МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

АЕРОКОСМІЧНИЙ ФАКУЛЬТЕТ

КАФЕДРА ПІДТРИМАННЯ ЛЬОТНОЇ ПРИДАТНОСТІ АВІАЦІЙНОЇ ТЕХНІКИ

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач кафедри
кан. техн. наук, доц.
___________О.В. Попов
«__»_________2022 р.

КВАЛІФІКАЦІЙНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ЗДОБУВАЧА ОСВІТНЬОГО СТУПЕНЯ МАГІСТРА

ЗА ОСВІТНЬО-ПРОФЕСІЙНОЮ ПРОГРАМОЮ
«ТЕХНІЧНЕ ОБСЛУГОВУВАННЯ ТА РЕМОНТ ПОВІТРЯНИХ СУДЕН І АВІАДВИГУНІВ»

Тема: «Підвищення зносостійкості деталей шасі літака Boeing 737»

Виконав: ___________**Є.Г. Астахов**

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Київ 2022

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE

NATIONAL AVIATION UNIVERSITY

AEROSPACE FACULTY

AIRCRAFT CONTINUING AIRWORTHINESS DEPARTMENT

PERMIT TO DEFENSE
Head of the Department
Ph. D., Assoc. Professor
_________________Popov O.V.
«___» ____________2022 year

MASTER'S DEGREE THESIS

(EXPLANATORY NOTE)

APPLICANT OF EDUCATIONAL DEGREE
"MASTER"
FOR EDUCATIONAL-PROFESSIONAL PROGRAM
"MAINTENANCE AND REPAIR OF AIRCRAFT AND AVIATION ENGINES"

Topic: "Increasing the wear-resistance of aircraft Boeing 737 landing gear parts"

Done by: _________**Y.H. Astakhov**

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KYIV 2022

NATIONAL AVIATION UNIVERSITY

Aerospace Faculty
Aircraft Continuing Airworthiness Department
Educational degree "Master"
Specialty 272 "Aviation transport"
Educational and professional program "Maintenance and repair of aircraft and aircraft engines"

PERMIT TO DEFENSE
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«___» _____________2022 year

THE TASK
to complete the thesis
ASTAKHOV YEHOR

1. Theme of work: **"Increasing the wear-resistance of aircraft Boeing 737 landing gear parts"** approved by the order of rector of September 29, 2022 No. 1786/st.
2. Term of work performance: from September 26, 2022 till November 30, 2022.
3. Initial data for work: statistical data on the results of operating experience of the chassis, damage, failures and malfunctions of structural units of the aircraft landing gear, the level of testability of the diagnostic object.
4. The content of the explanatory note: analysis of the aircraft parts damage due to friction; methodics of friction investigation procedures, determination of lubrication ability of greases with anti-friction additives, development of measures for labor and environmental protection.
5. List of mandatory graphic (illustrative) material: research scheme, results of analyzing the experience of operating gas turbine engines, the impact of damage on engine performance, development of neural network architecture, block diagram of the neural network learning process, diagnosis algorithm, diagnosis and recognition results.

Graphic (illustrative) material was made using Microsoft Office Excel, Power Point and presented in the form of presentations.

6. Timetable

Задания	Срок выполнения	Отметка про выполнение
Analysis of the operating experience of aircraft landing gear elements.	26.09.22 – 28.09.22	
Analysis of existing methods for monitoring and diagnosing chassis components. Statement of research objectives	29.09.22 – 10.10.22	
Selection and justification of the mathematical model of the aircraft landing gear working process and diagnostic features.	11.10.22 – 16.10.22	
Research of special additives for lubricants.	17.10. 22 – 25.10. 22	
Approbation of the composition of additives for plastic lubricants, its correction, development of a diagnostic algorithm.	26.10. 22 – 30.10. 22	
Development of methodological foundations for diagnosing the flow path of the aircraft landing gear in the main units and assemblies.	01.11. 22 – 03.11. 22	
Implementation of separate sections of work: occupational Safety and Health, environmental protection.	04.11. 22 – 07.11. 22	
Execution of an explanatory note and illustrative material.	08.11. 22 – 12.11. 22	
Preliminary defense of the thesis	13.11. 22 – 23.11. 22	

6. Section-specific consultants

- Part	- Consultant	-Data, signature	
		-The task given	The task accepted
Labour Protection	candidate of engineering sciences, assoc. professor Kazhan K.I.		
Environment Protection	candidate of engineering sciences, assoc. professor Pavlyukh L.I.		

7. Date of issue: «___»_____________2022 year.

Principal of qualification paper ____________________ __________________

The task was accepted for execution ____________________ __________________

REPORT

Explanatory note to the thesis: "Increasing the wear-resistance of aircraft Boeing 737 landing gear parts": 119 p., 50 fig., 69 sources.

The object of research is the recognition of aircraft landing gear malfunction patterns with damaged gas generator units.

Subject of study – diagnostics of the trunnion pin of an aircraft turbojet by-pass engine with a localization depth to the structural unit.

The aim of the thesis is to develop improved structure of aircraft grease for landing gear trunnion pin in case of damage to the structural units according to the parameters of the working process recorded in a steady state of operation based on experiment results.

Research methods.

To solve the set tasks, elements of the theory of aircraft design, methods were used: mathematical, natural, computer modeling and network classification.

The practical significance of the results of the thesis is to increase the efficiency of the technical operation of aircraft by increasing the likelihood of an accurate technical diagnosis when identifying the technical condition of an aircraft landing gear to a structural unit.

The recommendations developed by the author can be proposed for improving the methods and means of diagnosing aircraft landing gear.

AIRCRAFT GREASE, LANDIG GEAR, TRUNNION PIN, ADDITIVE, LUBRICATION.

Content

LIST OF CONVENTIONAL ABBREVIATIONS, SYMBOLS AND INDICES

AMG – aircraft hydraulic oil;

AN – Antonov aircraft;

UTC - universe time coordinated;

BMS – building management system;

MLG – main landing gear;

RH – right hand;

LH – left hand;

FDR – flight data recorder;

VHF – very high frequency;

APU – auxiliary power unit;

ATC – air traffic control;

NLGI - national lubricating grease institute;

PAO - polyalphaolefin;

ATS - aminopropyltrimethoxysilane;

OTS - octadecyltrimethoxysilane;

PTS - perfluorodecyltriethoxysilane;

Introduction

One of the most important conditions for ensuring a given level of flight safety and increasing the efficiency of using aircraft is the development and implementation into practice of effective lubricating materials and equipment for assessing their technical condition. The development of such lubricating materials is of particular relevance for such a complex dynamic object as a main landing gear during its operation according to its technical condition.

Relevance of the topic

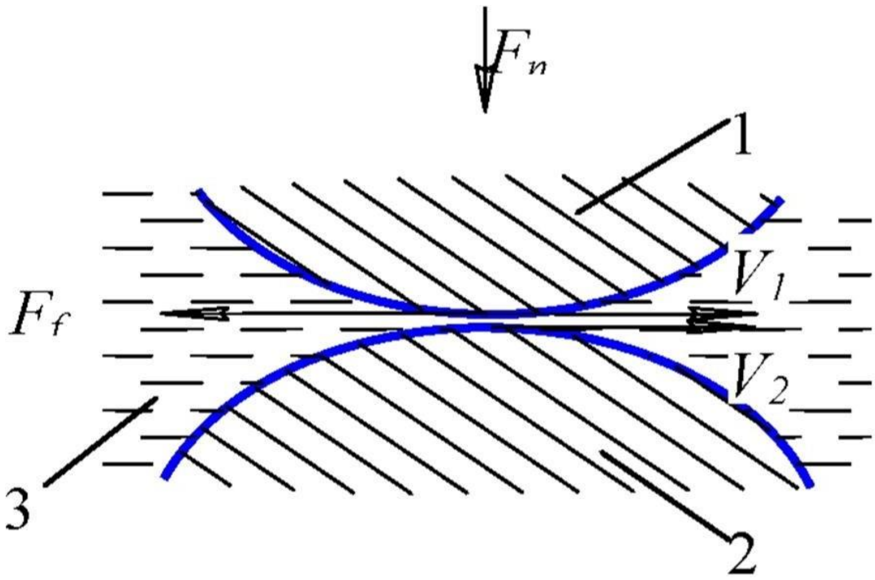
One of the most difficult tasks in the technical operation of aviation equipment is the diagnosis of the highly loaded structure elements and assemblys. According to ICAO, the occurrence of about 28-32% of incidents on the aircraft occurs precisely on landing gear. The functioning of the landing gear is based on complex physicochemical processes that take place in the trunnion pin assembly of the main landing gear and can cause the appearance of damaged structural units, and therefore, the diagnostics of the structural elements of the landing gear of a modern turbojet aircraft is carried out on the basis of the methods of parametric identification of the trouble shoot of the landing gear system.

The main purpose of diagnostics is to make a decision about the lubricating materials of the controlled object, i.e. recognition of the state (classification) of an object according to the diagnostic signs determined during the monitoring process is the final result of the diagnostic process. The reliability of the diagnosis as a whole largely depends on the quality and efficiency of the recognition. Therefore, the development of a state classifier is an important and urgent task in solving the general problem of monitoring and timely detection of damage to complex dynamic objects in the process of their functioning.

Part 1. Analysis of the aircraft parts damage due to friction

1.1 Friction as the main factor of aircraft damage

At present, it is customary to consider the triad of friction (figure 1.1): contacting bodies 1, 2 and the intermediate medium - body 3. When solid deformable bodies interact, external and internal friction are distinguished. In tribomechanics, external friction is mainly considered.



1, 2 – contacting bodies; 3 – intermedium body

Figure 1.1 - Surfaces interaction during friction

External friction is called the resistance to relative displacement that occurs between two bodies in the contact zones of their surfaces, accompanied by energy dissipation. There are two types of external friction: - static friction - friction of two bodies before the transition to their mutual movement; - friction of motion - friction of two bodies in relative motion.

The static friction is determined by the elastic preliminary displacement of the material in the contact zone. In turn, two types of motion friction are distinguished: - rolling friction - motion friction, in which the velocities of the surfaces in the contact zone are the same in magnitude and direction; - sliding friction - movement friction, in which the velocities of the surfaces in the contact zone are different in magnitude or direction. The friction force is a quantitative characteristic of friction. There are also two types of friction force: - the force of friction at rest - the greatest force of friction at rest before the transition to the relative movement of surfaces; - the force of sliding friction (movement) - the force of resistance to the relative movement of surfaces, directed tangentially to the surface in the contact zone.

Boundary friction is a type of friction in which the forces of resistance to the relative displacement of surfaces are determined by the properties of boundary films on the surfaces. Films on friction surfaces can be of various origins:

- pre-applied; - formed as a result of various processes during friction. Pre-applied films are called coatings. Electroplated coatings are used - copper plating, silver plating, cadmium plating, etc., electrochemical coatings - oxidation, thermal gas coatings - metallization and spraying, etc. A decrease in the coefficient of friction occurs due to the low resistance of the coating material.

Most of the friction units of aircraft structures, the parts of which operate under various conditions of contact interaction, have a sufficiently high wear resistance and ensure reliable operation of aircraft tribosystems for a given resource. However, as evidenced by the results of defect detection of rubbing parts, the cases of premature failure of tribo assemblies due to increased wear are not single.

The result of intensive wear in these cases is a decrease in the performance of the friction pair, and, consequently, a decrease in its durability, which in some cases leads to failures in operation. Let us consider some examples of increased wear of parts made of light alloys of various AT units, its causes and characteristic features of tribological damage. Parts operating in a gas or gas abrasive stream are subject to gas abrasive wear. These include propeller blades of aircraft engines, fairings, parts of the inlet devices of the gas-air path of engines.

Especially vividly, gas-abrasive wear is manifested on the details of the gas-air duct of helicopter gas turbine engines and rotor blades of helicopters operating on unpaved landing sites and in areas with high dust content. When the helicopter is operating in ground conditions, or when hovering at a low altitude, dust and sand are easily lifted into the air from the air flow thrown by the rotating propeller and are kept in suspension, forming a dust cloud. As a result, air containing a large amount of abrasive particles enters the engine intake system, which cause increased wear of the rotor blades and guide vanes of the gas-air duct.

Also, this dust cloud causes intense wear of the rotor blades. Our analysis of the causes and nature of damage to the blades of the propeller, made of high-strength aluminum alloy B95, of the AI-24 aircraft engine showed that a process of gas-abrasive wear develops on its working surface, the intensity of which is enhanced by the effect of a corrosive environment. Rotating at a speed of about 1265 rpm, the propeller blade is exposed to a stream of solid particles (dust, sand, small stones, ice particles, etc.).

When the aircraft engine is running on the ground, the propeller creates a vacuum in front of it, which stimulates an increase in high-speed flow containing solid particles, which, hitting the blade, damage the paintwork and cause brittle fracture. Multiple impacts of solid particles contribute to polydeformational destruction of the surface layer of the aluminum alloy. Chips, tears are visible on the surface (figuer 1.2). The degree of damage to the propeller blades depends on the operating conditions (presence of solid particles, humidity, temperature, etc.).

Figure 1.2 - A propeller blade of an AI-24 aircraft engine with a damaged surface

Gas-abrasive wear is also subject to compressor rotor blades and guide blades made of aluminum alloy. The hardness of particles, small stones, sand and dust is much higher than the hardness of the aluminum alloy from which the blades are made. Carrying out a scratching effect on a softer aluminum alloy and cutting off alloy particles with sharp corners, the blade becomes thinner along the trailing edge.

During further operation of such blades, as a result of repeated impacts of solid particles, small pieces of aluminum alloy are separated, which leads to a decrease in the chord size of the blade. The wear rate of the blades within one disk does not change, at the same time, the compressor blades of the last stages wear out more intensively than the first. In figure 1.3 shows the butt of the propeller blade, which is damaged as a result of fretting corrosion. It is made of B95 aluminum alloy.

Figure 1.3 - The butt of the propeller blade with a damaged working surface

During the operation and operation of the aircraft engine, vibration occurs, which stimulates the development of fretting corrosion processes in the areas of contact surfaces. At the same time, corrosion processes are activated on the surface of the aluminum alloy, which leads to the formation of aluminum oxides, which have a high affinity for oxygen. Aluminum oxide in hardness significantly exceeds aluminum alloy and, as a result, in the process of relative movement of the contacting surfaces, it scratches them, stimulating wear processes.

The development of fretting corrosion processes is accompanied by the initiation of microcracks in the middle of the slip bands, and, in the case of further deformation due to repeated loading, these microcracks merge and form long cracks that can be seen with the naked eye. Similar phenomena are observed when studying the details of aircraft friction units made of alloy steels.

It should be noted that even minor damage by fretting corrosion leads to a decrease of cyclic strength and more intense fatigue failure. In figure 1.4, a shows the sector of the cylinder block, the brake system of the AN-32, AN-72, AN-74 aircraft. Block material - magnesium alloy ML-10, its working medium is AMG-10 oil with a pressure of 85 kgf/cm2. Fault detection of this part showed that the reason for the loss of the unit's operability is fretting corrosion of the inner annular surface of its landing on the mating part.

When examining the contact points with an increase, traces of fretting corrosion are visible - numerous cavities and deep cavities, which is accompanied by a general increase in the diameter at the contact point in comparison with the initial one. This wear leads to a weakening of the block fit on the mating part and, as a result, to the transfer of loads to non-force fasteners. This leads to fatigue cracks and fracture of the part (figure 1.4).

Figure 1.4 - Damaged parts of the cylinder block

In figure 1.5, a shows the disc of the hub of the propeller fairing made of magnesium alloy. This part has pronounced defects in the form of fatigue cracks in the near-sleeve part of the body (figure. 1.5).

Analysis of the working conditions of the part shows that it is subject to significant vibrations from the air flow, as well as from the engine and propeller. Magnesium alloys, as a rule, have good damping properties; therefore, the occurrence of cracks can be associated with the deviation of the working conditions of the part from the design ones.

