The influence of the tread pattern on the performance of a tractor engine

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Abstract. The Republic of Uzbekistan is currently undertaking many reforms to improve all sectors of the economy and business, to bring the products of our enterprises to international markets in order to increase exports, as well as methods to improve the competitiveness of goods. Examples include the creation of new economic zones and the extension of incentives in existing trade and economic zones. The field of agricultural machinery plays a major role in the economy of our country, so improving all aspects of this industry, will give a significant boost to the economy of the country as a whole. This article deals with tractor tyres, and more precisely the influence of tread pattern, on technical and economic performance of tractors under sandy soil conditions. It will also highlight new designs and innovations in tractor tyres from the world's manufacturers, which improve the off-road capability, improve tractor economy, increase tyre life, and give a great advantage in application over standard tyres.

1 Introduction

At the present time, when Uzbekistan is an integral part of the international community and global financial and economic market, in order to modernise the national economy, technical and technological re-equipment of industries and production of products that meet the requirements of world standards, one of the urgent tasks is to train personnel - specialists on the basis of new requirements and methods, teaching them modern knowledge.

Mechanical engineering is the leading branch of the whole industry, its "core". The products of machine-building enterprises play a decisive role in the implementation of scientific and technological progress in all areas of the national economy [1-3].

2 Materials and methods

We don't usually think about the fact that a car's movement on the road is largely determined by a small contact patch. The contact patch is where the tyre touches the road. If it - this contact - is not there, the car will become completely uncontrollable. If the contact patch has poor grip, poor drainage, poor self-cleaning, bad road behaviour is inevitable. The reverse is also true.

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All the laws of physics that apply to the car on the road also apply to the tractor. Yes, the tractor is slower and less manoeuvrable, but on the other hand it does a much wider range of work than a car. And the tractors work not only on roads, but also in fields, on construction sites, in factories, etc. Tyres with different tread patterns are used for different applications.

We would like to point out that there are very strict requirements for tractor tyres. This is due to the complexity and specific nature of the operation of agricultural, construction and municipal tractor machinery.

Tractor tyres in particular must:

- have a high abrasion resistance to withstand the impressive loads of hours of continuous operation, cross-country manoeuvring and off-road driving;
- have minimal pressure on the cultivated layer of soil;
- ensure that the machine works efficiently on the right type of soil.

Before examining the classification of tractor tyres, it is worth clarifying the nuances of tractor tyre selection.

The first thing to consider when selecting tyres for your tractor is where you will be working. It is imperative that the tyre is suitable for the type of soil. For example, if the tractor is to be used on wet ground, you will need high cleats. In this case the gradient must also be steep. On wet soils it is also a good idea to use tyres with "self-cleaning" [1].

The second important point. Specialists recommend selecting tractor tyres according to the type of front wheel. For example, wide tyres with a variable grip should be fitted to the front drive wheels. For the passive front wheels, however, ribbed tyres are the better choice. The number of ribs is inversely proportional to the moisture content of the ground [4].

The towing capacity is then drastically reduced, which means that fuel consumption is also reduced. As for the rear wheels, the best option is to equip them with 23° inclined tyres [5].

Finally, when selecting tyres for tractor machines, you simply have to take their load and power capacity into account. Naturally, the load limits must not be exceeded under any circumstances.

3 Results and discussion

Research into the theory of wheel-engine-soil interaction has shown that for each tyre of a given size, the load can be selected to give the best traction and flotation properties.

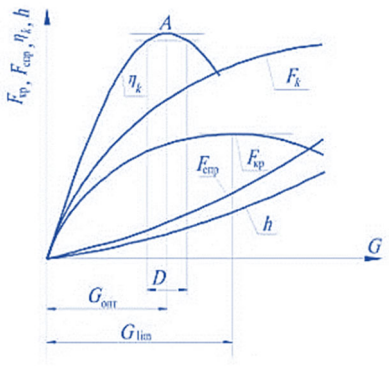

Fig. 1. Traction properties of the drive wheel: F_k - tangential traction force; F_{kp} - traction force of the wheel; $F_{спр}$ - drag force; $\eta_к$- wheel efficiency; h - track depth; G_{lim} - weight limit load; $G_{опт}$ - optimum weight load.

Studies [1, 4] have shown that the traction efficiency $\eta_к$ as a function of the varying vertical load varies according to the relationship in Figure 1, at zero load $G = 0, \eta_к = 0$ (here $\eta_к$- drive-wheel efficiency). Then, with increasing vertical load $\eta_к$ increases and reaches a maximum at point *A*. For the wheel, this vertical load will be the optimum load [6].

