Computer-integrated system of decision-making support of control of tires operation of trucks

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S u m m a r y . The question of computer-integrated system of decision-making support of control of tires operation of trucks is considered. The software of the program is based on an accumulation and use of databases: norms of tires life from producers data and state recommendations, basic and specified correction coefficients of tires life with a glance actual real-time use, statistical indicator of tires operation, their life, results of control the residual height of the tread pattern. K e y w o r d s : tires life, software, prognostication tires life, correction coefficient, control of tires use.

INTRODUCTION

Daily runs and load trucks has substantially grown in the last year. The management of technical maintenance of tires of trucks complicates under the circumstances, what to calls for development of system, necessary for cost decrease on their service.

ANALISIS OF LAST REASEACHES AND PUBLICATIONS

Analysing works by [24], tire power consumption [4], rubber chemistry technology [2, 3, 21], Theory of Viscoelastic properties to Undiluted Linear polymers [5], tire design [29], factors on tire wear [9, 13, 17, 18], research of tire wear [1, 6, 8, 10, 30] can observed that researches of the condition of tires of trucks has linked to safeguarding of road safety, economy and comfort and in many respects depends on running conditions.

Tires life sets definitely specific in each country, based on operating experience, quality of produced tires, the intensity of their operation, weather and road conditions.

Tire plants in different countries keep established and warranty norm of run. So for truck tires is 53-77 thousand km (manufacture Russia, Belarus) and 90-175 thousand km (EU production).

Operating norm of run establishes what the minimum run for economic reasons must perform tire and it uses automobile enterprises.

Operating norms of tires life are intended for the requirements planning automobile enterprises in tires and rational use of material resources, determine the level of rates and calculation business taxation.

MATERIALS AND RESULTS OF RESEARCHES

Forecasting and work capacity of tires at an appointed instant of time is used to determine the tires life by calculation method. Since treadwear is the only phasing

degradation failure of tires then this characteristic is used to establish the norms of operational run.

Wearing-out is a process of destruction and separation of material from the surface of the tire tread and the accumulation it permanent set by friction, which is manifestative in a gradual change in its size and shape. Wear - final result of wearing-out in units of length, volume or weight.

Among scientists of our country had the idea that there are three types of tire wear: fatigue, by rolling, abrasive.

When operating tires on macadam roads is observed abrasive wear. Outward manifestation of this kind is score marks, slight tears, cuts, etc.

The tires wear occurs on a mixed mechanism in actual operation at that correlation of various kinds and total failure rate changes depending on the environmental effects.

Wear intensity is the speed of the wear process.

Wear intensity determines moment of offensive blow limiting condition of the tire on treadwear.

Run up removal from service (tire life) L is running time of tire in kilometers until moment of reaching the limit state.

Taking into account importance and actuality of problem, it needs to decide the followings tasks: to specify determination of norm of tires life of trucks with a glance actual conditions their operation, to forecast an actual life and service life of tires with fixing of time for tire kit changing, to make a administrative decisions connected with operational process of tires. Any actions for management of a resource have to begin with creation of full-volume system of the record. It creates effective levers of influence on production for elimination of revealed defects. When carrying out maintenance and repair of trucks (Fig. 1).

The record has to be reduced to data acquisition for management of process of use of tires for the purpose of it optimization. The main total index is cost per unit in grn/1000 km of run in further to a realized tires life (run). There are situations when tires it is

