

Ensuring Machine and Tractor Aggregates Operability

G V Redreev, PhD in Engineering Sciences

Omsk State Agrarian University named after P.A. Stolypin
644008, Omsk, Institutskaya Pl. st. 1, Tel. (8-3812) 650-172

E-mail: gv.redreev@omgau.org

Abstract: the operability of the machine and tractor aggregates is ensured by processes which occur in machine units and considered as technical systems. In order to develop theoretical understanding of the processes in technical systems as the basis and purpose of the repair-serving actions, the author's concept is presented which relies on on the basic concepts of "processes in technical systems", "maintenance and repair of performers", "maintenance and repair of technology" "objectives of the maintenance and repair". Analysis of the basic concepts of "processes in technical systems" made possible to distinguishing four types of relations: of order, stipulation, exactingness, and non-contradiction. It is shown that the implementation of maintenance and repair of technology should be conducted according to the assessment of the effectiveness of processes in technical systems, revealed in complex diagnosis. The perfection of the design of the machine in terms of its technical operation can be estimated according to the degree of consistency of processes in technical systems, purposes of maintenance and repair. In order to increase the efficiency of the lubrication system, the modernised design of the centrifugal oil filter with permanent control of its cleaning power is offered, which allows changing the technology of the maintenance of engine lubrication system by separating the operations of crankcase oil replacement and the rotor filter cleaning.

1. Introduction

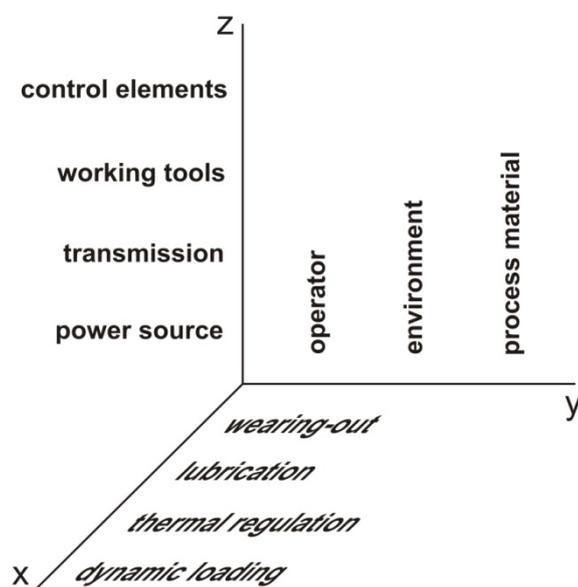
Maintaining and restoring functionality of machine and tractor aggregates (MTA) is provided in the result of of employees work with certain qualification. This work is focused and goal oriented and done with taking into account the processes that go on in the units, systems and components of MTA. To form the concept of operations of a group of such people, we have defined the following, presented earlier, basic concepts taking into consideration works of Teslinov AG [1, 2]: maintenance and repair performers; technology of maintenance and repair; processes in technical systems (TS hereinafter); objectives that are achieved as a result of activities of maintenance and repair performers.

Since the processes occurring in TS are both the basis as well as the objective of maintenance and repair actions aimed to increase the efficiency, their further profound and detailed analysis is needed.

When MTA are used as intended, gradually its technical condition worsens. These processes are related to the deterioration of dynamic and kinematic modes of components, aggregates and separate units of MTA, used under conditions of lubrication systems applications and temperature changes. They may be various for the same units included in the project of machine utilization [3] in the conditions of different climatic zones.

These processes are presented in picture 1.





Picture 1. - Processes in TS

The diagram in Pic. 1: «x» axis represents aggregated groups of processes occurring in the TS units and aggregates; the «z» axis shows the necessary and sufficient components of autonomous TS [4]; axis «y» performs people interacting with machines and affecting them, the environment and the material being processed.

On the base concept of "processes in TS" the following relationships take place:

1. Relations of order

These are relations between the processes in the TS. Processes can follow both parallel and in series; may cross other processes such like, for example, the process of lubrication.

