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8 Crankdisk to traction

The cylinder produces force, but it is the drive train that turns that force into useful motion. Beginning at the crankdisk, this chapter traces the path of power through the clutch, gearing, differential, and rear wheels, and concludes with the structural members that carry the resulting drawbar loads.

- The crankdisk converts the piston’s back-and-forth motion into rotary motion, turning the engine’s main output shaft.
- The pulley wheel is mounted on the crankshaft and provides a belt drive for stationary work, transmitting power to threshers, saws, or other machinery.
- The clutch connects or disconnects the crankshaft from the traction gearing, allowing the operator to start, stop, or idle the engine without moving the wheels.
- The first-motion pinion is the small gear on the crankshaft that drives the intermediate gear, beginning the power train to the rear axle.
- The intermediate gear transfers motion from the crankshaft pinion to the differential shaft, changing direction and reducing speed for traction work.
- The differential permits the rear wheels to rotate at different speeds while maintaining power transmission.
- The upper (cross) shaft carries the differential and serves as the main transverse drive shaft between the gearing and the rear axle.
- The final-drive pinion is the small gear on the cross shaft that meshes with the bull gear on each rear wheel. The bull gear is the large gear bolted to the rear wheel hub; it receives power from the final-drive pinion and turns the wheel.
- The rear wheels and axle convert the rotary motion of the bull gears into traction, propelling the engine forward or backward.

8.1 Crankdisk

On a single-cylinder traction engine, the crankdisk is the large, circular plate mounted on the main shaft that converts the piston’s back-and-forth motion into rotary motion. The crankpin is set off-center in the disk, and the connecting rod attaches to this pin. As the piston moves, the crankdisk turns the main shaft, providing the rotary power that drives the flywheel, pulley wheel, and traction gearing. The disk also acts as a counterweight, balancing the reciprocating mass of the piston and rod to reduce vibration and smooth the engine’s running.

The crankdisk is one of the defining features of many single-cylinder traction engines. It is simple, strong, and easy to manufacture, and it provides a broad, rigid structure for mounting the crankpin. Because the disk is large and heavy, it contributes to the engine’s rotational inertia, helping the engine carry through the dead centers and maintain steady motion under load.

8.2 Twin-Cylinder Engines: A Different Arrangement

Twin-cylinder traction engines use a completely different configuration. Instead of a single crankdisk, they employ a crankshaft with two crank throws, much like an automotive engine. Each cylinder has its own crankpin, set at an angle (often 90°) to ensure smooth, even torque and eliminate dead centers. This arrangement allows the engine to start from any position and provides more uniform power delivery.

In these engines, the crankshaft is a multi-throw forging or built-up assembly with webs and journals rather than a single disk. The mechanical principles are the same—converting reciprocating motion to rotary motion—but the geometry and construction more closely resemble later internal-combustion practice.

Summary Whether through a single crankdisk or a multi-throw crankshaft, this component is the mechanical heart of the power train, turning the piston's linear force into the rotary motion that ultimately drives the wheels.

8.3 Pulley Wheel

The pulley wheel is mounted on the crankshaft (or crankdisk shaft) and provides the engine's belt-power output for stationary work. Before tractors and electric motors took over, this was one of the most important features of a traction engine: it allowed the engine to serve as a portable power plant for threshers, sawmills, feed grinders, pumps, and countless other machines.

The pulley is usually a wide, flat, cast-iron wheel with a smooth rim designed to grip a heavy canvas or leather belt. When the engine is belted to a machine, the pulley becomes the primary power takeoff, and the traction gearing is typically disengaged so the engine can run at a steady speed without moving the wheels. The governor maintains constant RPM, and the pulley delivers smooth, continuous rotary power to whatever machine is being driven.

Because the pulley is mounted directly on the crankshaft, it turns at full engine speed. This makes it ideal for machinery designed to run at several hundred revolutions per minute. The pulley's diameter is chosen to give the correct belt speed for common farm equipment, and many engines offer optional pulley sizes to match specific applications.

