Application of multi-criteria in the selection of running systems for regional use of tractors in agriculture

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Abstract. The basis of the modern machine and tractor fleet of industrial and agricultural tractors are power vehicles with tracked and wheeled operating systems of various design designs. Both of these and other energy products have both their advantages and quite significant disadvantages. The article discusses the summary parametric and factorial characteristics of wheeled and tracked power vehicles used in field and transport work in the Amur region. The criteria for the formation of their traction properties, ways to reduce slipping, reduce the load of the machine-tractor unit on the soil, and the use of agricultural machinery during waterlogging are analysed. The results of a study on the use of mobile energy means in waterlogged conditions during the cultivation of agricultural crops, where their main advantages and disadvantages are reflected, the directions of choosing an energy means for use in agricultural production technologies are substantiated. It has been established that the use of tracked power vehicles with high traction properties, when aggregated with wide-reach machines in the fields of the region, will be more effective during periods of work when there is a large precipitation. At the same time, wheel energy means will also be in demand in the natural and climatic conditions of the Amur region as the most versatile structurally suitable means for performing most agricultural field operations as part of a tractor-transport unit. In this connection, the expediency of equipping the production and industrial complex and means of mechanisation of farms and agricultural enterprises of the region with energy means with various running systems in accordance with the used and scientifically based regional system of machines and technologies is justified. **Keywords:** energy means, comparative characteristics, performance indicators, running system, efficiency.

1 Introduction

The basis of the modern industrial and agricultural tractor fleet is represented by tracked and wheeled power packs of various designs. Both machines have advantages along with some significant disadvantages.

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That is why when buying a tractor (crawler or wheeled) it is necessary first of all to decide for which tasks it is intended, and at most to take into account such general factors as universality of use in technologies, operator's comfort and information about technological parameters, maintainability during repair and servicing, regional adaptability to operating conditions and possibility of production modernization, optimal cost of machines in proportion to the "cost-reliability-treatment-quality ratio", suitability for use in the processing industry, consumption and main fuel brand, suitability for use on asphalt public roads, and some others, of which the most important in today's conditions is the maximum production localization and certification on the territory of the Russian Federation.

2 Materials and Methods

Let us consider in more detail the necessary criteria most commonly used in the selection of the main undercarriage systems of tractors (Figure 1), optimally designed for the regional agriculture of the Amur Region, for which we will disclose the advantages and disadvantages of wheeled and tracked mover in more detail [1], in particular:

1) Economic factor - the purchase price of the product and the cost of maintaining its performance;

2) Traction and cross-country ability;

3) Slipping of the machine-tractor unit and technogenic influence on the fertile layer;

4) Manoeuvrability and minimum turning radius;

5) Ability to drive on public roads with paved surfaces. The main tractor running systems used are shown in Figure 1.

Fig. 1. Main tracked and wheeled undercarriage systems.

3 Discussion and Results

It is well known that the most important and responsibly important factor when choosing a tractor undercarriage system is the economic factor that directly affects the price of the final product, namely the purchase price of the product and the costs of maintaining its serviceability. As a rule, the price range of a wheeled or tracked implement differs greatly. The tracked undercarriage system is much more expensive than the wheeled one, as it has a larger number of units and parts, as well as additional elements in the design, has a more labor-intensive repair and maintenance with less durability, in connection with which additional costs are required to hire specialists for repair and maintenance of the undercarriage, as well as the use of an additional range of sealing elements, oils and greases.

Thus, it can be concluded that the repair and maintenance of the wheeled undercarriage system of a power vehicle will be less costly than that of a tracked one. Therefore, in terms of acquisition, repair and maintenance costs, the wheeled tractor will have more advantages, while being more reliable [3,8].

Traction and cross-country ability. At traction works the undercarriage of power device (tracked or wheeled) transfers force on a driving surface, thus the more intensive traction of the undercarriage with the ground - the more effective realization of power - driving qualities of the machine [4].

It is known that an important criterion of track belts efficiency (figure 2) is the area of the loaded surface, due to which the contact grip with the soil, created by driving and supporting elements of the caterpillar increases.

Fig. 2. Tractor with rubber metal crawler tracks.

A track drive on soils with low moisture content will cause slippage of between 2-5%, which is a significant advantage over a wheeled tractor of the same capacity. The tracked power unit is worse in wet conditions, where the crawler has no grip on the moist topsoil and the machine slips and sinks until it comes to a complete halt.