2. Relations of stipulation

These are relations between the concepts of "processes in TS" and "technology of maintenance and repair". Each process that occurs in TS defines the demands for technology of maintenance and repair.

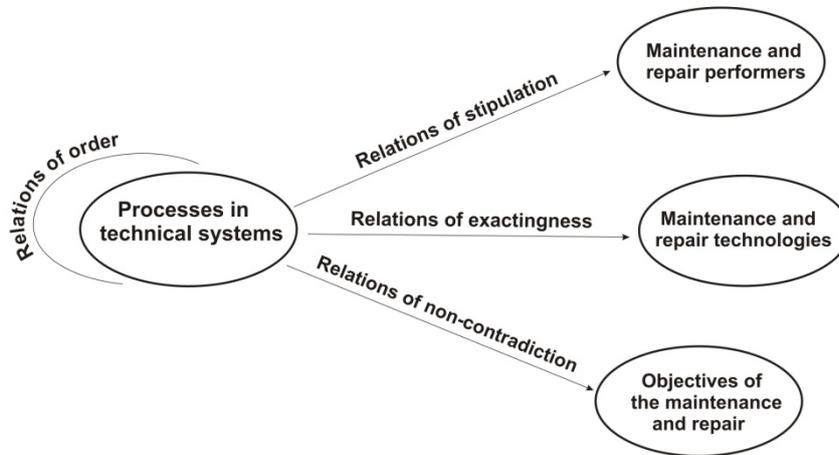
3. Relations of exactingness

These are relations between the concepts of "processes in TS" and "maintenance and repair performers". Activities of maintenance and repair performers depend on processes that take place in the TS.

4. Relations of non-contradiction

These are relations between the processes in the TS and objectives of the maintenance and repair. Processes in the TS (see Picture 1, the x-axis) worsen its technical condition; in this case we can say that they contradict the objectives of the M and R.

These relations on the basic concepts are represented in picture. 2.



Picture 2. - Relationships to the basic concepts "in the processes of the TS"

2. Results of the research

2.1 Relations on the basic concepts

2.1.1 Relationship of order

The processes that take place in technical systems worsen their technical condition. We determined four types of processes (see Picture 1.): wear, lubrication, thermal regulation and dynamic loading. The process of wear, lubrication processes deterioration and thermoregulation lead to gradual failure. Change of processes of dynamic loading – vibration increase, the instability of the radial forces on shafts, torsional vibrations, - results insudden failures.

The processes we defined have certain temporal and spatial order. This order depends on the complexity of the units constituting the aggregate. Since the MTA is composed of individual units, these processes can be distinguished as for machines as well as for components of their units and aggregates [5]. At the same time, it is necessary to consider the influence that a person (operator of MTA) has on these processes, as well as the impact of the environment and the material. The complexity and uncertainty of this effect is amplified by the fact that the person is also exposed to the surrounding environment [6].

The set of processes of the TS (in accordance with the composition of TS see Pic. 1, the z axis) can also be structured as follows:

- 1) Main process that implements the main function of the TS.
- 2) Processes that facilitate the main process of the TS.
- 3) Processes that support providing processes.
- 4) Management processes.

This separation allows ranking processes based on their functions. The degree of approximation processes to the main options can be considered as an appropriate degree of correlation processes in the TS and objectives achievable with the work efficiency of the MTA. The degree of correlation is the basis for ranking of technology of maintenance and repair (maintenance and repair operations). It should be noted that the ranking is meaningful only when the target of maintenance and repairs defined.