The pulley wheel also plays a role in balancing the crankshaft assembly. Its mass contributes to the rotational inertia of the engine, helping smooth out the power pulses from the single cylinder. When not in use, the pulley simply freewheels with the crankshaft, but when belted up, it becomes the engine's external power output, turning the traction engine into a stationary engine on wheels.

8.4 Clutch

The clutch on a traction engine is a sliding-hub friction clutch built directly onto the crankshaft. Its purpose is to connect or disconnect the engine from the traction gearing, but unlike automotive clutches, it is not required for starting the machine from rest. A traction engine can start smoothly from zero RPM with the clutch fully engaged; the clutch is only needed when the operator wants to let the engine run without moving the wheels, or when backing into a belt.

8.4.1 Sliding Hub and Actuating Fork

The clutch consists of a hub that slides on the crankshaft, guided by a keyway so it can move axially but must rotate with the shaft. A lever arrangement on the operator's platform ends in a fork that fits into grooves machined around the hub. Pulling the lever moves the fork, which in turn slides the hub along the crankshaft to engage or disengage the clutch.

8.4.2 Spokes, Shoes, and Expanding Action

The hub carries a set of spokes, each ending in a friction shoe. These shoes face outward toward the inner surface of the pulley wheel, which acts as the clutch drum.

In the disengaged position, the spokes sit at an angle, pulling the shoes inward so their effective circumference is smaller than the inside of the pulley. The pulley spins freely around the crankshaft.

When the operator engages the clutch, the fork pushes the hub forward. This action straightens the spokes, forcing the shoes outward. As the spokes approach a straight line, the shoe circle expands until it grips the inside of the pulley wheel.

This expanding-shoe geometry gives the clutch a strong, positive friction fit while remaining simple and robust.

8.4.3 Over-Center Locking

A key feature of this design is the over-center action. As the spokes are pushed past their straight-line position, the geometry “locks” the shoes outward. This prevents the clutch from slipping out of engagement under load. The operator feels this as a distinct snap or firm detent when the clutch lever goes over center.

8.4.4 Retention Systems: Pawls and Pins

Different manufacturers used different methods to keep the clutch from popping out of engagement:

Some engines use a ratchet and pawl on the clutch lever quadrant. Once the lever is pulled over center, the pawl drops into a tooth and holds it there.

Others use a locking pin or latch that the operator drops into place after engaging the clutch.

A few rely solely on the over-center geometry, though this requires careful adjustment to prevent accidental disengagement.

8.5 When the Clutch Is Actually Needed

Unlike automotive practice, the clutch is not used to ease the engine into motion. Traction engines produce enormous low-speed torque and are perfectly happy to start from rest with the clutch fully engaged.

The clutch is only required when:

- Running the belt pulley while keeping the engine stationary
- Backing into a belt, where the pulley must already be turning
- Stopping the machine without stopping the engine
- Idling the engine while adjusting gearing or preparing to move
- In normal forward operation, the clutch is simply engaged and left there.

8.5.1 Backing Into a Belt

When a traction engine is backed into a belt, the pulley wheel must already be turning before the belt can be taken up. Because the clutch is what connects the crankshaft to the traction gearing, the clutch must be engaged for the wheels to turn the engine backward.

As the engine rolls backward, the pulley wheel turns with it. The belt—already looped over the pulley—initially slips freely on the rim. As the engine continues backing, the belt becomes taut. The increasing tension creates enough friction for the belt to begin turning with the pulley. Once the belt is fully stretched and friction is established, the belt and pulley rotate together, and the machine being belted begins to turn.

This is the only situation in normal operation where the clutch is required to engage a moving engine. In all forward work, a traction engine can start from rest with the clutch fully engaged; its immense low-speed torque makes slipping the clutch unnecessary. But when backing into a belt, the engine must already be rotating—driven by the wheels—so the clutch must be engaged to transmit that motion to the pulley.

Summary The traction-engine clutch is a sliding-hub, expanding-shoe friction clutch with an over-center locking action. It is simple, strong, and perfectly suited to the slow-speed, high-torque work of a steam traction engine. Its purpose is not to modulate power during starts, but to give the operator control over when the engine’s rotation is delivered to the traction gearing or the belt pulley.