The bushing shown is pressed into the body and works in tandem with the bolt. It is logical to assume that the bolt-bushing and bushing-body mates are subject to fretting corrosion, as a result of which the interference in the landing sites weakens and fatigue cracks appear. Under the further influence of vibrations, cracks increase and in the thinnest places, which are a kind of stress concentrators, turn into through cracks. The restoration of such defects is currently not performed and the part is removed from service.

Figure 1.5 - Disc of the propeller fairing

The development of fretting corrosion processes was observed on the working surfaces of the wing mechanization rack made of VT22 titanium alloy, the steering wheel mounting bracket made of ML-5 magnesium alloy at the points of its attachment, as well as at the points of contact between the casing and the flame pipes made of titanium alloy (figure. 1.6).

Figure 1.6 - Flame tube showing signs of wear

Many aircraft parts made from light alloys are subject to mixed wear. So, for example, a part operating in sliding friction without lubrication can also undergo fretting wear. In figure 1.7 shown a part of the body of the lock of the main leg of the landing gear of the AN-24 aircraft, made of magnesium alloy ML-5. During opening and closing of the landing gear flap, the tongue slides over the lock body. As seen from Fig. 6, the sliding surface is smooth and even, indicating normal wear. In the closed position, the tongue of the lock, under the influence of vibrations, wears out the surface on which it lies most of the time.

Constant vibration and the pressing force between the body and the lock tongue will lead to the development of fretting corrosion. As a result, a depression appears on the working surface, which can cause jamming in the operation of the lock and the impossibility of opening the chassis flap. The wear of the sliding surface causes a weakening of the sash pressing, as a result of which strong vibrations arise, which intensifies the processes of fretting corrosion and can lead to serious breakdowns.

Figure 1.7 - The working surface of the body of the lock of the landing gear of the An-24 aircraft

For surface hardening and restoration of worn parts, such technological methods as surface plastic deformation, chemical heat-treatment, electrospark alloying are currently used at aircraft repair enterprises, various spraying technologies and many others. Priority area in technological processessurface hardening and restoration of parts of friction units of modern technical devices are complex methods that involve both sequential and simultaneous use of two or more methods. Representatives of such technologies should be considered: thermal spraying with further laser treatment; surface mechanical treatment; electromagnetic surfacing with simultaneous surface plastic deformation, etc.

One of the most common surface hardening methods used in aviation technology is surface plastic deformation. The prospect of this method lies in its use in combination with other technological methods. Of the coatings, galvanic and electrolytic ones are widespread in the repair of aircraft. These include: chrome plating, zinc plating, nickel plating, cadmium plating, phosphating, brass plating, nickel-phosphorus coating, etc.

Each type of coating has its own purpose. For example, a nickel-phosphorus coating is applied in order to increase the wear resistance of the rubbing surfaces of parts operating under conditions of friction without lubrication, as well as to protect against gas corrosion of parts operated at temperatures of 700–

800 ° C. The further development of these methods is facilitated by the intensification of scientific research in a new scientific direction - composite electrolytic coatings. These coatings are obtained from suspensions, which are electrolytes, to which a certain amount of highly dispersed powders is added. A part to be hardened is used as a cathode.

During the passage of an electric current through the electrolyte, metal (first phase or matrix) and powder particles (second phase) are deposited on the parts. To apply composite electrolytic coatings on aluminum and magnesium alloys, their working surfaces are pre-coated with an electrically conductive polymer layer. The main method of chemical-thermal treatment of aircraft parts operating under friction conditions is nitriding. This method competes with vacuum-plasma coating, which has a number of advantages over composite electrolytic coatings.

When choosing a method of surface hardening of aircraft parts, it is necessary to take into account the following: science intensity of technological support for surface hardening; resource costs for technological support for applying hardening protective coatings; ensuring the growth of profits while increasing investments in this area.

These requirements are met by the technology of electrospark alloying, which has technological simplicity, provides a multiple increase in the wear resistance of machine parts under various wear conditions, and uses a wide range of coating materials. The efficiency of this method is increased by using composite oxide electrodes instead of expensive tungsten-containing hard alloys.

In comparison with traditional chemical-thermal treatment, the electrospark alloying method has energy consumption by three orders of magnitude less with the cost of equipment less than that of composite electrolytic coatings, by one order of magnitude. Plasma, detonation and gas-flame spraying are used among the thermal methods of coating deposition. The restoration of parts by the method of plasma spraying is carried out by understating the size of the repaired area by the thickness of the working layer of the coating, followed by applying a layer with an allowance for machining.

One of the promising methods of surface hardening and restoration of parts is laser treatment. Processes of laser treatment of coatings obtained by other methods are of particular scientific and practical interest. The widespread introduction of technological methods for surface hardening and restoration of parts made of light alloys will contribute to solving the most important national economic problems associated with saving energy, reducing the material consumption of products, increasing labor productivity, and improving the environment.

1.2 Analysis of the landig gear damage of Boeing 737-800 because of the regular wear

03 March 2016 - Destruction of the main landing gear VT-JGD 737-900 after landing. The aircraft 737-900, VT-JGD, 33740/1350 operated by Jet Airways, immediately after landing in Mumbai on March 3, 2016 at 1622 UTC, crashed the right main landing gear.

Figure 1.8 - Collapsed Landing gear

The landing was carried out by the co-pilot who performed a controlled flight on the line. The aircraft landed safely on runway 27 and during the takeoff, 16 seconds after landing, at 58 knots, the rear axle pivot of the right main landing gear broke and the right main landing gear collapsed. The plane began to deviate to the right of the center line. The pilot tried to leave the runway via taxiway N9 using the tiller, but the plane stopped at the taxiway.

The right landing gear was damaged, the aircraft rested on the right engine, nose and left landing gear. A hydraulic fluid spill occurred due to damage to the right main landing gear. The maximum G-force recorded during landing was 1.44 G. The detected sparks between taxiways # 7 and # 8 as the engine hood rubbed against the runway and notified the fire department and apron. Fire brigade reached the aircraft and sprayed a foamy fire extinguisher on the # 2 engine and the right landing gear area on the spilled hydraulic fluid to prevent a fire. Passengers left the L1 entrance using the passenger stairs.

The report shows that the right trunnion failed due to thermal damage to the base metal resulting from improper grinding of the chrome plate, which probably occurred during the last overhaul this was done at M / s ST Aerospace Solutions, Oslo , Norway, 11.07.2013. A crack has occurred in the area of unhardened martinsite on the outer diameter of the trunnion pin. The crack resulted from intergranular separation as a result of hydrogen embrittlement during the processing of the cadmium plate. The crack propagated in the mode of transgranular fatigue with plastic separation at final failure. Multiple cracks were found near the source of destruction.

SUMMARY:

A Boeing 737-900, VT-JGD of Jet Airways, performing scheduled domestic passenger flight 9W-354 from Delhi to Mumbai with 120 passengers and 8 crew members 03-03-2016 crashed at Chhatrapati Shivaji International Airport in Mumbai. The aircraft landed safely on Runway 27 at 16:22 UTC and was about to leave the runway via taxiway N9 when the right main landing gear collapsed. The aircraft was unable to leave the runway and failed on taxiway N9 with a tail protrusion on runway 27. Runway 09/27 was closed to flight and the aircraft was removed. Runway 14/32 was used for all air traffic. The repair was completed by 05:30 UTC on 04/03/2016, the aircraft was towed to the hangar.

According to FDR, the “G” load during landing was 1.44 G. 16 seconds after landing on the take-off run at 58 knots, a roll to the right of 4.57 ° occurred, and the plane turned right with a noise like a tire. burst into the cockpit. To maintain directional stability, the first mate moved the tiller. The aircraft left taxiway N9, and after the vacation the aircraft stopped independently on the taxiway, the tail section of the aircraft did not completely move away from runway 27. The flaps were moved to 40 if the situation required evacuation.

According to ATC, sparks were observed from the right landing gear while the aircraft was moving along runway No. 27 between taxiways No. 7 and No. 8. ATC informed the crew, fire station and control room. At 4:27, a fire extinguishing system foam fire extinguisher sprayed the fire extinguisher on the right side of the engine, and also spilled hydraulic fluid to prevent a fire. The Commission of Inquiry determined the cause of the accident: "The stud axle chain of the right C-pillar is out of order due to thermal damage to the base metal as a result of improper grinding of the chrome plate, which probably occurred during the last major overhaul."

Flight history. Jet Airways Boeing 737-900, VT-JGD, performing a regular domestic passenger flight 9W-354 from Delhi to Mumbai with 120 passengers and 8 crew members, had an accident at Chhatrapati Shivaji Airport. Airport, Mumbai. The aircraft landed safely on Runway 27 at 4:22 pm UTC and was about to leave the runway via taxiway N9 when the right main landing gear collapsed. Nobody was hurt on board. The plane was seriously damaged.

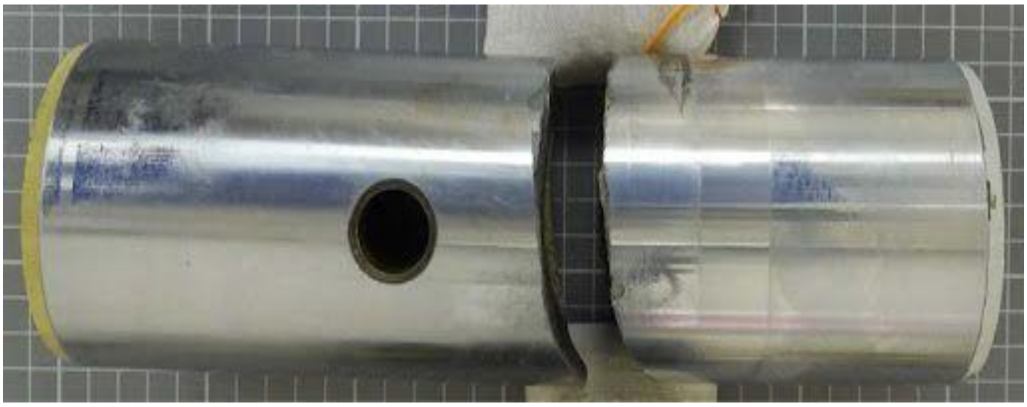


Figure 1.9 - Broken forward trunnion pin

Prior to the air flight 03.03.2017, the aircraft successfully completed 4 flights (Delhi-Mumbai, Mumbai-Delhi, Delhi-Mumbai and Mumbai-Delhi). The emergency flight (Delhi-Mumbai) became the 05th flight of the day. Delhi-Mumbai flight starts at 1415 UTC and the plane departs at 1428 UTC from IGI airport in Delhi. The flight proceeded without incident prior to landing in Mumbai.

The landing was carried out by the co-pilot, and the aircraft was flying along a controlled line. Both crews were cleared by Jet Airways to perform SLF duties. With the landing signal flare, the plane floated a little, landing was normal.

The aircraft landed with a "G" payload of 1.44. 16 seconds after landing, during the landing run, at about 58 knots, a roll to the right by 4.57 ° occurred, and the plane began to deviate to the right with a noise that felt like a burst tire to the cockpit crew. To maintain directional stability, the first mate moved the tiller. The aircraft left taxiway N9 and after the vacation the aircraft came to a stop on its own on the taxiway, the tail of the aircraft did not completely move away from runway 27. Taxiway number 9 is about 2600 meters / 8550 feet from Runway 27. The flaps were moved to 40 if the situation required evacuation. After that, the captain contacted Jet Airways' dispatch / service personnel on VHF 2, and the F / O controlled VHF 1. The APU was sequentially started and engine No. 2 was stopped, and later engine No. 1 was also stopped. The PIC advised the flight attendants not to turn the doors OFF until instructed to do so.

According to ATC, sparks were observed from the right landing gear when the plane was moving along runway 27 between taxiways No. 7 and No. 8. This was also reported to the crew, fire department and control room. In addition, sounded an emergency call and immediately announced a fire at the crash site. Fire Tenders noticed that the plane got stuck in the N-9 taxiway.

A hydraulic leak has occurred and the starboard engine almost touches the ground. There were no signs of fire or smoke on the planes involved in the accident, the reported. During the fire safety tenders, a foam cover was installed to reduce the risk of leakage. Upon arrival at the passenger stairs, passengers were safely unloaded through the L1 door, no emergency evacuation was carried out.

Aircraft damage. The plane was seriously damaged. During the landing run, the right landing gear collapsed and the aircraft was resting on the nose, the left main landing gear (MLG) and the right engine mount. The following major damage occurred to the aircraft.

Figure 1.10 – Left hand wing damaged by the shock-strut

a) The right MLG is partially separated from the glider.

b) Both doors of the right MLG and attachment are bent and cracked.

c) The rear end of the right MLG pierced the composite panel above the wing surface.

d) The suspension arm mount is displaced and the assembly is displaced.

e) The RH MLG beam is sheared and gouged along the front top and bottom edges at 03 points.

f) The right MLG beam at the rear of the trunnion raceway assembly, pin assembly, cross bolt are damaged and the trunnion is sheared.

g) All fixing rods and brackets for the right upper fixed trailing edge of the panel are bent and torn.

h) Right bottom fixed rear edge panel, retaining rods and bracket no. 115A27110 damaged.

i) The RH MLG beam fitting is scratched at the lower end.

j) Damaged transmission unit No. 5 of the right inner shield and mounting.

k) The right MLG outboard beam support fitting and the intermediate link support assembly are damaged.

l) Right trailing edge flap inner torsion tube and hawses are bent and damaged.

m) Right engine intake shrouds, fan hoods removed on bottom surface.

n) Right engine thrust reversers are badly broken on the underside and the latches are damaged.

o) A hydraulic fluid leak has occurred on taxiway N9 due to damage to the RH MLG.

The landing gear has 21,000 flight cycles / 10 years, and a trunnion trunnion limit of 75,000 flight cycles. The chassis lubrication method is via a grease gun. The chassis lubrication interval is 560 cycles or 90 days. Detailed information on the right pivot pin (as of 03.03.2016).

1. The pin was first installed on the VT-JGC on 06/05/2003.

2. The pin was repaired on 11/07/2013 and reinstalled on VT-JGD on 08/06/2013. Service details for VT-JGD chassis are listed below:

• On the day of the accident, the aircraft completed 04 sectors, namely Delhi-Mumbai (02) and Mumbai-Delhi (02). The emergency flight was flight 05 days, i.e. Delhi-Mumbai.

• The last extended transit inspection was carried out 02-03-2016 in Delhi.

• The last 30 days inspection and stopover was performed on 02-03-2016 in Delhi.

• The last A4 check was carried out on January 31, 2016 in Mumbai.

• The last C check was carried out on 07/18/2015 in Mumbai.

• All 03 Chassis maintenance were carried out on 07.02.2015.

• Chassis lubrication (LH, RH and NOSE) carried out on 17 February 2016 in Delhi.

• Lubrication of the trunnion assemblies of the left and right left and right left and right channels in the rear and rear of the housing was performed on February 10, 2016 in Ahmedabad.

• Post-accident VT-JGD axle trunnion inspection was carried out on 15-04-2015 in Delhi.

• Pin on S. No. 2, installed on VT-JGD, broke down on 03.03.2016.

• The forward left / right pin (left and right) VT-JGM could not be sent to the NTSB because the aircraft was deregistered.

The analysis results for a broken RH MLG VT-JGD stud are as follows:

Cracked rear trunnion right MLG VT-JGD

1. The initiation of the fracture was due to thermal damage to the base metal from improper grinding of the chrome plate, which probably occurred during the last major overhaul.

2. A crack has occurred in the area of unhardened martinsite on the outer diameter of the trunnion. The crack resulted from intergranular separation as a result of hydrogen embrittlement during the processing of the cadmium plate. The

crack propagates in the transgranular fatigue mode with plastic tear-off upon final failure. Multiple cracks were found near the source of destruction.