expedient to place out of service earlier, than there will come their limiting state by the main technical criterion - wear of a tread up to the limiting value.
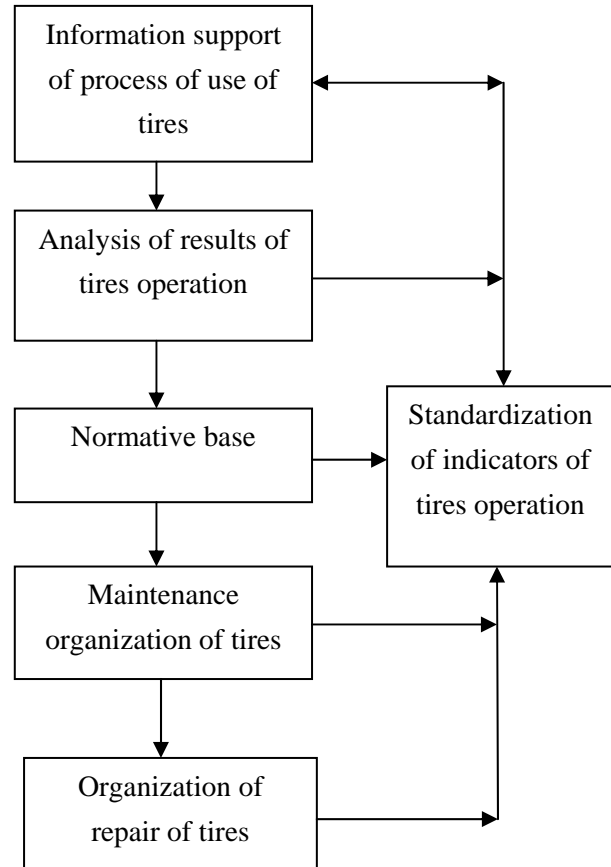

Fig. 1. Actions for optimization of a tires life

All these tasks are commutated and their decision is possible by special the developed computer-integrated system of decision support – complex program.

The initial stage is the creation of a database of trucks and tires. Database [25, 26] is renewed (daily operation) when tires is dismantled, tires life is exhausted and new tires is installed. Technical condition and character of treadwear is estimated as it is a measure of grade of service of trucks and tires in automobile enterprises.

Each accounting system must be well organized and function. This is no easy task. This is complexity of the organization of proper collection of data about laid-up tires. But the necessity of these actions determines the economy. The losses of life tires constitute

10-25 percent depending on the type of vehicles in any automobile enterprises.

So for tires of tippers are characterized by small average annual runs and according to prolonged service life. This suggests that the change in performance also depends on the time during which the running time is carried out notably the operation rate.

Physical aging causes increased wear of tire tread, increases occurrence probability of traumatic failure.

Thus, the input to the system is time and operating conditions. The transition intensity from operable state to a failed state depends from them, and then what process will prevail. Output system - a tires life failed.

The methodical, normative and programmatic support of the system is developed with a glance specifics of motor transport enterprise. The normative support is developed individually for every model of truck and for every tires model. Developed system keeps the structure and working-capacity by modification and adaptation to the conditions of concrete enterprise (Fig. 2).

