTV, you must understand the following four alignment angles:

- ***Toe-in*** and ***toe-out***. The inward or outward pointing at the front of the front wheels.
- ***Camber***. The inward or outward tilt of the wheel when viewed from the front of the ATV or UTV. A wheel has a positive camber when the top is tilted out.
- ***Caster***. The forward or backward tilt of the wheel when viewed from the side of the ATV or UTV. This is similar to the caster on a piece of furniture.
- ***Thrust angle***. Tracking of rear tires in relation to the front tires.

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Figure 18-38. Caster, camber, toe, and thrust angles must be measured and compared to specification when performing a four-wheel alignment on an ATV or UTV.

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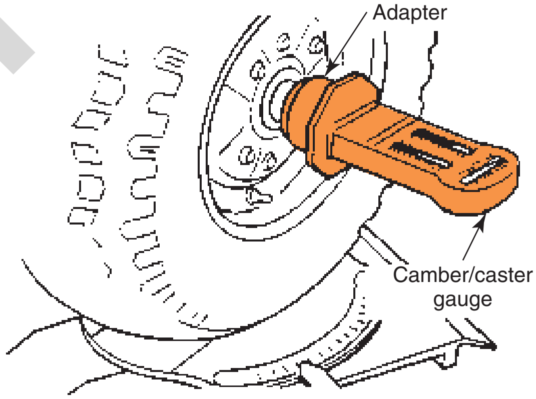
Figure 18-39. Checking an ATV suspension for toe-in using a toe-in gauge or bar. The tips of the pointers are aligned with the centers of the tires at axle height.

To check for a toe-in condition, place the vehicle on a level surface with the front wheels facing straight ahead. Secure each side of the handle bars or steering wheel with tie downs to prevent turning and to maintain a locked position. Mark the center of both tires with chalk to indicate the axle center height. Align the toe-in gauge with the marks on the tires, **Figure 18-39**. Check the readings on the gauge scales. Slowly move the vehicle back until the wheels have rotated 180° and the marks on the tires are aligned with the gauge height on the rear side. Measure the toe-in on the rear part of the tires at the same points. When the toe-in is out of specification, adjust it by changing the length of the tie rods equally while measuring the toe-in.



Honda Motor Co., Ltd.

Figure 18-40. Checking the camber and caster alignment on an ATV.

When checking the camber and caster, remove the wheel cap, cotter pin, and front axle nut. Install an attachment or adapter onto the front axle. Put the camber and caster gauge onto the adapter, **Figure 18-40**, and measure the camber. Set the turn gauge under the front wheels and measure the camber and the caster. Camber and caster are not adjustable on most machines. If they are out of specification, check the suspension and frame for damage and replace any parts necessary, then recheck alignment.

Typically, thrust angle cannot be easily measured without electronic alignment equipment. Any change in thrust angle will coincide with rear alignment problems on an ATV or UTV. This may be caused by a bent frame or suspension component.

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Troubleshooting Frame and Suspensions Systems

Consult the service manual and use the following information to troubleshoot frame and suspension problems.

Frame Problems

The following are common problems that may occur with a motorcycle frame and their potential causes:

Abnormal Engine Vibration

- Cracked or damaged engine mounts.
- Cracked, damaged, or bent welded portions.
- Bent or damaged frame.
- Engine problems.

Abnormal Noise When Riding

- Damaged or bent engine mounts.
- Damaged welded points.
- Damaged or bent frame.

Steers to One Side When Accelerating or Decelerating

- Bent frame.
- Bent fork.
- Bent swingarm.

Front Suspension Problems

The following are common front suspension problems and their causes:

Hard Steering

- Steering head bearing adjustment nut too tight.
- Faulty steering head bearing.
- Damaged steering head bearings.
- Insufficient tire pressure.
- Faulty tire.

Steers to One Side or Does Not Track Straight

- Unevenly adjusted right and left shock absorbers.
- Bent fork.
- Bent front axle; wheel installed incorrectly.
- Faulty steering head bearings.
- Bent frame.
- Worn wheel bearing.
- Worn swingarm pivot components.

SAMPLE

Front Wheel Wobbling

- Bent rim.
- Loose nut on axle.
- Worn front wheel bearings.
- Faulty or incorrect tire.
- Incorrect front fork oil.

Wheel Turns Hard

- Brake misadjusted.
- Faulty wheel bearing.
- Faulty speedometer gear.

Soft Suspension

- Weak fork springs.
- Insufficient fluid in fork.
- Faulty anti-dive system.

