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Getting the best from tractor tyres

By J. Quealy*

The amount of pull a tractor develops depends largely on tyre efficiency and with so many tyre size options for the one tractor model it is very easy to make the wrong decision on tyre fitment.

Tyres provide two main functions. They transfer axle horsepower to drawbar pull and they support the weight of the tractor.

Tyres were not a major consideration in tractor performance before this decade, as the lower power and comparative working conditions did not place heavy demands on the tyre. Today, we must understand tyres in more detail. With a single tyre now commanding a retail list price of up to $2,000 and the big four-wheel drive units having eight tyres fitted, the cost is up to $16,000.

Tyre efficiency varies with tractor weight, soil conditions, inflation pressure and tyre size. Excessive wheel slip causes very inefficient power conversion at the drawbar, wastes fuel, shortens tyre life and reduces the area covered per hour by the tractor. This can be overcome by ballasting the tyres to increase tractor weight.

However, adding to the all-up weight of the tractor increases rolling resistance, forces the tractor to penetrate the soil and requires extra power just to move it along. Weight must also be related to engine power as any tendency to apply weight indiscriminately places undue strain on drive train components.

Some manufacturers nominate the gross operating weight their units must not exceed to ensure that stress limits of the drive train are not over extended. Should the operator do so, or the dealer allow it to happen, manufacturer warranty complications will occur, particularly with 4-WD-all-wheel-drive units.

Wheel slip is the real measure of tractor and tyre efficiency and is also the safety fuse for tractor transmissions. The correct wheel slip to deliver maximum drawbar power varies from 6 per cent on very firm soils, to 16 per cent on soft soils.

Under most field conditions, tractor drive wheel slippage should range between 10 and 15 per cent. This range is a compromise for various soil types as it would be impractical to add or remove weight when working on different soils. The method of calculating wheel slip is outlined in another article, "matching tractors and implements".

When it comes to tractor weight and tyre ballasting, traditional habits must first be overcome. Past practice for tractor pre-delivery has been to automatically water-fill the tyres to the 75 or 90 per cent level. Today however a few things must be considered before weighting the tractor.

Ballasting

Most high power tractors have an inbuilt gross operating weight. For 4-WD all wheel drive tractors it is total tractor weight and for most two wheel drive tractors it is gross weight over the drive axle. The base weight of the tractor is also generally declared.

Add to the base weight extras such as fuel loading air conditioned cabs and the effects of tyre size options and dual wheels, and then subtract

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the total base weight from the allowable gross weight. This will tell whether the tyres can be ballasted without exceeding the warranted weight of the tractor. Optimum weight for both two wheel drive and 4-WD tractors can be determined where maximum tractor operating weights are not nominated. After the tractor is weighted to the recommended level, a wheel slip check should be done using a high-draft implement. Weight distribution on a two-wheel-drive tractor is generally 75 per cent of total tractor weight on the rear wheels and 25 per cent on the front. Ideally, a 4-WD unit should have half the total tractor weight on each axle when the tractor is working. Because there is weight transfer from front to rear when the tractor is under load, it is generally accepted that stationary weight distribution for 4-WD is 65 per cent on the front, and 35 per cent on the rear axle. Accepting that overall tractor weight is distributed on this basis, total tractor weight for ideal wheel slip can be estimated. The power of the tractor is multiplied by a factor to obtain an approximation of the best total tractor weight. The factor for tractors of different power (kW) is given in table 1. Alternatively, another simple and proven formula calculates the required weight over the drive axles rather than the overall weight of the tractor. The calculation is:

Optimum weight over drive axles = \[ \frac{\text{PTO power (kW) x 490}}{\text{speed (km/h)}} \] (for 2 wheel drive)

= \[ \frac{\text{Rated engine power (kW) x 490}}{\text{speed (km/h)}} \] (for 4 wheel drive)

Both formulae clearly highlight how the variation in tractor operating speed affects drawbar pull. For example, calculated load for a 90 kW PTO power two-wheel-drive tractor at 6.5 km/h is 8,730 kg and at 10 km/h is 5,760 kg. The ready-to-work weight of the tractor without ballast should be

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**Table 1. Factors for approximation of optimum tractor weight (power in kW)**

