Method of determination of transmission oils reasonable useful life

Dmitrichenko N.F.

D.Sc. in engineering, Prof.
National Transport University,
Kyiv, Ukraine,
E-mail: dmitrichenko@ntu.edu.ua

Bilyakovich O.N.

PhD in Technical Sciences, Associate prof.
National Aviation University,
Kyiv, Ukraine,
E-mail: oleg65@voliacable.com

Savchuk A.M.

PhD in Technical Sciences, Associate prof.
National Aviation University,
Kyiv, Ukraine,
E-mail: tolik_savchuk@bigmir.net

Milanenko O.A.

PhD in Technical Sciences, Associate prof.
National Aviation University,
Kyiv, Ukraine,
E-mail: milanmasla@gmail.com

Turytsia Yu.O.

PhD in Technical Sciences, Associate prof.
National Aviation University,
Kyiv, Ukraine,
E-mail: yuliya_tur@ukr.net

Abstract
Establishment of regularities of formation of thickness of a lubricant layer from operational and rheological factors in non-stationary conditions on which it is possible to predict features of lubricant process and durability of the tribomechanical systems was the purpose of work. When performing experimental studies TAD-17i oil was used as lubricator.
The essence of method of determination of rational term of use of oils in units of transmissions of vehicles – is the determination of parameters of lubricant actions of tests of transmission oils in a condition of delivery and oils, that are drained from real units of vehicles with a certain frequency, when modeling work of gear clutches and the analysis of graphic dependences of change of above-mentioned parameters on the size of run of vehicles under control. As a result in work there are presented algorithm of sampling of the studied lubricant mediums.
Keywords: THICKNESS OF LUBRICANT LAYER, VEHICLE, FRICTION COEFFICIENT, OIL

Intorduction

It is known that the oil is a design integral element in units of transport means transmissions. The oil ability to perform and keep functions of constructional material for a long time is determined by its operational properties. The general requirements to transmission oils (TO) are determined by constructional features, appointment and operation conditions of transmission units.

The main functions of TO are the following:

- protection of contact surfaces against wear, sticking, pitting and other damages;
- reduction of energy losses by friction;
- heat removal from contact surfaces of tribocoupling;
- reduction of noise and vibrations of tooth-wheel, reduction of shock loads.

There are two basic ways of determination of the oil change moment: according to condition and given service life. Both should be based on determination of limit values for the most important indexes. On condition, the oil change should be carried out on the basis of indexes evaluation results while in operation. The change on given period (by resource or rules) is executed without reference to condition.

The certain periodicity of oils change is regulated by operating instructions of different components and units of machines. In accordance with the author of paper [1], the operating practice of combustion engines showed that the periodicity of oils change was premature and technically unjustified: most often, aiming to increase the engine life, the designer reduces it.

Service life of oil depends on its properties, friction couple and operating conditions; therefore, its value should be exceptionally unique for each type of tribosystem, which is meant the set of contacting elements and the work processes proceeding interactively in tribocouplings.

In this regard, determination of oil reasonable useful life on the basis of scientifically grounded criteria of their quality is of great importance.

Study of the previous results

Unfortunately, the available data are of contradictory and ambiguous nature, they note that there is no exact scientifically grounded criteria of lubricants selection for specific tribocomponents [2].

For example, in the paper [3], it is noted that oils useful life is determined by the appropriate value of their acid index, which increase by 0.5 – 0.6 mg KOH/g for the oils applied in hydraulic systems of metal-processing equipment, causes sharp increase in wear rate.

In the paper [4], it is also pointed out that there is correlation between increase in wear intensity in a node of friction and in the total acid index of oil.

The author of the paper [5] points out at additive depletion, as the main criterion that causes the necessity of oil change.

According to V.D. Moiseev, one of the main indexes, by which the lines of oil change are determined, is the content of undissolved pollution collecting in the oil in process of its aging [6].

Authors of the paper [7] select the additive depletion as criteria of rejection of oils. It is characterized be decrease of the total base number and pollution, which can be evaluated by growth of insoluble impurity concentration. At that, change of engine oil should take place in case of achievement of at least one of specified indexes of its limit value.

Average value of concentration of insoluble impurity in engine oil is 0.65% in case of the existing system of its change [7].