Hard Suspension

- Bent fork components.
- Bent damper rod (bottom link).
- Incorrect fluid weight.
- Bent fork tubes.
- Clogged fluid passage.

Noisy Front Suspension

- Worn slider or guide bushings (bottom link).
- Insufficient fluid in fork.
- Loose fork fasteners.
- Lack of grease in speedometer gearbox.

Rear Suspension Problems

The following are common rear suspension problems and their causes:

Rear Wheel Wobbling

- Distorted wheel rim.
- Worn wheel bearing or swingarm bearing.
- Defective or incorrect tire.
- Loose nuts or bolts on rear suspension.
- Loose nut on axle.
- Worn axle or hub splines.

Soft Suspension

- Weak spring(s).
- Oil leakage from damper unit.
- Air or gas leakage.
- Incorrect shock absorber adjustment.

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Hard Suspension

- Incorrectly mounted suspension components.
- Incorrect shock absorber adjustment.
- Bent swingarm pivot.
- Bent shock absorber rod.
- Damaged swingarm pivot bearing(s).
- Faulty suspension linkage.
- Damaged linkage pivot bearings.

Noisy Rear Suspension

- Loose nuts or bolts on rear suspension.
- Worn swingarm and rear cushion-related bearings.

Workplace Skills

Most businesses require new employees to be drug tested before they begin working. If a job requires driving a company vehicle, the company will review the applicant's driving history to ensure he or she is a responsible driver. Drug testing and a clean driving record are often required by the business' insurance company to ensure the applicant will not be deemed a high risk.

Nobody should be under the influence of drugs or alcohol while working. However, people working with machinery and power equipment pose a higher risk of injury to themselves and their coworkers, as well as damage to shop equipment and customer vehicles. Reckless driving and working while under the influence of drugs or alcohol are actions for which an employee may be justifiably dismissed. In some instances, legal action may be taken if an accident or injury was determined to be caused by an individual who was under the influence of alcohol or drugs at the time.

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Summary

- The design of the chassis, which includes the frame and suspension system, is a major factor determining the handling characteristics of a motorcycle.
- The frame is the backbone of any powersports vehicle. It serves as the skeleton on which virtually everything is attached.
- The material used for a frame is chosen to match the motorcycle's function. Aluminum frames are used for on-road sport motorcycles with medium- and large-displacement engines and motocross motorcycles. Other frames are made of steel.
- There are two cradle frame designs: single cradle frame and double cradle frame.
- On the backbone frame, the engine hangs from the top of the frame and acts as a structural member.
- The diamond frame is used mainly on small and medium motorcycles due to its simplicity, light weight, and excellent serviceability.
- The delta-box frame features a strong steel or aluminum triangle between the steering head and the swingarm pivot.
- The pentagonal frame, or five-sided frame, is made of cast and extruded aluminum and has good torsional rigidity.
- A stamped frame consists of two pieces of stamped sheet metal welded together.
- The purpose of the suspension system is to allow the wheels to follow an irregular surface with a minimum amount of shock transmitted to the frame.
- Telescopic front suspensions are made of a pair of inner fork tubes and outer fork sliders that telescope into one another. Within the set of inner fork tubes on either side is a spring and an oil-damping system. Some systems use a cartridge damper within the outer fork sliders.
- A telescoping fork assembly consists of an inner fork tube, an outer fork slider, two triple clamps, a spindle, and related fasteners. The fork tubes are shock-absorbing devices that hold the front wheel in place. Telescoping fork assemblies can use a conventional or inverted design.
- A telescoping fork's compression stroke is the inner fork tube's movement into the outer fork slider when striking a bump in the road. During the inner fork tube's rebound stroke, the fork spring causes the outer fork slider to extend.
- Steering geometry refers to the angles formed by the various front suspension and steering system components on a motorcycle. Factors that determine steering geometry are rake, trail, and offset.
- Typical front suspension service consists of changing fork oil, lubricating and adjusting steering head bearings, and rebuilding the forks. A technician must follow the manufacturer's procedure outlined in the service manual when performing each service on a motorcycle.
- A typical motorcycle rear suspension consists of a swingarm and one or more shock absorbers.
- The single-shock rear suspension system uses an adjustable shock absorber, levers, and links to provide rising rate operation.
- A dual-shock rear suspension has a shock absorber on each side of the frame.
- An increasing number of motorcycles use a progressive link rear suspension.
- Shock absorbers work much like a front-suspension telescoping fork.
- Shock absorber springs are mounted over the damper (shock) body. They are fastened to the shock absorber by collars or clips. Shock absorbers are bolted to the frame and swingarm through rubber or steel bushings.
- Properly balancing a motorcycle's suspension from front to rear is the most critical adjustment for a good ride and performance.