<table>
<thead>
<tr>
<th>Speed (km/h)</th>
<th>2 wheel drive tractor</th>
<th>4 wheel drive tractor</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.5</td>
<td>PTO power x 97 = kg of total weight</td>
<td>PTO x 85 = kg of total weight</td>
</tr>
<tr>
<td>8</td>
<td>PTO power x 79 = kg of total weight</td>
<td>PTO x 70 = kg of total weight</td>
</tr>
<tr>
<td>10</td>
<td>PTO power x 64 = kg of total weight</td>
<td>PTO x 58 = kg of total weight</td>
</tr>
<tr>
<td>11.5</td>
<td>PTO power x 55 = kg of total weight</td>
<td>PTO x 49 = kg of total weight</td>
</tr>
</tbody>
</table>

---

**Table 2. Weights added by ballasting to 75 and 90 per cent levels**

<table>
<thead>
<tr>
<th>Tyre Fitment</th>
<th>75% fill</th>
<th>90% fill</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.4-30</td>
<td>340 kg</td>
<td>410 kg</td>
</tr>
<tr>
<td>18.4-34</td>
<td>380 kg</td>
<td>440 kg</td>
</tr>
<tr>
<td>18.4-38</td>
<td>420 kg</td>
<td>490 kg</td>
</tr>
<tr>
<td>23.1-30</td>
<td>540 kg</td>
<td>670 kg</td>
</tr>
<tr>
<td>23.1-34</td>
<td>600 kg</td>
<td>730 kg</td>
</tr>
<tr>
<td>30.5-32</td>
<td>820 kg</td>
<td>980 kg</td>
</tr>
</tbody>
</table>

---

**Table 3. Wheel slip traction test**

<table>
<thead>
<tr>
<th>Test weight (kg)</th>
<th>Excess gross operating weight</th>
<th>Tyre pressure (kPa)</th>
<th>Ley (dry)</th>
<th>Fallow</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 7 511</td>
<td>189 kg</td>
<td>110</td>
<td>5% slip</td>
<td>10% slip</td>
</tr>
<tr>
<td>2. 8 740</td>
<td>1 040 kg</td>
<td>88</td>
<td>5% slip</td>
<td>9% slip</td>
</tr>
</tbody>
</table>

The tyre load with 23.1-34 (duals) at 88 kPa is 20 kilo Newtons, and at 110 kPa is 24 kilo Newtons.

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**Table 4. Resistance (Newtons) per metre width of implement, based on a speed of 7.2 km/h.**

<table>
<thead>
<tr>
<th>Implement</th>
<th>Working Depth</th>
<th>Sandy Soil</th>
<th>Sandy Loam</th>
<th>Clay</th>
<th>Heavy Soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disc plough</td>
<td>20 cm</td>
<td>5,840</td>
<td>6,570</td>
<td>8,470</td>
<td>11,680</td>
</tr>
<tr>
<td>Scavenger</td>
<td>15 cm</td>
<td>2,920</td>
<td>7,300</td>
<td>9,490</td>
<td>11,680</td>
</tr>
<tr>
<td>Cultivator</td>
<td>8.7 cm</td>
<td>2,190</td>
<td>3,650</td>
<td>4,818</td>
<td>7,300</td>
</tr>
<tr>
<td>Tandum Disc</td>
<td>7.5 cm</td>
<td>1,460</td>
<td>3,650</td>
<td>5,840</td>
<td>8,760</td>
</tr>
<tr>
<td>Offset Disc</td>
<td>10 cm</td>
<td>2,920</td>
<td>5,840</td>
<td>8,030</td>
<td>8,760</td>
</tr>
</tbody>
</table>

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available and once the working speed is known, the need to add ballast can be simply assessed. In the above examples, there is a weight difference of three tonnes for the speed variation. This weight may have to be carried unnecessarily and once ballast is in the tyres it is really there for all time. A little homework is therefore worthwhile. Furthermore, maximum tractor life is said to be achieved at the unballasted weight; additional weight reduces component life including tyres. Working a tractor at even 10 per cent over-ballasting can reduce component life by up to 50 per cent.

