# OIL AND GAS PRODUCTION

# Impact of oil on the vibration behavior of the pumping unit gear

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*To reduce power losses due to friction and to reduce the deterioration intensity of surfaces wear, and to prevent jamming, burrs, corrosion and better heat removal the interacting surfaces of parts shall have proper lubrication. Lack of lubricant, its nonconformance with the recommendations of manufacturers and pollution cause heavy wear, breach of geometrical dimensions and increase in clearance.*

Heavy wear of working surfaces is one of the main reasons for decrease in efficiency of reduction units of stepping oil-well pumping unit (SOWPU) SOWPU. Therefore it is important to find proper lubricants for reduction units and define their lubricating properties. Over time, the quality of oil deteriorates, condensate is created, and therefore it is necessary to evaluate the effect of lubricants on reduction units’ performance.

The wrong choice of lubricant or its untimely replacement can lead to changes in center-to-center distance, shaft misalignment, worsening of working conditions of parts and acceleration of their breakdown. Therefore it is necessary to evaluate the impact of lubricants on the vibration characteristics of a reduction unit.

It is particularly important to analyze the factors of influence of the quality of lubricants on the wear process of working surfaces of the teeth and the methods and means of control of their technical condition during lubrication of SOWPU reduction units’ toothed gearing.

In mechanical engineering, crankcase lubrication system is widely used for gear lubrication. Surfaces of SOWPU reduction units’ toothed gearing are lubricated by immersion into a liquid lubricant bath. Oil is poured into the gear case so that the teeth row is completely immersed in it. During rotation oil is gathered by the teeth, is sprayed and penetrates into the inner walls of the casing and flows down to its bottom. A suspension of oil particles in the air is generated inside the casing, that cover the surfaces of parts located inside the casing.

Lubricants are used to reduce expenditure of energy for friction, reduce of the temperature of parts of movable coupling, removal of wear products, surface protection against corrosion and also contribute to the maintenance of the temperature regime of parts.

In double and triple-reduction units with common oil bath, oil with a viscosity with qualities between those essential for high-speed and low-speed steps is used. At higher speeds the centrifugal force throws oil from teeth, and gearing works with insufficient lubrication. In addition, there is a significant increase in power loss for oil mixing and its temperature also increases. A proper lubricant is chosen based on the experience in operation of machines. The principle of choice of a proper lubricant is as follows: the higher the tooth contact pressure, the greater the viscosity of the lubricant should be; the higher circular velocity of the wheel, the lower the viscosity should be. The required lubricant viscosity grade is determined depending on contact stress and angular velocity of the wheels.

During the operation, SOWPU reduction unit is constantly exposed to the external environment. Important physical and chemical property of oil is its ability to oxidize. In normal atmospheric conditions, mineral oils retain their properties for a long time. During operation and oil heating and its interaction with the air, its physical and chemical properties and performance are changed. This is manifested as formation of new products during oxidation: acids, resins, pyrobitumens, carbenes and carboids which in the most cases is the cause of complications during operation of heavily loaded gears and friction units, as well as of emergence of lacquer films on friction surfaces and sedimentation. Sometimes oils used for lubrication of toothed gearing become almost completely solid due to oxidation [1–7].

Viscosity of lubricants is the most significant indicator that determines whether they pass through the channels and small gaps of friction units.

The presence of moisture in lubricants significantly affects the quality of lubrication of parts of a reduction unit, which leads to wear intensification. Amount of moisture affects the nature of wear. If water content in oil is only 5% wear products are dark gray-brown and small, it contains a very small amount of metal particles. At humidity level of 50% (a monomolecular layer of water covers the surface) gray metallic powder is formed. Up to 50 % humidity - wear particles mainly consist of oxides, at more than 50% - mostly of metal. The intensity of wear is significantly affected by film which is formed on the friction surface.

An inspection of equipment delivered for repair was conducted at Boryslavska service center, in particular, amount of oil in the crankcase and its quality were determined. Each piece of equipment was characterized by low oil level in the crankcase, besides oil it also contained a sufficient amount of water and oil of unknown origin (Fig. 1). The studies of the study are presented in Table. 1.