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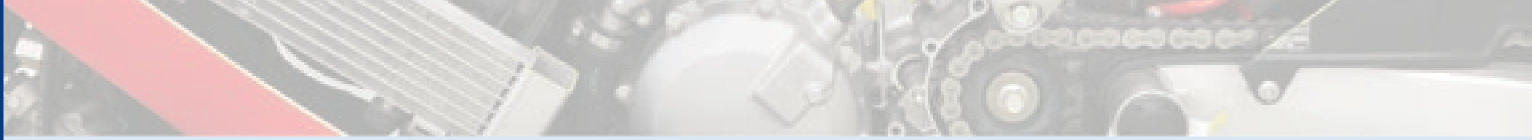

- A motorcycle's front and rear suspension systems should be inspected at manufacturer-specified intervals for any problems that could affect rider safety. Examine the condition and operation of the front telescoping fork assembly and its attached wheel assembly. Watch the operation of the rear suspension's swingarm assembly and shock absorbers, and check the parts, including its wheel assembly, for wear, damage, and proper alignment. Check for worn pivots, loose fasteners, steering head issues, unlubricated grease fittings, loose wheel bearings, suspension misalignment, and similar problems.
- In order to perform a four-wheel alignment on an ATV or UTV, a technician must understand four alignment angles: toe-in and toe-out, camber, caster, and thrust.
- Frame problems a technician is often asked to troubleshoot include abnormal chassis noise, engine vibration when riding, and the motorcycle steering to one side when accelerating or decelerating. Common front suspension issues involve hard steering or steering to one side. Problems related to both front and rear suspensions include wheel wobble, noisy system components, and a suspension that feels too hard or soft.

Review Questions

Answer the following questions using the information provided in this chapter.

1. *True or False?* Triangulation adds strength to a frame.
2. Which frame has one down tube and one main pipe at the front of the engine?
   A. Single cradle frame.
   B. Double cradle frame.
   C. Backbone frame.
   D. Delta-box frame.
3. The engine hangs from the top of the _____ frame at the rear and acts as a structural part of the rear suspension.
   A. single cradle
   B. double cradle
   C. backbone
   D. pentagonal
4. What are the two phases of fork operation in motorcycle telescopic front suspensions?
   A. Compression and rebound.
   B. Compression and exhaust.
   C. Intake and compression.
   D. Rebound and transition.
5. In a motorcycle's telescoping fork assembly, the _____ on the lower triple clamp passes through the steering head, which allows the fork to be turned to the right or left.
   A. damper rod
   B. swingarm
   C. thrust plate
   D. spindle
6. *True or False?* Rake is the location of the fork tube's centerline in relation to the steering stem's centerline and is the same on all motorcycles.
7. In a motorcycle's steering geometry, as rake is increased, trail is _____.
   A. decreased
   B. increased
   C. unchanged
   D. offset by caster and camber angles
8. A _____ helps to eliminate unwanted steering oscillation and wobble.
   A. suspension system
   B. pivoting link
   C. telescoping fork
   D. steering damper

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9. *True or False?* Bearing preload adjustment of a motorcycle's steering head bearing is a challenging task that requires removing the steering head assembly and front wheel assembly.
10. *True or False?* It is not necessary to replace sealing rings, washers, and snap rings when rebuilding a telescoping fork.
11. A(n) _____ rear suspension provides initial soft rates for small bumps and ripples and increasingly stiffer rates for rougher riding surfaces.
    A. single-shock
    B. dual-shock
    C. progressive link
    D. inverted
12. *True or False?* It is critical to properly balance a motorcycle's suspension from front to rear.
13. All of the following are steps in the inspection process of a motorcycle's front and rear suspensions, *except*:
    A. inspect front telescoping fork seals for leakage and observe fork operation.
    B. measure and check toe angle of the front and rear tires against specification.
    C. check rear shock absorbers for oil and air leakage and observe operation.
    D. inspect steering neck, triple clamps, and front chassis for straightness.
14. *True or False?* A wheel has a positive camber when the top is tilted in when viewed from the front of the ATV or UTV.
15. Which of the following is a possible cause for a motorcycle's hard rear suspension problem?
    A. Weak telescoping fork springs.
    B. Bent swingarm pivot or damaged pivot bearing(s).
    C. Worn axle or hub splines.
    D. Bent or damaged frame.