2.1.2 Relations of stipulation

The processes which occur in the TS define the requirements to the technology of SP and P. When performing diagnostics of units and systems of the MTA, through which the main function is implemented, diagnostic information about the state of the components and assemblies implemented in supporting processes is necessary, and thensupported processes are needed. In this connection it is necessary to conduct a comprehensive diagnosis of machines that comprise the MTA, with the aim to determine the parameters for all structured processes. This will permit to determine required repair-

serving influences. The implementation of maintenance and repair technologies will be performed depending on the processes effectiveness evaluation in the TS defined via comprehensive diagnosing. Maintenance and repair technologies can be realized depending on the type of TS processes as well as on their effectiveness evaluation.

Processes in the TS can be divided in terms of the way they flow on a linear (continuous), cyclic and cyclic breaks. Linear processes require continuous monitoring the aim of which is to determine pre-failure condition and conducting maintenance and R timely. For cyclic processes the control of individual stages of the cycle can to be combined with the entire cycle control.

2.1.3 Relationship of exactingness

Processes in the TS determine the activities of maintenance and R performers. The design features of the machines that comprise the MTA, determine the specificity of processes in these machines. In this regard, diagnostic parameters with maximum informative value should be chosen. Obtained information will be dependent on the adequacy of diagnostic instrumentation of physical entities occurring during the processes in the machines, errors in measurement, and the correct interpretation of the set of measured diagnostic parameters.

2.1.4 Relationship non-contradiction

The degree of inconsistency is taken corresponding to the degree of deterioration of the technical condition. The longer the failure-free operation of a machine unit, the greater is the consistency (non-contradiction) of processes in this unit. According to the degree of consistency of processes in the TS, the maintenance and R., we can judge about the perfection of the construction of the technical system. Thus, the measure can be taken as a criterion of the perfection of machine construction in terms of its technical exploitation. This criterion has a qualitative difference from such indicator as maintainability. We will define it as the coefficient of the technical perfection of the structure. Numerically it can be determined through the degree of consistency of processes. On the basis of the criterion of the excellence of machine design it is possible to identify directions of perfection of the structure of such a machine. When using the machine for the purpose of it is simpler to find the solution of problems of optimization of process of technical exploitation.

2.2 Engine lubrication system

2.2.1 Lubrication system effectiveness

Tractor engines of Russian production are not sufficiently equipped with effective built-in diagnostic tools. This is of a current importance for the units of system of greasing of engines due the fact that it is known that about 90% of faults are the result of wear. To ensure trouble-free operation of the engines the constant monitoring of both the oil quality and condition of units lubrication systems is of a high importance [7, 8].

In practice of operation of automotive diesel engines during servicing of the lubrication system, the problem is observed, namely that the centrifugal oil filter, cleaning oil from abrasive particles, is an important component of engine lubrication system; however, the lack of filter state control means leads to delayed cleaning of the rotor, which may be a cause of the engine underutilization from 10 to 50% [9].

We hypothesized that the full use of automotive engines resource can be achieved through efficient operation of centrifugal oil filter via permanent operational control of its cleaning ability.

The study of the efficiency of the centrifugal filter can provide solution of two tasks that are of theoretical interest for us and that have indisputable practical application/

1) task of justification of a control device design in order to regulate the frequency of cleaning the rotor of the centrifuge deposits;

2) task of controlling oil replacement frequency.

2.2.2 Centrifugal filter control device

The basic parameter for the centrifugal oil filters is the rotor revolution frequency. Its limit value for different motors varies from 5000 to 5500 min^{-1} . The drop of rotor frequency can be explained by different factors:

- accumulation of significant amount of deposits in the rotor sleeve;
- decrease of inner dimensions of nozzle holes (in nozzle centrifuges);
- crankcase oil viscosity increase;
- oil pressure decrease in the rotor caused by oil leakages via worn out "rotor axis-rotor bushing" coupling;
- oil pressure decrease in the engine lubrication system.

According to the applied in diagnostics process division into two stages aimed to detect the rotor frequency drop lower than the limit value, the control of the frequency is necessary. From now forth, by using the algorithm developed by us, it is possible to discover causes of the rotor frequency drop.