*Table 1*

Water content in scavenge oil

| Equipment | Crankcase volume, l | Factual volume of scavenged oil | |
|---|---|---|---|
| | | Oil content, l | Water content, l |
| RU* Ts2NSh-750 | 135 | 85 | 20 |
| RU Ts2 NSh -750 | 135 | 42 | 12 |
| RU Ts2 NSh -315 | 37,8 | 15 | 8 |
| RU Ts2 NSh -450 | 109 | 30 | 15 |
| RU RN-650 | 63 | 22 | 4 |

*RU – reduction unit

The presence of water in lubricant almost always has a negative impact on work unit friction because it causes corrosion of metal surfaces. After stopping of a reduction unit and cooling of hot parts water condenses on the walls of crankcase and details. High level of humidity and penetration of water into the crankcase greatly enhances the intensity of corrosion. So, in this case, lubricants should be of high demulsifying properties, including the ability to provide rapid water sedimentatuin and prevent formation of stable water-oil emulsions.

It is possible to neutralize the effect of water on wear toothed gearing using soft metals as additives to the oil.

Corrosivity of oil depends on presence in it not only water, but also acid additives containing chemically active substances, that are corrosive towards metals. Low molecular weight acids react with metals even at normal temperatures, while high molecular weight acids react with oil in the presence of water and oxygen through hydroxide. The property oil to protect parts from corrosion in the presence of water and oxygen can be improved through the use of additives Technical maintenance of reduction unit is basically a systematic lubrication of units and a timely replacement of scavenged oil. The maintenance also includes elimination of leaks in the lubrication system.

Different factors influence on the lifetime of SOWPU reduction units. It is necessary to look for new approaches to improve their lifetime. Increase in the load or contact pressure results in increased heat generation in the contact patch and therefore increases the likelihood of a gear pair wear. Load increase without additional heat removal leads to an increase in surface temperature, reducing oil viscosity at inlet and increasing coefficient of friction, so that different kinds of wear occur.

Vibration resulting from manufacturing and assembly errors has a significant impact on carrying capacity of hydrodynamic oil film.

Viscosity is the main indicator of the property of the oil to create an oil film with high load capacity, which prevents from and reduces surface wear. Oil viscosity depends on various factors, primarily on temperature, i.e. viscosity decreases with increasing temperature. It is established that in the same operating conditions more viscous oils form a thicker film which simultaneously increases its carrying capacity and thus reduces wear compared to less viscous oils. Besides that, the ability to prevent or reduce oil wear depends on the type of film that is formed on friction surfaces through the use of surface- active or inactive oil.

Studies suggest that reducing the roughness of working surfaces of wheel teeth can significantly reduce the maximum instantaneous temperature in the contact zone of the teeth. Perhaps there is some optimal surface roughness which provides the largest carrying capacity of a transmission. In addition, of importance are oil film thickness and total height of microroughnesses of conjugate surfaces of a toothed gearing.

To important physical and chemical properties of oil belongs its ability to oxidize. In normal atmospheric conditions, mineral oils retain their properties for a long time. But it changes its physical, chemical and performance properties during operation by heating, and interaction of oil with air in the presence of crystal-active components at high temperature. New products are formed during oxidation: acid, asphaltenic gums, carbenes and carboids that mostly cause complications during operation of heavily loaded gears and friction units, as well as of emergence of lacquer films on friction surfaces, and sedimentation.

Oil properties and its viscosity significantly affect the maximum instantaneous temperature at the surface of toothed gearings. Since the temperature spikes on the tooth surface are high at initial and final point of contact when sliding velocity is at its greatest value, edge shocks that lead to oil film dissection are possible.

The way and amount of oil feed also play a significant role in occurrence of different kinds of wear.

As for gear SOWPU reduction units are characterized by operation at the time of launch, it is particularly important in the event of a load. A thin oil film must be maintained on friction surfaces, oil excess must be removed from the friction zone prior to coming into direct contact, otherwise expenditure of energy for squeezing and spraying of oil on the friction surfaces can be increased. Ideal lubrication takes place when oil stream is fed into the exit area of teeth mesh. This results in rapid removal of heat with oil, it is discharged into the crankcase, and by the time of teeth mesh an effective thin oil film remains on their surfaces.

Determination of vibration levels of a reduction unit, depending on the oil quality in a reduction unit crankcase and at the time of launch under load, was conducted at the experimental test bench installation, which is a scalable model of a SOWPU reduction unit type Ts2NHh-750B. The model is equipped with a 2.2 kW electric motor with a nominal speed 1420 rpm, two cone-belt drives with a total reduction ratio of 5.53, a reduction unit with a total reduction ratio of 37.1 . Load on a balancer head is fed by a 600 mm long spring with a diameter of 45 mm. Vibration signal was measured on the casing of a reducer closest to output shaft bearing by means of information-measuring system, comprising a piezoelectric transducer, an amplifier, an independent power supply and a laptop. The signals were processed in the Mathcad environment.