The software of the control system of technical state of tires is built by module principle and it is an application package, it is bound up with the methodical, normative and documentary support of the system [12]. The bond between the relatively self-contained program modules realizes by management of the main program – device executive and through the data flow.
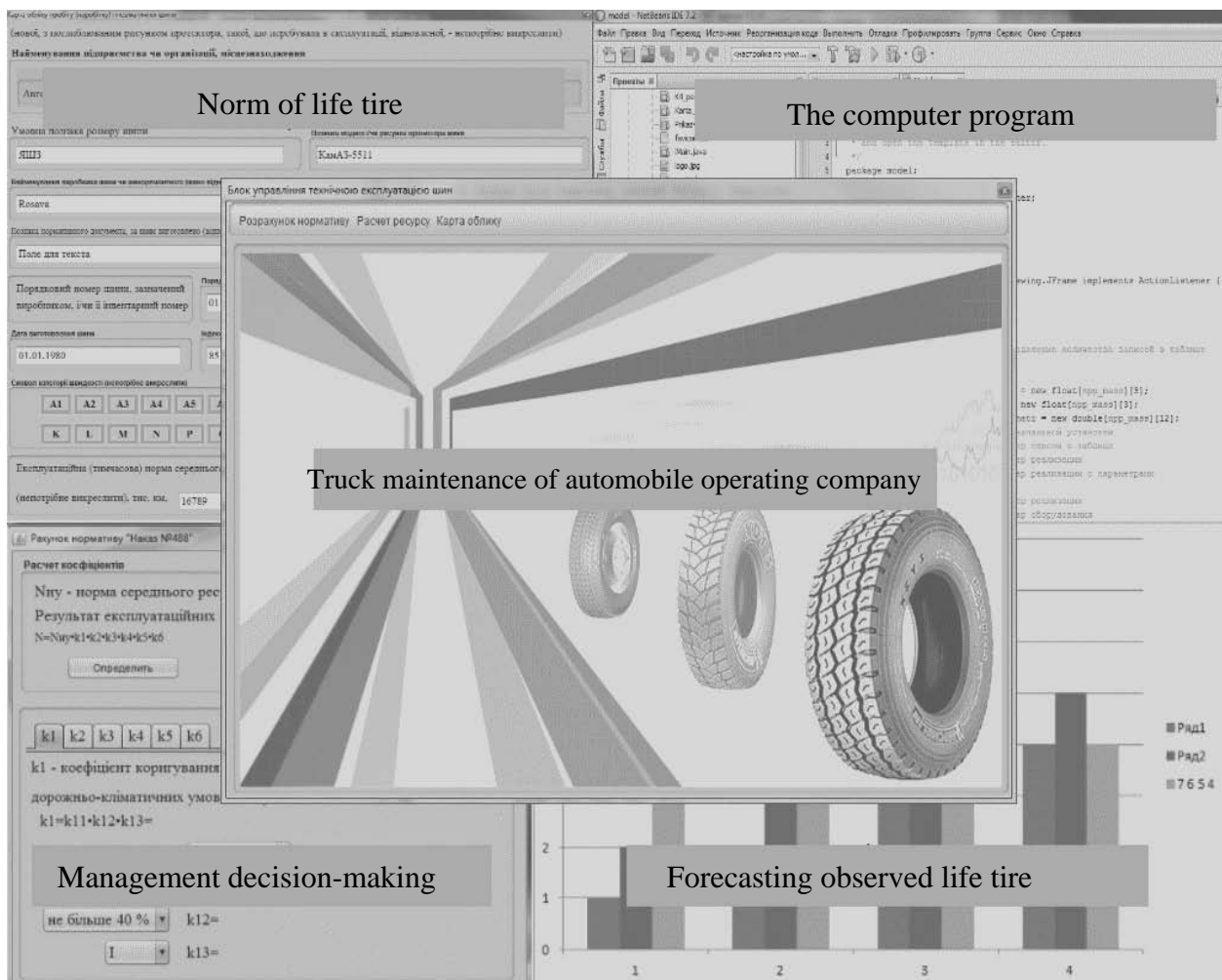

Fig. 2. General view of software

The program of organization of module interface is built on the basis of the documentary providing of control system. The created interface behaves to active, that provides work of operator in the conversationally, that conforms to the requirements which are produced to the information systems of the last generation.

Operation of the program is based on an accumulation and use of databases: norms of tires life from producers data and state recommendations, basic and specified correction coefficients of tires life with a glance actual real-time use, statistical indicator of tires operation, their life, results of control the residual height of the tread pattern in the cards of accounting.

The front pages of electronic card include total technical characteristic about a car tire and columns about damage and types of treadwear. The contextual menu is used for filling of the card, speeded up the input of information (Fig. 3, a).

Predictable tire life can view on the other tabs of the program after entering the data.

The program takes account of the wear rate of tires, and it is adjusted after the introduction of all the necessary data.

The program has a handbook on which model of tire is selected and you can update data on the tires.

All data for the program is changed simply by editing the appropriate ranges.

The next is the pages of calculations of tires life on the correction coefficients under order № 488 [16] (Fig. 3, b) on general computer-integrated system of control by technical maintenance of tires (Fig. 4).

The program is determined statistical indicators: mathematical expectation, roof-mean-square deviation, etc. Installs the percent of safe operation during the specified life (for stable operating conditions 95 percent is recommended, for variable operating conditions – 90% percent [7, 23, 27, 28]), following which the recommended prognosis of tires life fixes, which asserts by order on motor transport enterprise.

Modeling of manufacturing processes in the enterprise becomes possible on basis of the use of banks and information databases, as well as the technical condition of vehicles and their components that will use application package and automate the management of the technical influence.

Organization of accounting and control tires on automobile enterprises allows to identify the causes of increased tire wear. This set of measures and means a subsystem of information, including the provision of appropriate component (documentary, condition-monitoring, etc.). On the basis of information supplied by this subsystem manages the technical impact on tires and spare parts, affecting their wear.

