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Predicting the Residual Performance Resource of Pneumatic Tires

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Abstract: This study aims to predict the residual performance resource of pneumatic tires used in agricultural machinery, particularly tractors, to optimize their lifespan and maintenance strategies. Understanding the durability and wear characteristics of pneumatic tires is essential for ensuring efficiency and reducing unexpected failures. The research employs static and dynamic prediction methods to estimate the remaining service life of tractor tires. The static prediction assumes a linear degradation over time, while the dynamic prediction incorporates periodic evaluations of tire conditions, allowing for more precise estimations. The study follows ISO 13381-1:2015 standards for machine condition monitoring and diagnostics, integrating statistical models and probability analysis to assess failure rates and maintenance schedules. The results indicate that dynamic prediction provides a more accurate assessment of residual tire life compared to static methods. The study also finds that proper monitoring can significantly extend the operational lifespan of tractor tires, reducing maintenance costs and minimizing machine downtime. With a 95% confidence level, the research confirms that effective diagnostics and predictive maintenance strategies enhance the reliability and efficiency of agricultural machinery.

Keywords: Machine, Aggregate, Pneumatic, Tire, Performance Resource, Prediction, Faulty, Evaluation, Static, Dynamic.

Introduction

Machine-tractor units are considered one of the main factors in determining the technical diagnosis (diagnosis) and performance prediction, performance resource in the effective use of tire parts [1,2,3]. It has been proposed to diagnose GOSNITI control tools according to the principle of their use in agricultural production: mobile, portable and stationary. In addition to existing diagnoses, professor I.P.Terskix also proposed to distinguish between the types of control of the production enterprise: technological, repair, operation and special.

Methodology

General maintenance is targeted to be conducted by international standards:- OEE (Overall Equipment efficiency) overall efficiency of technological tools,- MTBF (Mean time

Between Failure) average non-stop operation time, - MTTR (Mean Time to Repair) the average running time until repair is recommended to carry out monotoring of indicators. Control of the technical condition of agricultural techniques international standard ISO 13381-1: 2015 “Контроль состояния и диагностика машин. Прогнозирование. Часть 1. Общее руководство” (ISO 13381-1:2015" Condition monitoring and diagnostics of machines-prognostcs-Part 1: General guidelines", IDT) is conducted on request and instructions. The effective use of diagnostic tools makes it possible to reduce the time of failure of the walk-through part of the tractor due to technical failures, significantly increase the time between overhaul, as well as reduce maintenance and repair costs [4-15]. Assessment of residual resources 9,5-42 Y-183 and 13,6 R38 YR-318; 15,5-38 Y-166 and 18,4/15-30 R-319 data on the residual life in tractors equipped with geometric-sized tires allow pre-preparation of exchange and repair funds, reducing the likelihood of sudden failures and accidents. When obtaining the necessary information about the residual resource of tires, it is important to know the results of all previous diagnostics carried out at diagnostic posts. The results of the diagnosis of each tractor tire are recorded in the control-diagnostic table. By predicting the residual resource, it is determined that the tire has the maximum allowable values of the state. The residual resource of the tire is targeted to make predictions based on static and dynamic methods [16-30]. Static prediction is characterized by the fact that the next change in the found value of the parameter depending on the time is conditionally assumed to be linear (Figure 1).

