Research of evaluation criteria quality control of the worked oil, charged into the main gearbox of «VR-14»

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Abstract. The main unit of the helicopter transforming torque from the motor shaft to the rotor and to the drives of the helicopter units is the main gearbox. The operating conditions of the reducer relate to the field of high-cycle fatigue. Oil is supplied by the gearbox lubrication system, to reduce the main gearbox mechanisms kinematic connection working parts friction coefficient and it necessary cooling. The reliability of the lubrication system largely depends on the quality of the oil used in accordance with the regulatory requirements for it, which regulate the properties of fresh oil. Regulatory requirements contain indicators that characterize its reliability, but do not reflect the requirements imposed on the properties of oils that are in use. The working oil requirements are presented by the product developer. It is used and indicated in the chemotological map of the design documentation with the reflection of these requirements and in the operational documentation. The quality control evaluation criteria of the «BP-14» main gearbox of Mi-8AMT / MTV (Mi-8) helicopters is discussed in the article. The measures aimed at improving the reliability, preserving the quality of the used oil and evaluating its parameters, as well as ensuring the durability of the whole mechanism. It was found in the course of studying the requirements for fresh oils and workers that the existing requirements do not allow us to estimate the real state of the oil and the technical condition of the system as a whole due to its partial replacement with fresh oil for different ones. The characteristics of the oil deteriorate, and at the during operation there are no requirements for oil having a working life in the design and operational documentation. The article proposes to define the following indicators for determining the quality of working oil and deciding on further operation: “determining the amount of mechanical impurities” according to GOST 10577 and “determining the purity class” according to GOST 17216

1. Introduction

A gearbox is provided in order to transfer torque from a high-speed gas turbine engine to the screws helicopters. The torque transmission to the screws is due to the transmission coupling. The Mi-8, Mi-8MTV-1, Mi-8AMT helicopters and their modifications main transmission units are the main gearbox BP-14, the intermediate gear PR-8, the tailing gear XP-8, the transmission shafts with the brake rotor brake.

The main gearbox is a separate unit it consists of bodies fastened together. There are inside: the main gearbox mechanism with a planetary stage, the drive units and the oil system of the gearbox [1].

The gearbox lubrication system purpose is to supply oil to all moving parts - gear wheels, bearing supports, splined connections to reduce the coefficient of friction and effective cooling [2]. In addition to ensuring sufficient heat removal and lubricating properties, lubricating substances have to retain their
properties for a sufficiently long operating time, considering the different operating modes and the
downtime of the helicopter in changing meteorological conditions. However, the quality of the oil
deteriorates due to mechanical loads and chemical processes during operation: the destruction of viscous
additives hydrocarbon chains under high pressure conditions, oxidation as a result of contact with air,
emulsification and foaming with air and moisture. Thus, irreversible processes occur in the oil, which
cause changes in its properties. For example, due to an increase in viscosity, the efficiency of the system
is reduced, the frictional moment on the bearings and other nodes increases, and the heat sink intensity
decreases. The corrosion occurs due to the increase in acidity.

To reduce the negative impact viability oils properties of the whole mechanism, it is replaced with a
fresh one. There are two operation methods that determine the stage of oil change: the operation of the
oil as it is, and the operation according to the operating time and service life. The oil change as a state
is carried out on the oil observation basis according to the samples analysis results taken during
operation, which is based on the establishment of limit values for the most important indicators
(kinematic viscosity, acid number, additive concentration). Replacement on the appointed term
(operating time, service life) is made regardless of the oil condition, design features and the aircraft
equipment (AT) operating conditions. The frequency change oil according to the established regulations
on the AT-based product is individual for each type of aircraft and oil grade [3].

2. Results and discussion
The working oil requirements are determined by the product designer and indicated in the chemotology
map of the design documentation.

The following synthetic oils are used for the Mi-8 brand and its modifications serial helicopters in
the oil systems of the main gearbox BP-14 and turbo-shaft engines TB3-117: B-3B according to the
specifications TU 38.101295-85, LZ-240 according to the specifications TU 301-04 -010-92, TURBONYCOIL-98 (TN-98) to DEF STAN 91-98/2 specification.

Consider the main adverse points occurring during operation in the main gearbox BP-14. There are
cases of oil flooding in BP-14 main gearbox operation process. It is due to the humid air vapor presence
it has passed through the cooler, in violation of the gearbox storage rules or the oxidation of oil itself
[4]. The oxidation process when the oil interacts with oxygen dissolved in the air is another source of
water in the oil. It should be noted the use of synthetic oils for BP-14 gearbox have drawbacks, it is high
hygroscopic and the ability to form corrosive compounds. Thus, under the catalytic effect of additives
and various impurities, water promotes the hydrolysis of the oil to form alcohols and acids. When they
interact with mechanical impurities, oil-insoluble compounds are formed, which precipitate and
concentrate on the oil filter sections [5]. It should be noted on the working surfaces of moving parts a
thin solid coating is formed, which can lead to parts jamming. All this leads to a decrease in the basic
properties of the oil, which characterizes the ability to maintain its physicochemical parameters (e.g.
thermal oxidative stability). Therefore, the indicators “water content” and “kinematic viscosity” in oil
are subject to periodic monitoring.