A tractor should be ballasted for an average work condition not for the most severe condition. For high power tractors, weight should be added to contain wheel slip below 16 per cent at 8 km/hour and above.

The examples in Table 2 show the weight added by water-ballasting to 75 and 90 per cent levels. Multiply these weights by the number of tyres fitted and you are talking about tonnes, not kilograms, per tractor.

Should it be necessary to add ballast to the tyres, it should be remembered that less water in the tyres allows for a bigger air chamber to cushion the shocks encountered in everyday work. When the tyre is filled to 90 per cent and the tractor is over ballasted, the small air chamber is further reduced when the tyre strikes an object. The shock waves momentarily travel through the transmission with resultant shock load on drive train components as well as the tyre casing.

Four-wheel-drive tractors

4-WD-all-wheel-drive tractors are designed to operate with half the load on each axle when the tractor is under load. Static load condition for 4-WD tractors is generally said to be 60-40 front to rear. However with the variety of implements now available — some causing more weight transfer to the rear axle than others — it is preferable that the static load ratio be 60 to 66 per cent on the front.

Under load, the weight transfer to front and rear wheels depends on the depth of working (deeper cultivation transfers more weight to the rear wheels) and how far the centre of pull of the implement is behind the drawbar (a shorter pull transfers more weight to the rear wheels.)

On this point, with the variety of options available for the same tractor model, actual static weight distribution may be very different from the optimum design weight. It is important therefore, that actual front and rear axle weight is known and the ratio calculated. Keeping in mind the tractor manufacturer’s gross operating weight it may be necessary to ballast only the front tyres to restore the desired ratio. For example, with a permitted gross operating weight of a popular 4-WD tractor model being 15,500 kg, static weights (with operator) without ballast are 6,740 kg (43.5 per cent) on the rear wheels, and 8,760 kg (56.5 per cent) on the front wheels. With ballast in the front tyres, the front weight is increased to 10,100 kg (60 per cent). The inside duals should be ballasted only to the 75 per cent level.

Ballasting the outer dual should only be done if approved by the tractor manufacturer.

It should be noted however that where the static weight distribution of the tractor is already 60-40 or 65-35 front to rear, and extra weight is really necessary, water ballast should be added to front and rear tyres in the same ratio as the static weight distribution of the tractor.

Two-wheel-drive tractors

When ballasting two-wheel-drive tractors on dual wheels, first determine if ballasting only the inside tyres will do the job. The additional weight that will be achieved is shown in the Dunlop tractor tyre manual. Remember, the outer dual assembly in itself provides additional weight without ballast as well as additional traction. Should further evaluation show additional weight is required to contain wheel slip, add water to the outer tyre of the dual assembly if approved by the manufacturer.

Try ballasting all tyres at about two-thirds full rather than 90 per cent. The reduction in weight is around 200 kg per tyre in the bigger sizes and that could save unnecessarily lugging a tonne of weight on the rear drive axle. It will be easy to top up if necessary.

An example of the lack of performance benefits achieved from over-weighting a high power two-wheel-drive tractor is illustrated in Table 3 by the comparative performance of a model 1466 tractor from International Harvester.

The allowable gross operating weight is 7,700 kg and with the inside tyre of the dual assembly ballasted, the tractor is weighted within the allowable maximum, and wheel slip is acceptable. When the outside dual is also ballasted, allowable gross operating weight is exceeded by 1,000 kg, with no operating advantages. To continue working with more than one tonne excess weight on the drive axle must result in stress fatigue for the drive train.

The test confirms that almost all high power tractors have a declared inbuilt performance against permitted all up weight. Ballast should not be added until an initial slippage test in the soil condition to be worked is first evaluated. Slippage of around 10 to 15 per cent is considered acceptable.

Matching implements to tractor

Since 1970 there has been a continuing increase in power and weight of tractors, to offset cost increases and the lack of farm labour. In consequence, there is a belief that attaching the biggest implement behind the tractor is necessary if the tractor giant is to earn its keep. However, this has to be balanced against the speed of working.