According to E.S. Venzel, quality-control criteria for engine oil are alkalinity and dispergative stabilizing property; their limit values correspond to1 mg KOH/g and 0.3. At that, the water content in oil should not exceed 0.3-1% [8].

According to the paper [9] quality-control criteria values for engine oils should be the following: change of kinetic viscosity + 30% from initial value; the water content – 0.05-1%; alkalinity - 1 mg KOH/g; pH index - up to 4-5.5; acid index - 2-6 mg KOH /g.

As for numerous quality-control criteria concerning transmission oils, it is necessary to point out the considerable difficulty of their search in the information sources.

In this regard, it is necessary to use the paper [10], where normative standard indicators of physical and chemical parameters for oils under supply condition are given.

In some sources, it is said about number of hours of expected life only. In particular, the value of service life is 500 hours and determined by use of one of the most widespread grades of domestic transmission oils TM-3-18 (TAP-15V in accordance with GOST 23652-79) [11].

According to authors of paper [12], the increase of TO viscosity in comparison with initial one (in case of 100 ^{0}C) by more than for 50% is the integral criterion determining the necessity of TO change. At the same time, preschedule change of above-mentioned oils causes the increase of run-in wear of friction couples and performance depression of sealing elements and resin seal due to its "keratosis" and cracking.

Authors of paper [13] suggested the criterion for quality standard of lubricants. The initial evaluation characterizes bearing capacity depending on different physical-mechanical and chemical operating conditions of friction joint.

Such scarce data on the nomenclature and limit values of quality-control indexes of oils cause the need of their change within the time limits, which are fixed often unreasonably by production plants of machines even if oils have not lost completely the functional properties yet. It is the reason of their non-economic use.

Besides, in machines operation manuals, there is no interrelation between operating conditions, the modes thermal and mechanical loads with oils life. In most cases, both for alloyed oils and for oils without additives, service life is determined identically, usually, the periodic control of oil quality in operating organization is not carried out.

All of this in total leads to the considerable material losses due to both frequent machines faults and uneconomical use of oils.

The oils life can be extended in case of application during operation of special measures, which slow down the negative process reaction rate in oils. One of such methods is purification of oils from pollution. Its efficiency is obvious, at that, its level increases with the growth of cutoff filtration rating. The capabilities of sophisticated technology allow filtering of pollution particles, which are less than 5 microns in size.

However, the significant increase in cutoff filtration rating is not always economically sound, as purification costs double in case of transition to the next purity level.

Beside filtering, the improving of oils properties can be achieved by addition of the alloying additives instead of worn ones [14]. However, addition of oils additives has not been widely used yet.

Tribotechnical tests of local scientists prove that unreasonably frequent change of oils can cause the significant harm to tribosystems - the long-life becomes less, because it functions under nominal condition caused by fluctuations of liquid phase properties [15; 16].

At the same time, it is established that ageing process influence positively the properties of lubricants within a certain range. It is indicative of possibility of transmission oils life extension [17, 18, etc.].

On the basis of above-mentioned review, it is possible to determine that the problem of formation of useful life of lubricants, particularly of transmission oils, is relevant and requires theoretical justification and empirical support.