8.6 Pinion, Intermediate, and Differential

8.6.1 First-Motion Pinion

The first-motion pinion is the small gear mounted directly on the crankshaft (or crankdisk shaft). Once the clutch is engaged, this pinion becomes the engine's first point of contact with the traction gearing. Because it turns at full engine speed, it must be small, strong, and precisely fitted.

Its job is straightforward: to transmit the crankshaft's rotation into the gear train and begin the necessary speed reduction.

Since the crankshaft, intermediate shaft, and rear axle are all parallel on virtually all traction engines, the first-motion pinion meshes directly with the intermediate gear without changing the direction of rotation. Only a few unusual machines—such as certain road rollers and the Shay locomotive—depart from this parallel-shaft arrangement.

8.6.2 Intermediate Gear

The intermediate gear is the large gear that meshes with the first-motion pinion. It provides the second stage of speed reduction and carries the full torque of the engine after the clutch.

Its functions are:

- Speed Reduction:
  The intermediate gear is significantly larger than the first-motion pinion, reducing engine RPM to the slow, powerful rotation needed for traction work.
- Torque Transmission:
  It passes the engine's torque to the differential gear on the upper (cross) shaft.

The intermediate gear is mounted on its own short shaft with bearings, usually supported by a heavy bracket cast into the frame. In some engines, the intermediate gear can be slid out of mesh to provide a neutral position, allowing the engine to run without turning the differential or wheels. This is separate from the clutch and is part of the traction gearing arrangement.

Because the shafts are parallel, the intermediate gear simply passes rotation along the line of gears without redirecting it.

8.6.3 Differential

The differential sits in the same plane as the intermediate gear. Many traction engines use a flat sun-and-planet differential arrangement. Instead of bevel gears, many traction engines use a crown gear cast into a platter that forms the rotating carrier.

The differential consists of:

- A pinion gear, which turns with the ring gear and rotates the differential platter
- Two or more planet gears, mounted on pins between the crown gear (in the platter) and the sun gear
- A sun gear, splined or keyed to the cross shaft, which drives the final-drive pinions

How the mechanism actually works

- The intermediate gear drives the ring gear, which is fixed to the platter.
- The platter carries the crown gear cast into its face.

- The planet gears run between the crown gear and the sun gear on the cross shaft.
- As the platter rotates, it carries the planet gears around, which in turn drive the sun gear.

Differential action

When both wheels turn at the same speed, the planet gears simply orbit without spinning on their pins.

When the wheels need to turn at different speeds (as in a corner): the planet gears rotate on their pins, allowing the sun gear to turn faster or slower than the platter, which lets each wheel rotate at the speed it needs.

Why this design was used

It is compact and flat, fitting neatly between the frame rails

It is extremely rugged and tolerant of dirt and misalignment

It handles high torque at low speed

It integrates cleanly with the cross shaft and final-drive pinions

Some engines include a differential lock, which slides a collar to tie both sun gears together for plowing or heavy pulling, where wheel slip is more likely than turning.

8.6.4 Final-Drive Pinions

Once torque leaves the differential's sun gear and enters the cross shaft, it reaches the final-drive pinions—one on each end of the shaft. These pinions are small, hardened gears of equal size, keyed or splined to the cross shaft so they rotate with it.

Their job is simple and crucial:

to deliver the differential's output directly to the bull gears on the rear wheels.

Because the pinions are small and the bull gears are very large, this stage provides the largest single speed reduction in the entire traction-drive system. This reduction is what allows a traction engine to move slowly, steadily, and with enormous pulling power.

- The pinions must be:
- precisely aligned
- well-lubricated
- extremely robust

They carry the full torque of the engine after all previous reductions.

8.6.5 Bull Gears

The bull gears are the large, heavy gears bolted directly to the hubs of the rear wheels. They are often the largest gears on the entire machine, sometimes several feet in diameter, and they form the final mechanical link between the engine and the ground.

When the final-drive pinions turn, they mesh with the bull gears and rotate the wheels. Because the bull gears are so large relative to the pinions, they multiply torque dramatically while reducing speed to the slow, controlled pace needed for field work, hauling, or road travel.