Also, natural wear of friction pairs occurs in the process of product operation, as a result of metal
particles enter the oily environment. In cases of critical or non-design loads, or deficiencies of a
production nature it leads to further wear of friction pairs, changes in the geometric dimensions of the
kinematic connection parts, distortions, the tracks and bearings occurs rolling elements deformations,
which increased vibrations, clogged channels of the oil system, erosion wear of sliding surfaces or
rolling (in this case bearings). These circumstances worsen the parameters of the main gearbox, and
entail prerequisites for an accident. Therefore, oil from the gearbox is periodically monitored for the
content of wear products to prevent the above negative consequences.

To solve the problems of controlling the performance properties of the oil and determining the
limiting state during the operation of the main gearbox BP-14, the following measures were developed
and implemented:

1. sampling for water availability (in accordance with the Maintenance Schedule (RO) of the Mi-
8AMT / MTV helicopter every 2 months);
2. sampling for the maintenance of wear products in oil (in accordance with the Directive letter of the UNPLG GVS FSNST MT RF dated April 6, 2005 No. 5.10-21GA and the TN-98 Oil Sampling Control Methodology, considering the introduction of temporary standards for iron content in TB2-117, TVZ-117 engines oil and main gearboxes BP-8 (BP-8A) and BP-14 every 50 hours);

3. sampling for the purpose of controlling the quality of the oil (when working in accordance with the Work Programs for assessing the main gearboxes BP-14 technical condition when operating according to the technical condition for the regulated operating conditions, more than those established during the manufacture or repair of resources or service life) would;

4. oil change in the BP-14 main gearbox and in engines TV3-117 with a frequency of 300 hours, but at least 1 time per year (in accordance with the PO per helicopter). Also, oil change when changing the grade of oil (manual for technical operation (OM) on BP-14).

In the course of studying the requirements of the operational and regulatory technical documentation for the Mi-8 helicopter and its modifications, differences were found. E.g. Program No. 78-769-754ПП (works on the evaluation of the BP-14 main gearboxes technical condition with a phased increase in service life to the 1st repair (overhaul) over 15 years, after operation and storage in the original packaging, up to 19 years) is sampling oil for analysis only for the presence of water and mechanical impurities. After operating time more than 100 hours or the lifetime of 6 months the last quality control or after the last replacement, the kinematic viscosity is monitored. The same is indicated in Bulletin No. K7870-14 БЭ-Г (informing operating organizations about the resource establishment for the BP-14 main gearboxes produced by JSC Gearbox-PM before the 1st overhaul and overhaul of the technical condition up to 4000 hours for the regulated operating conditions in Civil Aviation (GA)), the addition is to perform an oil analysis, replace it, if it is impossible.

Thus, we obtained three controlled indicators that required current regulatory documents: kinematic viscosity, water mass fraction, mechanical impurities content.

The undissolved phase content in the oil can be assessed visually, by weighing, by determining the sieve composition of the particles. The contamination visual method is difficult to determine. This method has a low sensitivity and classifies the “absence” of mechanical impurities and water, when there are separate particles of contamination and water droplets with 15-20 µm average size in the oil. Therefore, they strive to use methods and devices capable of fixing particles smaller than 5 µm in size for a more accurate result.

The most common method for determining mechanical impurities is weighing. The basic principle of weighing is to determine the weight of the filter after passing a certain amount of oil through it.

GOST 6370 “Oil, petroleum products and additives. The determination of mechanical impurities method. The method essence consists in filtering the tested products with preliminary dissolving slowly filtered products in gasoline or toluene, washing the precipitate on a filter of the White Ribbon or Red Ribbon brands with a solvent, followed by drying and weighing. The mechanical impurities content is judged by the filter weight (in mass%). Mass fraction of mechanical impurities up to 0.005% inclusive is estimated as their absence.

GOST 10577 “Oil products. The mechanical impurities determining content method. The method essence consists in determining the mass of mechanical impurities that are retained by membrane filters with a pore size of 0.8-0.9 µm. when filtering the test oil through them. The content of mechanical impurities is judged by the filter weight (in wt.%).

The results obtained by determination the index of mechanical impurities according to GOST 6370 and GOST 10577 may differ due to the different structure of the filter material. Figure 1 shows the scanning electron microscopy (Tesla Vega II) of the filtration materials structure:
A filter paper is obtained using a special technology from carefully cleaned and pressed, without sizing, long-fibrous paper pulp. The filter paper has a fibrous structure with overlapping fibers in different directions (Figure 1a, b). The filter paper porosity depends on its density and decreases with increasing density. Filter paper "White ribbon" - has a high filtration rate and the pore size is ~ 8-12 μm. Filter paper brand "Red Ribbon" - has a moderate filtration rate and the pore size is ~ 5-8 μm. Thus, the long fibers of the filter paper perform the role of a prefilter, e.g. the particles are retained at the intersections of the fibers, both on the surface and in the thickness of the filtering material [6].