We used scavenge and pure I-40 oil for the investigation. We obtained scavenged oil from a SOWPU reduction unit that had been operating for 5,000 hours. Fig. 2 and 3 show frequency spectra depending on oil quality in the crankcase gear. Comparison of Fig. 2 and 3 indicates that oil quality significantly influences on spectra of a vibration signal. In the low-frequency part of the spectrum, this effect manifests itself mainly in the first few harmonics of frequency of teeth mesh. In particular, the most significant is the increase in the amplitude of spectral components of vibration signal at the second double frequency of teeth mesh (Table 2).

*Table 2* Vibration amplitude at teeth mesh frequency harmonics for a high speed shaft in case of use of I-40 oil of different quality

| Teeth mesh frequency and its harmonics | Amplitude, relative units | | Amplitude growth, % |
|---|---|---|---|
| | I-40 oil (clean) | I-40 oil (scavenge) | |
| Fz1 | 5 | 4,7 | – |
| Fz1* | 40 | 69 | 72.5 |
| Fz1* | 50 | 71 | 42 |
| Fz1* | 107 | 164 | 53.3 |

In addition, growth of virtually all vibration frequencies from 500 to 2000 Hz (Table 3) is also essential. Higher frequencies do not take into account low sensor sensitivity at the high-frequency range (vibration level amounts to almost zero at obtained frequencies over 3000 Hz, and in 2000 ... 3000 Hz range spectra difference is negligible with an allowance for errors).

*Table 3* Vibration amplitudes at middle and high frequency ranges in case of use of I-40 oil of different quality

| Frequency range, Hz | Average vibration level at the frequency range, relative units. | | Vibration level increase, % |
|---|---|---|---|
| | I-40 oil (clean) | I-40 oil (scavenge) | |
| 350...450 | 20.9 | 33.8 | 61.4 |
| 500...700 | 39.1 | 72.9 | 86.6 |
| 700...1000 | 42.6 | 115.2 | 170 |
| 1000...1200 | 20.6 | 92.7 | 351 |
| 1200...1350 | 36 | 254.8 | 608 |
| 1350...1450 | 31.1 | 154.5 | 395 |
| 1450...1700 | 75.8 | 167.8 | 121 |
| 1700...1780 | 88.7 | 100.1 | 12.8 |

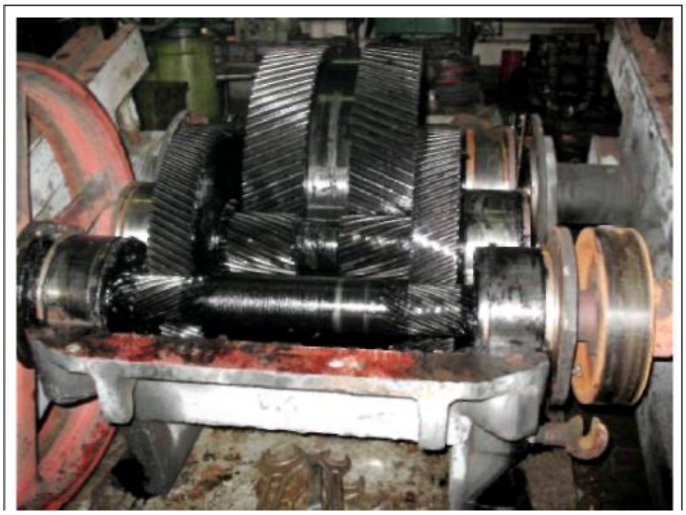

Fig. 1. Reduction unit with oil and water in the crankcase

In the Tables 2 and 3 amplitude is measured in relative units – counts of an AD converter used in the research.

A significant increase in vibration level is observed for the range of 1000 ... 1700 Hz, that corresponds to vibrations caused by friction between the elements of reduction gearing construction. It can be explained by the fact that scavenge oils usually contain large amounts solid impurities, that are formed as a result of destruction of gear units material during the process of wear. The presence of impurities leads to increase in friction and therefore increase in vibration level.

Therefore, the deterioration of oil in the gearbox during wear leads to increased vibration. This in turn may accelerate the process of deterioration and reduce no-failure operation of a reduction unit. Therefore, timely replacement of oil is an important factor in improving the reliability of SHHNU reduction units.