3. The material meets the requirements for heat treatment.

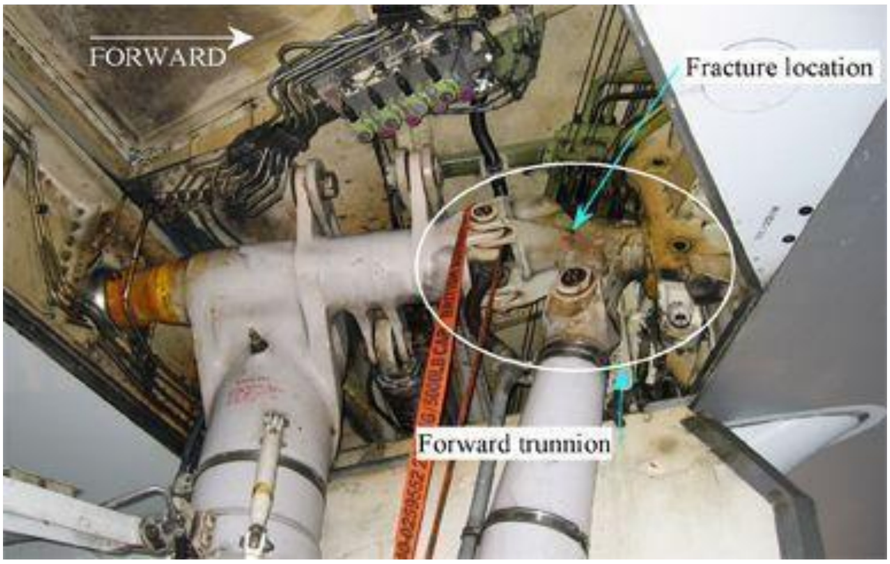


Figure 1.11 - Forward trunnion pin fracture

AIRCRAFT MAINTENANCE

Boeing B 737-900 VT-JGD (MSN 33740) was manufactured in July 2003. On the day of the accident, the aircraft operated 36,560:08 glider hours and 21,426 cycles, and also had a valid airworthiness certificate and permission to fly. The aircraft and engines were under continuous maintenance in accordance with an approved maintenance program consisting of calendar period maintenance and flight hours / cycle maintenance.

WEATHER:

The weather was not conducive to the accident.

RH MLG VT-JGD trunnion failure initiation was due to thermal damage to the base metal as a result of improper grinding of the chrome plate, which probably occurred during the last overhaul. The crack has occurred in the area of unhardened martinsite on the outer diameter of the trunnion. The crack resulted from intergranular separation as a result of hydrogen embrittlement during the processing of the cadmium plate.

The LH MLG VT-JGA chain pin also failed due to fatigue due to a black streak that was likely a pre-existing crack. Chicken wire cracking was observed over the entire chrome-plated surface of the pin. The fractured rear trunnion pin contained an intergranular fracture at the fracture surface measuring 0.018 inches outside diameter. Fatigue cracking was observed originating from a 0.22 inch intergranular crack. The initiation of fracture was due to thermal cracking, which propagated during the hydrogen embrittlement treatment. After service, fatigue cracking begins in the existing crack until final fracture due to plastic tearing.

CIRCUMSTANCES, CAUSES TO ACCIDENT:

In the aftermath of the accident, the report indicated that the right trunnion failed due to thermal damage to the base metal resulting from improper grinding of the chrome plate, which likely occurred during the last overhaul. The crack has occurred in the area of unhardened martinsite on the outer diameter of the trunnion. The crack resulted from intergranular separation as a result of hydrogen embrittlement during the processing of the cadmium plate. The crack propagated in the mode of transgranular fatigue with plastic separation at final failure. Multiple cracks were found near the source of destruction.

1.3 Analysis of the lubricant materials in aviation

Classification and basic properties of lubricants

A lubricant is a substance introduced on the surface of rubbing bodies in order to reduce friction coefficients and increase wear resistance (figure 1.12). All lubricants can be classified into solid, liquid, plastic and gas. Consider only liquid lubricants, commonly referred to as oils. Liquid lubricants by their origin are divided into vegetable or animal, petroleum and synthetic. According to their purpose, oils are divided into transmission, motor, industrial, instrument, etc.

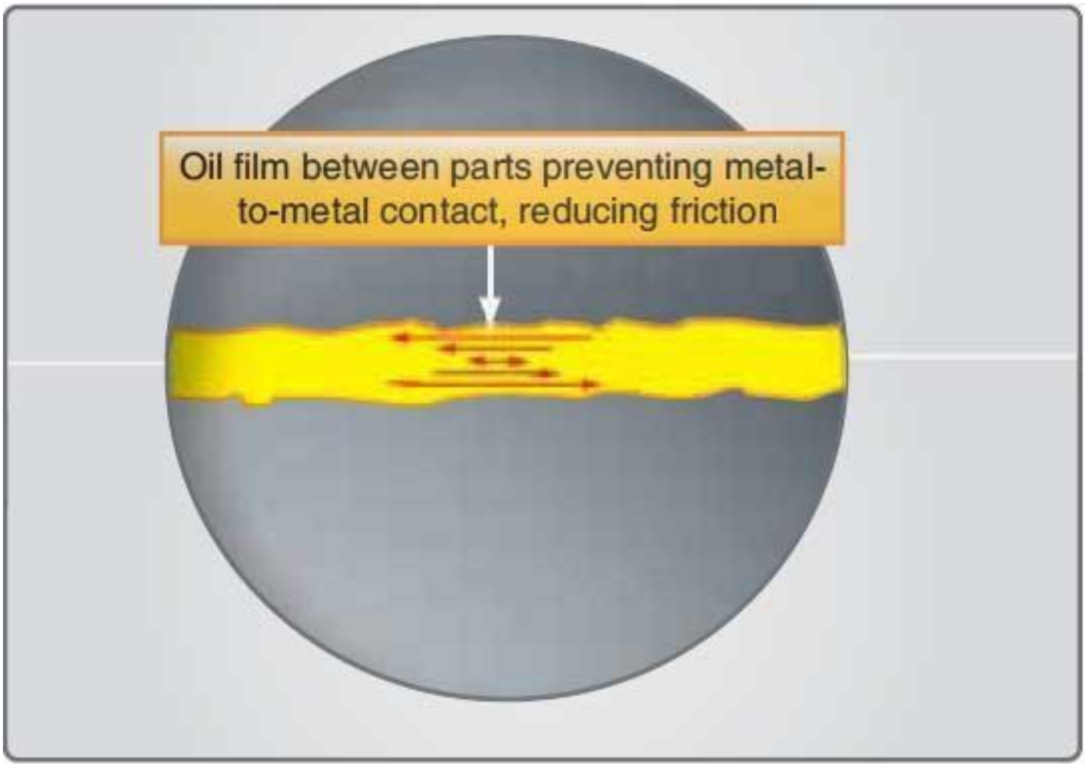


Figure 1.12 - Lubricant implementation

Depending on the purpose, special requirements are imposed on oils. So, requirements are imposed on transmission oils: viscosity, viscosity index, pour point. For heavily loaded friction units, an important characteristic is the dependence of viscosity on pressure. The following requirements are imposed on engine oils: viscosity, viscosity index, pour point, flash point, ash content, base number, etc. Important for all lubricants are properties such as resistance to oxidation, low corrosiveness, protective properties (protection of metal from oxidation), detergent properties.

To ensure the required properties of oils are widely additives and antifriction additives are used. An additive is an organic, oil-soluble substance that is added to the oil to give it the desired properties. Distinguish between extreme pressure, antiwear, antioxidant, antioxidant and anti-shock additives. Compounds containing sulfur, chlorine, phosphorus, silicones, fatty acids, etc. are used. Additives are solid, oil-insoluble substances, sometimes called solid lubricants. The most common extreme pressure additives, which are powders of some metals and compounds.

These include graphite, molybdenum sulfides, copper, etc. The main characteristics of oils used in problems of the hydrodynamic theory of friction are viscosity and stickiness. Tack is the ability of a lubricant to form tightly bonded layers with a surface. Stickiness determines the presence of sliding at the interface between the surface and the lubricating layer. Only one of the first Petrov's formulas for calculating the coefficient of friction in a plain bearing is taken into account. In further solutions of hydrodynamic problems, it is assumed that there is no sliding at the surface - lubricant layer boundary. Thus, stickiness is not taken into account in hydrodynamic problems. At the same time, it should be borne in mind that with an increase in travel speeds and with the use of various new lubricants, it may be necessary to take it into account.

The most important characteristic of a lubricating oil is its viscosity. Experiments have established that the shear resistance force of a flat surface located on a liquid layer is equal to the value of F, = u/A. f h where A is the surface area (figure 1.13). Dividing the left and right sides of the equation by the surface area (taking into account the nonlinearity of the shear rate distribution in the lubricating layer), we obtain di du where and is the current value of the lubricating fluid velocity is the dynamic viscosity of the lubricant. This formula was obtained by Newton and therefore liquids, the shear resistance of which is described by the above equation, are called Newtonian liquids.

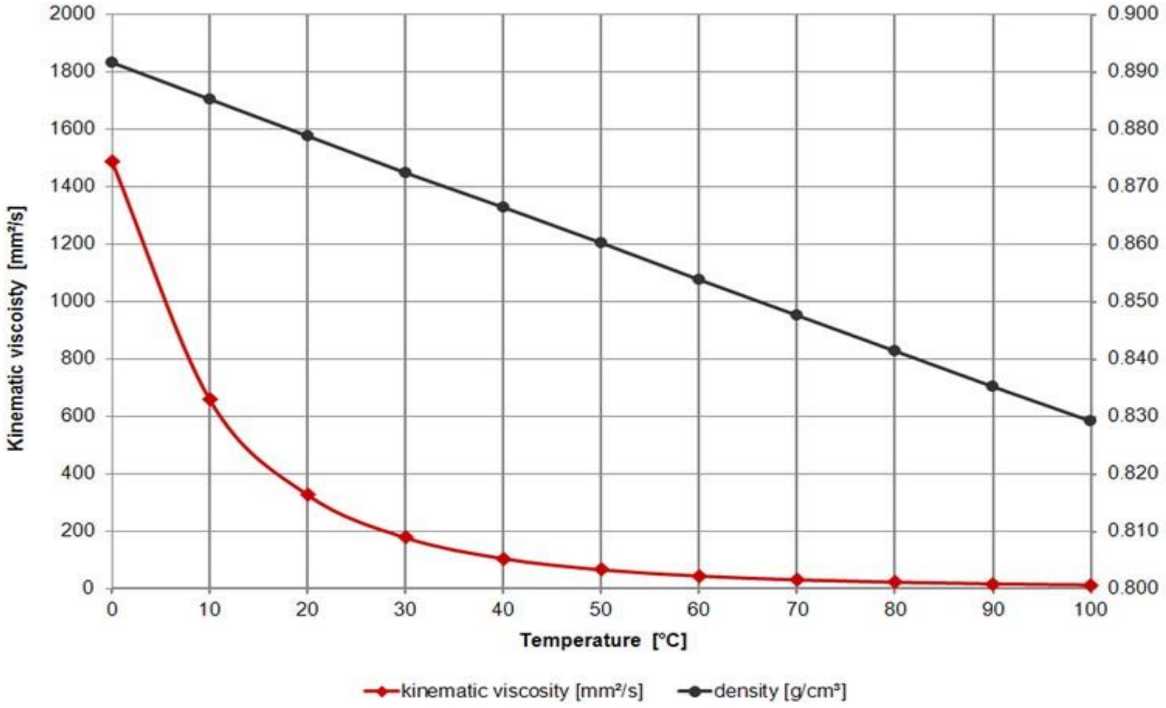


Figure 1.13 - Engine oil viscosity

Fluids in which the shear resistance does not obey the above dependence are called non-Newtonian fluids. These include some synthetic oils as well as oils with additives. In accordance with Newton's formula, the dynamic viscosity of a lubricant is the coefficient of proportionality between the shear stresses and the shear rate gradient in the lubricating layer. The unit of measurement of dynamic viscosity is Sha. Previously, the unit used was 77 (poise) = 0.177a • s or 1 cPa. In a number of technical problems, the unit is used - the kinematic viscosity of the lubricant, determined by the ratio v = -, where Y is the density of the oil. L The unit of kinematic viscosity is 1 m / s. Previously, L was used as the unit 1 Cm (flow) = 1 cm / s. thirty

To simplify the selection of oils in operation, oils are divided into viscosity classes. For example, in the domestic classification there are 21 classes for motor oils, and in the foreign, in accordance with the classification, there are 10 classes. For example: engine oil of class 6, which has a kinematic viscosity of about 12 cSt at 100 ° C. According to foreign classification, this oil corresponds approximately to oil. The viscosity of the oil is not constant and depends on temperature and pressure. Experimental dependences of viscosity on temperature are more complicated, therefore different empirical formulas are used by different authors.

Oils depending on feedstock, production conditions and cleaning methods can have different properties. The aggregate different properties of the oil determines its quality and applicability for one purpose or another. The values of the main physical and chemical parameters oils are regulated by standards (quality certificates), which give understanding of the possibility of oil behavior during operation and serve for control checks of oil quality by comparing experimental data with technical conditions. In addition to the classification of engine oils by classes and categories, the viscosity classification is communicated by the oil manufacturer to the consumer and other physicochemical characteristics of engine oils.

Mineral oils.

In aircraft engines, mineral oils operate under harsh conditions created by high external temperatures in the cylinder-piston group and high specific loads in the crank mechanism. To ensure the required lubrication conditions for the engine in conditions of high temperatures and specific loads use high-viscosity specially refined oils. Such oils must have high lubricity, not aggressive to metals, alloys and other structural materials and have sufficient stability to oxidation at high temperatures and under storage conditions.

Synthetic oils.

Mineral oils have limited performance properties, due to unsatisfactory viscosity temperature characteristics and low stability at high temperatures and pressures. Therefore the last four decades, synthetic oils withpredetermined characteristics (figure 1.14). The main difference between synthetic oils and mineral oils isthat unlike mineral oils, the bases of which are products refineries, synthetic ones are practically identical molecules that are products of petrochemical synthesis. Due to this, the physicochemical properties and stability of synthetic oils are much higher than mineral oils.

Figure 1.14 - Synthetic and mineral oil comparison

Greases

Greases are lubricants that specially thickened in order to provide lubrication, conservation and sealing of those friction units and parts for which to create forced circulation of conventional liquid lubricant is impractical or impossible due to special operating conditions and design of the friction unit. Consistency greases occupy an intermediate position between liquid oils and solid lubricants. They are colloidal systems (solid or semi-solid gels), characterized by a high concentration of the dispersed phase.

High the degree of structuring of the dispersed phase gives the lubricants plasticity, elasticity and a number of other properties due to which they significantly differ from liquid lubricants (figure 1.15). Lubrication at low temperature and no load retains its original appearance and behaves like solids: does not spread under the influence of its own mass, held on vertical surfaces and is not thrown off by inertial forces from moving parts.

However, even at relatively low loads exceeding the limit the strength of the structural frame, and when heated, the lubricant begins to collapse e.g. flow like a plastic body, but at the same time it does not flow out of the friction zone through seals do not leak. When the load is removed, the flow stops, and the lubricant regains the properties of a solid. This is what the advantage of using lubricants compared to liquid lubricants materials.

Figure 1.15 - Different types of aircraft grease

The main functions of greases are the same as liquid oils and consist of the following: a decrease in the friction force between surfaces moving relative to each other; reduced wear and prevention of scuffing (galling) of rubbing surfaces; seal gaps between mating parts. The specificity of lubricants lies only in their field of application:

- suitability for lubricating heavily worn friction pairs;
- the ability to use in unsealed or open

nodes;

- the ability to firmly adhere to lubricated surfaces (figure 1.16);
- long terms of operation and storage, etc.