Membrane filters are produced by making colloidal solutions from acetylcellulose, applied in a thin layer on glass plates and subjected to regular evaporation, during it gelation occurs, lead to the formation of open colloidal membrane structure. Membranes with porosity are obtained in very wide limits depending on the gelatinization conditions [7].

Membrane filters have a smooth and uniform surface. Such a surface creates a contrasting background that contributes to a better particles visibility. Membrane filters are sieves with medium pore sizes in a narrow range of 0.8-0.9 μm with a clear microporous structure and a stable pore configuration (Figure 1c, 1d). Thus, they play role of a surface filtration material, since particles almost completely linger on the filter surface.

**Figure 1.** Electron micrograph of filter material: (a) - White Ribbon filter paper (magnification 500x), (b) - Red Ribbon filter paper (magnification 500x), (c) and (d) - Cellular cellulose membrane filter brand MFAS-HB produced by Vladipor (magnification 500x and 1000x)
The paper keeps impurities on the surface as well as inside the filter fibers, thereby creating a secondary filter layer. This layer does not allow to determine the nominal porosity of the filter paper the specified retention range of filter paper of the Red Ribbon brand and the White Ribbon brand can be used as recommendations.

Membrane filters have greater particle trapping efficiency. Particles larger than the nominal porosity remain on surface, while smaller particles pass through the filter if other interactions in the filter do not keep them in the filter matrix.

Based on the above, the membrane filter uniform pore size with a clear microporous structure and stable throughput provides greater accuracy in determining the content of mechanical impurities.

The gear oil system will be discussed further. The energy is transmitted and controlled by means of a pressurized fluid inside a closed circuit in the oil system of the gearbox. Fluid is simultaneously played a role a lubricant and means of energy transfer. The solid particles presence in the liquid reduces its lubricating properties, lead to wear parts. Contamination by particles affects the reliability and safety of the system. The degree of contamination should be monitored and should not exceed the level adopted for this system. For example, particles up to 5 µm have a significant effect on the wear of friction units, since getting into the gaps between the working surfaces of the engine parts and units, thereby jamming them, having an abrasive effect, and also cause blockage of various nozzles and throttle valves. The particles, getting into the oil system, contribute to the rupture of the oil film, worsening the lubrication mode and causing an increased oxidation of the oil.

The particle size distribution of oil pollution is determined by sedimentation and microscopic methods. Optical methods of sedimentation analysis are widely used, based on a photo colormetric method for measuring the amount of settling particles, which are used to determine the size of wear particles present in oil. Microscopic method for determining the pollution particle size distribution is based on counting the number of particles, studying the appearance and particles shape. The particles nature can be determined using a special device SPECTROSCAN, based on X-ray fluorescent analysis of elements in a solid, powdered, dissolved state, as well as deposited on the surface or deposited on filters.

GOST 17216 “Industrial cleanliness. Liquids purity classes”. The standard establishes a classification of industrial cleanliness of liquids used in the manufacture, operation and repair of machines and devices (working fluids of hydraulic drive systems and machine controls, tool drives; lubricating oils, liquid fuels, solvents), as well as coding industrial cleanliness of liquids used in hydraulic systems depending on the number and contamination particles size in 100 ± 0.5 cm3 of the analyzed liquid.

The contamination particles are all foreign particles, including sand grains, oxidation and wear products, bacteria colonies and their metabolic products. The pollution particles size, except fibers, is determined by the greatest measurement result. Fibers consider particles with a thickness of no more than 30 µm with a length to thickness ratio of at least 10 µm. GOST 17216 provides for working fluid purity classes: 00, 0, 1, 2 etc. to 17. The contamination particles larger than 200 µm (not counting fibers) are not allowed in oils. Aircraft engine oils are usually of 8 ... 13th grade purity. The 8th class of cleanliness usually has oil during the control flushing of a new engine, and the 13th class - before replacement in operation according to the rules established for each engine. Particular attention should be paid to the fibers that can pass through the filters grids together with the oil oxidation products to contribute to nozzle clogging. As practice shows, fibers appearing in oil are the nap of synthetic and cotton cleaning materials.

3. Conclusion

Investigating in practice the programs implementation to ensure the oil quality and vital components of the BP-14 main gearbox, it was found that testing samples in accordance with GOST 6370 in terms of "mechanical impurities" does not evaluate the contamination formed during operation in the gearbox, and controls only the quality of the oil itself for its compliance with the manufacturer’s specifications. This circumstance can be solved by introducing an oil assessment procedure into the design and
operational documentation by the developer of the main gearbox BP-14 for compliance with the requirements of GOST 17216 and GOST 10577 not only in the manufacture and assembly of gearboxes with strict observance of industrial hygiene, but also during operation products, but also in the manufacture and supply of oil before refueling it in the main gearbox.

Thus, to determine the source of pollution, using GOST 10577 and GOST 17216 with a description of the appearance of the solid non-evolving phase in oil, the problem of ensuring the early detection of faults in main gearboxes will be solved.

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