SAMPLE

Suggested Activities

1. Visit local motorcycle shops to find two examples of each common frame design. Compare the frames, making note of:
    A. Triangulation.
    B. Gusseting.
    C. Diameter of frame tubes.
    D. Type and size of engine mounting brackets.
    E. The motorcycle's intended use.
2. Complete the suspension inspection summary on a motorcycle.
3. From Activity 2, explain what should be done to improve the motorcycle's mechanical condition.

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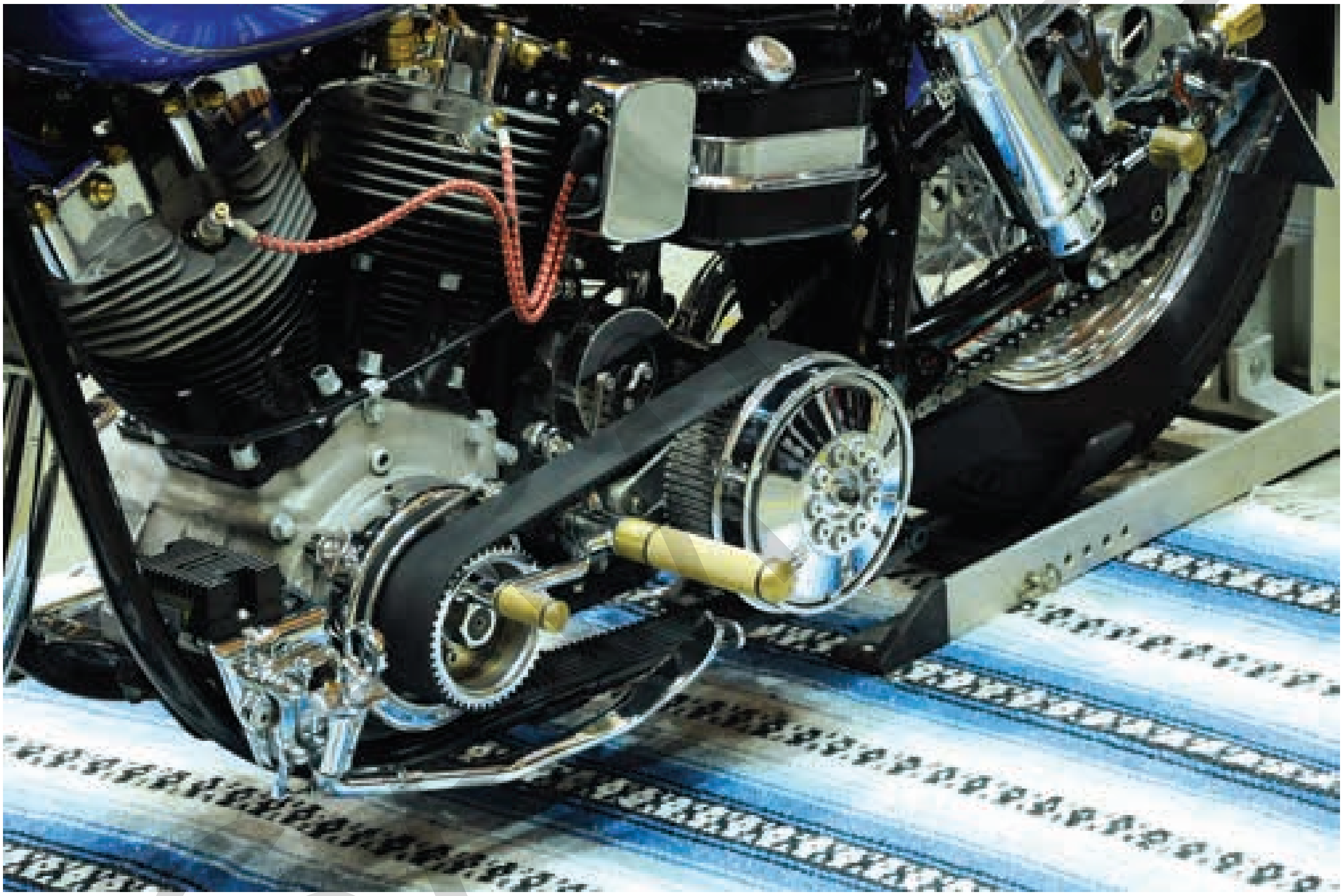

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Both the primary and final drives are exposed on this motorcycle. Note that it is equipped with a belt-type primary drive and a chain-type final drive.

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