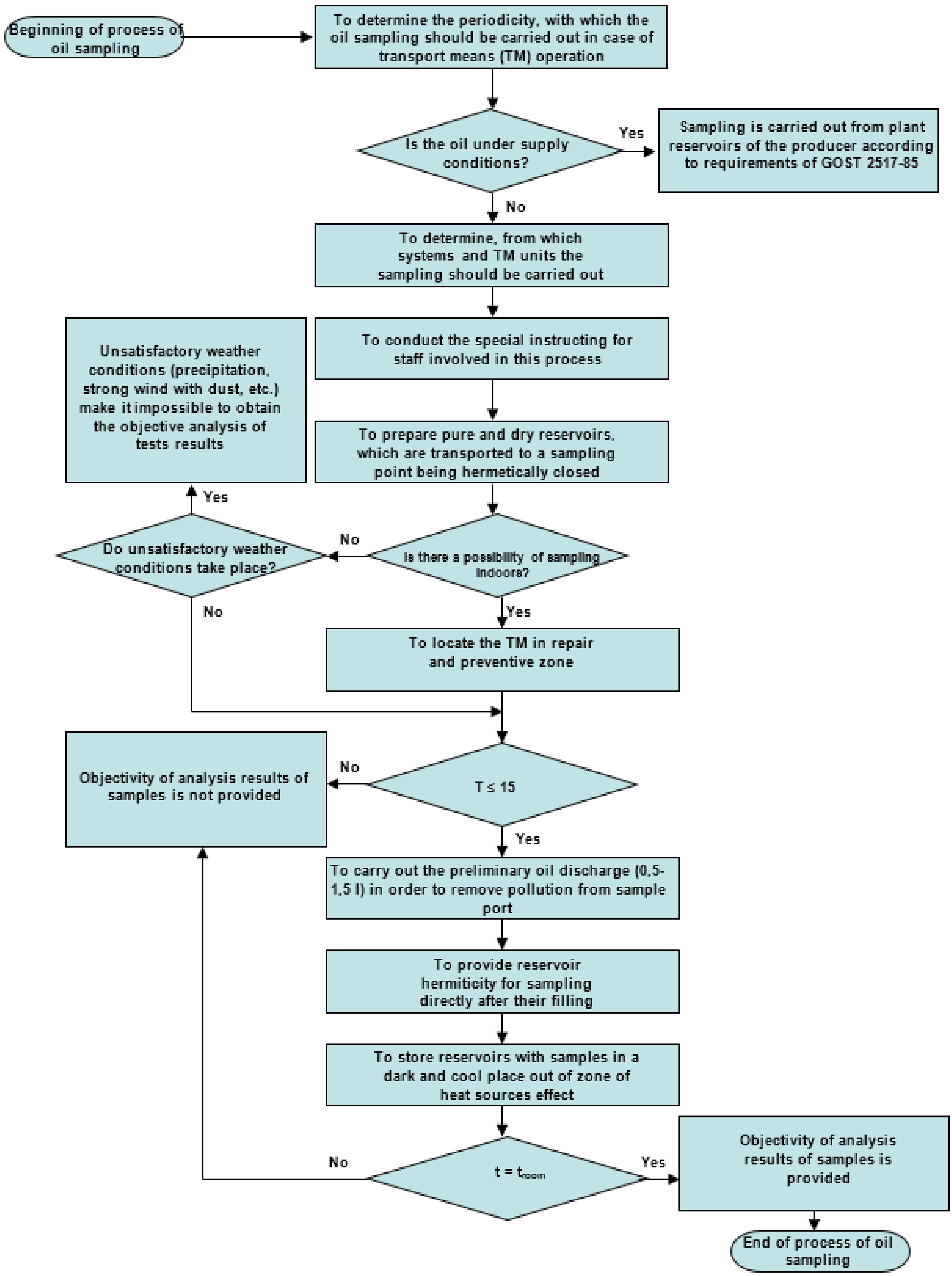

Figure 1. Algorithm of sampling of transmission oils: *T, min*. - time duration after functioning of systems and units of transport means, from which the oil sampling is carried out; *t* - oil sample temperature; t_{room} - room temperature

Description of method of determination of transmission oils useful life

It is known that as a rule, the value of limit lubricant layer (LLL) thickness and friction coefficient are accepted to be used as the basic parameters determining lubricant actions efficiency under the conditions of the limit lubrication mode. They can be evaluated when tribotesting for the appropriate laboratory equipment.

The thickness value of an oil film in case of the limit mode of friction is defined to a lesser extent viscosities of oil, and in the bigger - by physical and chemical properties lubricant the environments, dynamics of their change, a complex of the factors reflecting such features of interaction of working surfaces of cogwheels as their initial status, extra earnings, the high-speed, thermal and load modes of operation, nature of change of these parameters in time [19].

It is obvious that LLL thickness in gearing influences its life time. In order to provide the optimum thickness of an oil film in above-mentioned tribocoupling, lubricant should be selected according to operating conditions.

It is known that between values of LLL thickness and friction coefficient in case of the limit lubrication mode, there is a certain correlation; at that, the more value of LLL thickness is, the less value *f* will be [20].

We are of the opinion that the analysis of mechanism of LLL thickness values change and friction coefficient during the long period of transmission oils operation is the base for development of method of determination of oils useful life in the units of transmission transport means (hereafter - method).