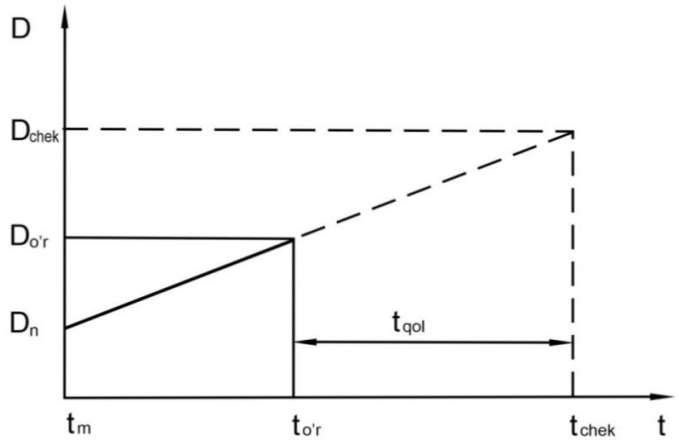
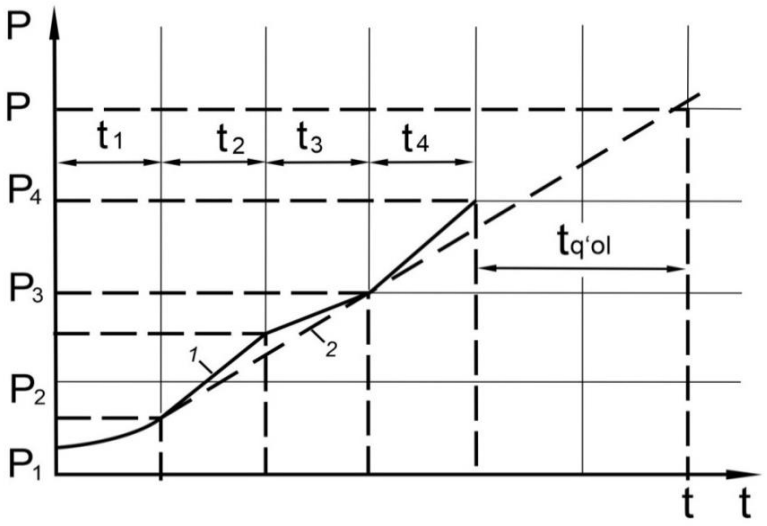


Figure 1. Static prediction with linear variation of its parameter as a function of time (t)

D_n by associating the initial value of its parameter with the measured $D_{o`r}$ and continuing this line, we find its intersection with the boundary position of the D_{kel} parameter. The t_r - t_{chek} time interval indicates the approximate duration of the work, after which the tire replacement is tasted. Dynamic prediction involves the use of intermediate tire status check data on the parameter being evaluated, allowing the use of multiple points (at least three) as a function of running time to create a curve. Under certain operating conditions, it became known to obtain the parameter (Figure 2) and the residual service life prediction more accurately (taking into account the continuation of the wear service curve later).



1-parameter of working time; 2-residual service life.
Figure 2. Dynamic prediction

The determination of the residual resource of the wheel tires using the method of dynamic prediction is considered an optimal diagnostic option.

It is known that the Acorn is considered one of the main factors in increasing the thoroughness performance of the tractor walking part, increasing the working resource of the tractor [31-50].

Result and Discussion

The probability that normalized parametric properties within a given runtime t do not extend beyond the allowable limits is expressed in the simplest case for [51-60].

$$\lambda(t) = \lambda = \text{const}$$

$$P(t) = e^{-\lambda t} \quad \text{ва} \quad F(t) = 1 - e^{-\lambda t}, \tag{1}$$

Working time distribution density until faulty

$$f(t) = df(t)/dt = d(1 - e^{-\lambda t})/dt = \lambda \cdot e^{-\lambda t}, \tag{2}$$

By the law of exponential distribution, the average operating time up to failure is

$$\dot{t} = \int_0^\infty P(t) \cdot dt = \int_0^\infty e - \lambda t \cdot dt = \frac{1}{\lambda}, \tag{3}$$

It is known that for active control of linear dimensions, the time-sharing density prior to the failure of the aggregate walk-through section will be reduced to the exponential law of failure rate $\lambda = 5 \cdot 10^{-4}$ failure-free/hour.

Working time $\dot{t} = 100$ P(t) for 100 hours it is necessary to determine the probability of working without failure and the average time of failure of the walking part $\dot{t}$.

The probability of a smooth running time

$$P(t) = e^{-\lambda t} = P(t) = e^{-0,0005100} = e^{-0,05} = 0,9512, \tag{4}$$

These can be expected to have failed 5 out of 100 measurement systems for 100 hours of operation.