Centrifuge rotor balancing is done on the manufacturing plant, and according to the recommendations it is forbidden to set any additional details on the rotor as it can put it out of balance and cause rotor axis break down as it becomes weakened by the port holes for oil feeding and removal.

We have developed centrifugal oil filters of two designs with variable reactance transducers which have utility model patents. Iron containing rotor details served as the source of impulses. In the first modification the steel nozzle of the rotor were used as the source [10]. The other modification employed the rotor nut [11]. The crankshaft position sensor of VAZ engine was used as the sensor.

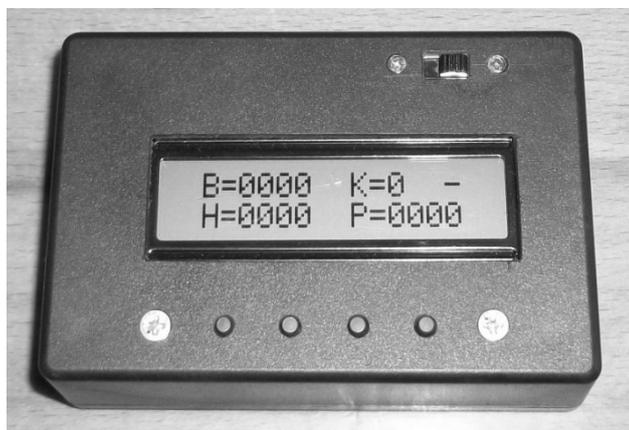
To register the centrifuge rotor frequency drop lower than the limit value a transducer and an indicator were developed set together in one case (pic.3).



Picture 3. – Indicator with the transducer and the sensor (left)

The indicator is made using light emitting diodes, when the rotor frequency drops lower than the limit value the red diode lights up.

The transducer is made on a programmable microcontroller with specifically designed programming unit (see pic. 4) in order to make it usable on centrifuges of other manufacturers.



Picture 4. Programming unit

The oil replacement frequency is determined by its condition which is characterized by the interdependence between its numerical values and its qualitative characteristics and the motor operation time:

$$\Pi = F(t) \quad (1)$$

One of the basic characteristics of oil which can be the reason for its replacement is the change of oil viscosity. It is considered counterproductive to use oil if its viscosity increases by 35 %. In this paper we will not consider cases of crankcase oil viscosity decrease because of its contamination with fuel or coolant.

Oil viscosity influences centrifuge operation. One may state that viscosity increase can be allowed until it does not influence the centrifuge rotor frequency, that means until oil viscosity value does not decrease to the limit of the centrifuge's decontamination capacity (its rotor frequency). Thus the centrifuge rotor frequency may serve as an additional parameter for identifying the moment of oil replacement in the engine crankcase.

2.2.3 Oil replacement frequency control

There are two ways of oil replacement frequency control - by changing oil quantity and by using oil with different replacement frequency.

Let us consider oil replacement frequency control by changing the oil quantity. According to publications on the topic [12] the change of crankcase oil volume in internal combustion engines does not influence overall oil consumption. It means that the increase of oil feed leads to more frequent oil replacement in the same proportion. However, in the conditions of normal operation this method could be difficult to apply from the technical point of view because of equipment design features; oil leakages caused by oil feeding lines or sealing units failures can lead to significant oil losses.

In common situation the condition for carrying out oil replacement separately from continuous operation periods is:

$$C_{rec} + C_{diag} < \Delta C \times t_{rplc} + V \times C_i \times P_k(T_{\pi}) \quad (2)$$

- where C_{rec} - cost of crankcase oil pan reconstruction in rubles;
- C_{diag} - cost of a diagnosing device in rubles;
- ΔC - specific value of losses because of tractor (vehicle) downtime, in rubles/h;
- t_{rplc} - oil replacement time, h;
- V - oil pan capacity, l;
- C_i - cost of i-brand oil in rubles/l;

$P_k(T_n)$ - Probability of connecting oil lines and sealing parts failure during the period of oil usage.