Principle of method is the determination of parameters of lubricating actions of transmission oils samples (LLL thickness and friction coefficient) under supply condition, and also of oils, which are discharged from real units of transport means with a certain periodicity, in case of modeling of gear systems operation and the analysis of graphic dependences of above-mentioned parameters change on run value of transport means under control (TMUC).

This method can be maintained in case of performance of research several stages.

At the first stage, it is necessary to carry out sampling of transmission oils according to specially developed program of full-scale tribotechnical tests depending on value of TMUC run with periodicity of 10 000 km of run. At that, value of the maximum TMUC run, in case of which, it is necessary to carry out sampling, must exceed standard value for a certain oil grade by 1.5... 1.9 times.

Sampling algorithm of lubricant media under investigation is presented in Fig. 1.

At the second stage, the tribotechnical tests on laboratory installation are conducted with fixing of values of LLL thickness and friction coefficient in the medium of oil samples under investigation up to sta- bilizing of the specified parameters of lubricant actions. Test conditions should be maximally close to real operating conditions of gear systems in the units of transmission of transport means.

At the third stage, it is necessary to construct graphic dependences of values of LLL thickness and friction coefficient on the value of TMUC run. According the nature of these dependences, the conclusion on useful life of specific grade of transmission oil is drawn.

As an example, the dependences of values of LLL thickness and friction coefficient on the value of TMUC run are shown in Fig. 2 and 3. They were obtained after tests in the medium of oil TAD-17i, which samples were taken in the range of 0... 90000 km of TMUC run.

The analysis of these dependences shows that there is a possibility of effective use of TAD-17i in this range of TMUC run. The limit parameter values of oil lubricant effect, which feature is sharp reduction of thickness of limit lubricant layer and, consequently, significant growth of friction coefficient in a contact zone of tribocoupling, were not recorded (Fig. 2, 3).

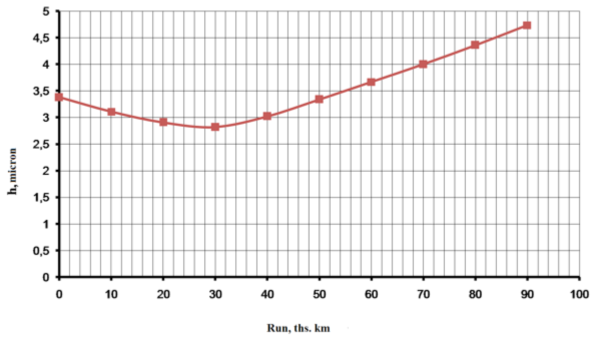

Figure 2. Dependence of thickness values of limit lubricant layers on value of run of transport means under control

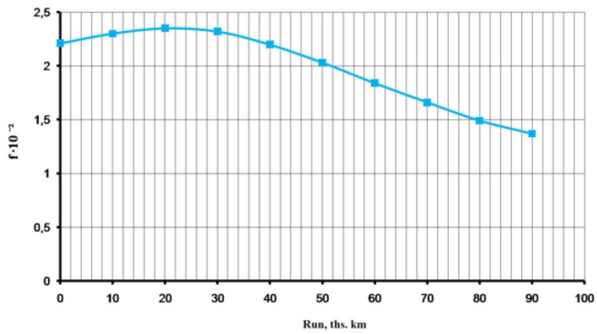

Figure 3. Dependence of values of friction coefficient on value of run of transport means under control