For example, if the efficient working speed of a tractor is 8 km/h and this is reduced to 6.5 km/h the load on the final drive increases by about a quarter. Oklahoma Agricultural Engineers estimate that
when maximum load is applied, estimated transmission life is 10,000
hours at 8 km/h; and 6,500 hours 6.5 km/h and 1,700
hours at 5.5 km/h.
This therefore suggests that it is
better to put the improved tractor
efficiency to work at the higher
tillage speed rather than hang on a
heavier load that has to be worked
in a lower and slower gear ratio.
What must be determined, is how
big the plant should be.
The real objective of farming is to
get the work done at the right time
of the season. This often means
beating the weather, so the element
of area to be worked in a given time
is the key to efficient farming.
This can be simply calculated by
dividing the area to be worked by
the estimated hours available for
doing it. For example, 250 ha to
work in five days working 10 hours
a day, requires a rate of 5 ha/hour.
The decision to be made against the
power available is what size
implement to use. Should the job be
done with a big implement at slow
speed or with a smaller implement at
faster speed. The engineering
formula is:
width of implement (metres) =
12 x ha per hour
speed (km/hour)
The factor of 12 is an adjustment to
allow for turning losses,
overlapping, wheel spin etc.
To take the example further, the
width of implement to do the 5
ha/hour would be:
12 x 5 ha/hour = 10 metres
6 km/h
12 x 5 ha/hour = 8 metres
7.5 km/h
The most important question is
whether the tractor will pull this size
implement.
Assuming the soil to be worked is of
average density and a chisel plough
with a draft load of 6,000 Newtons
per metre of width is used, the
drawbar power required to do the
job is shown in table 6.
Our example shows that the
drawbar power required is the same.

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Table 5. Comparison of single tyres and duals

<table>
<thead>
<tr>
<th>EXAMPLE 1</th>
<th>LARGE SINGLE</th>
<th>DUAL WHEELS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tyre size/ply</td>
<td>24.5 x 32 (10)</td>
<td>18.4 x 38 (6)</td>
</tr>
<tr>
<td>Loading radius</td>
<td>800 mm</td>
<td>802 mm</td>
</tr>
<tr>
<td>Ground contact area</td>
<td>0.598 x 2 = 1.19 m²</td>
<td>0.423 x 4 = 1.69 m²</td>
</tr>
<tr>
<td>Tyre load</td>
<td>36.4 kN at 124 kPa x 2</td>
<td>17.4 kN at 83 kPa x 4</td>
</tr>
<tr>
<td>Tangential load</td>
<td>72.8 kN</td>
<td>69.6 kN</td>
</tr>
<tr>
<td>Tyre load (single tyre operation)</td>
<td>30.6 kN x 2</td>
<td>14.5 kN x 4</td>
</tr>
<tr>
<td>Replacement tyre and tube cost</td>
<td>$1354.00</td>
<td>$736.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EXAMPLE 2</th>
<th>LARGE SINGLE</th>
<th>DUAL WHEELS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tyre size/ply</td>
<td>23.1-30 (8)</td>
<td>18.4-34 (6)</td>
</tr>
<tr>
<td>Loaded radius</td>
<td>746 mm</td>
<td>754 mm</td>
</tr>
<tr>
<td>Ground contact area</td>
<td>.32 x 2</td>
<td>.415 x 4</td>
</tr>
<tr>
<td>(at about 8 cm penetration)</td>
<td>1.04 m²</td>
<td>1.66 m²</td>
</tr>
<tr>
<td>Tyre load</td>
<td>29.8 kN at 110 kPa x 2</td>
<td>16.42 kN at 83 kPa x 4</td>
</tr>
<tr>
<td>Tangential load</td>
<td>59.6 kN</td>
<td>65.7 kN</td>
</tr>
<tr>
<td>Tyre load (single tyre operation)</td>
<td>25 kN x 2</td>
<td>14.6 kN x 4</td>
</tr>
<tr>
<td>Replacement tyre and tube cost</td>
<td>$936.30</td>
<td>$607.75</td>
</tr>
</tbody>
</table>

Table 6. An example calculating draw-bar power.