Compared to oils, greases have several advantages:

- low specific consumption (sometimes hundreds of times less);
- a simpler design of machines and mechanisms (which reduces the weight, increases reliability and service life);

- a longer period of "inter-lubrication" stages;

- significantly lower operating costs for maintenance technology.

Greases are more effective in high temperatures and contact loads in friction units operating periodically or with frequent stops.

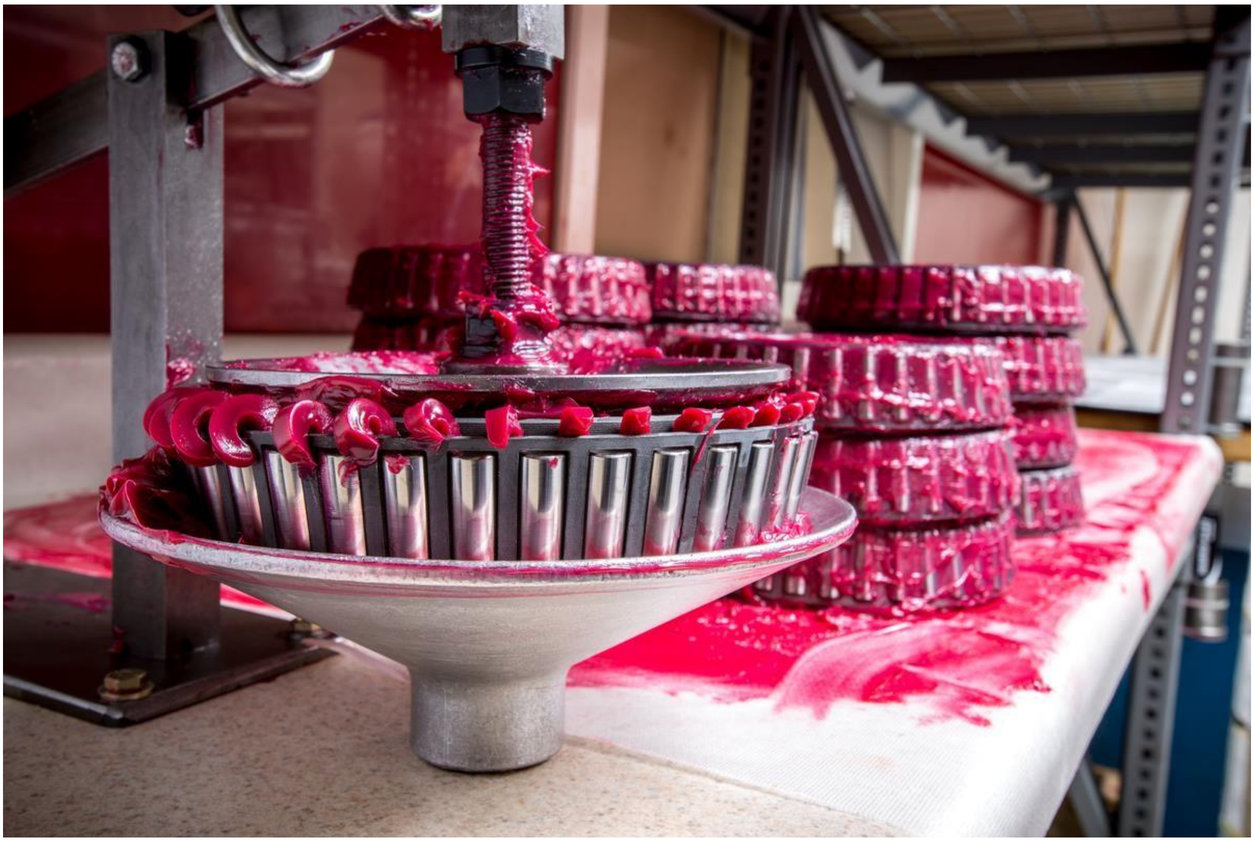


Figure 1.16 - Roller bearings lubricated with plastic grease

The disadvantages of lubricants include:

- lack of removal of heat and wear products from lubricated parts;

- a more complex system for supplying a grease lubricant to friction unit;

- low chemical stability of soap lubricants, which leads to their increased oxidation and deterioration of operational properties.

Greases, which are ointment products, are obtained by adding various thickeners to the oil base, under by the action of which the oil becomes inactive. They consist of solid structural framework thickener (dispersed phase - depending on the class of grease, the content thickener in it can be from 5% to 30% of its mass) and liquid oil, included in the cells of this solid framework (dispersion medium - 70 - 90%). Mineral and synthetic oils are used as a base. The thickeners can be salts of high-molecular fatty acids (soaps), solid hydrocarbons (ceresins, petrolatums) and some products inorganic (bentonite, silica gel) or organic (pigments, crystalline polymers derived from carbamide) origin.

The most common thickeners are metal soaps and hard hydrocarbons. The concentration of soap and inorganic thickener is usually does not exceed 15%, and the concentration of solid hydrocarbons reaches 25%. In addition to grease base and thickener, greases include special additives required to improve performance (to regulate the structure and improve functional properties). To them relate:

- fillers - solids, usually inorganic oil-insoluble origin (graphite, molybdenum disulfite, mica and etc.). They improve anti-friction and sealing properties and can make up 10 ... 15% of the grease weight;

- structure modifiers – surfactants (alcohols, acids, etc.). Contribute to the formation of a more durable and elastic structure of the lubricant and make up 1 - 2% of the mass of the lubricant;

- additives - poorly soluble surfactants, added in an amount of 1 - 5% by weight of the grease.

Mostly the same what are used in commercial oils; antioxidants, stabilizers, corrosion inhibitors. In addition, lubricants usually contain some water, playing the role of a stabilizer. A feature of greases is the reversibility of the process. Classification of greases and requirements for them. Greases are distinguished by their field of application, by the type of base, by the nature of the thickener, by the consistency (density). By purpose, lubricants are divided into:

- general purpose antifriction
- technological - to facilitate technological processing metals by pressure;
- conservation (protective) - to protect metal products from corrosion;
- sealing - for sealing rubbing surfaces, oil seals, slots,and other parts (figure 1.17);
- for special purposes;
- frictional - to increase friction to prevent slippage of surfaces;

- running-in - to improve the running-in of rubbing surfaces details and others.

Figure 1.17 - Aircraft grease implementation

The vast majority of greases belong to the first two groups, moreover, the first group is usually used in motor transport. By the type of base, lubricants are based on oil, synthetic, vegetable oils, on a mixture of the above oils. By the type of thickener, lubricants are divided into soap, hydrocarbon, organic and inorganic.

Plastic greases are classified according to the type of applied metal soap (salts of higher carboxylic acids) for calcium, sodium, lithium, aluminum, etc. Since the type and quantity thickener (up to 30% by weight) determine the performance properties of the lubricant, therefore, as a rule, it is present in its name: calcium grease, lithium grease, etc.

Performance properties and quality indicators of greases

The performance properties of greases are related to individual indicators their physical and chemical properties. The main properties of greases, according to which can make a comparative assessment of their quality and predicting performance are: tensile strength, effective viscosity, penetration, dropping point, colloidal and chemical stability, corrosive properties (water resistance, acid resistance, content of acids, alkalis, water), the content of mechanical impurities. Of all the quality indicators of lubricants, the main ones are temperature dropping and penetration rate. Because they are the days off parameters for evaluating and comparing lubricants with each other.

Plastic properties of lubricants

Ultimate strength, effective toughness and penetration characterize plastic properties of lubricants when exposed to external forces. Shear strength is the corresponding junction shear stress grease. This is the minimum load at which irreversible destruction of the lubricant framework occurs and it behaves like liquid. In the working temperature range, the tensile strength of plastic of lubricants is from 0.1 to 3 kN/m^2.

When a force is applied to the lubricant in excess of the ultimate strength shear, it flows, and its properties in this case (the amount of losses for internal friction in the lubricant) are characterized by effective viscosity, i.e., internal friction between mutually moving layers. In fact, this value determines the starting characteristics of mechanisms, the ease of feeding and refueling in friction units.

With an increase in the strain rate gradient, the viscosity of the plastic lubricants decreases to a certain minimum value. Curve of viscosity change with change in shear rate at constant temperature characterizes the viscosity properties of the lubricant: the steeper curve, the better the lubrication. With a constant strain rate gradient the viscosity of the grease only changes with temperature.

Penetration - the number of permeability (in 0.1 mm), which characterizes consistency (degree of softness) of greases and is an indicator the depth of immersion (penetration) into the test lubricant of the cone standard sizes. In a device called a penetrometer, penetration is determined by the number of divisions marked by an arrow on the indicator scale device, and corresponds to the number of tenths of a millimeter of depth immersion of the cone in the grease.

Plastic lubricants are distinguished by the physical and chemical stability. Physical stability indicators are thixotropic properties, dropping point of the lubricant and colloidal stability.

Mechanical stability is characterized by thixotropic properties, i.e. the ability of lubricants to recover almost instantly its structure (frame) after leaving the zone of direct contact rubbing parts. This unique property makes it easy to held in unsealed friction units. Dropping point is a conditional criterion for the onset of melting: minimum drop temperature of the first drop of lubricant heated in the capsule Ubbelohde thermometer.

Colloidal stability is understood as the resistance of consistent lubricants to release a part of their constituent oil (syneresis) in the process mechanical and temperature effects during application, storage and transportation (figure 1.18).

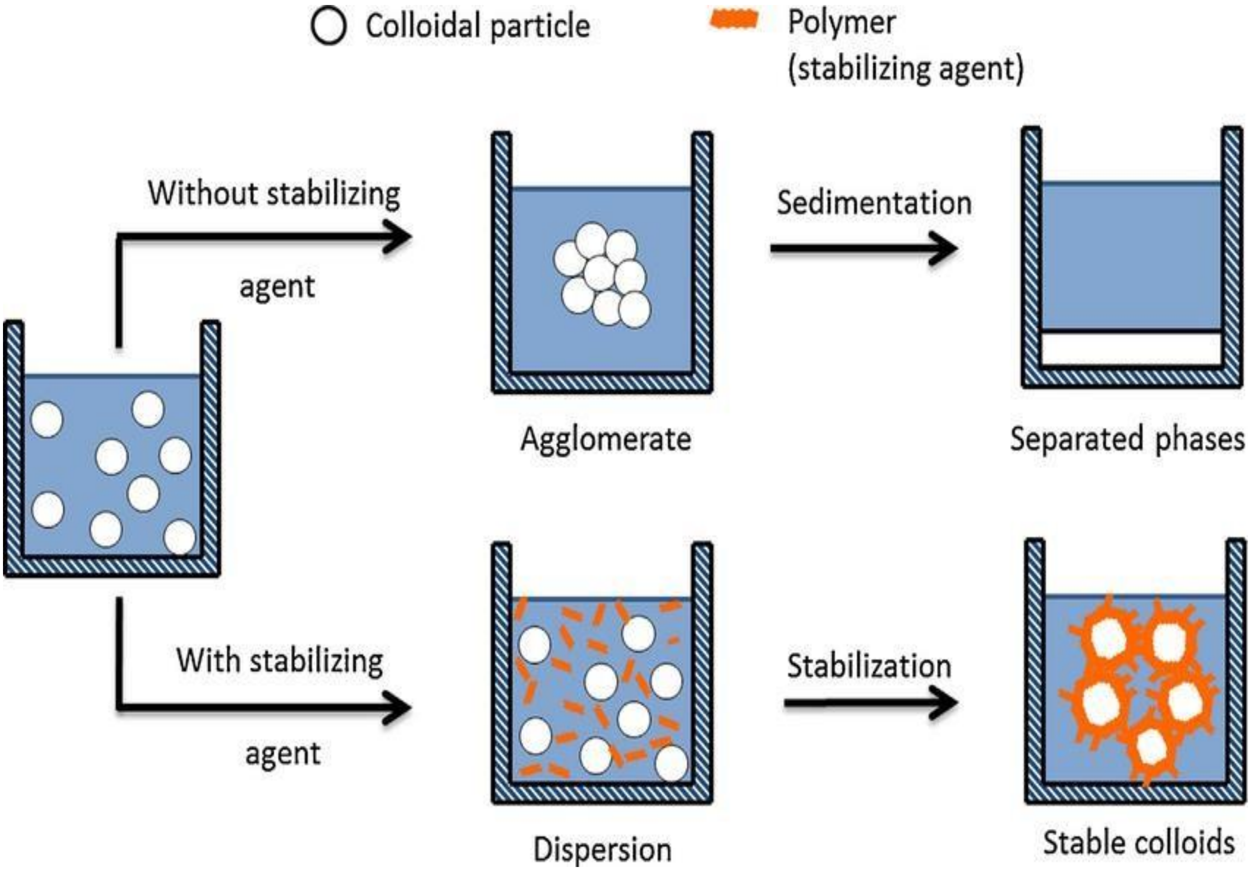


Figure 1.18 - Schematic representation of colloidal stability

Colloidal stability is assessed using a special device, where a layer of lubricant with a load is pressed for 30 minutes. to layer filter paper laid on the glass. By the amount of oil, transferred from grease to paper (as a percentage by weight), is judged as colloidal stability of the lubricant. The more oil is on the paper, the colloidal the stability of the lubricant is worse.

Chemical stability is the resistance of a lubricant to oxidation with atmospheric oxygen under conditions of use and during storage. AT free acids are formed in lubricants as a result of oxidative processes, crusts and seals on the surface. In addition, the oxidation of lubricants causes changing their mechanical properties (ultimate strength, viscosity, etc.) and increases corrosiveness.

In addition, lubricants are assessed:

- thermal stability - the ability of a lubricant to maintain its properties when exposed to elevated temperatures;

- volatility - the amount of oil (in%), evaporated from the lubricant for a certain period of time when it is heated to the maximum application temperatures;

- water resistance - a characteristic of the stability of the lubricant to dissolution in water, ability to absorb moisture, vapor permeability of the lubricating layer moisture and water washable from lubricated surfaces.

1.4 Implementation of greases for the aircraft parts protection from regular wear.

AeroShell Grease 33

Synthetic multi-purpose grease with corrosion and oxidation inhibitors for various components and assemblies. The grease was developed in cooperation with Boeing for Boeing (fig. 1.11). It can be used for regular lubrication of McDonnell Douglas, Airbus, BAe Regional Aircraft, Canadair, Lockheed, Embraer, Fokker and Gulfstream aircraft (figure 1.19). In 1995 Boeing called on 20 lubricant manufacturers formulate a product that meets its step-change specification.

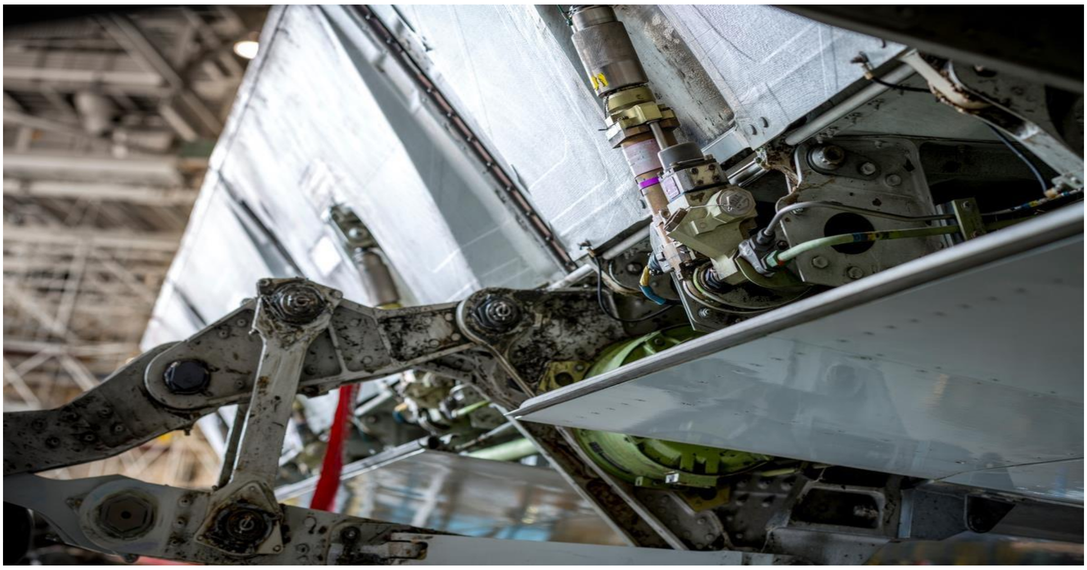


Figure 1.19 - Boeing 737-800 spoilers lubricated with grease AeroShell 33

AeroShell Grease 33 is a multipurpose synthetic airframe grease formulated with a thickened lithium complex synthetic base oil with corrosion and oxidation inhibitors and load-carrying additives (figure 1.20). Useful operating temperature range from minus 73 ° C to plus 121 ° C. Extend relubrication intervals and reduce costs by offering improved protection against corrosion and wear.