In tractor theory [1, 4], the drive-wheel efficiency is estimated by the following formula:

$$\eta_к = (1 - \delta)\left(1 + \frac{F_{спр}}{F_к}\right) \quad (1)$$

where δ - slip, in fractions of one; $F_{спр}$ - rolling resistance force due to crushing of the ground by the propeller and rut formation, N; $F_к$ - tangential traction force, N.

One of the relationships that really depict the interaction of the drive wheel with the ground is [2]

$$F_{спр} = \int_0^h br \cos\alpha_0 \sigma_0 th\left[\frac{K}{\sigma_0} r \ln h\right] dh \quad (2)$$

And

$$h = \int_0^h br \sin\alpha_0 \, \sigma_0 th\left[\frac{K}{\sigma_0} r \ln h\right] dh. \quad (3)$$

A tractor working on sandy ground is very difficult if its propulsion system is not properly selected. From a study [5] carried out in desert conditions we can conclude: the choice of optimum tyre pressure as well as engine type (toroidal, wide-profile, arch, pneumatic rollers) will give an increase in speed and economy of the tractor. But we must not miss the fact that pneumatic tyre rollers show the best results on sand, but their dimensions and related technical difficulties do not allow their use on tractors [7, 8].

It must be kept in mind that the tractor will not always work on sandy soil, but will be operated under different road conditions. Figure 2 shows that the bearing capacity p_s depends considerably on the relative moisture content W. As can be seen from the figure, the bearing capacity p_s of sand first increases with increasing relative humidity *W and* then decreases again.

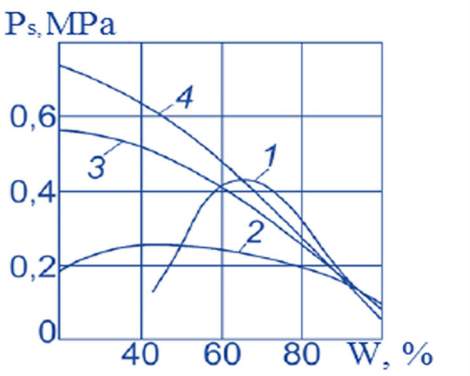

Fig. 2. Dependence of bearing capacity of soil on its moisture content: 1 - sand; 2 - sandy loam; 3 - loam; 4 - clay.

Therefore, it is advisable to adapt the tractor for work in sandy regions of our country by choosing the optimum tyre pressure and using low pressure engines. This is due to the fact that sand has a lower carrying capacity than other types of soil. The effect of tyre pressure on cross-country ability on sandy ground is shown in Figure 3.

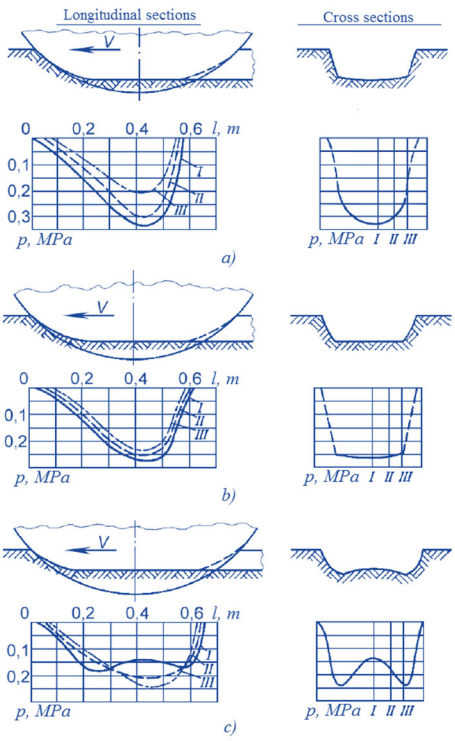

Fig. 3. Deformation of tyre 12.00-18 and sandy soil (γ = 1.3 g/cm^3) under a load of 15 kN and at shell air pressure: *a*-p_w =0.20 MPa; *b*-p_w =0.10 MPa; *c*-p_w =0.05 MPa.

The contact area of a tyre on soft ground is larger than that of a tyre on a flat, hard surface. Deformation of the tyre significantly complicates the process of interaction of the wheel with the ground, as it leads to changes in the shape of the contact surface and the nature of pressure distribution in the contact (Figure 3). Here l is the length of the bearing surface in the cross-section in question. This increases the area of the tyre subject to deformation, but also reduces the pressures and deformation in the middle part of the contact. The shape of the deformed tyre profile on soft ground and on hard ground is different when the deflection h_s is equal.

Tire and Rim Association (TRA) tractor tyre classification is an American system that creates standards for rims and tyres.

The most popular tractor tyre pattern is the R-1 (Figure 4). Invented more than half a century ago and continuously upgraded since then, it combines three of the most important things for off-road work: high traction, self-cleaning ability and not too much soil compaction. However, when it is not used on drive wheels (where traction is not required) or on the road (where self-cleaning and soil care are not required), the drawbacks of the design arise: resistance to wear because the contact patch is full of "voids", poor driveability, rolling resistance that increases fuel consumption and vibration that wears out tractor parts. The letter code R itself indicates the tyre's "specialisation" - Rear (drive) axle in the tractor [9].