Total draft of implement (Newtons) x tractor speed (km/h) = 3600

In this example:
(10 m implement x 6,000 Newtons draft per metre) x 6 km/h
3600
= 100 kW drawbar power

(8 m implement x 6,000 Newtons draft per metre) x 7.5 km/h
3600
= 100 kW drawbar power

The speed and width of implement
diffs but the area covered remains
the same. Loading the tractor does
require some experience and
commonsense and requires time and
and effort but working the narrower
implement at a faster speed will, in
many instances, double the useful
life of the tractor and its tyres.
If you know the usable drawbar
power for a tractor, the implement
width most suitable can be
determined by simply reversing the
formula.

100 x 3,600 = 10 m
6 km/h x 6,000 N draft

Table 4 is a guide to the resistance
per unit width of the implement to
be used. This will vary with the soil
condition, moisture content and
speed. It is based on a speed on 7.2
km/hour.

Tyre size and ply rating
The increase in high power tractors
and the obvious need to use that
power requires closer assessment of
tyre size and ply rating for tractor
fitment.
Higher power ratings generate torque absorption for the tyre that requires consideration of the tangential pull valves for tyre selection. The tangential pull value of a tyre is the maximum horizontal pull the tyre can continuously withstand excluding momentary and occasional peak loads.

Drive wheel tyres on tractors operating at high sustained torque have a lower load table for both single and dual wheel fitment. Severe sidewall buckle and early failure when working in the field quickly indicates whether the tyre can meet these standards. Assuming the tyre size is correct for the weight of the tractor, such a problem is generally resolved by fitting a higher ply rating tyre.

**Soil compaction**

One of the design objectives of the tractor manufacturer is for the tractor to work as near to the surface as possible. This makes it easier for the tractor to work and reduces soil compaction. The specific surface pressure under the wheel which determines how severe the top soil compaction will be and the section width of the tyre will determine its ability to stay on top. The Swedish Agricultural College has found that larger tractors give only an insignificant increase in soil compaction; compaction mainly depends on ground pressure between the tyre and the surface, and internal tyre pressure approximately equals external ground pressure between soil and tyre. Therefore, tyres that allow operation at lower inflation pressures should be chosen.

To reduce compaction the tractor should be operated at the lowest recommended air pressure for the actual load and speed condition. Adding unnecessary water ballast increases tyre load and requires more air pressure, and therefore increases pressure between tyre and soil.

In tyre terms the compacted standard for agricultural purposes is obtained with a static pressure of 190 kPa (28 psi) in the tyres under load. At this pressure, roots of plants begin to experience more restriction to penetration and plant growth decreases. At 380 kPa, root penetration is poor and at 770 kPa it completely stops. Tyres that will operate at load around 100 kPa (14 psi) offer the greatest benefits where soil compaction is a problem. Wider, low pressure tyres for the front wheels should be considered more often where soil compaction is a problem, as the damage by front tyres will not be overcome by the drive tyres.

It should be clearly understood that tyres with a higher ply rating do not carry higher loads at lower air pressures; higher ply ratings permit higher loads at a higher air pressure, and lower pressures must carry less load. Tyres should work as near to 100 kPa as possible without overload, and for this reason dual wheels are becoming popular.

Extensive field testing has proved that smaller section dual wheels give better traction than single large sections. The most noticeable improvement is on hard clay surfaces. In these conditions, tread bars cannot penetrate and the increased ground area contact of the duals gives better traction without excessive tyre distortion.

Dual wheels are claimed to be unsuitable for row-crop work but this has been offset by the recent development of quick-hitch dual kits which allow a set of duals to be added or removed in about twenty minutes. The single tyre will generally handle the row-crop work and the duals are used for heavy cultivation and haulage work. The single tyre would require a higher air pressure.

Duals can be fitted without significantly increasing the total weight of the tractor by using an alternative tyre size with a closely similar loaded radius to ensure working gear ratios are unaltered. If a tractor is working on single tyres with maximum ballast, switching to duals without ballast will produce about the same drawbar pull, but soil compaction will be considerably reduced.

A large single tyre is compared to dual wheels of similar loaded radii but a narrower tyre section in Table 5. Dual wheels give greater ground contact without any disadvantage in load carrying, but at a lower air pressure. The saving in tyre replacement cost is particularly significant.

With the availability of quick-hitch duals, it is now possible to also match one of the narrower section, larger rim diameters with an existing large section tyre. It can be achieved at much less cost than would be the case when two large section tyres are paired.

