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Tractor Tire and Ballast Management

William W. Casady, Department of Agricultural Engineering

Careful management of ballast and tire inflation pressure can maximize tractive efficiency, minimize compaction, increase tractor drivetrain life and increase profitability.

Tractive efficiency measures how well a tractor uses the power available at the axle to pull an implement through the soil. Improving tractive efficiency reduces costs through improved fuel efficiency and increases the productivity of your tractor. Improving tractive efficiency doesn't usually require an investment in new equipment. The time spent in improving tractive efficiency provides immediate fuel savings and improved performance.

Lightly ballasted tractors and tire inflation pressures maintained at minimum levels for safe operation and satisfactory tire life also protect the soil. Overinflated tractor tires are a common cause of poor tractive efficiency and compaction. Large forces from overinflated tires and over-ballasted tractors compact the soil, squeezing soil particles closely together and reducing pore space. Crops grown in soils damaged by compaction are less likely to survive moisture extremes such as heavy rain and droughts. Low inflation pressures and properly ballasted tractors minimize the forces applied to the soil surface, which minimizes compaction and improves long-term productivity of the soil.

The best approach to maximizing tractor performance and minimizing compaction is to first select an equipment set that is best suited to the tractor that will pull it. Ideally, each piece of equipment should be sized so that the tractor delivers maximum power to the soil at speeds of 4 to 5 miles per hour. If a tractor is used for both primary and secondary tillage or light-duty work such as planting, the primary tillage implements should be relatively narrow and the light-duty implements should be wider so that each implement requires similar total draft forces when pulled at appropriate speeds.

When practical limitations such as cost or width restrictions prevent choosing implements that are well matched to the tractor, maximum performance can be achieved only by adjusting ballast and tire pressures throughout the season. In practice, except for front-end weights, tractor ballast is often considered fixed. A suitable optimization for a variety of uses should be determined when the tractor is placed in service. An optimum configuration of ballast and tire pressures is generally a compromise between maximum power transfer and acceptable levels of soil compaction.

Tractive efficiency

Tractive efficiency is the fraction of power available at the axle that is actually delivered to an implement through the drawbar. Power is transmitted most efficiently to surfaces that do not deform under pressure and where traction is great enough to prevent the wheels from slipping (Figure 1). Tractive efficiency on soils is limited both by rolling resistance and by wheel slip. Maximum power is available at the peak of each of the curves in Figure 1 where tractor parameters are commonly optimized to allow 8 to 15 percent slip. Power is limited by excessive rolling resistance on the left side of the curves and by excessive wheel slip on the right side of the curves. Maximum tractive efficiency results from a compromise between minimizing rolling resistance and minimizing wheel slip.

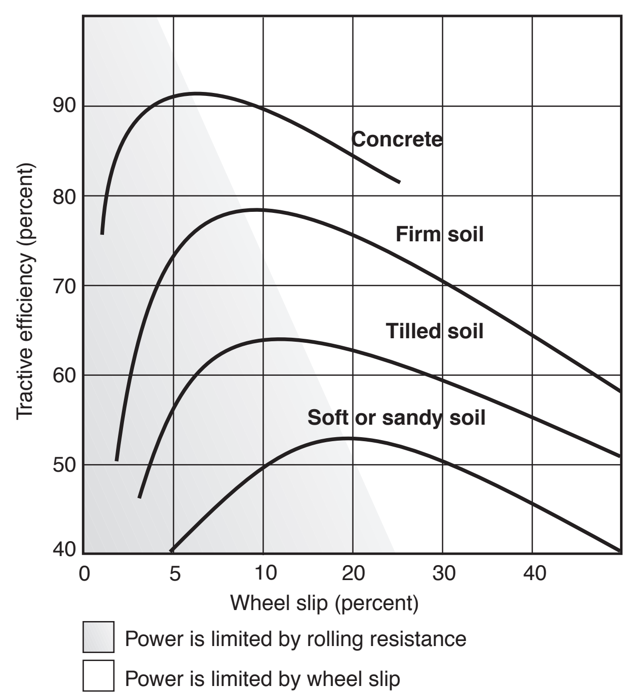

Figure 1. Maximum power is available at the peak of each curve — a compromise between rolling resistance and wheel slip.