At the same time wheeled power tools have other features: in particular with all wheels of the same diameter, the tracks of one side run one after the other in the same track, which reduces losses in overcoming rolling resistance of the rear pair of wheels, but increases compaction of the soil. It has been noted that trailering reduces the drag coefficient as the slip resistance is reduced.

Series tracked power vehicles have an optimum slipping ratio of 10-15% in traction work. A comparative slipping graph for wheeled and tracked tractors is shown in Figure 3.

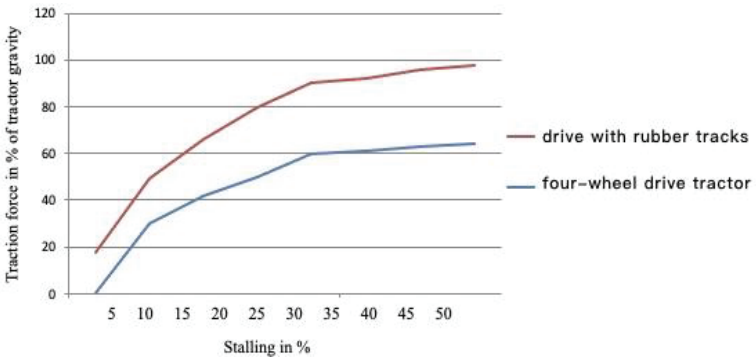

Fig. 3. Traction force vs. tractor weight graph.

The results show an increase in tractive effort on a tractor with a tracked undercarriage system as opposed to a wheeled tractor. In this way, the increased contact area of the undercarriage with the undercarriage promotes an efficient and pinpoint application of the power tool in labour-intensive tasks such as basic tillage and sowing with combined aggregates, deep loosening and chiselling of the soil.

3.1 Machine-tractor traction and the technogenic impact on the topsoil

At use of the machine-tractor units having big weight and high power characteristics, the caterpillar tractor can carry out work with the minimum towing within 3-6 %, whereas the wheeled power vehicle is capable to tow MTA of the same weight parameters, applying the big power with increase of towing in 15-40 % [3], that reduces working speed of MTA, reducing its productivity. It is noted that slipping is one of the main factors of anthropogenic reconsolidation, which subsequently requires significant material costs to carry out decompaction of the fertile layer and restore its fertile characteristics.

As researches of authors [2, 5] show, neither of two running systems gives significant advantages in solving the problem of decreasing pressure of running systems on the ground (figure 4). We will consider normal distribution of tractor load through the undercarriage system on the driving surface. In doing so, we will assume positions A (wheeled tractor) and B (tracked tractor). The data was obtained by instrumented strain gauging, where

1, 3, 5, 7, 9, 11 - ground pressure pulses.

2. EXPECTED soil pressure from the wheels of the propulsion vehicle.

4.ACTUAL soil pressure from wheels of energy vehicle.

6.ACTUAL soil pressure from wheels of energy vehicle.