AeroShell Grease 33 was one of the products that met Boeing's requirements. It fit the bill and could be used at all but 9 of the 359 lubrication points on Boeing 737.

Figure 1.20 - AeroShell Grease 33

Preventing corrosion can mean reduced maintenance costs costs for longer component life. In modified ASTM D1743 test, lightly loaded lubricated bearings rotate, immersed in a 3% salt solution and then stored at 52 ° C and 100% humidity for 12 hours. No corrosion was observed with AeroShell Grease 33, and the bearing with Competitor MIL-PRF-81322F grease shown. corrosion between rollers and track.

Wear protection under extreme pressure can mean increased component life and lower maintenance costs. In the ASTM D2509 standard test, the cup rotates on 800 rpm on the block with a load of 18 kg for 10 minutes at continuously supplied with fresh grease. Less wear scar was measured using AeroShell Grease 33 compared to with competitor grease MIL-PRF-81322F.

Mechanical stability is important as the lubricant must stay where you put it. Mechanical stability is measuredusing industry standard penetration test before and after repeated work with grease to make sure become too soft or too hard in use. Lubrication either squeezed through the holes in the plate over 100,000 double shocks or 50 h shift at 80 and 100 ° C by turning the tube containing the heavy solid roller. The first test is repeated with 10% water. AeroShell Grease 33 shows less change in permeability in both tests compared to other tested greases.

Oil separation is the tendency of the base oil to separate from the thickener. Slow, controlled separation provides grease, but excessive separation can leave grease it is too difficult to provide adequate protection. In a standard industry test, which lasts 30 hours at 100 ° C, AeroShell Grease 33 has a separation of 3.4 weight percent which is well within the maximum 5 percent by weight in specifications and better than competitors that have been tested.

Mobil grease 28

Mobilgrease 28 is a fully synthetic grease consisting of a synthetic hydrocarbon oil and a non-soap thickener. Mobilgrease 28 has extreme pressure properties over a very wide operating temperature range (especially at low temperatures) and excellent resistance to water washout.

Application area

Mobilgrease 28 is recommended for the lubrication of roller and plain bearings at low to high speeds, screws, worm gears and other mechanisms(figure 1.21).

Figure 1.21 - Mobilgrease 28 in a speed reducer

The grease provides minimal resistance to starting at extremely low temperatures down to -55 ° C and good characteristics during long-term operation of high-speed bearings at temperatures up to +180 ° C;

Mobilgrease 28 is used in rolling and plain bearings industry where extreme temperature conditions, high speeds and the possibility of water washout are present; The grease is designed for severe conditions of use in aviation, therefore it has proven itself well for various equipment operating in the Far North; It can be operated under shock loads, and the high level of mechanical and thermal stability prevents lubricant degradation and formation of deposits.

Benefits:

- Very good wear protection over a wide temperature range;
- Durability leading to minimum operating requirements;
- Compatible with conventional mineral oil based greases with non-soap thickeners;
- Durable performance.

ERA VNII NP-286M

Application area

ERA grease (VNII NP-286M) is used to lubricate gears with an average power of electromechanics, rolling bearings of control systems, bearings with low specific loads. t is efficient at temperatures from -60 ° C to + 120 ° C.

ERA (VNIINP-286M) - high mechanical, antioxidant stability; good anti-corrosion properties, anti-wear and extreme pressure properties, does not cause swelling of rubber products (figure 1.22).

VNIINP-286M grease is used in gyroscope rotor bearings. VNIINP-286 grease is made from a mixture of hydrocracking and hydroisomerization oils and thickened with hydrogenated castor oil acids and stearic acid lithium soap. VNIINP-286 grease contains extreme pressure and antioxidant additives. It is used in gyroscope rotor bearings (fig.1.14).

Figure 1.22 - Grease VNIINP-286M

Benefits. Possesses low colloidal stability, high mechanical stability and water resistance, surpasses all other lubricants for gyroscopes in frost resistance; It is efficient at a temperature of minus 60 up to plus 120 ° C.

1.5 Lubricant materials additives

To improve the properties of greases, thickening additives are added to them, which give the greases a number of necessary qualities - a high dropping point, a wide operating temperature range, good lubricating properties, etc.(figure

1.23). Thermostable greases are produced using higher acid salts. Among them, a special place, due to their exceptional properties, is occupied by lithium salts of higher acids, in particular 12-hydroxystearic acid.

However, due to the high cost of the acid, additives and lubricants based on it are also overpriced. In this regard, the goal of this work was to obtain thickening additives and lubricants based on ricinoleic acid salts, as effective and inexpensive analogs of 12-hydroxystearic acid salts.

Solid lubricants remain suspensions of resin or other binder and solvent until they harden. They use molybdenum disulfide, graphite, carbon black, etc. as a thickener. After solidification (evaporation of the solvent), solid lubricants turn into sols with a low dry friction coefficient.

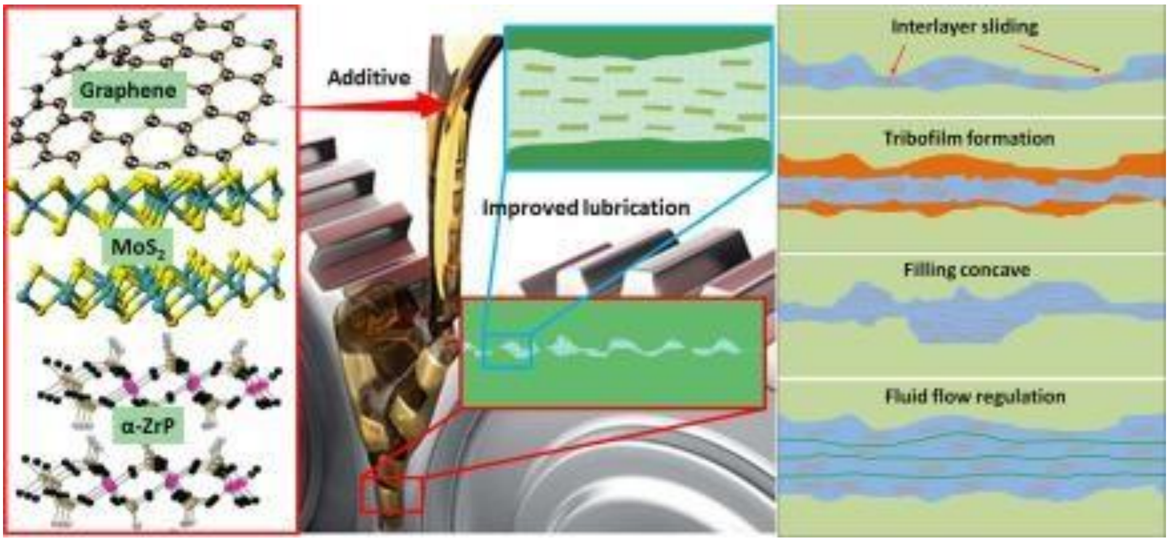


Figure 1.23 - Lubricant additives principle of work

The process of obtaining ricinoleic acid salts was carried out by saponification of castor oil with aqueous and alcoholic solutions of lithium and sodium alkali, followed by removal of solvents. As a result, white crystalline substances were obtained, practically insoluble in water. The product yield was at least 70%. The obtained compounds were identified by spectroscopy.

There are two main ways to reduce friction and wear:

1. The use of chemically active additives, which either increase the ability of the lubricant to withstand heavy loads, or, acting directly on the metal, smooth out its microroughness.

2. The use of greases with cladding additives containing fine particles of a special substance or compound (in the form of the finest lamellar inclusions) - molybdenum disulfide, graphite or ceramics. These inclusions, deposited on the metal surface, make it smoother.

In connection with the tightening of the operating modes of friction units, additives - additives and fillers - are introduced into most of modern greases. The following types of additives are used: antiwear (figure 1.24.), extreme pressure, antifriction, protective, viscous and adhesive. Many of them are multifunctional, i.e. improve several properties at the same time.

As fillers, highly dispersed, oil-insoluble substances are used that improve the performance of the lubricant, but do not form a colloidal structure in it. Fillers with a low coefficient of friction are often used: graphite, molybdenum disulfide, sulfides of some metals, polymers, complex compounds of metals, etc. Oxides of zinc, titanium and monovalent copper, aluminum, tin, bronze and brass are widely used in thread, sealing and antifriction lubricants for heavy loaded sliding friction units. Typically, these fillers are added in a volume of 1 to 30% of the amount of lubricant.

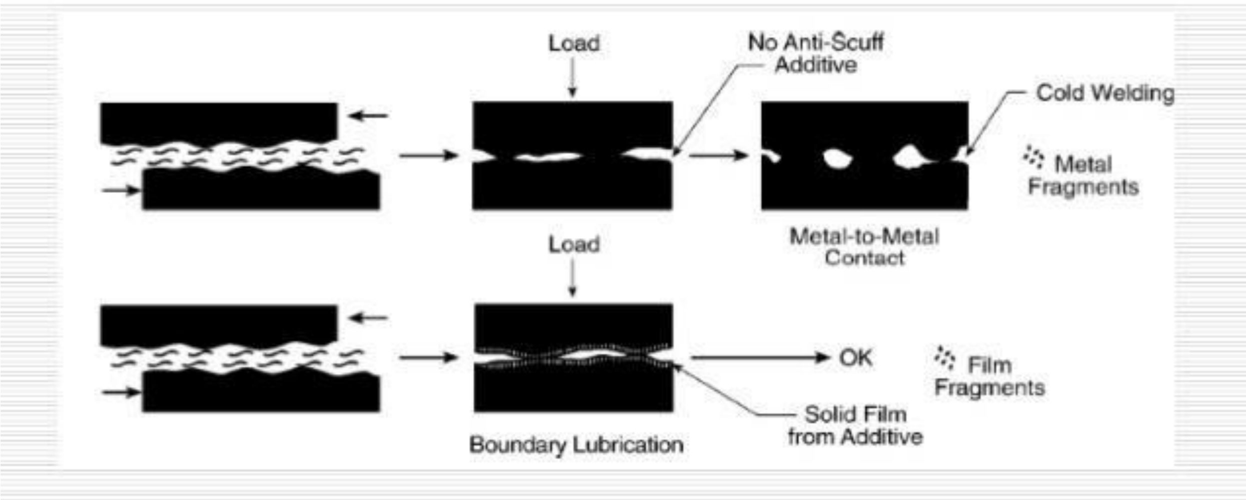


Figure 1.24 - Effect of antiwear additives

Abroad, two classifications are widely used, developed by the National Lubricating Grease Institute (NLGI). The viscosity classification groups all lubricants into 9 grades by penetration range. The amount of penetration is determined by immersing a standard metal cone in the grease for a specified time. The deeper the cone plunges, the lower the NLGI class, the softer the lubricant and, accordingly, the easier it will be squeezed out of the friction zone. Lubricants with a high NLGI number, on the other hand, will create additional drag and return poorly to the friction zone. Another, fairly widely recognized, classification groups greases into 5 grades based on automotive applications.

In our country, several classification systems are used - by consistency, by composition and by fields of application. By consistency, lubricants are divided into semi-liquid, plastic and solid. Plastic and semi-liquid are colloidal systems consisting of a dispersion medium, a dispersed phase, additives and additives.

Conclusion to the part 1

External friction is called the resistance to relative displacement that occurs between two bodies in the contact zones of their surfaces, accompanied by energy dissipation. There are two types of external friction:

- static friction, that is friction of two bodies before the transition to their mutual movement;
- friction of motion, that is friction of two bodies in relative motion.

There are two main ways to reduce friction and wear.

1. The use of chemically active additives, which either increase the ability of the lubricant to withstand heavy loads, or, acting directly on the metal, smooth out its microroughness.

2. The use of greases with cladding additives containing fine particles of a special substance or compound (in the form of the finest lamellar inclusions) molybdenum disulfide, graphite or ceramics. These inclusions, deposited on the metal surface, make it smoother.

The main functions of greases are the same as liquid oils and consist of the following: a decrease in the friction force between surfaces moving relative to each other; reduced wear and prevention of scuffing (galling) of rubbing surfaces; seal gaps between mating parts.

Part 2. Methodic of friction investigation procedures

2.1 Analysis of friction investigation machines

The equipment manufactured for studying the surface in conditions of mechanical contact with the indenter (counterbody) can be divided into 4 categories:

1. Nano hardness testers and scratch testers (adhesion testers) - devices for studying thin/thick coatings and materials in the nano and micro / macro range by instrumental (measuring) indentation methods;
2. Tribometers and visualization modules - profilometers All equipment is completed with specialized software;
3. Tribometers - devices for studying the behavior of materials and coatings under surface friction and sliding depending on time, speed, pressure, temperature and humidity, as well as on the presence and type of lubricant;
4. Profilers and atomic force microscopes (nanoscans) are devices for studying the surface profile and roughness, building a 3D surface model;

Friction and Wear Test Machine for metal cylinders and shaft-cylinder pairs influenced by climatic conditions (figure 2.1).

Application area

This test bench is used (developed) to study and test the Shaft-Cylinder pair in the range of discharged wear, taking into account climatic conditions. Total wear is limited to 2.5 mm, of which 1.5 mm can be attributed to the cylinder. Consists of:

- Thermal insulation of the test space
- Holder, base plate mounted servo; test area with spring loaded base
- Loading block with weights; adjustable; optionally with electrical load regulation during test

Description

Friction rate, normal force, temperature and humidity can continuously vary within the ranges indicated below. The actual test setup is located in a climate controlled test chamber and the test can be observed through an inspection window. The test bench is delivered fully assembled. The base machine can be equipped with optional accessories to meet different requirements. Such accessories include, for example, external climate control units and safety devices**.**

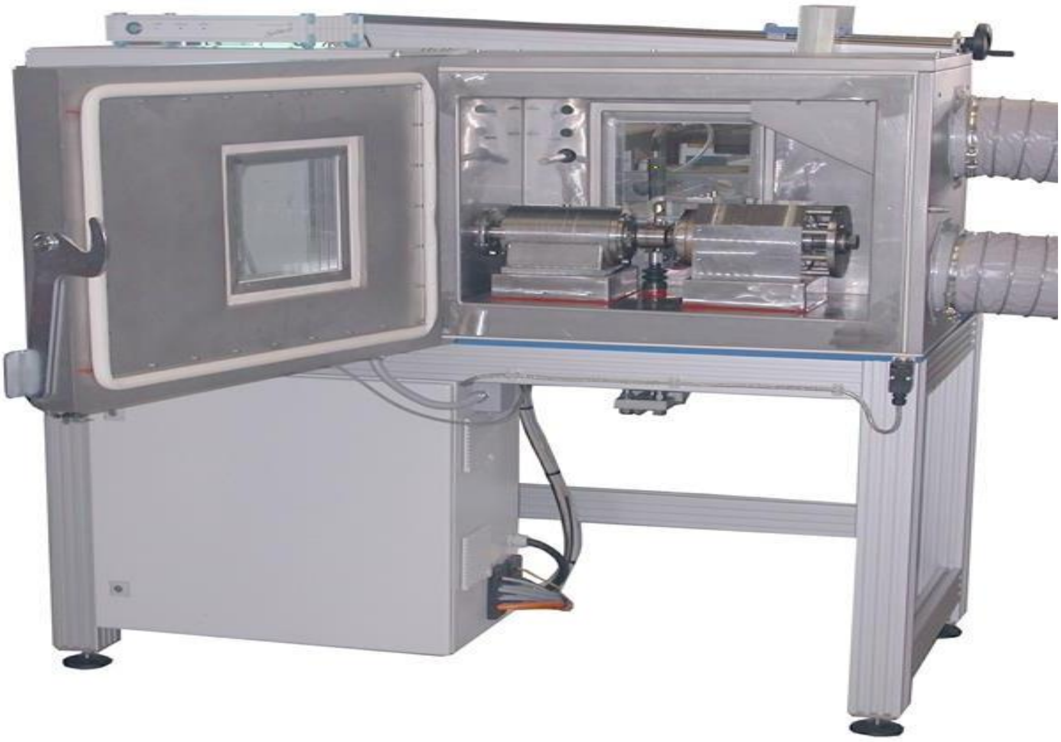


Figure 2.1 - Friction and wear test machine for metal cylinders and shaft-cylinder pairs.