Fig. 4. Tractor tyre.

For the front steering wheels of 2 WD tractors, the F-1 tyre pattern (Figure 5) is well suited. "The speciality of this pattern is the steering wheels. Good handling due to the continuous centre rib, low rolling resistance, and low vibration. However, on the field in the mud, its disadvantages become apparent: an almost complete lack of self-cleaning and a rather high specific pressure on the ground. As in the last figure, the name of this one also encodes the application - Front - front tyre.

Fig. 5. The F-1 tyre.

I-1 tyres are sometimes used on the carrier wheels of small tractors (Figure 6). These are trailed tyres, not tractor tyres, and their name also implies the use of I - implement - agricultural trailer. The difference from the F-1 tyre is both in number (there are more of them) and rib depth (it is shallower). This reduces the specific pressure on the ground and increases the tyre's wear resistance.

Fig. 6. Tractor tyre - I-1.

Both industrial and agricultural tractors have recently been operating more and more often on tyres with a "hockey stick" pattern (Figure 7). The "hockey stick" is a logical development of the "Christmas tree", preserving its advantages and removing its disadvantages. The central part of the tread works on the road and the lateral part works off the road. Accordingly, the central part has considerably more rubber, which has reduced on-road vibration and reduced tread abrasion. However, the lateral parts are still working as they were on the road.

Fig. 7. Stick type tyre.

New technologies, innovations to tractor tyre design from MitasAircell. Innovations in Mitas Aircell tyres (Figure 8.). Mitas introduces the unique AirCell internal tyre, which allows large agricultural tyres to be inflated by +/- 1 atm (0.8 atm to 1.8 atm) in just half a minute - more than 10 times faster than the current air inflation method. The MitasAirCell is located on the rim inside the tyre and occupies about 30% of the tyre volume.AirCell is continuously inflated to 8 atm during tyre use, releasing some pressure on demand, allowing rapid pressure increase in the agricultural tyre by adjusting pressure in seconds rather than minutes (Figure 8).

Fig. 8. Innovative Mitas Aircell tyres.

The AirCell is not in contact with the tyre itself and therefore, generates no additional friction or heat. The Mitas AirCell is made from durable rubberised materials that retain their shape even under high pressure, so the volume of the outer tyre is independent of the pressurised air of the AirCell.

Fig. 9. Mitas Aircell tyre principle of operation.

Michelin Ultraflex allows tyres to operate at lower pressures while remaining stable and durable. Increased area; distributes the load more evenly and reduces soil compaction. The soil will enable the crop to make better use of water and nutrients. Performance optimisation starts with the innovative tyre body based on MICHELIN Ultraflex technology. Agricultural tyres designed with state-of-the-art MICHELIN Ultraflex technology operate at lower than standard pressures, while remaining durable and robust (Figure 9). MICHELIN Ultraflex

technologies produce a greater imprint, which protects the farm's soil from compaction and rutting. Air and water penetrate more freely. Conditions are thus improved for maximum crop response. The larger size significantly increases traction, resulting in a clear reduction in wheel slippage, allowing you to work faster and save on fuel! Reinforced sidewalls and special rubber compounds make MICHELIN Ultraflex agricultural tyres extremely durable, even at lower pressures. A consumption comparison reflects fuel savings of up to 25% with MICHELINUltraflex agricultural tyres.

Fig. 10. Michelin Ultraflex tyres at low and normal pressures.

These technologies offer great opportunities. In particular, the Mitas Aircell technology is used in combines, the advantage being that the tyre pressure is automatically lowered when the bunker is filled with grain, while the tyre pressure rises when the bunker is unloaded. The advantage is that tyre pressure is automatically reduced when the bunker is full of grain and increased when the bunker is unloaded - this ensures a good contact surface any time the combine harvester is in use. Also when the field is uneven, or when the field is at an angle, the tyre pressure can be changed individually. This will cause the combine harvester to tilt and the cutterbar to be parallel to the field. In the end, this will give good wheat mowing [10, 11].

4 Conclusion

To summarise, the choice of tractor tyres and the tread pattern depends on where the tractor will work and what kind of work it will do. For our country, it is important to use the cultivated land efficiently, because the area of fertile land is shrinking. We must also take into account the economy, because a poor use of resources is not acceptable in this industry, it will lead to high costs and a reduction in profits. Therefore, the correct choice of tractor tyres, although not the main task, but it can lead to increased efficiency and reduced fuel costs. Let's not forget about new technologies, they will find their application in the agricultural sector.

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