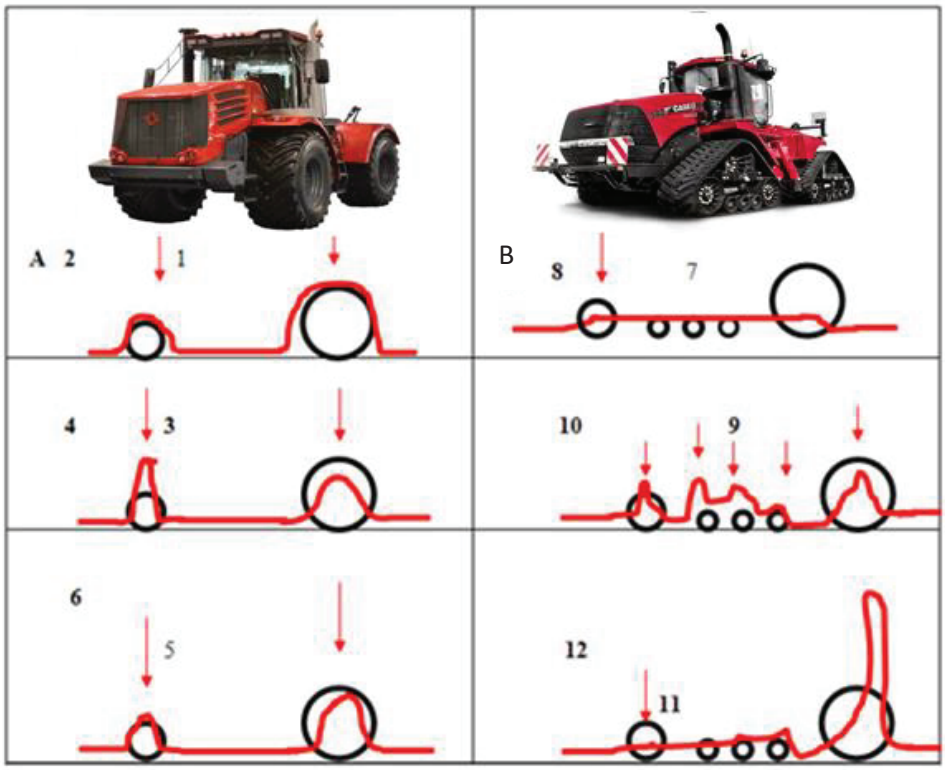

Fig. 4. Soil pressure of wheeled and tracked undercarriages.

Position A. When a properly balanced wheeled tractor with large radial tyres inflated with air (in accordance with the instructions) hits the ground, the measured ground pressure does not increase significantly. This is because the tyres change their original geometry, expand and lengthen on the ground surface under the transmitted load, thereby increasing the contact area of the tractor's undercarriage with the driving surface.

A very different picture is seen with a tracked power tool (Figure B).

8. EXPECTED soil pressure from the tracked power vehicle (static soil pressure is: weight of the tracked mover divided by the total contact area of the tracks with the soil).

10. ACTUAL soil pressure from the tracked power unit.

12. ACTUAL soil pressure of the crawler power unit.

Thus, it is proved that the pressure of the tracked power unit on the ground is not uniform, therefore the tracked power unit does not equalize the vertical load on the contact strip of the propulsor. It is noted that each supporting wheel of the tracked undercarriage system has a different value of pressure on the ground.

During the analysis of works of the authors directed on research of pressure of the tractor on the ground, spent in the state of Ohio, the USA, when the process of influence of wheels of power vehicles on such physical parameters of soil, as an index of rise, density, porosity, air permeability received the data that correctly balanced tractor with correctly inflated tyres (to the necessary low pressure according to load on the axle) have the least pressure on the ground. The second most effective indicator was the tracked power vehicle [7].

3.2 Manoeuvrability and minimal turning radius

The ability to steer the power tool steadily during turns and technological U-turns of the tractor is the most important factor. Their increase leads to decrease of MTA productivity due to pre-digging of working tools or disconnection of drives of trailed machines at crossing [5, 6].

In case of comparison by these parameters, the caterpillar tractor will be more manoeuvrable in comparison with the wheeled power vehicle, because structurally the caterpillar belts can operate both separately from each other and in different directions, which contributes both to trajectory stability in a turn and reduction of the turning radius in comparison with the wheeled undercarriage system.

3.3 Ability to travel on paved public roads

As a rule, in various climatic conditions of the Amur region, tractors quite often have to follow working areas and return to the park on paved roads. Despite the fact that modern tracked power vehicles are equipped with rubber and rubber-metal joints, there is damage to the road surface when turning. However, wheeled power vehicles can reach significantly higher operating speeds on paved public roads and are safe in a variety of driving and manoeuvring conditions. The conclusion can be drawn that the criterion of driving on paved roads is a moot point for identifying the clear leader of one mover or another.

4 Conclusion

In this connection, to summarise the conclusions of the research carried out, it is quite debatable to select the undercarriage system directly for the conditions of regional use.

At the same time, it has been determined that the use of tracked power tools with high traction qualities, when combined with wide-shaft machines on the fields of the region will

be more effective when used in the period with high precipitation, as well as in spring during field works, preparatory and seeding activities.

The wheeled power vehicle, on the other hand, can be considered more suitable for most agricultural field operations due to its versatility, and it can also be used more extensively as part of a tractor-transport unit.

Thus, in order to reduce costs and increase productivity when carrying out basic agricultural operations to cultivate large-area fields, it is advisable to equip the production and technical base of farms and enterprises in the region with different types of energy tools in accordance with the regional system of machines and technologies used.

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