Testing process:

- Accelerated test
- Long term test
- Stop of the test depends on time or when the limit value of the measured value is exceeded
- Control of climate parameters in the test area before the start of the test
- Data recording range configurable

Dimensions WxDxH: 1365 mm x 720 mm x 1500 mm

(without external climatic chamber)

Weight: 400 kg.

Amsler type friction machine for continuous wear measurement.

Friction machines of the Amsler type are widespread in industrialized countries (models MI, MI-1M, SMTs-2, 2070SMT-1, etc.). The modernized friction machine makes it possible to continuously measure not only the friction force, but also the wear of rubbing samples (figure 2.2). Continuous wear measurement allows you to accurately determine with high accuracy the wear resistance of both rubbing bodies and different layers within the same sample.

The friction machine is equipped with a vibrometer to measure the vibration amplitudes of its own body. Identical values of the vibration amplitudes of the bodies of friction machines of the same design are a necessary condition for the reproducibility of experimental studies.

Figure 2.2 - Amsler type friction machine for continuous wear measurement

The main friction pattern of the machine is a “shoe-roller”, an additional one that does not allow wear of the test pair is a “shaft-sleeve”. When using the friction scheme - “shaft-sleeve”, according to the requirement of the constancy of the pressure diagram in the friction zone, wear of the elements of the friction pair, especially the bushing, is not allowed.

This friction scheme makes it possible to study friction in liquid media, as well as in films formed on rubbing surfaces as a result of the interaction of the liquid and the material under study. Technical characteristics: electric motor power - 1.2 kW; shaft rotation frequency - 5 - 200 (1000) min-1; load - 10.0 ... 3000 N; temperature - 20 ... 2500 C; discreteness of wear measurement - not less than 0.1 microns; discreteness of determining the coefficient of friction - not less than 1.0 • 10-3; relative measurement error - no more than 5.0%; max outer diameter of samples Dnap - no more than 8.0 • 10-2 m; min internal diameter of samples is not less than 1.0 • 10-2 m.

Plint and Setta-Shell four-ball machines.

Designed for testing liquid and plastic lubricants in laboratory conditions with rolling and sliding friction. Time to pitting, frictional force, scuffing index, critical load, weld load, wear scar diameter and other indicators are measured. It is possible to heat the lubricant in the test bowl and control its temperature using a built-in thermocouple.

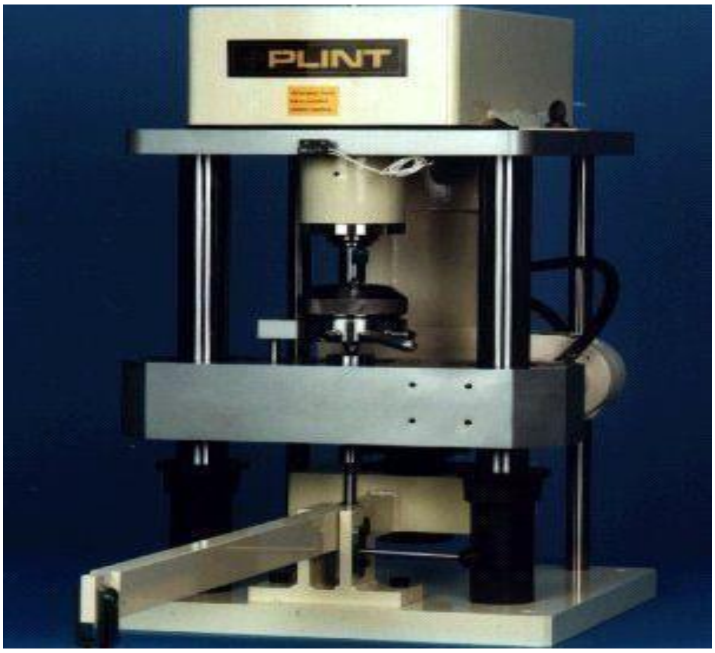


Figure 2.3 - Plint machine

Friction machines type SMTs.

Friction machine SMTs-2 (figure 2.4) is intended for testing materials for friction and wear during rolling, rolling with slippage and sliding (figure 2.5). Tests can be carried out according to three different patterns of contact of samples that simulate the work of parts in friction units.

Figure 2.4 - Friction machine SMTs-2

The samples are loaded with a spring mechanism, and the displacement carriage is balanced by a counterweight, which allows testing at low loads on a friction pair. The maximum load on a friction pair is 2000N.

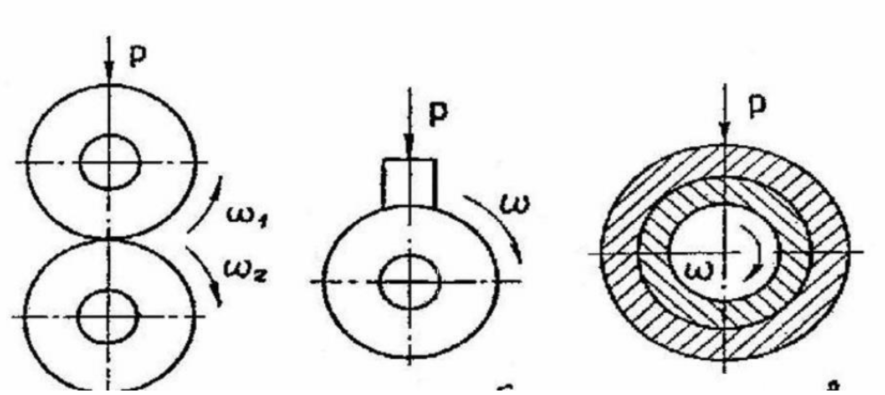


Figure 2.5. Principle of work

Setting for circular friction wear. The Tribocenter presents installations that allow you to carry outwear testing of materials cylindrical sample on a metal or abrasive disc counter. The figure shows a schematic diagram of the original laboratory installation, which implements the plane-to-plane friction scheme. Experimental installation of friction in a circle on a monolithic abrasive. The VKA experimental setup is designed to test materials for abrasive wear during friction on the surface of the grinding wheel (figure 2.6) Moving can be carried out in a circle (along the old track) or in a spiral (along the new track).

Figure 2.6 - Experimental installation of friction in a circle on a monolithic abrasive.

Universal Friction Tester MMW-1

The universal friction machine with vertical adjustment of the loading unit is designed for testing on rolling friction, sliding and combined types of rolling and sliding motion under contact pressure in various test media (oil, water, slurries, abrasive liquids, etc.) to simulate the process friction at a point, line and plane with automatic measurement of the coefficient of friction and temperature.

Sample contact patterns: finger-disc, three fingers-disc, single-ball, three-ball, four-ball, ring-disc. Experimental setup for wear during sliding friction on metal or monolithic abrasive. The unit is designed for comparative assessment of the resistance of materials and surface coatings to mechanical wear during friction (figure 2.7) sliding on a counter metal disc, a monolithic abrasive wheel or abrasive cloth. To avoid overheating of the sample during friction simulating the operating conditions of the drilling tool in the bottomhole zone, the surface of the monolithic abrasive in the friction section is fed into as a coolant.

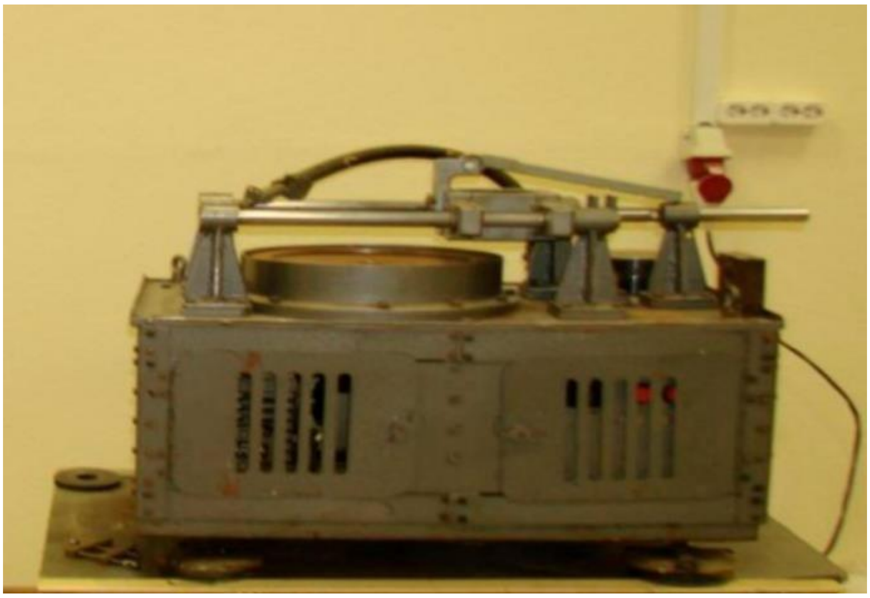


Figure 2.7 - Experimental setup for wear during sliding friction on metal or monolithic abrasive

2.2 Machine for experiment procedure

The wear resistance of nanoparticle suspensions in polyalphaolefin (PAO 6) was studied using a block-on-ring tribotester. ZrO_2 nanoparticles were separately dispersed at 0.5, 1.0, and 2.0 percents of weight polyalphaolefin using an ultrasonic bath for 2 min. As a result, friction and wear were reduced for all nanoparticle suspensions compared to the corresponding values recorded for the base oil. The best result was obtained with 0.5 percents of weight ZrO_2. No agglomerations or uniform deposition of ZrO_2 nanoparticles were found on the worn surfaces.

The resistance to extreme pressure of CuO, ZnO and ZrO_2 nanoparticles suspended in polyalphaolefin in amounts of 0.5, 1.0, and 2.0 percents of weight. A dispersion of nanoparticles was obtained in an ultrasonic bath for 2 min. Extreme pressure resistance tested with an extreme pressure 4-ball (steel) lubricant tester. With all the different nanoparticle contents in polyalphaolefin, extreme pressure properties were better than that of simple polyalphaolefin. Extreme pressure resistance was better for CuO nanoparticles and worse for ZrO_2. The resistance of ZrO_2 nanoparticles to extreme pressure was the same regardless of their content in polyalphaolefin.

The surface of ZrO_2 nanoparticles was modified using a silane coupling agent KH-560 and dispersed them in machine oil. They investigated the tribological properties of such a nanolubricant using a four-ball tribotester and a thrust ring. The addition of ZrO_2 nanoparticles to engine oil contributed to the absence of wear and a decrease in the coefficient of friction by up to 27 percents compared to plain oil. The best result was obtained for 0.5 percents of weight ZrO_2 nanoparticles.

The specially developed procedure for chemical coating of the surface of ZrO_2 (ZrO2NP) nanoparticles with long hydrocarbon chains (saturated with C-8, C-10, and C-16) was used in order to obtain stable dispersions of ZrO_2NP in lubricating oils without reducing their attributes as additives to lubricants. During tribological tests with these lubricants, they found that the dispersion of long chain ZrO_2NP in base oils reduced the friction coefficient and wear rate of the base oils compared to those of crude lubricating oils.

After studying the tribological behavior of TiO_2 nanoparticles suspended in the lubricating oil of a servo system by sonication without the addition of a surfactant, it was found that as the volumetric concentration of the phenanoparticles increased, the caloric content and flash point of the phenanolube decreased while its viscosity remained unchanged. The wear rate and friction coefficient values increased due to the agglomeration of the TiO_2 nanoparticles caused by the absence of any surfactant during the preparation of the nanolube.

Using a ball-on-disc tribotester, investigation of the tribological properties of castor oil with various concentrations of MoS_2 nanoparticles was carried out. The addition of MoS_2 nanoparticles to the oil resulted in low values of the coefficient of friction and the rate of adhesive wear. However, MoS_2 nanoparticles in excessive concentration can agglomerate into large particles, reducing the above-mentioned beneficial effects. Gold nanoparticles dispersed in motor oil, synthesized using pulsed laser ablation. After nine months, there was almost no agglomeration. This was due to the attachment of engine oil additives or pyrolyzed/oxidized molecules to the nanoparticles, which limited the attractive interactions between the nanoparticles.

Using a disk-on-disk tribotester, the tribological properties of mineral oil with dispersed nanoparticles of graphite and soot, graphite nanofibers and carbon nanotubes were closely investigated. Spherical nano-sized particles suspended in mineral oil prevent direct contact between mating surfaces and significantly reduce the coefficient of friction. In contrast, fibrous nanoparticles with a high aspect ratio degraded lubrication between mating surfaces due to a higher degree of agglomeration.

After studying the effect of the concentration of IF-WS_2 nanoparticles (IF-WS2NPs, where IF stands for inorganic fullerene) in a polyalphaolefin base oil at room temperature under the boundary lubrication regime. They found that increasing the concentration of nanoparticles resulted in a low friction coefficient compared to polyalphaolefin plain oil even at a very low concentration of IF-WS_2NP of 0.1 percents of weight. Above 1 percents of weight NPs, the friction coefficient value decreases. The same behavior was observed for IF-MoS_2 nanoparticles dispersed in the base oil.

The effect of temperature on the tribological characteristics of polyalphaolefin mixed with 1 percents of weight IF-MoS_2 nanoparticles at 20 ° C and 70 ° C was investigated. There was found a high and unstable friction coefficient value at 70 ° C, while it was lower and more stable at 20 ° C. This is due to the increased tendency of particles to agglomerate at higher temperature.

The tribological behavior of hollow MoS_2 nanoparticles dispersed in liquid paraffin at 1.5 percents of weight nanoparticles showed that wear rates were the lowest. At higher concentrations, the probability of interparticle collisions was higher, which contributed to an increase in NP agglomeration. The results of other tribological tests showed that re-doped IF-MoS_2 nanoparticles helped to reduce agglomeration and gave stable suspensions in polyalphaolefin base oil. The addition of unalloyed IF and 2H NPs resulted in lower friction coefficient values compared to plain polyalphaolefin oil. The re-doped IF-MoS_2 NPs showed half the value. This was due to the improved dispersion of the re-doped nanoparticles and the increased conductivity of the tribofilm formed by these nanoparticles, which prevented tribocharging at the surface.

The studying of tribological behavior of MoS_2 nanoparticles added to a base oil with various surfactants such as aminopropyltrimethoxysilane (ATS), sorbital monooleate (SPAN 80), octadecyltrimethoxysilane (OTS), perfluorodecyltriethoxysilane) and perfluorodecyltriethoxysilane (PTS) showed that the lowest friction coefficient values were obtained for mixtures containing ATS and SPAN. The particle size of MoS2 NPs for these additives was smaller as compared to others. The ATS and SPAN molecules remained firmly grafted to the particles, preventing agglomeration even under shear stress, unlike other additives. The amino group covalently binds the ATS molecules to MoS_2, while the hydrogen of the –OH groups binds to the S atoms of MoS_2.