Modern tractors are designed to transmit large amounts of power to the soil. Transmitting that power requires large frictional forces, or traction, at the soil surface. Traction can be increased by increasing either weight or contact area. Additional weight creates greater forces at the soil surface, causing greater soil compaction and increased soil strength. The increased soil strength resists the forces applied by a tire as it transmits power to implements in contact with the soil, but the additional weight causes a deeper track, which increases rolling resistance. Wide tires and dual tires increase contact area, flotation and traction, and reduce both depth of track and compaction.

Soil compaction

Soil compaction is an increase in bulk density and a decrease in pore space of the soil that is often caused by applying pressure to the soil with tractors and other heavy equipment such as trucks, combines and grain carts. Compaction can cause a physical barrier to normal healthy root growth, causing symptoms of water stress and nutrient stress. The effects of reduced pore space are reduced water infiltration, water holding capacity, and air exchange.

In years when moisture is either in short supply or excessive, the pore space in a well-structured soil acts as a reservoir and conduit system for water, buffering the effects of moisture extremes. An ideal soil is composed of about 50 percent pore space allocated equally to air and water. Pore space also allows roots to displace soil as they grow. But heavy wheel traffic, especially under wet soil conditions, damages soil structure and packs soil particles closely together, reducing pore space. Tightly packed soil is a serious condition for plants. Roots encounter a physical barrier to growth because there is nowhere to move the soil, and the reservoir and conduit system for air and water is shut down. Any practice that minimizes soil pressure also minimizes compaction. Maximizing tractive efficiency and minimizing compaction are often compatible goals and both increase profitability.

Managing tractor parameters

There are three ways to maximize tractive efficiency of tractors and to minimize compaction: power management, ballast management, and tire inflation pressure management.

Power management

Tractor drivetrains are not designed to provide maximum power in lower gears. Maximum power delivered at low speeds requires large forces that can cause premature wear on drivetrains. Maximum power delivered at higher speeds requires smaller soil forces and smaller traction requirements. Implements with large draft requirements, such as primary tillage tools, should be sized so they can be operated at minimum speeds of at least 4 or 5 miles per hour. Pulling an implement at higher speeds reduces both drivetrain wear and soil compaction when the tractor is properly ballasted. The combination of smaller implements pulled at higher speeds reduces the weight needed to achieve maximum tractive efficiency, which minimizes the pressure applied to the soil surface and reduces soil compaction.

Ballast management

Ballast should be used to achieve just enough traction to transmit power to the ground without excessive wheel slip. Some power is always lost to wheel slip. Excess ballast causes a deeper track that increases rolling resistance. Power is lost from an over-ballasted tractor because the wheel must climb out of the deeper track that it creates. Optimum ballast is a compromise between wheel slip and rolling resistance. Eliminating wheel slip by adding ballast does not maximize power transmitted through the tractor drawbar.

Tilled or soft soils require more ballast for traction. Tillage reduces soil strength, which increases the depth of tracks and reduces traction. More power is lost to both rolling resistance and wheel slip on tilled or soft soils than on no-till or firm soils. Loose or slippery residue can also cause high amounts of slip -- even on otherwise firm soils.

Ballast should be distributed between the front and rear of the tractor in the correct proportions to achieve maximum tractive efficiency and stability (Table 1). The location of the drawbar on a tractor causes weight transfer from the front axle to the rear axle when the tractor is pulling an implement. Weight transfer is especially evident on a two-wheel-drive tractor when the front end becomes so light that steering becomes difficult.

Table 1. Front and rear weight distribution.

	Weight distribution	
Tractor design / Implement type	Front	Rear
Two-wheel drive / Trailing implement	25%	75%
Two-wheel drive / Semi-mounted implement	30%	70%
Two-wheel drive / Mounted implement	35%	65%
Front-wheel assist / Trailing implement	40%	60%
Front-wheel assist / Mounted implement	45%	55%
Four-wheel drive / Trailing implement	55%	45%
Four-wheel drive / Mounted implement	60%	40%

A similar effect occurs when adding or removing ballast especially to the front weight bracket because it is not centered over the front axle. Adding ballast to the bracket on the front of a tractor reduces the weight on the rear axle. For example, adding 100 pounds on the front increases total tractor weight by 100 pounds but may increase the weight on the front axle by 150 pounds and reduce the weight on the rear axle by 50 pounds.