- Bull gears are typically:
- cast iron or steel
- bolted to the wheel hub or wheel spokes
- open to the air (not enclosed), requiring regular lubrication
- designed with wide, deep teeth to handle dirt, misalignment, and shock loads

Their exposed nature is intentional: traction engines operate in dusty, muddy, and uneven environments, and enclosed gearboxes would trap grit and moisture. Open gearing can be cleaned, inspected, and lubricated easily.

8.6.6 Traction Wheels

The traction wheels are the final stage of the power train. They convert the rotary motion of the bull gears into forward or backward movement of the engine.

Traction wheels on steam engines are:

- large in diameter to provide leverage and smooth travel over rough ground
- wide to distribute weight and prevent sinking
- fitted with cleats or lugs for grip in soil, gravel, or loose material
- built with massive hubs to carry the bull gears and axle loads

The wheels are mounted on a fixed rear axle, but the differential allows each wheel to rotate at its own speed when cornering. Under heavy pulling, one wheel may slip; under turning, one wheel may rotate faster. The gearing accommodates all of this while delivering steady torque.

The combination of:

- high torque from the gearing
- large wheel diameter
- and positive traction from the lugs

gives the traction engine its characteristic slow, powerful, unstoppable movement.

8.7 Hitch and Drawbar Loads

Once the engine can generate tractive effort, the next question is how that force reaches the implement being pulled.

Plowing engines are designed to pull extremely heavy, continuous loads, often under shock conditions as the plow enters and leaves the soil. Because of this, the drawbar and hitch arrangement must transmit all draft forces through the engine’s structural members — the hornplates, cannon bearings, and rear axle — without placing any load on the boiler shell.

This requirement is not optional or stylistic. It comes directly from boiler-design principles that were already well understood in the traction-engine era and are explicitly stated in modern historical-boiler regulations: a boiler is a pressure vessel, not a structural frame, and must not be subjected to bending, twisting, or external mechanical loads.
Any such load can distort seams, stays, or firebox sheets and reduce the boiler’s safe working pressure.

8.7.1 Hitch

On a plowing engine, the lower cannon bearing carries the rear axle and already absorbs:

- wheel thrust
- bull-gear reaction forces
- torque from the cross shaft
- side loads from uneven ground
- shock loads from traction work

It is the strongest structural point on the rear of the machine and is designed to carry mechanical loads. For this reason, the hitch or drawbar bracket is tied directly into the cannon-bearing structure, not the boiler.

This ensures that:

- all draft forces pass through the axle and hornplates,
- no bending moment is applied to the boiler barrel,
- the firebox and stays remain undistorted,
- and the boiler's maximum allowable working pressure (MAWP) is not compromised.

8.7.2 Why the Boiler Cannot Carry Hitch Load

Boilers are strong in internal pressure tension, but weak in:

- bending
- twisting
- external point loads
- frame-type stresses

Riveted shells and stayed fireboxes are especially vulnerable to distortion. Even small deflections can:

- misalign the crankshaft and gearing
- distort the firebox sheets
- overstress stays
- reduce MAWP
- or cause leaks at seams and rivet lines

For these reasons, both historical practice and modern boiler codes agree: the boiler must not be used as a structural member.

8.7.3 Hitch Load

On a plowing engine, the load path is:

Plow → Hitch → Drawbar Bracket

Drawbar Bracket → Lower Cannon Bearing / Axle Structure

Axle Structure → Hornplates

Hornplates → Engine Frame

The boiler is not part of this chain.

This arrangement keeps the pressure vessel isolated from mechanical strain while allowing the engine to deliver enormous draft forces safely.

8.7.4 Why This Matters for Plowing Engines Specifically

Plowing engines experience:

- continuous high drawbar load
- shock loads from soil engagement
- long periods of sustained torque
- uneven ground and side loads

These loads are far greater than those seen in road haulage. If transmitted into the boiler, they could distort the pressure vessel enough to reduce its safe operating pressure or cause structural damage.

By routing the load through the cannon bearing and hornplates, the engine can pull safely at full power without risking the boiler.