Should the narrow section tyre not carry the tractor load as a single tyre fitment, a higher ply rated tyre could be fitted to the inside of the dual assembly.

The use of triples is attracting interest because even greater operating efficiencies are possible; the development of more dependable attachments are available; and many manufacturers have already engineered triples into their tractor drive trains.

Triples would allow earlier cultivation after rain because of significantly reduced tracking and soil compaction. The improved power efficiency is said to be 15 per cent with up to 20 per cent more flotation and traction than dual wheels. The Unverferth system for attaching the triples is quick and simple to assemble.

While tractor tyres wear at different rates in varying conditions there is no significant loss of traction in an agricultural tractor tyre until more than half of the original tread depth has been worn away.

Much emphasis is made from time to time on the merits or otherwise of varying tread designs. However, the angle of the tread bars makes little difference to traction in most soil conditions and Australian tractor tyre makers have not changed from the 45° angle, bar tread. Most suppliers offer a range of options. In loose, sandy conditions, a shallow-ribbed or blocked tread pattern with a flexible casing that will work at low air pressure is the best tyre fitment.
Where flotation is a consideration and traction is also necessary, a deep open pitch bar pattern is best. Fit the largest tyre section width possible to carry the load at minimum air pressure. Wide section tyres with smaller rim diameters are generally best for flotation but the flexible baggy casing will cause tyre wear in dry abrasive soils.

Where maximum traction is required, narrower section tyres with larger rim diameters will generally do a better job than a wide section tyre of the same approximate loaded radius. For example 18.4 x 34 will wear better and give better traction than 23.1 x 26 in abrasive soils. But 23.1 x 26 will provide much better flotation in sticky cohesive soils.

Where extra flotation is required duals will do the job most successfully. When a single tyre fully ballasted tends to work deep in the soil or where wheel slip is excessive remove the water ballast and fit duals.

For row-crop work and field cultivation, fit narrower section tyres with larger rim diameters as a quick-hitch dual assembly. Should the single wheel row crop work require it, use a heavier ply rated rated tyre on the inside dual. Adjust the air pressure for the single tyre operation.

Where sandy frictional soils or dry black abrasive soils are encountered for short seasonal periods brought about by weather conditions, reversing the direction of the tyres will reduce tyre wear and irregular lug wear without seriously affecting traction. It is not necessary to remove the tyre from the rim; just the complete wheel assembly.

The problem of wheel slip is often more noticeable when wide-section tyres are fitted for continuous work in hard frictional soil conditions where penetration is required but difficult to achieve. Severe casing and lug distortion combined with excessive wheel slip causes rapid tyre wear.

In hard unyielding soils, penetration and traction is best achieved with narrower section tyres fitted as duals.

The increased surface area of the lugs provides better traction and therefore less wheel slip and tyre wear.

Wider front tyres on ratio drive (front wheel assisted) 4WD tractors reduce rolling resistance for the rear tyres that follow. The bigger footprint, gives traction without compaction. It is preferable to have a slightly over dimension front tyre within the tolerance allowed for a ratio drive four wheel drive tractor rather than slightly under dimension. The benefit is longer tyre life.

**Air pressures and speed**

Finally, a word on air pressures and speed. Modern tractors are designed to achieve high speeds. Several are capable of 40 to 50 km/hour. However, the maximum speed rating for agricultural tractor tyres is 30 km/hour.

Tractor tyres are designed to operate for field conditions and air pressures are determined for these conditions. In operating on hard roads or for travelling distances at speeds with normal working pressure, more damage is done to the tyre.

Heat may be developed under the tread bars which weakens the rubber material and cord fabric. There may be no sign of damage but later the tyre will fail.

With low inflation pressure on hard surfaces there is an undesirable distortion of the tyre during which the tread bars squirm while going under and coming out from the load. On hard and abrasive surfaces this action wipes the rubber off the tread bars and wears them prematurely and irregularly; the sidewalls crack at the base of the lugs.

In these conditions, pressure in the tyre should be increased to the maximum recommended for that tyre size to reduce movement of the tread bars. With either road or field work, side cracking indicates that air pressure is too low.