The static (no-load) weight distributions shown in Table 1 should be maintained by adding and removing ballast from the front and rear of the tractor. Front-wheel-assist and four-wheel-drive tractors should have relatively more weight on the front than two-wheel-drive tractors because the front wheels also provide traction.

Tire and inflation pressure management

Tires should be selected and managed to provide maximum contact area with the soil surface. Contact area depends on the size, type and number of tires as well as tire inflation pressure. Properly inflated radial tires provide a larger and flatter footprint than bias-ply tires. Large, dual, radial tires maintained at minimum tire inflation pressures transmit power to the soil through the largest area. Increasing the contact area of tires reduces the pressure exerted by the tire on the ground. The pressure exerted by a tire on the soil surface near the lugs is roughly 2 pounds per square inch greater than the tire inflation pressure. When dual tires are used in place of single tires, each tire carries a smaller portion of the weight of the tractor; hence, tire inflation pressures can be reduced. Whenever tire pressures are reduced, the tire flexes over a larger area and further reduces the pressure applied to the soil surface.

Determining optimum ballast and tire pressure configurations

The optimum ballast and tire pressure configuration for a tractor depends on (1) the type and size of the tractor, (2) the type, size and number of tires, (3) soil type and soil condition, and (4) draft, which depends on the type, width and operating depth of the tillage tool or other implement. Variables such as tire size and implement type can be controlled, but soil characteristics can vary considerably within a field. Hence, an optimum configuration must be determined for average conditions. Several optimum configurations may be determined for various types of field operations and soil types. The following procedure is a step-by-step guide to determining an optimum configuration.

Step 1. **Select a field operation** such as chisel plowing, field cultivating or planting and equip the tractor according to guidelines in the owner's manual, your experience or other available guidelines.

Step 2. **Weigh and record each axle separately.** Fill mounted tanks such as fuel tanks and sprayer tanks. If mounted equipment is used, weigh the tractor with the mounted equipment.

Step 3. **Determine tire type and size** from the tire codes on the sidewall of the tires. Tires may be either radial or bias ply. Radial tires will have a star marking; (*, **, etc.). Bias ply tires will have a ply rating (4-ply, 6-ply, etc.). Tire size codes are based on tire design and rim diameter, for example, 18.4R-38.

Step 4. **Check and adjust weight distribution.** Refer to the owners manual or to Table 1 and adjust front and rear weights so that the weight of the tractor is properly distributed between the front and rear axles. Record the final weight of each axle.

Step 5. **Determine the weight supported by each tire.** Divide the axle weight by the number of tires on the axle.

Step 6. **Adjust tire inflation pressures.** Refer to the tire inflation pressure chart for your tires, which is available from your tire dealer. Locate your tires on the chart by tire size. Determine the minimum tire inflation pressure listed in the chart for the weight supported by each tire, as calculated in Step 5. Adjust tire inflation pressures as necessary. Refer to "Tire Load and Inflation Pressure Guidelines" for more information about tire management. Caution: Do not overinflate tires! Tires with lower ply ratings or lower star markings have lower maximum pressures. For example, the maximum inflation pressure for a one-star radial is lower than the maximum pressure for a two-star radial. Maximum pressures should be used only if necessary to support the load on the tire.

Step 7. **Assess tractive efficiency by measuring or observing wheel slip**. Refer to "Measuring Wheel Slip by Counting Tire Revolutions" to measure slip. Wheel slip can be estimated by observing the appearance of the track. *If the track is scrambled* so that the lug marks are completely broken, slip is high. *If the track is well-defined* and the lug marks are unbroken, slip is low.

Step 8. **Add or remove ballast to optimize slip**. *If slip is high or greater than 15 percent*, excessive power is being lost to wheel slip. Excessive wheel slip may be caused by (1) soil that is too wet, (2) a draft force that is too large, (3) tires that provide inadequate contact with the soil surface because they are too small or overinflated, or (4) a tractor with inadequate ballast

- Consider equipping the tractor with larger tires, dual tires or radial ply tires.
- Ballast may also be added to improve traction. Increased ballast will cause greater soil pressures and increase compaction. Consider using dual tires to decrease soil pressure and remember to adjust tire pressures.