2.3 Plant for wear-resistance testing

Much of the tribological research methods relate to the influence of external factors on the durability and effectiveness of the lubricant [1, 2]. To obtain reliable test results of triboconjugation elements, reproduction and convergence of results in repeated experiments, a clear structure of the tribological research methodology is required, which should include: experimental means for conducting research (scheme and design of the installation); samples to be studied or objects of research (material, construction, manufacturing accuracy); research conditions (nature of the load, kinematic and temperature factors); control - measuring instruments and their metrological verification; methods of processing the results of experimental research. The development of rational test cycles is one of the necessary conditions for optimization and selection of friction pairs. The study of unstable modes of operation on the tribotechnical characteristics of the friction unit deserves special attention [3, 4].

The most informative indicator of the effectiveness of the lubricating action is the thickness of the lubricating layer in contact. At the present stage of development of tribology, there are many methods of measuring the thickness of the lubricating film, the classification of which is based on the qualitative differences of physical processes in determining this parameter. The most common methods include the following: X-ray, magnetic, interference, fluorescent, strain gauge, electrical (resistance, capacitance, breakdown, voltage drop) [3, 5, 6, 7, 8].

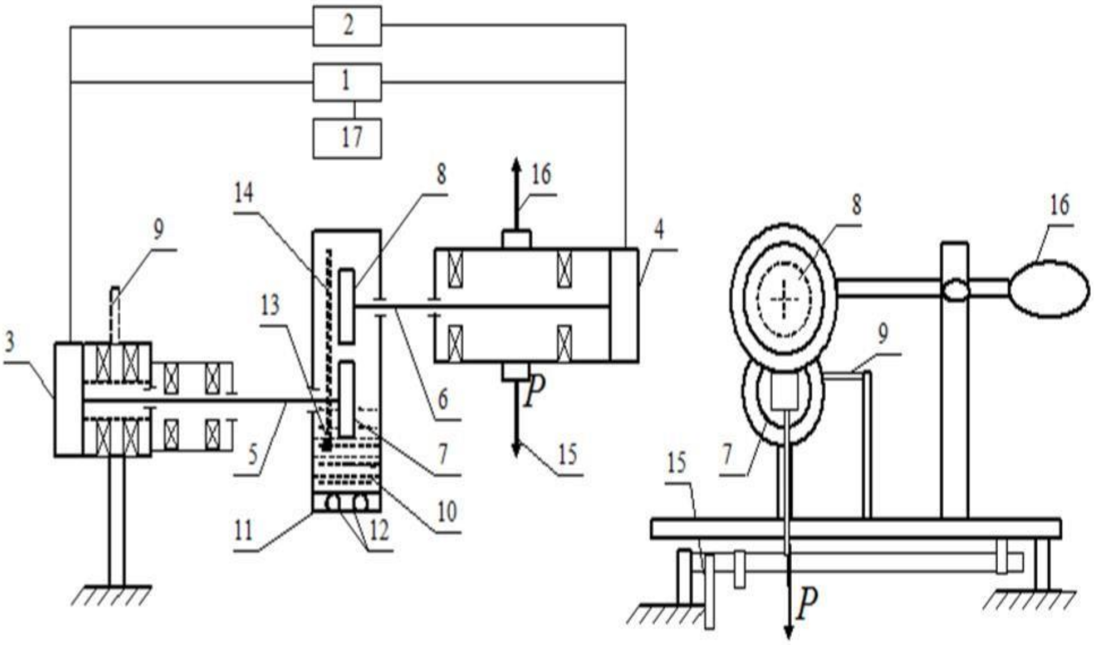
The main requirements for the reliability of the results obtained using these methods are sufficient accuracy, stability and inertia, as well as ensuring the measurement of the thickness of the lubricating layer under the existing contact conditions - kinematic, power, temperature.

However, the results of X-ray and magnetic methods are affected by wear products [9], the interference method is characterized by increased sensitivity to the temperature of contact surfaces and the degree of purity of their processing [7], the luminescent method does not provide reliable data for structuring lubricating layers [3]. improving the calibration dependences of the influence of elastic deformations of the surface layers of metal in contact on the micro-displacement of the strain gauge [6].

In operational practice, the study of lubricating action in the presence of a number of advantages and simplicity have become widespread electrical methods [5]. Improving the productivity of machines, expanding the range of load - speed parameters and operating environments require the creation of comprehensive methods for assessing the performance of the friction unit at different operating modes.

Methods and results of research. We have created a device for evaluating the tribotechnical characteristics of triboelements which allows to obtain more reliable research results, provides tests in rolling, sliding, reversing without re-equipment of the device, is characterized by expanding the range of slip between contacting rolling elements.

As shown in figure 2.8, a device for evaluating the tribotechnical characteristics of triboelements comprises two drives 5, 6, on the output shafts of which are mounted test rollers 7, 8; the rotation of the drives is carried out by programming the control unit 2 stepper motors 3, 4, connected to the power supply 1. Stepper motor 3 is mounted on the motor scales, to which is attached the strain gauge registration moment of friction 9. The lower test sample 7 is immersed in lubricant 10 located in the vessel 11, the lower body of which includes two thermocouples 12, the thermocouple 13 is attached to the rod 14. The load means consists of a system of levers with a load 15 and counterweights 16.



1 – power supply, 2 - control unit, 3, 4 - stepper motors, 5, 6 – driwers, 7, 8 – test rolleers, 9 – strain gauge, 10 – lubricant, 11 – vessel, 12, 13 – thermocouples, 14 – rod, 15 – load, 16 - counterweight

Figure 2.8 - Scheme of tribotechnical complex for evaluation of lubricating, antifriction and rheological characteristics of lubricants

The device works as follows. The tribosystem, which consists of two movable rollers 7, 8 in contact during friction, and lubricant 10, is placed in the bath 11. The tribosystem by means of the load means 15 is loaded with a predetermined force P and rotary actuators 5, 6 drive the rollers.

Rotation modes (sliding, rolling, sliding rolling, reverse) are programmed by control unit 2. Friction torque, roller speed, lubricant temperature, voltage drop in the lubricating layer in contact are recorded and processed on personal computer 17 in real time with a graphical representation of their changes.

2.4 Results dermination. Equipment and methods.

Classification of construction diagrams and friction machines.

Friction units used in products are divided by contacts: point (spherical bearings, hinges, etc.), linear (gear drives, cam pairs, radial plain bearings, etc.) and on a flat surface (thrust bearings). Schemes that simulate the operation of most real friction units are implemented on machines of the type: end, shaft-sleeve, roller. The transition from one scheme to another is associated exclusively with the replacement of the friction unit.

For testing friction units - piston-cylinder, plunger pair, cylindrical guide bushings, plug connectors, guide pins, etc. machines with reciprocating motion (figure 2.9). The shape and dimensions of the samples depend on the test scheme and the type of machine. In tests of the second category, a rotating sample is made of the same material as the part of a full-scale assembly or (if this condition is difficult to fulfill) a stationary sample is made of a material with a higher thermal conductivity.

Figure 2.9 - Special machine for tribotechnical tests

To carry out one series of tests, the samples are made from the material of the same brand and melt and using the same technology. Macro- and microstructure, as well as the hardness of the samples should be close (maximum deviations in hardness - no more than ± HB 10 or ± HRC 1). The roughness of the surface of the working part of the samples - according to GOST 2789-73 for one series of tests of friction pairs - 7 - 8 class, antifriction - 9 - 10 (if, according to the test conditions, the processing of the samples does not correspond to the processing of a real friction unit).

In the presence of a coating, not only its average thickness is monitored, but also the dependence of the thickness along the working part of the sample. Data on the material of the samples are entered into the card, where its name, type of heat treatment, type and thickness of the coating are indicated. When testing the tribotechnical characteristics of materials, the following parameters are subject to control and registration: load, test temperature, average temperature of the friction surface, sliding speed, friction force (moment), friction path (number of revolutions, cycles), pressure in the vacuum chamber, composition of the surrounding gas environment (if necessary), technical resource.

The nominal load is determined by calculation from the nominal contact area of rubbing samples Aa (mm2). To do this, select the nominal pressure per unit of contact area from the test conditions and find the value of the normal load from it. The value of the rated load should not differ from the specified one by more than 3%. Method of technological control of tribotechnical characteristics of materials and hard-lubricating coatings. The method belongs to laboratory tests of the first category (reference tests) and serves for the comparative assessment of materials and coatings, control of the stability of their tribotechnical properties, obtaining initial data for tribotechnical calculations, etc.

The essence of the method: three hemispherical indenters are pressed against the sample - a flat ring made of the material under study (or a coating on it) - a counter-sample with a constant load. The ring is rotated relative to the indenters with a constant sliding speed and the coefficient of friction and the intensity of their wear are determined. Test temperature 293 K.

Scheme and test conditions. Tests are carried out according to finger or end circuits, which makes it possible to obtain two limiting cases for the overlapping coefficient. Environment - vacuum or atmosphere according to specified conditions. During vacuum tests, the pressure of the medium is 10-4 Pa. Loads: according to the finger scheme - 2.5 N, end - 7.5 N. The sliding speed of the samples is 1 m/s. The temperature is normal (293 K). Test time 3600 seconds or until the coefficient of friction reaches the specified value.

A decrease in one of the samples operating according to the end scheme may be caused by the need, on the one hand, to completely overlap the rubbing surfaces, and on the other hand, to measure wear by the same method as by the finger scheme, i.e. using a profilometer - profilograph. The frictional force between the samples during their frictional contact is measured with the serial tensometric equipment and is recorded with potentiometer or others (figure 2.10).

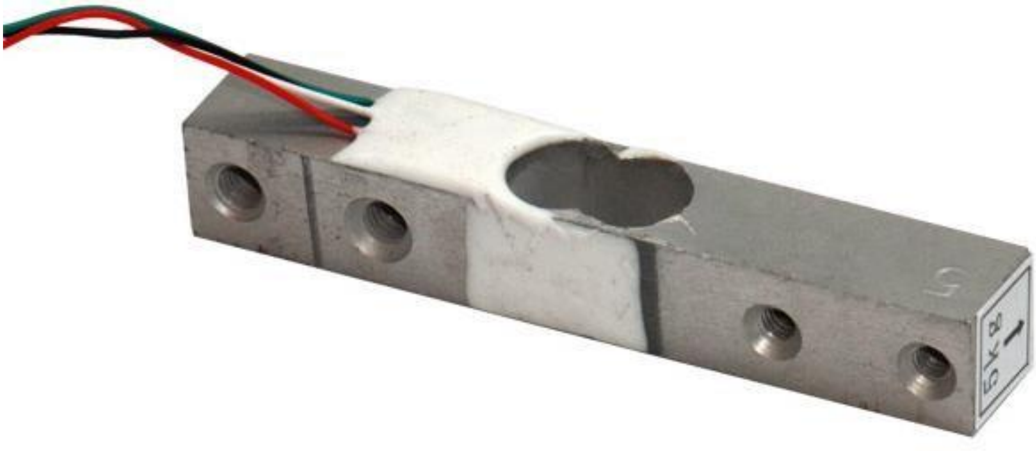


Figure 2.10 - Tensometric equipment

The wear of the solid lubricant coating is determined by taking the profilograms of the friction track with an optimometer or a profilometer profilograph (for example, "Caliber-252").The wear of the indenter and of the end pattern specimens is controlled by linear and weight measurements. Vacuum measurements are conducted using standard vacuum gauges.

Method for determining the friction coefficient on the scheme of shaft-bushing of the rotary motion. The method is intended for testing cylindrical plain bearings in atmosphere and vacuum at temperatures of 290 - 600 K. The essence of the method: the bushing is pressed against the sample-shaft by a radial constant load; the shaft rotates relative to the sleeve at a given sliding speed. Test pieces: rotating - shaft, stationary - bushing. Requirements for specimens must correspond to technical specifications for parts and full-scale friction unit. In the absence of similar technical specifications.

In one mode from a batch of material, tests are subjected to tests on less than five samples of the same shape and size. Registered parameters: load, speed, temperature of tests and friction surfaces, force (moment) of friction, wear (linear, weight), pressure in the test chamber, composition of the gas medium (if necessary). The test mode must simulate the contact, kinematic and thermal operating conditions of a full-scale friction unit. Method for determining the friction coefficient on the scheme of rotary motion.

The method is intended for testing materials and coatings used in thrust bearings, sliding bearings, and other units in an atmosphere and vacuum at temperatures of 300 - 600 K. Consists in determining the coefficient of friction and wear resistance of materials with end contact under load of cylindrical annular samples, one of the which rotates at a given speed, the other - stationary - counter-sample. The requirements for the samples must correspond to the specifications for the details of the full-scale friction unit. In the absence of similar technical specifications. In one mode from a batch of material, at least five samples of the same shape and size are tested.

Registered parameters: load, speed, test temperature and in the friction zone (near the surface), friction force (frictional moment), wear (linear, weight), pressure in the test chamber, composition of the gas medium (if necessary). The test mode should simulate the contact, kinematic and thermal operating conditions of a full-scale friction unit, the criterion for this is the product of the average contact pressure and the sliding speed, which is closest to the full-scale one.

The tests may be carried out at the special stand, which consists of an high-vacuum pumping unit, a high-vacuum valve, a friction chamber with a load-measuring device and an instrument stand. A diagram of the friction chamber and a load-measuring device for testing according to the end scheme. Test samples - ring and counter-sample are located in the chamber. The ring rests on a ball bearing unit and is rotated through an electromagnetic clutch by an electric drive. The counter-sample is fixed with a screw on the rod.

The load between the counter piece and the ring is created by the rod located in the support. The stem has a cup, into the radial slots of which a strain gauge is inserted, which enters the central part of the slots of the pusher located in the flange of the chamber. The pusher is hermetically connected to the flange by a bellows. The load is transferred to it using the linkage by the weights. Strain gauges are glued to the strain girder to measure the friction forces between the samples. On the flange of the chamber there is a sealed outlet for withdrawing from the chamber wires of strain gauges, a thermocouple and a sample heater, as well as pressure sensors. The chamber is connected to the ERA-300-2 pumping unit through the valve. To convert and amplify signals from strain gauges glued to the strain gage of the load-measuring device, standard strain gauge equipment can be used.

Check the compliance of the samples with technical documentation: measure their diameters, height, cleanliness and hardness of rubbing (end) surfaces, the thickness of the anti-friction coating. On the contacting surfaces there should be no shells, chips, burrs and other defects visible to the naked eye, and in the presence of antifriction coatings - delamination, swelling, damage and uneven thickness. The measurement results, indicating the grades of materials and coatings, are recorded in the test log.

Conclusion to the part 2

The equipment manufactured for studying the surface in conditions of mechanical contact with the indenter (counterbody) can be divided into 4 categories:

- Nano hardness testers and scratch testers (adhesion testers) - devices for studying thin/thick coatings and materials in the nano and micro / macro range by instrumental (measuring) indentation methods;
- Tribometers and visualization modules - profilometers All equipment is completed with specialized software
- Tribometers - devices for studying the behavior of materials and coatings under surface friction and sliding depending on time, speed, pressure, temperature and humidity, as well as on the presence and type of lubricant;
- Profilers and atomic force microscopes (nanoscans) are devices for studying the surface profile and roughness, building a 3D surface model. Friction and Wear Test Machine for metal cylinders and shaft-cylinder pairs influenced by climatic conditions

Methods and results of research. We have created a device for evaluating the tribotechnical characteristics of triboelements which allows to obtain more reliable research results, provides tests in rolling, sliding, reversing without re-equipment of the device, is characterized by expanding the range of slip between contacting rolling elements

Part 3. Determination of lubrication ability of greases with anti-friction additives

3.1 Materials used in the project

AeroShell Grease 33

AeroShell Grease 33 is a multipurpose synthetic airframe grease formulated with a thickened lithium complex synthetic base oil with corrosion and oxidation inhibitors and load-carrying additives (figure 3.1). The usable operating temperature range is –73 ° C to + 121 ° C.