Another parameter of oil that can cause its replacement is the content of mechanical impurities.

The speed of impurities separation in the centrifuge is calculated in the following way [13]:

$$\frac{dw}{dt} = 0.01x\gamma Q\varphi \quad (3)$$

where x – is the impurities content on the centrifuge entry in % (of weight)

γ - suspension density, kg/l

Q – centrifuge flow rate, l/min

φ - oil decontamination index [13]

In general case the change of overall impurities content in oil can be represented as the difference between impurities content in the oil that enters the centrifuge and that leaves it.

As the speed of impurities separation is proportional to their concentration and, correspondingly, to the total content of impurities in oil, the following can be put forth:

$$\dot{w} = k - aw \quad (4)$$

where k - is the speed of impurities feed in the oil in g/h

a – is proportionality factor taken from the right part of equation (3)

The solution of the equation is as follows:

$$w(t) = \frac{k}{a}(1 - e^{-at}) \quad (5)$$

Dividing both parts of the equation (5) on the weight of the crankcase oil we receive the dependence of mechanical impurities concentration in oil from the time of engine work.

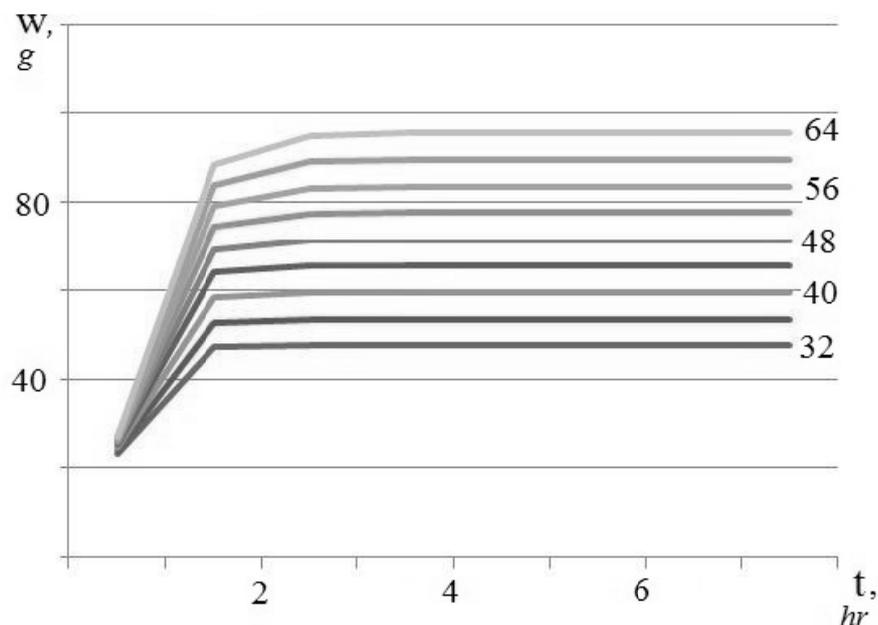
Calculations for engine YMZ-238NB centrifuge were done. With crankcase capacity $V=32$ l, suspension density $\gamma = 900$ g/l, centrifuge flow rate $Q = 720$ l/h and value of oil decontamination index $\varphi = 0,01$ [10], the value of the proportionality factor a according to (3) comprises $0,225 \text{ hour}^{-1}$. The speed of impurities supply into oil comprises 50 mg/hp hour [13] or with engine YMZ-238NB power equal to 215 hp , $k = 10,75 \text{ g/hour}$.

The solution of equation (4) with known values of a and k will be as follows:

$$w(t) = 47,48(1 - e^{-0,225t}) \quad (6)$$

Likewise the values of numerical indices can be calculated with different increased values of YMZ engine crankcase capacity.

The graphs of the dependence (6) are presented on the picture 5.