If slip is low or less than 5 percent, excessive power is being lost to rolling resistance and ballast may be removed to increase tractive efficiency. Removing ballast reduces the weight of the tractor and will decrease the severity of compaction.

NOTE: Decrease tire inflation pressures when ballast is removed or when dual tires are used. Increase tire pressures when ballast is added or when dual tires are removed. Weigh each axle separately to determine

Tire load and inflation pressure guidelines

Tires should be inflated according to “tire load and inflation pressure tables.” The loads listed in the tables are the maximum loads for a given tire design and inflation pressure that will provide safe operation and acceptable tire life at the maximum rated speed. Most tables are based on recommendations published by the Tire and Rim Association and are standardized by tire type and size. Consult the table published by the manufacturer of your tires for specific information.

Radial tires can be inflated at pressures as low as 6 pounds per square inch (psi), depending on the design of the tire and the application. The lowest tire pressures are usually recommended only for tractors with dual tires pulling drawn (as opposed to mounted) equipment on relatively flat surfaces. Tire pressures listed in the tables should be increased by 4 psi for a tractor with single tires operated on sloping surfaces or equipped with mounted equipment to prevent tire damage from side forces.

When operating at lower pressures, an additional 4 psi is also recommended if the tire is operated under harsh conditions or under heavy loads where greater torque on the wheel could cause rim slip. Dual tires are highly recommended under those conditions. When dual or triple tires are used, the maximum weight allowed per tire is smaller, because at any instant in rough terrain, an individual tire may carry more than its share of the load.

The loads in the “tire load and inflation pressure tables” are for safe operation at the indicated tire pressures at maximum rated speeds, which are generally 25 miles per hour. Load and inflation tables often include footnotes allowing increases in maximum loads for tires that are always operated below the maximum rated speed. For example, the loads in the Firestone Farm Tire Data Book can be multiplied by 1.07, 1.11 and 1.34 if the tractor will not be operated at speeds above 20, 15 and 10 miles per hour, respectively.

the load on the tires and use a tire inflation pressure chart to determine the correct tire pressure.

Step 9. **Repeat Steps 4-8** if ballast adjustments are made and until slip is approximately 10 percent.

Measuring wheel slip by counting tire revolutions

This procedure requires two people and can be performed in only a few minutes without any special tools. One person operates the tractor and one person counts tire revolutions.

1. *Make a clearly visible mark on the tire* or plan to use the valve stem to count tire revolutions. Chalk makes a good temporary mark.
2. *Lay out a course*. Choose a section of a field with conditions similar to average conditions. The course should be long enough to provide extra space at each end of the course for starting and stopping.
3. *Set a flag* in the field off to the side of the course to mark the beginning of the course. Prepare to operate the tractor and implement under average or normal operating conditions and speeds.
4. *Begin operating the tractor* far enough behind the mark that normal operating conditions are reached before the tractor passes the flag at the beginning of the course.
5. *Note the position of the valve stem or chalk mark* as the tire passes the flag.
6. *Walk parallel to the tire at a safe distance* from the tractor and implement.
7. *Count 20 tire revolutions*. Stop at the moment the tire mark or valve stem reaches its original position for the 20th time.
8. *Mark the end of the course*. Lift the implement.
9. *Return to the beginning of the course*.
10. *Operate the tractor at the same speed* on undisturbed soil parallel to the original course without the implement in the ground.
11. *Count tire revolutions once again* as the tractor travels the entire course. This time, instead of marking the end of the course after 20 revolutions, count the number of revolutions between the beginning and the end of the course. Because the tractor is no longer pulling a heavy load, slip should be almost eliminated and you should count fewer than 20 revolutions.
12. *Use the equation below to determine slip*. Each missing tire revolution under no load accounts for 5 percent slip that occurred during the first pass when the tractor was pulling the implement. For example, 19 revolutions indicates 5 percent slip, 18 revolutions indicates 10 percent slip and 17 revolutions indicates 15 percent slip, etc. The formula for slip is as follows:

$$\%\ \text{slip} = 100 \times \frac{(\text{loaded revolutions} - \text{no-load revolutions})}{\text{loaded revolutions}}$$

Example: During the first pass with the tractor and implement, 20 revolutions are counted. During the second pass with the implement raised 18 revolutions are counted.

$$\%\ \text{slip} = 100 \times (20\text{-}18)/20 = 10\%$$

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