Tractor ballasting

Often, Australian tractors are overballasted. Correctly setting ballast to match a tractor’s main duties can result in fuel savings of five to eight percent. Establishing correct ballast involves identifying goal weights for your main operations and measuring the actual weights at each axle, ideally while the equipment is mounted. Once ballast has been set in the right ball park, further adjustment may be unnecessary, since efficient traction can be achieved simply by adjusting tyre pressure. Taking a common-sense approach minimises the need for ballast changes but ensures that gross ballasting errors are avoided.

Introduction

Although setting up a tractor with correct ballast can be an involved process, consider the overall costs to your business of not getting it right. Incorrect ballasting may result in increased fuel consumption, higher ‘lifetime’ service costs, and increased compaction of and damage to soil. A recent European study found that correct ballasting of tractors can result in fuel savings in the range of five to eight percent (Intelligent Energy Europe, 2012).

Problems with an overballasted tractor

- Increased fuel consumption and a reduction in productive field output (because of hauling excessive weight).
- Increased mechanical wear as a result of higher torque loadings in the tractor’s drive train.
- Increased soil compaction.

Problems with an underballasted tractor

- The potential for increased wheel slip that reduces field output.
- Increased tyre wear in certain conditions.
- The creation of deep tyre furrows in very wet conditions.

Importantly, both overballasting and underballasting limit the driver’s ability to change the tractor’s tyre pressure so as to optimise traction.

A common-sense approach

While opinions vary regarding the degree of precision warranted in tractor set-up, the technical literature agrees that when it comes to ballasting, the rule of diminishing returns applies.

Grossly incorrect ballasting has a substantial negative effect on fuel efficiency and on tractor performance overall. Provided ballast is set in the right general range, however, little fuel-efficiency benefit can be achieved from constantly tweaking ballast to compensate for different soil conditions or variations in the weight of mounted equipment (Zoz & Wiley, 1995).

The aim of the approach recommended in this paper is to achieve a standard ballast set-up that is not heavier than it needs to be and that falls within the range necessary to allow the fine-tuning of traction by adjusting tyre pressure.

Quick tips

- **Tyre pressures are key.** Once the correct ballast has been established, tyre pressure can be used to optimise tractive efficiency.
- **Don’t overballast.** Experts have observed that farmers in Australia tend to overballast their tractors.
- **Don’t sweat it!** Provided your tractor weight is in the right ball park, ballast adjustments do not have an overwhelming impact on efficiency.
- **Cast-iron weights are better than fluid.** Although adding water to tyres is cheaper, it may harm and decrease the lifespan of your tyres. This is particularly the case for radial bias tyres.
- **Buy the right rims and tyres.** Make sure that the rims can accommodate cast-iron weights and the tyres are large enough to allow the use of lower pressures at any given tractor weight.
- **Read the manual!** Manufacturers provide optimal ballast recommendations for various applications.
- **Minimise labour and workplace health and safety (WH&S) risk.** If your operations demand changing ballast on a regular basis, consider hydraulic hitches that make it easy to pick up weight as required.

Two general approaches are recommended. The one you choose will depend on your farming system and capacity to dedicate tractors to tasks.

1. Establish a single ballast set-up that meets the typical needs of the tractor across all its operations.
2. Change the ballast only for long-term operations that have distinctly different ballasting needs.

Note that frequent ballast adjustment still may be necessary to ensure effective steering and stability. If your operations and safety requirements do demand changing ballast on a regular basis, consider hydraulic hitches that make it easy to pick up or drop weight as required.
Tractor ballasting

Caution
The information provided here is intended as general guidance only. Farmers should first check manufacturer’s guidelines/manuals and follow safety precautions, especially when ballasting for potentially dangerous conditions, such as having a front loader or driving over uneven or hilly terrain.

The ballast set-up process
Adding the appropriate ballasting weight and positioning it correctly requires consideration of vehicle and operator weight, the optimal distribution of weight between axles, tyre pressures, mounted implements and travel speed.

NSW Farmers recommends the following six steps:

1. Consult your supplier and the tractor manual.
2. Identify your gross goal weight.
3. Identify the goal-weight distribution by axle.
4. Measure the actual weight and its distribution.
5. Precisely adjust ballast to achieve goal weights.
6. Observe results in the paddock, then fine-tune by adjusting tyre pressures.

The ballasting process involves collecting data that is particular to your tractor, mounted equipment and operations. We recommend that you create a table on which to record this information.

Step 1: Consult your supplier
NSW Farmers believes that all manufacturers and suppliers of farm machinery should provide high-quality documentation and after-sales service in relation to tractor set-up.