The average performance up to failure is as follows.

$$\dot{t} = \frac{1}{\lambda} = \frac{1}{0{,}0005} = 2000 \text{ hours.} \quad (5)$$

The break time of the walking parts of the aggregate has a normal distribution with parameters.

$$M_T = 1000 \text{ hours and } \sigma_T = 200 \text{ hours.}$$

Number of working hours T_1= 200 hours, T_2 = 600 hours, T_3 = 1200 hours it is necessary to determine the likelihood of failure-free operation of systems.

Working hours T_1= 200 by the hours formula (3.24) we find:

$$P(t) = 0{,}5 - \Phi_0((200 - 1000/200)|/200) = 0{,}5 - \Phi_0(-4{,}0) = 0{,}5 + 0{,}4999683 \approx 1{,}0, \quad (6)$$

In this case, the probability of failure-free operation of the tire is T = 120 units per 1.0 hours.

1. Working hours T_2 = 600 for the case when the hour is:

$$P(t) = 0{,}5 - \Phi_0((600 - 1000/200)|/200) = 0{,}5 - \Phi_0(-2{,}0) = 0{,}5 + 0{,}48 \approx 0{,}98. \quad (7)$$

2. T_3 = 1200 coaT for the case when the hour is:

$$P(t) = 0{,}5 - \Phi_0((1200 - 1000/200)|200) = 0{,}5 - \Phi_0(-1{,}0) = 0{,}5 + 0{,}33 \approx 0{,}17. \quad (8)$$

According to the result table of the Laplac formula $P(t_\gamma) = 0{,}5 - \Phi_0(z_\gamma) = 0{,}95$, that $\Phi_0(z_\gamma) = -0{,}45$, We find the argument of the Laplac function $z_\gamma = -1{,}65$.

From the equation $z_\gamma = (t_\gamma - m_t)/\sigma$, $t_\gamma = m_t + z \cdot \sigma = 1000 + (-1{,}65 \cdot 200) = 670$ we determine that it is a hours.

For exploitation conditions, the gamma-percentage time until t_γ is faulty must be determined at $\gamma = 0.95$, i.e. $P(t_\gamma) = \gamma = 0.95$ is the time when the tires become unusable with probability.

Thus, with a probability of 0.95, it was found that non-fault operation is performed by parts for 670 hours. The main indicators of the durability of tractor tires are service life and resources. In accordance with ISO 16949 and GOST 27.003, it is used for tires, which are the main process that determines the transition of the resource to a border state as an indicator of durability. The tire performance resource is the operating time of the system from the start of operation to the transition to the limit position. The tire resource is a reserve of possible working time and is measured in hours. If the main process determining the transition to the marginal state is input, then the service life is used as an indicator of durability [61-72].

The average performance resource is the mathematical expectation of the resource:

$$\dot{T} = \int_0^\infty t \cdot \int_P (t) \cdot dt, \quad (9)$$

that $\int_P(t)$ – resource allocation density for a certain walking part tire package.

Gamma-percentage resource is the working time that does not reach the limit state with the probability γ expressed in percent of the tire.

$$P(T_{P\gamma}) = 1 - \int_0^{Tp_\gamma} \int_P (t) \cdot dt = \frac{\gamma}{100}, \quad (10)$$

The service life of the tire, the calendar duration up to the transition to the limit position at the time of use, is measured in years or months. The average service life is the mathematical expectation of the service life

$$\dot{T}_{сл} = \int_0^{\infty} t \cdot f_{sl}(t) \cdot dt, \qquad (11)$$

where $f_{st}(t)$ – is the lifetime distribution density for a known set of tires.

Conclusion

Gamma-percentage service life depends on the duration of the calendar from the moment the tire starts to work, during which gamma is expressed as a percentage

$$P(T_{st\,\gamma}) = 1 - \int_0^{Tsl_{\gamma}} f_{sl\,\gamma}(t) \cdot dt = \frac{\gamma}{100}, \qquad (12)$$

Shelf life is estimated like the indicators used to assess durability, such as the average shelf life and gamma percentage storage time.

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