References

1. Zolotov V.A. (2009) Scientific and methodical bases of prediction of oils change periodicity in engines. *Trenie i smazka v mashinakh i mekhanizmakh*. Rostov, Rostov State Transport University, No 2, p.p. 8-13.
2. Kholodilov O.V. (2009) Study of contact phenomena in case of friction by means of invariants. *Trenie i smazka v mashinakh i mekhanizmakh*. Rostov, Rostov State Transport University, No 5, p.p. 41-48.
3. Michnik B.Kh. (1986) Research of lubricating properties of hydraulic oils of the ITS series with various degree of oxidation. *Trenie i iznos*. Gomel, V.A. Belyi Metal-Polymer Research Institute NAS of Belarus, Vol. VII, No 6, p.p. 1112-1115.
4. Moon Woo-sik, Kimura Yoshitsugu (1990) Deterioration of engine oils and its effect on their wear-preventing property. *Proc. Jap. Int. Tribol. Conf.*, Nagoya, Oct. 29, Nov.1,Vol.1. Tokyo, p.p. 433-438.
5. Obelnitskiy A.M. *Toplivo i smazochnye matepialy.* [Fuel and lubricant materials. Textbook for technical colleges]. Moscow, Vysshaya shkola, 1982. 208 p.
6. Moiseev V.D. (1991) Two models of the description of pollution process of engine oil. *Dvigatelestroenie*. No 1, p.p. 36-38.
7. Mikhaylov A.N. (1991) Substantiation of periodicity of change of operating engine oil of tractor diesel. *Dvigatelestroenie*. No 3, p.p. 32-34.
8. Ventsel E.S. *Povyshenie iznosostoykosti tribosopryazheniy gidrodinamicheskim dispergipovaniem masel*. [Wear resistance increase of tribocoupling by hydrodynamic dispersion of oils. Diss. of Doctor of Technical Sciences]. Kharkiv, KhNAHU, 1990. 397 p.
9. Mikutenok Yu.A., Shkapenko V.A., Peznikov V.D. Smazochnye sistemy dizeley. [Lubricating system of diesel engines]. Leningrad, Mashinostroenie, 1986. 125 p.
10. Badishtova K.M., Bepshtadt Ya.A., Bogdanov Sh.K. *Topliva, smazochnye materialy, tekhnicheskie zhidkosti. Assortiment i primenenie.* [Fuels, lubricant materials, technical liquids. Range and application]. Moscow, Khimiya, 1989. 432 p.
11. Pozenbepg Yu.A. *Vliyanie smazochnykh masel na dolgovechnost' i nadezhnost' detaley mashin*. [The influence of lubricants on the durability and reliability of machinery components]. Moscow, Mashinostroenie, 1970. 315 p.
12. Zaskalko P.P. (2009) Transmission and gear oil are the most important constructional material of the modern machines. *Trenie i smazka v mashinakh i mekhanizmakh*. Rostov, Rostov State Transport University, No 4, p.p. 26-29.
13. Sorokin A.N., Karpov A.S. (1996) Research technique of the tribological characteristics of lubricants and criterion for their evaluation. *Zavodskaya laboratoriya*. Mascow, No 12, p.p. 53-54.
14. Barraco M., Carbonell M.,Torres R., Adria M.A.,Valero C., Trillas E. (1992) Problematiea de los aceites Reutilizacion o eliminacion controlada lubricantes usados. *Fluidos: Oleohidraul. Neum. autom*. No 7, p.p. 612-616.
15. Litvinov A.A. *Fiziko-khimicheskie osnovy primeneniya smazochnykh matepialov v uzlakh treniya aviatsionnoy tekhniki*. [Physical and chemical bases of use of lubricant materials in nodes of friction of the aircraft equipment: Manual]. Kyiv: Kyiv Institute of Civil Aviation, 1985. 80 p.
16. Shutkov E.A. (2005) Integral method of processing of results of oil spectrum analysis for determination of changes of wearing rate of the diesel details. *Vestnik mashinostroeniya*. No 12, p.p. 28-31.
17. Druet K., Romanowski P. (1991-1992) Wlasnosci uzytkowe starzonych olejow smarowych. *Zag. eksploat. mosz*. No 2-3, p.p. 229-241.
18. Bilyakovich O.N. *Vliyanie zagryaznennosti transmissionnykh masel na smazochnoe deystvie i sostoyanie poverkhnostnykh sloev tribosopryaz*heniy. [Influence of pollution transmission oils and lubricating action on the condition of the surface layers of friction couples: Diss. of Doctor of Technical Sciences: 05.02.04] Kyiv, Kyiv Institute of Civil Aviation, 1996. 273 p.
19. Holweger W., Beckmann P., Ott R. (2004) New results about the behaviour of lubricants in the contact with machinery elements. *Tribology and Lubrication Engineering: 14 International Colloquium Tribology*, Ostfildern, Jan. 13-15, Vol. 3. Ostfildern, Techn. Akad. Esslingen, p.p. 1673-1678.
20. Kuzmin I.S., Pazhikov V.N. *Melkomodul'nye tsilindpicheskie zubchatye peredachi: Raschet, konstruipovanie, ispytanie*. [Fine-grained cylindrical gears: Calculation, design, testing]. Leningrad, Mashinostpoenie, 1987. 272 p.