The program allows to analyze the causes of failing of tires and set differentiated norm of life tires for various vehicle.

The norm of tires life is estimated as follows:

- for a 90 percent safe operation:

$$l_{norm} = \overline{l} - 1{,}28 \cdot \sigma , \qquad (1)$$

- for a 95 percent safe operation:

$$l_{norm} = \overline{l} - 1{,}645 \cdot \sigma , \qquad (2)$$

where: $\overline{l}$ – mathematical expectation of run to writing off, thousand km, σ – roof-mean-square deviation, thousand km.

The process of prognostication of tires life on results control the residual height of the tread patter of tires following.

The forecast of the tire life:

$$L_{i(o,d)} = 10^3 \cdot \left[(0.85...0.90) \cdot H_{in} - H_{\lim} \right] \bigg/ \left[\frac{\overline{h}_1 - \overline{h}_i}{L_{act,i} - L_1} \right] , (3)$$

where: H_{in} – the initial height of a new track, mm, 0.85...0.90 – the coefficient, which considers the heightened wear rate in the process of wearing-in, $H_{\lim}$ – the limiting value of the remaining-tread depths (it is defined by road regulations), mm, $\overline{h}_1$, L_1 – the height of the tread and tire life at the first measurement which is carried out in 8,000…10,000 km after the process of wearing-in ends, mm, thousand km respectively, $L_{act,i}$ – the actual tire life at the moment of the measurement, thousand km.

Fig. 3. Software: a – table of information about tire, b – result of calculation tires life

Chart of Account of Pneumatic Tires

| 1 | Routine run and residual height of the tread pattern | Run at writing off | Technical state of tires | Forecast of factual life and date of tire changing |

Norm of life

Control Unit by Technical Maintenance of Tires

Dialog of management technical effects and technical maintenance

Complex of technical effects on tires and truck components

Antecedent diagnosis state of tires and truck components

Setting of norm of life

Subsequent use

- writing off;
- welding-on with pressure of re-tread;
- variable stock

Analysis of results of calculations of life

1

The calculations of tires life

The calculations of tires life

Calculation of intensity of wear, life and determination of type of treadwear

The calculations of life by statistical data

Choice of correction coefficients

Database of measuring of residual height of the tread pattern

Database of run of tires on criterion «treadwear» by enterprise database. Runs and percent of outage on criterion «damage»