Most vendors offer a wide range of options for their machines including wheels, tyres, hitch points and ballasting packages. All of these items have implications for gross weight and your ability to achieve tractive and general operating efficiency.

A tractor’s technical capacity and the willingness of its supplier to advise and assist you in the set-up process are important considerations when selecting a machine.

Refer to Tractor purchasing considerations.

Step 2: Research and document goal weight
Goal weight is the ‘ball park’ gross weight that is optimal for your machine and its operations. You need to identify this before undertaking the process of adding or removing ballast.

Strictly speaking, gross weight is the sum of the tractor, ballast, the operator and any additional load (for example, a front-mounted tank).

Recommended gross weights for given loads and ground speeds are provided by manufacturers and can be sourced from the tractor’s manual or from the supplier.

If you are using the same machine for operations with different loads and ground speeds, you may wish to identify goal weights for each of these operations.

The specific documentation for your machine should be your primary reference. Typically, the information is provided in matrix form, requiring you to look up the weight for the ground speed and load of the operation.

A generic example is given in Table 1. This table provides optimal gross tractor weights for given tractor types, PTO power and operating speed. The numbers represent the kilograms required per kilowatt at the PTO. Note that this approach does not factor in weight of mounted equipment.

<table>
<thead>
<tr>
<th>Tractor type</th>
<th>Ground speed (km/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;7 km/hr</td>
</tr>
<tr>
<td>2WD &amp; MFWD</td>
<td>80</td>
</tr>
<tr>
<td>4WD</td>
<td>65</td>
</tr>
</tbody>
</table>

Table 1: Optimal gross tractor weight per PTO power (kg/kW) at various operating speeds. Values were converted from US units (Hanna, et al., 2010)

Step 3: Determine weight distribution
Weight distribution is critical to performance and safety. Optimal distribution may vary considerably for different tractor types, hitch points and mountings. Table 2 provides generic recommendations. As with gross weight, the manufacturer’s recommendations should be your primary reference.

<table>
<thead>
<tr>
<th>Tractor type</th>
<th>Type of operation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Towed/drawbar</td>
</tr>
<tr>
<td></td>
<td>Front</td>
</tr>
<tr>
<td>2WD</td>
<td>25%</td>
</tr>
<tr>
<td>MFWD</td>
<td>35%</td>
</tr>
<tr>
<td>4WD</td>
<td>55%</td>
</tr>
</tbody>
</table>

Table 2: Front-to-rear axle ratio as a percentage of total weight – adapted (Hanna, et al., 2010)

Step 4: Measure current weight on each axle
Before setting the operating weight of your tractor, we recommend that you confirm the actual weight of the machine. The published weights for your tractor as provided by the manufacturer are unlikely to exactly represent your tractor’s actual specifications and options. In addition, mounted equipment contributes to the gross weight and its distribution.

It is important to obtain separate measures for the weight on each axle and make sure that measurements are made while:

- the fuel tank is at half capacity,
- the operator is in the seat of the cab, and
- ideally, the main implements are mounted.

1 For 2WD and MFWD tractors, rated power is usually stated at the power take-off (PTO). For 4WD tractors, however, rated power is typically quoted at the engine (engine power). PTO power is approximately equal to 85 percent of engine power (Michelin North America, Inc., 2001).
Tractor ballasting

There are varying opinions about how exactly one needs to be when factoring in mounted items when establishing goal weight. Significant benefits can be achieved without factoring in mounted equipment.

To weigh or not to weigh?
It is important to realise that step 4 need only be done once as part of identifying the ballast needed to achieve your goal weight. Nonetheless, you will need to assess the costs and benefits of taking this step.

If you have a weigh bridge on farm that fits your tractors, or easy access to public weight bridge, taking step 4 is relatively easy. If you don’t, the decision may be less obvious. Portable scales cost in the order of $9,000. We recommend that you explore options for borrowing or renting these. Your tractor supplier, service contractor or farming group may be able to loan scales out.

Step 5: Add/remove the appropriate weight
Referring to your recorded goal weights, add or remove ballast from each axle as required. Be aware of the weight limitations that may be inherent to the type of tyres on your tractor. The principal ways to add ballast are:

- adding cast iron weights, and
- filling the tyres with fluid (water or calcium chloride solutions).

Adding fluid to radial tyres is not recommended!
Modern radial tyre construction is best suited for the addition of cast iron ballast (where required by calculation). Cast iron weights help the tyre retain its inherent benefits of improved performance by retaining its large square footprint. The addition of liquid ballast may initially appear to improve performance. This, however, can be at the expense of reduced tractive efficiency and may result in tyre damage from heavy impact. Further, it is suspected that calcium chloride solutions (the antifreeze liquid that is usually added) may cause corrosion problems with valve stems and rims.