During an oil replacement it is necessary to consider that characteristics of oil poured into the crankcase gear are the same or slightly better than in the passport of the reduction unit.

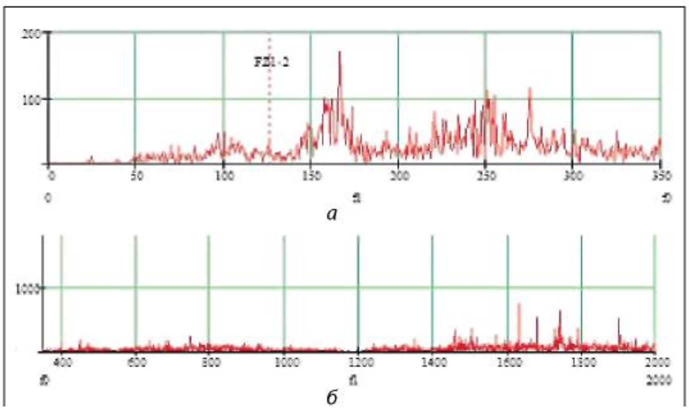


Fig. 2. Frequency spectra during lubrication of a toothed gearing with clean I-40 oil: at low (*a*), and middle and high (b) frequencies

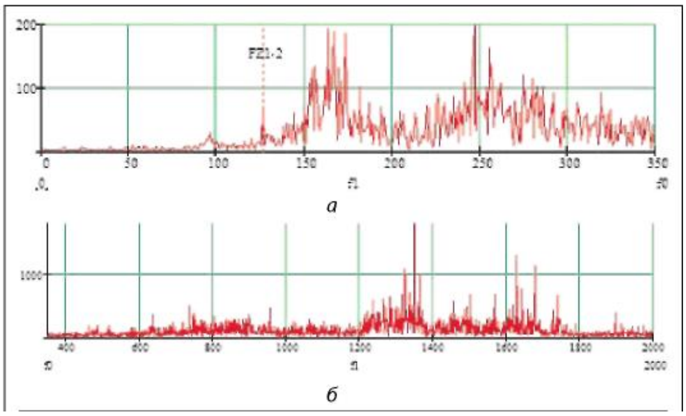


Fig. 3. Frequency spectra during lubrication of a toothed gearing with scavenge I-40 oil: at low (*a*), and middle and high (b) frequencies

Modern industrial machinery must be designed to ensure small material and energy costs during their manufacture, as well as great life length and reliability with minimal operating costs and maintenance. Full implementation of the technical and economic potential of the equipment is possible only in the case of lubrication of friction couples with the use of quality lubricants that fully meet operating conditions of their use.

Modern lubricants capable of withstanding high mechanical and thermal loads, reducing energy consumption and provision of protection against wear, corrosion and deposit formation that infringe the normal operation of the equipment. High performance of lubricants is achieved by of special alloyage with the use of additives with different functionality.

A wide range of lubricants is created to meet the consumers' requirements for this kind of products, including engineering companies, as well as with due compliance with the requirements of applicable regulations, in order to meet specific tasks of lubrication of machines.

Modern requirements for lubricants are based on well-known and practically applicable classifications and specifications, which specify the most important characteristics of lubricants in the form of test results obtained with the help of a famous (in most cases standardized) method. This makes it possible for all interested parties (manufacturers of lubricants, engineering companies, and consumers of their products) to share complete information about the properties of lubricants and their appropriate use.

Considering the aforementioned we can draw up the following conclusions.

With the development of technology, increase of lifetime and reliability of machines are becoming more and more important, therefore study of causes of breaking of parts during operation and development of methods for increasing of durability of machines is urgent.

Increase in durability of machine parts leads to costs reduction for spare parts and materials for their production, reduce of staff and labor intensity during operation, maintenance servicing and repairs.

Difficult operating conditions of modern machinery have rapidly increased requirements for lubricants.

Deterioration of oil quality during wear of a reduction unit leads to increased vibration levels. This in turn may accelerate the process of wear and reduce reduction unit lifetime. Therefore, timely oil replacement is an important factor in improving of the reliability of SOWPU reduction units.

One of the most urgent tasks of modern engineering is rational use of oil, which in many cases determines performance and durability of machines.

During lubricating and filling works it is important to strictly adhere to deadlines and use oil sorts recommended by the manufacturer.

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