Database of norm of life by order №488

Database of norm of life by enterprise database
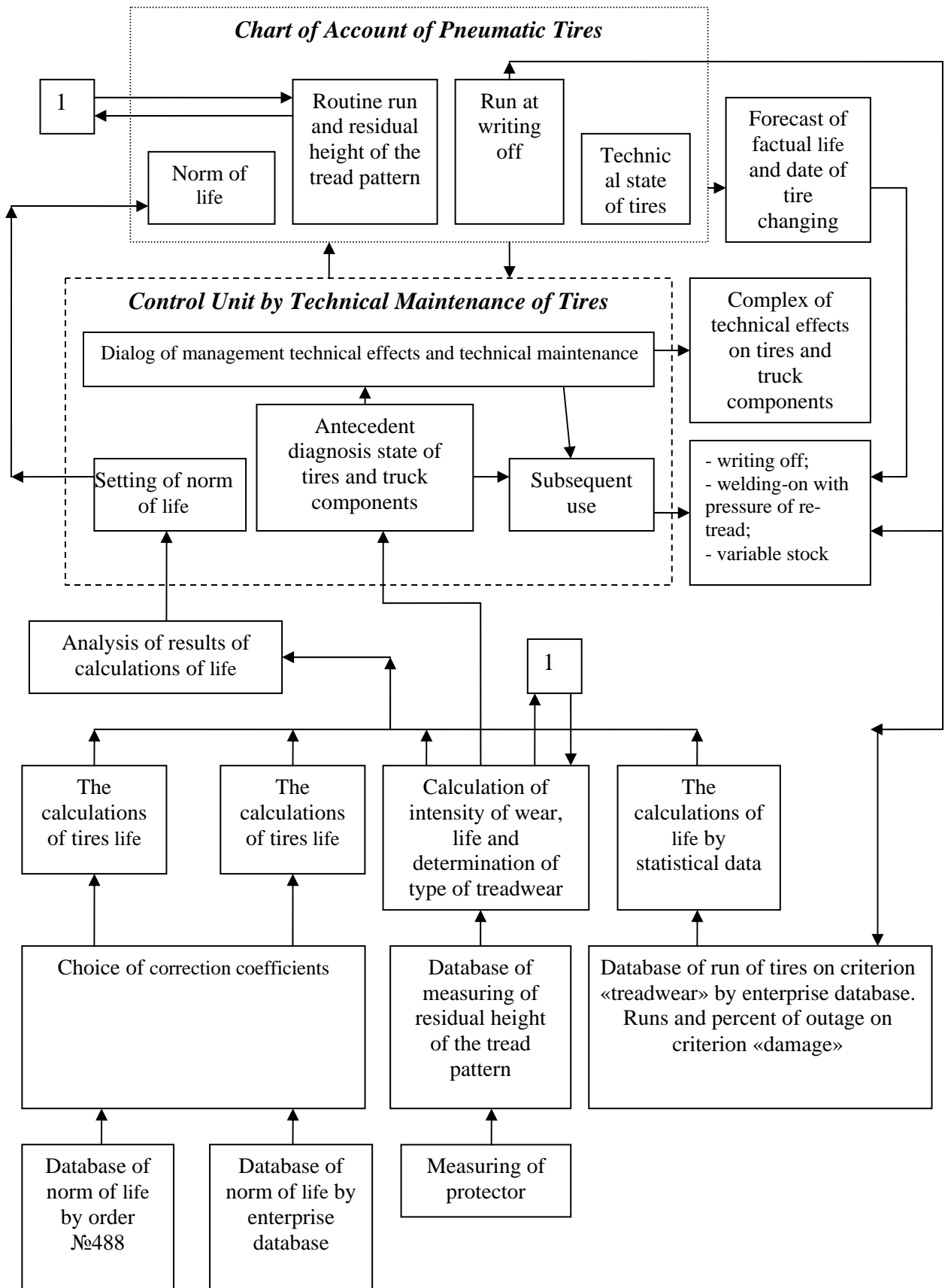
Measuring of protector

Fig. 4. The plan of computer-integrated system of control of tires operation

The minimum necessary number of measurements for each tire is nine. The average remaining-tread depths are calculated for each tire and pair of tires (at the use of the doubled tires) for the operated and driving axle of tires severally by dependence:

$$\bar{h}_i = \frac{\sum h_i}{9},$$
$$\bar{h}_{i\kappa} = \frac{\sum \bar{h}_i}{m}, \qquad (4)$$
$$\bar{h}_{i\theta} = \frac{\sum \bar{h}_i}{n},$$

where: h_i – the value of the i-measurement of the remaining-tread depths, mm, $\bar{h}_i, \bar{h}_{iop}, \bar{h}_{idr}$ – the average remaining-tread depths of each tire, the operated tires of the trucks, the driving tires of the trucks, mm, m, n – the quantity of the operated and driving tires of the trucks, unit.

Bundle of different factors influence on tires life [11, 14, 15, 19]. A calculated technique is based on the method of correction coefficients of base run which is determined by producer, for the tires of foreign producers base middle – in concordance with [16, 20] for the tires of production of the Union Independent State.

Tires life N of trucks is estimated by equation:

$$N = N \cdot k_1 \cdot k_2 \cdot k_3 \cdot k_4 \cdot k_5 \cdot k_6 \cdot k_7, \qquad (5)$$

where: N_{ny} – basic (middle) run, thousand km, k_1 – the correction coefficient depending on traffic and climatic conditions of operation and it takes into account the type road carpet, longitudinal tilt of road and chemical pollution rate (values of coefficient k_1 are borrowed from a state technique), k_2 – the correction coefficient takes into account the run of truck in the special conditions (site areas, excavations), k_3 – the correction coefficient depending on locations of tire on a truck, k_4 – the correction coefficient depending on the high-speed of tires of trucks, k_5 – the correction coefficient depending on deflection of the internal pressure in tires from normative values, k_6 – the correction coefficient depending on the ratio of kilometers traveled in the city limits to total that allows to take into account intensity of wear at the expense of accelerations and braking, (values are borrowed from a state technique), k_7 – the correction coefficient depending on load-carrying capacity use k_c relative to optimum load-carrying capacity trucks.