Picture 5. - Dependence of impurities content in the crankcase oil of the engine YMZ-238NB from the operation time with different crankcase capacity (from 32 to 64 l)

Certainly, the presented graphs illustrate somehow idealized dependences. In reality impurities content increases with time, that means $k=f(t)$. Dependence (4), with preliminary assumption of linear dependence k from t , will be:

$$\dot{w} = k(t + B) - aw \quad (7)$$

where B is the proportionality factor.

The solution of the equation will be:

$$w(t) = C(1 + Dt - e^{-at}) \quad (8)$$

where C, D – are proportionality factors.

Experimental studies as well as the calculation of factor B numerical value in dependence (7) and applying the solution in equation (8) together with known limit values of impurities content in crankcase oil, makes it possible to calculate engine operation time until oil replacement with different crankcase capacities.

3. Conclusions

The concept, developed by the authors of the paper, relies on the basic concepts of "processes in technical systems", "performers of maintenance and repair, technology maintenance and repair, technical maintenance and repair", has permitted us to allocate four types of the arising relations: order, demand, dependence, and non-contradiction. The implementation of technologies and maintenance must be carried out depending on the assessment of the effectiveness of processes in technical systems, which is identified during the comprehensive diagnosis. Important improvements in the technical operation of the machines are the increase of efficiency of functioning of system of greasing. For this purpose, the improved design of centrifugal oil filter with continuous control of its cleansing abilities is proposed, which allows changing the technology of maintenance of the lubrication system of engines through the separation of actions of crankcase oil replacement and rotor filter cleaning.

Reference

- [1] Conception thinking in solving complicated and knotted problems. / Teslinov A.G. – S. Petersburg: Piter, 2009. – 288 p.
- [2] Conceptual design of complicated solutions. / Teslinov A.G. – S. Petersburg: Piter, 2008. – 288 p.
- [3] Okunev G.A., Ruzhyev L.L. Technical reequipment of manufacturing enterprise, search for effective options // ChSAA Bulletin. – 2014. – Vol. 70. – Pp. 108-115.
- [4] A chance for adventure. / Compl. by A.B. Selyutsky. – Petrozavodsk: Karelia. 1991. – 304 p. with pict. – (Technics – youth - creativity)
- [5] Maintenance fundamentals, 2nd Edition / R. Keith Mobley - Elsevier Inc., 2004. – 418 p.
- [6] Maintainability, Maintenance, and Reliability for Engineers / B.S. Dhillon - Taylor & Francis Group, LLC, 2006. – 214 p.
- [7] Nakagawa T. Maintenance theory of reliability. - (Springer series in reliability engineering). Springer-Verlag London Limited. 2005, p.274
- [8] Khairy A.H. Kobbacy, D.N. Prabhakar Murthy Complex System Maintenance Handbook. - (Springer series in reliability engineering). Springer-Verlag London Limited, 2008, p.648
- [9] Alliluev V.A. Technical operation of machine and tractor fleet / V.A. Alliluev, A.D. Adanyin, V.M. Mikhlin. – Moscow: Agropromizdat, 1991. – 367 p.
- [10] Utility model patent №100139 “Centrifugal oil filter” Published 10.12.2010 bull. №34 / Redreev G.V., Degtyarev A.A., Siryak A.S., Klyuev I.A.
- [11] Utility model patent №134994 “Centrifugal oil filter” Published 27.11.2013 bull. №33 / Redreev G.V., Siryak A.S., Klyuev I.A.
- [12] Under the general editorship of A.S. Orlin, M.G. Kruglov. Internal combustion engines: Systems of reciprocating and compound engines / S.I. Efimov, N.A. Ivashchenko, V.I. Ivin et al. – 3rd Edition, updated and revised. – Moscow, Mashinostroenie, 1985. – Pp. 243-244.
- [13] Grigoryev M.A. Purification of oil and fuel in automobile and tractor engines. / M.A. Grigoryev. . – Moscow, Mashinostroenie, 1970. – 270 p.