Nonetheless, adding water or calcium chloride solutions is typically a cheaper method of ballasting. It can be suitable for tractors using bias ply tyres and can also help add ballast to the front axle of MFWD tractors to control power hop without exceeding optimum inflation pressures. Always remember, however, not to exceed 40 percent fluid fill on rear axle tires and to fill all tires on an axle to the same fluid level. Also, it is best to monitor your rims for corrosion.

Step 6. Fine-tune traction using tyre pressure
Now that you have set a correct goal weight for the machine, you can use tyre pressure to fine-tune the set up. Make a time to observe traction under real-world conditions in the paddock and experiment with different tyre pressures. Adjusting tyre pressure is the easiest and most effective way to achieve an optimal ‘slip to grip’ ratio for given surface and load conditions.

It is important to obtain the right tyres to begin with. Larger tyres allow operating at lower inflation pressures, increasing tractive efficiency. A study has found that selection of tractor tyres that allow operation at lower pressures for any given weight can provide great efficiency gains than ballast optimisation (Zoz & Wiley, 1995). Tyre selection may involve trade-offs due to the constraints on track width that exist on many farms. Once again, this is an area where NSW Farmers believes suppliers should be providing high quality advice at purchase and after sales.

Refer to supplementary paper: Tractor tyre selection

Which method?
Research into ballasting methods reveals competing views and approaches.

The International Society for Terrain-Vehicle Systems (ISTVS) recommends a method called gross traction ratio (GTR) that factors in average travel speeds, tractor (engine) loading, soils, and operation with different implements.

Prominent agricultural and biosystems engineer, Mark Hanna, takes a different approach which factors in specific conditions (see Tables 1 and 2).

The ISTVS method will recommend a weightier ballasting point than Mark Hanna’s (by about 10–15%) but is likely a good approach for cases where a tractor is used for various field operations without adjusting its ballast very often. This is because the ISTVS method approximates the best ballast point for average as opposed to specific conditions.

If you wish to explore results for different methods, NSW Farmers has developed a calculator for the ISTVS and Hanna methods (see Further Information).

Fulcrum effects
When adding ballast, it is useful to understand and compensate for transfer effects when weights are added to the front of the tractor. As shown in Figure 1, the front axle may act as a fulcrum: transferring the moment of rotation, it effectively reduces the weight on the rear axle.

Refer to supplementary paper, Tyre pressure.
Tractor ballasting

Worked examples

1. With reference to Figure 1, how will the axle weights change if 400 kg in suitcase weights (W1) are added, the distance between the centre of the suitcase weights and the centre of the front axle (D1) is 1.5 m, and the distance between the front and rear axles (D2) is 4 m?

\[
W1 \times D1 = W2 \times D2
\]

\[
400 \times 1.5 = W2 \times 4
\]

\[
600 = 4 \times W2
\]

W2 = 150 kg

In this case, the front axle weight would increase by 550 kg (400 + 150) and the weight on the rear axle would decrease by 150 kg.

2. Optimally ballast a 4WD tractor with a rated PTO power of 150 kW to pull a towed tillage tool at 7 km/h.

From Table 1 we calculate the optimum tractor weight.

\[
150 \text{ kW} \times 65 \text{ kg/kW} = 9,750 \text{ kg.}
\]

We determine from Table 2 that we must distribute 55% of the weight on the front axle and 45% in the rear.

Front axle weight = 0.55 \times 9,750 \text{ kg} = 5,363 \text{ kg}

Rear axle weight = 0.45 \times 9,750 \text{ kg} = 4,388 \text{ kg}

We weigh the tractor using portable scales and obtain the following unballasted weight on each axle:

Front axle weight = 4,200 \text{ kg}

Rear axle weight = 5,600 \text{ kg}

This indicates that the front axle requires an additional 1,163 kg, while the rear axle is over ballasted by 1,212 kg.

Using mounted suitcase ballasts on the front of the tractor will therefore allow one to increase the weight on the front axle, while decreasing it on the rear using the fulcrum dynamics explained in the first example.

Assuming the distances D1 and D2 remain 1.5 m and 4 m respectively, we can derive that:

Approximately 846 kg must be added as front suitcase ballasts (W1). This will reduce the weight on the rear axle by about 320 kg and means that only 890 kg of weight (W2) should be removed from the rear axle.

Further information

NSW Farmers ballast calculator

Portable tractor scales

List of public weighbridges locations in Australia

Ballasting calculators for John Deere Tractors

Ballasting, tyre pressures, wheel slip and their relation to tractor performance

Traction and tractor performance
www.agmachinery.okstate.edu/tractors/TractionTractorPerformance.pdf

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Tractor ballasting

References


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