The calculation of tires life of truck which are proposed in comparison with the factual data shows that the deviation is 4-5% (the difference between the calculation data on the orders of the Ministry of transport and communications of Ukraine from 20.05.2006, №488 and the actual run of tires is up to 30-40%).

Tire life is determined by cards of tires as the number of days since the installation of the tires before the date off.

In the analysis of experimental data is calculated type of vehicle. Analysis of the results of experimental studies made it possible to the following conclusions:

1. 96% of the empirical distribution of the tire life obeys the normal law.

2. Distribution described by the Weibull law, implemented in research units.

3. Average wearing life for different types of vehicles is significantly different.

The software enables to the normative tires life of trucks on the basis of the gamma-percent actual tires life that includes:

a) validation for the previous sample data (full or truncated),

b) determination of distribution law of tires life,

c) calculation of resource characteristics of tires,

d) to establish normative tires life at a level of given percent of no-failure operation, which depends on it dispersion, and is characterized by the coefficient of variation. If we assume that the distribution of the actual tires life is subject to the normal law, the norm may be assigned to on addictions taking into account the functions of the Laplace (for 95%, 90%, 80%, 70% and 60% no-failure operation).

The software enables to forecast the tires life on data of the constant control of residual height of tread pattern and to identify the intensity of wear. The measurement data are entered in the registration cards of tires, the forecast of their actual tires life to be specified after each measurement, since the intensity of wear changes constantly in the process of exploitation. The average residual height of tread pattern is calculated both for each tires and for managed and leading and dual tires separately.

Hence, normative tires life is assigned several ways, depending on the level of production processes on auto enterprise.

The software enables to compare calculated values. Comparison of the designated normative tires life with the actual data includes:

1) appointment of the normative tires life (L_{norm}),

2) on hand to database of actual tires life (L_i),

3) calculation of resource characteristics of tires,

4) determination (ΔL) deviation of the average tires life ($\overline{L}$) from normative (L_{norm}),

5) determination of the argument (z) for functions of the Laplace (ratio ΔL to σ),

6) the choice of the values of the normalized normal distribution function ($\Phi(z)$),

7) the calculation of the levels of reliability,

8) assessment of the calculated level of reliability,

9) decision making about the fixing normative tires life which is corrected.

For the assessment of accordance of the actual tires life in conditions of real operation requires data on the dynamics of wear of tread and dispersion of wear on different running time.

Abrasion tire occurs in various gases and in some cases corroding liquids. Studies have shown that these environments affect the abradability of rubbers, and especially on the abradability of rubbers based on unsaturated rubbers.

General environment for tires is air, oxygen is chemically-active medium towards all rubbers, accelerates the destruction and structuralization of rubber from them.

During the operation, as well as during storage of rubber products is observed deterioration in their physical and mechanical properties: rubber cracks, becomes brittle and less strong.

Aging - feedback on the rubber oxygen, heat, light and especially ozone.

Therefore, management of tires life of means of transport provides:

a) fixing of normative tires life on the basis of experimental data of control residual height of tread pattern,

b) forecasting gamma-percent tires life according to statistical data valid sample and data constant process control of their wear with the definition of intensity,

c) increase the tires life of tires through the improvement of maintenance system of element of running gear on the actual technical condition,

d) reduction in the percentage of early failures of tires for the criterion «damage» due to their retirement from operation at accessible of a zone of critical wear,

e) efficient use of the tires life due to the constant control of residual height of the tread pattern.

In the process of studying the dynamics of the tire wear was found that for tires of tippers depending on the operation rate is prevails one of the processes either wear or aging and aging-related increase in the probability of chance failure.

The operating conditions and the specific use of trucks render material effect on the operation rate.

Run of tire depends on operation rate.

The developed measures of management by technical condition of tires allow to improve indicators of efficiency of technical operation of trucks by optimization $\alpha_{TT} \rightarrow opt$ at the expense of expected positive increment of components of technical readiness coefficient which provides economic efficiency

$$\Delta\alpha_{TR}^{incr} = \Delta\alpha_h^{incr} + \Delta\alpha_{TA}^{incr} + \Delta\alpha_t^{incr} + \Delta\alpha_{TL}^{incr} \text{ , (6)}$$

where: $\Delta\alpha_h^{incr}$ – increment at the expense of effective use of a tires life with regard to constant control of residual height of tread pattern ($\bar{h}$), $\Delta\alpha_{TR}^{incr}$ – increment at the expense of management volumes of technical actions that determined the proposed layout of technical condition of element of running gear of trucks (Fig. 4), $\Delta\alpha_t^{incr}$ – increment at the expense of stock management of tires by forecasting the tires life, $\Delta\alpha_{TL}^{incr}$ – increment at the expense of management of tires life.

Effective solution complexes planning management and optimization problem in managing technical effects possible on the basis of operational updates on the state of internal and external factors control system (vehicle and it components, the system keeping it technical condition, or the whole enterprise). It becomes especially important in the development and implementation of new systems (strategies) technical influences. The best option is to use an individual objective information on each vehicle. Diagnosis and prognosis are tool supplying such data. However, when using such a system there is the problem of storing and processing large volumes of information containing current, valid and limit values of diagnostic and structural parameters, mean-time-between-failures, actual run of vehicle and their. To solve this problem can be used data warehouse or data bases. According to the operation automation to reduce labor costs to perform statistical operations by 70-90 %.

CONCLUSIONS

The developed system allows to assort, choose, necessary information displays and printer.

The complex of the application programs completes creation of informative and instrumental parts of the component support of control system by the technical state of trucks on the basis of information about intensity and character of treadwear of tires.

The program allows:
- to calculate and fix the normative tires life of trucks in concordance with running conditions (by system of correction coefficients or from own statistical data),
- to forecast the observed tires life and their service life (from statistical data or from data of control the residual height of the tread pattern),
- to make decision about purchase new tires, their retention cycle, setting of replacement age of tire kits, forming of temporal variables of tire kits, repeated their use after welding-on with pressure of re-tread.

The program gives the complete and objective picture of tires operation, provides support of acceptance of administrative decisions during tires operation, that is important with a glance their price.

Based on the analysis of complex research and different works forms the following types of tasks on the automobile enterprises:

1. Accounting and analytical types are design work orders and reports costs and maintenance and running repair, analysis of running time and running costs on vehicles and its individual components.

2. The planning and management types are planning and control of the vehicles for maintenance and repair, accounting and inventory control, the formation of a complex of the technical effects, etc.

3. Reference types are the creation and use of data banks in construction, operation and properties of reliability vehicles and aggregates, standards and maintenance and running repair.

4. Optimization types are the detection of a rational periodicity maintenance and planned unit replacement, resource vehicles and its systems.

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КОМПЬЮТЕРНО-ИНТЕГРИРОВАННАЯ СИСТЕМА ПОДДЕРЖКИ ПРИНЯТИЯ РЕШЕНИЙ УПРАВЛЕНИЯ ЭКСПЛУАТАЦИЕЙ ШИН ГРУЗОВЫХ АВТОМОБИЛЕЙ

Александр Кравченко, Ольга Сакно

А н н о т а ц и я . Рассмотрен вопрос о компьютерно-интегрированной системе поддержки принятия решений управления эксплуатацией шин грузовых автомобилей. Компьютерное обеспечение программы основано на накоплении и

использовании баз данных: нормативы ресурса шин по данным производителей и государственных рекомендаций, базовые и уточненные коэффициенты корректирования ресурса шин с учетом фактических условий эксплуатации, статистические показатели эксплуатации шин, их ресурс, результаты контроля остаточной высоты рисунка протектора. Программа учитывает интенсивность износа шин и корректируется после введения всех необходимых данных. В программе имеется справочник, по которому выбирается модель шины и можно самому обновлять данные по шине. Все данные для программы изменяются простым редактированием соответствующих полей.

К л ю ч е в ы е   с л о в а : ресурс шин, программное обеспечение, прогнозирование ресурса, коэффициент корректирования, управление эксплуатацией шин.