Figure 3.1 - Aeroshell Grease 33

Applications

For many years, aircraft operators have tried to rationalize the lubricants used in aircraft and reduce the number of different lubricants in their inventory. Boeing recently began researching a new general purpose anti-corrosion lubricant. The challenge was to create a non-clay-based grease that would extend the life of components and mechanisms and have improved wear and corrosion resistance. This led to the emergence of the new Boeing BMS 3-33 specification.

Due to the wide range of operating temperatures, loads and other environmental conditions required for various aircraft components, several different types of grease are used during regular lubrication of aircraft components with different desired properties. In developing the BMS 3-33 specification, Boeing took into account the properties of the various types of lubricants used in aircraft and wrote a lubricant specification that would provide improved performance and that could be used in the widest range of lubricants. This performance level is largely adopted as the SAE AMS 3052 specification, which in turn forms the basis of the Airbus AIMS 09-06-002 specification.

AeroShell Grease 33 is BMS 3-33B approved and offers the improved performance required by this specification and other specifications mentioned above. AeroShell Grease 33 can be used for the regular lubrication of Boeing aircraft that are prescribed MILPRF-23827C or BMS 3-24. AeroShell Grease 33 can also be used in certain Boeing aircraft applications requiring MIL-G-21164. Other applications on Boeing aircraft that require MIL-G-21164 and other lubricants are pending, and Boeing will publish details of the full range of applications in due course. See the latest Boeing Service Letter BMS 3-33 General Purpose Aircraft Grease for current status.

AeroShell Grease 33 can be used for regular lubrication where MIL-PRF23827C is specified on aircraft manufactured by McDonnell Douglas, Airbus, BAe Regional Aircraft, Canadair, Lockheed, Embraer, Fokker and Gulfstream (excluding hub bearings for which higher temperatures apply. 121 ° C and sliding applications requiring molybdenum disulfide). AeroShell Grease 33 contains synthetic oil and cannot be used with incompatible seal materials. Other aircraft manufacturers estimate this for use on their planes. Operators should regularly check with these manufacturers for the latest information. Using AeroShell Grease 33 can provide operators with the following benefits:

- Reduced inventory
- Easier maintainability (one of the main lubricants for most applications)
- Reduced maintenance costs
- Less chance of product misapplication

Properties:

Oil type: Synthetic hydrocarbon / ester

Thickener type: Lithium complex

Base oil viscosity mm² / s:

- at -40 ° C - 1840
- at 40 ° C - 14.2
- at 100 ° C - 3.4

Useful operating temperature range ° C: -73 to +121

Dropping point ° C: 216

Penetration at 25 ° C: 297

Penetration untreated at 25 ° C: 290

Bomb oxidation pressure drop from 758 kPa (110 psi) at 99 ° C:

- at 100 hours kPa (psi) - 3.5 (0.5)
- at 500 hours kPa (psi) - 34 (5)

Oil separation at 100 ° C in 30 hours% m:	2.0
Watertightness loss (79 ° C)% m:	<6
Evaporation loss 500 hours at 121 ° C:% m:	<10
Average load in hertz, kg:	60
Anti-friction bearing performance at 121 ° C h:	1200+
Copper corrosion in 24 hours at 100 ° C:	Passes
Bearing protection 2 days at 52 ° C:	Compliant
Color:	Green

ERA (VNII NP-286M)

Application. For gears of gearboxes of electric mechanisms and bearings of aircraft control systems operating in the temperature range from minus 60 ° C to 120 ° C (figure 3.2).

Figure 3.2 - ERA VNII NP-286M

Benefits

- Retains working properties at temperatures from - 60 ° C to 120 ° C.
- Passes a mandatory military acceptance by the customer's representative.
- The shelf life of the product in a closed container is 5 years.

Properties

Color:	gray to light brown ointment
Dropping point, ° C, not less:	180
Effective viscosity at -50 ° C, Pa * s, no more:	900
Tensile strength at 50 ° C, Pa, within:	200-350
Colloidal stability% no more:	22
Mass fraction of water:	absent
Content of mechanical impurities:	absent
Corrosive to metals:	withstands
Mass fraction of free alkali in terms of NaOH,%:	no more than 0.1

Mobilgrease 28

ExxonMobil Aviation, Italy.

Description. Mobilgrease 28 is a synthetic aviation grease with a wide temperature antiwear grease formulated to combine the unique properties of a polyalphaolefin (PAO) synthetic base fluid with an organo-clay (non-soap) thickener (figure 3.3). It provides outstanding performance over a wide temperature range.

The absence of paraffin in the synthetic base fluid, together with its high viscosity index compared to mineral oils, provides excellent pumpability at low temperatures, very low starting and operating torque and can contribute to lower operating temperatures in the load zone of rolling bearings.

Figure 3.3 - Mobilgrease 28

The clay thickener gives Mobilgrease 28 a high dropping point of about 300 ° C, which provides excellent high temperature stability. Mobilgrease 28 resists water wash-off, provides excellent load carrying capacity, reduces frictional resistance and prevents excessive wear. Tests show that Mobilgrease 28 effectively lubricates rolling bearings at high speeds and temperatures. Mobilgrease 28 has also shown excellent lubrication properties in heavily loaded sliding mechanisms such as flap screw jacks.

Features and Benefits.

A special requirement for aviation lubricants is the need to withstand high temperature loads, providing excellent starting and low torque at low temperatures. To meet this combination of requirements, ExxonMobil scientists selected synthetic hydrocarbon base oils for Mobilgrease 28 due to their low volatility, exceptional thermal / oxidation resistance and excellent low temperatureproperties. The formulators have selected a specific thickener chemistry and proprietary additive combination that helps maximize the benefits of synthetic base oils. Mobilgrease 28 meets the requirements of the main specifications of military and commercial aviation.

Benefits and Potential Benefits:

- Synthetic base oil with high viscosity index (VI), wax free. Provides a wide operating temperature range - excellent high and low temperature performance Provides thicker fluid films to protect equipment parts operating at high temperatures from wear.
- Low starting resistance at very low temperatures
- Wear and corrosion protection
- Outstanding bearing protection, helps extend bearing life and reduce bearing replacement costs.
- Extreme pressure protection characteristics
- Avoids excessive wear even under shock loading
- High thermal / oxidation stability
- Extended relubrication intervals
- High resistance to water washout
- Retains excellent lubrication performance in adverse weather and other water conditions.

Applications:

Mobilgrease 28 is formulated to lubricate plain and rolling bearings at low and high speeds, as well as splines, screws, worm gears and other applications where high friction reduction, low wear and low lubrication friction losses are required. The recommended operating temperature range is -54 ° C to 177 ° C (-65 ° F to 350 ° F) with appropriate relubrication intervals. Mobilgrease 28 is recommended for use in landing gear assemblies, control systems and actuators, screw jacks, servo drives, engines with sealed bearings, oscillating bearings, and helicopter rotor bearings in military and civil aircraft.

Properties

Grade -	NLGI 1.5
Viscosity of base oils of greases at 100 C, mm2 / s, AMS 1700 -	5.7
Viscosity of base oils of greases at 40 C, mm2 / s, AMS 1697 -	29.3
Bomb Oxidation, Pressure Drop, 100h, kPa, ASTM D942 -	PASS
Color, Visual -	Dark red
Copper Strip Corrosion, 24 Hrs, 100 C, Rating, ASTM D4048 -	1B
Dirt, #particles 25 to 74 microns, FTM 3005 -	Pass
Dirt, # particles 75u or more, FTM 3005 -	0
Dropping Point, ° C, ASTM D2265 -	307
Evaporation Loss, 22 hrs, 177 C, wt%, ASTM D2595 -	6
Falex Block Oscillating Wear Ring, 35k Cycles, 90 Degree Angle, Aluminum / Bronze Block, mm, ASTM D3704 -	PASS
Four-ball wear test, scar diameter, mm, ASTM D2266 -	0.6
Load capacity, wear resistance index, kgf, ASTM D2596 -	40
Low Temperature Torque, -54 ° C Operation, 60 min, Nm, ASTM D1478	0.05
Low Temperature Torque, -54 ° C Start, Nm, ASTM D1478 -	0.43
Grease life at 177 C, h, ASTM D3336 -	PASS
NBR-L, AMS 3217/2 Compat, 70C 158 h, vol.%, FTM 3603-	6
Oil separation, 30 h at 177 ° C, wt%, ASTM D6184 -	3.5
Oxidation Stability, Pressure Drop, 500h, kPa, ASTM D942 -	PASS
Nib machined X 100,000, 1/16 holes, 0.1mm, FTM 313 -	303
Penetration, Processed, 60X, 0.1mm, ASTM D217 -	293
Rust Resistant, 48 Hrs at 125 F, Rating ASTM D1743 -	PASS

Texture, VISUAL -	Smooth, buttery
Thickener, wt%, AMS 1698 -	Clay
Water washout, loss at 41 C, wt%, ASTM D1264 (mod.) -	1

ROYCO 27

ROYCO 27 Aircraft Instrument and Gear Bearing Grease is a multi-purpose formula that provides fantastic corrosion resistance and rust protection along with excellent lubrication. The anti-wear coating has a light brown color for easy recognition. It is ester based and consists of a durable lithium stearate thickener that works well in a variety of conditions.

ROYCO 27 Aviation Instrument and Gear Bearing Grease lubricates and protects. The grease is water resistant, so it is impervious to moisture to prevent water damage and preserve sensitive engine components. ROYCO 27 grease has a long shelf life and a service life of up to three years.

Figure 3.4 - ROYCO 27 grease

ROYCO 27 Aviation Instrumentation and Gear Bearing Grease is available in several sizes to suit your needs. Choose the small 14oz pre-filled cartridge for single use or opt for the giant 400lb drum. The grease is great value and is a must-have addition to any workbench. Same day delivery is available for some sizes of this premium grease.

Approvals / References / Specifications

NATO Specification: G-354

US Military Specification: MIL-G-23827

US Military Specification: MIL-PRF-23827 Type 1

Applications

ROYCO 27 is designed for use in highly loaded gears and drives as well as tools and high speed bearings at temperatures ranging from -100 ° to 275 ° F.

Specifications

ROYCO 27 meets all requirements and is MIL-SPEC certified:

MIL-PRF-23827C

Armor penetration, mm:

- Worked: 287 points
- Unprocessed: 275 points

Stability, 100,000 shocks: 310

Evaporation, 100 ° C / 22 hours,%: 1.0

Storage stability: no complete separation

Oxidation resistance, 100 hours, 210 deg. F: 2 psi

Rust Prevention: PASS

Dropping point, ° C: 190

Oil separation 100 ° C, 72 hours, wt%: 2.3

Load Wear Index: 37

Low temperature. Torque, Nm, -100 F:

- Start: 0.38
- Running: 0.03

TRIBOLUB-2N

SPECIFICATIONS

MIL-PRF-83261 compliant, outstanding quality Tribolyub-2N is a wide range of operating temperatures range, extreme pressure and anti-wear characteristics, non-migratory nature, low content of foreign and / or opaque particles, high resistance to microwave energy and compatibility with plastic and elastomeric seals (figure 3.5). The shelf life exceeds 10 years.

Tribolyub-2NMS retains the same physical properties as Tribolube-2N, but specially designed with MoS2 to improve its excellent extreme pressure and antiwear properties. Tribolyub-2NWS retains the same physical properties asTribolyub-2N, specially designed with a special pressure boosting additive that improves the already excellent extreme pressure and antiwear properties.

Figure 3.5 - Tribolub 2N

Applications:

Aircraft drives, gears, cardan rings, rolling bearings, rolling and sliding ball bearings. It is especially suitable for use in miniature bearing applications. Blower motors, motor-generators, plastic couplings and gears, servo motors, microwaves, speedometer cables, motorcycle and automotive distributors, typewriters, business cars, etc. Other applications include sub-fractional power gearmotors, camera drive systems, microswitch assemblies, gearboxes. gears and scientific instruments.

Characteristics:

Temperature range -100ºF to 450ºF

Untreated Penetration at 77ºF - 330

Penetration worked at 60 moves 340 worked

Stability at work - 349

Dropping point - 460ºF

Evaporation at 400ºF - 4.60%

Oil separation 24 hours at 400ºF - 13.40%

Water washout 1 hour at 105ºF - 2.20%

Density - 1.85 g / cm

Bomb oxidation 100 hours at 250 ° - (- 1.50) psi

Wear steel on steel,1200 rpm, 40 kg, 167ºF, 2 hours, 52100 Steel - 0.78mm

Friction coefficient 1200 rpm, 90 ° F, load 15 kg - 0.089

Welding point load - +800 kg.

Oil lubrication and lubrication technologies are essential to reduce friction and wear losses in machines. Lubrication (grease, oil, solid lubricants) is a key factor in the effectiveness of a friction system. The Four Ball Tester, also known as the Shell Four Ball Tester, is used to characterize lubricant performance such as Wear Prevention (WP), Extreme Pressure (EP) and Friction Behavior (various test standards are listed below).

The tester consists of four balls in the shape of an equilateral tetrahedron, as shown in the figure below. The top ball rotates and contacts the three bottom balls, which are held in a fixed position.

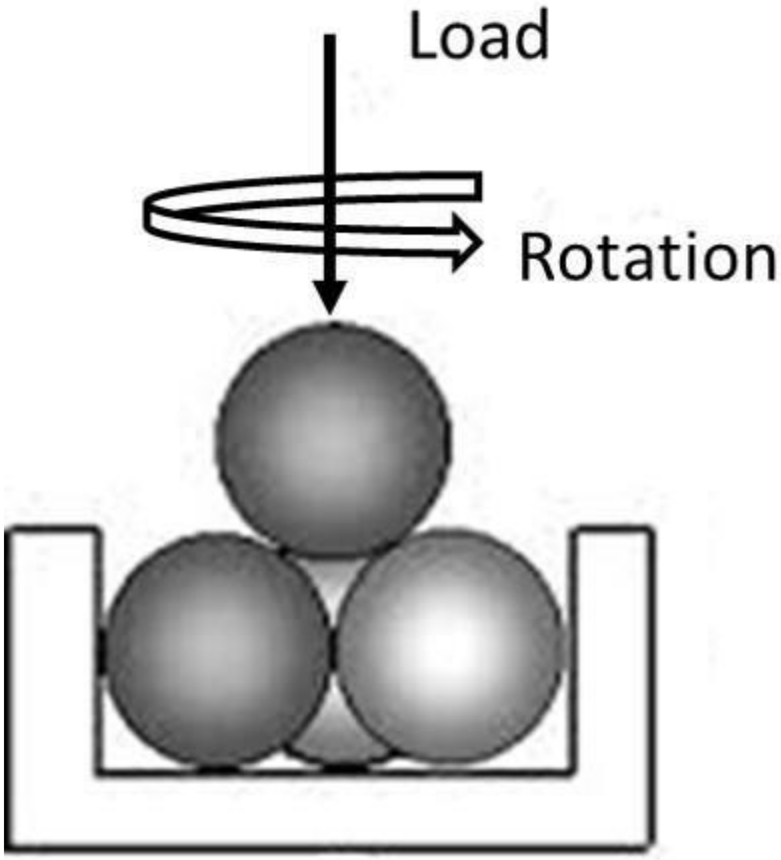


Figure 3.6 - Four ball tester

Four ball tester circuit

Back pressure test with four balls

When testing the extreme pressure properties of a lubricant, the ability of a lubricant to function under extreme pressure is determined. The test starts at “low” loads — loads at which the lubricant functions well, a proper lubricating film forms and no scoring is found.

The load is gradually increased according to the test standard until the grease disappears, which means that the lubricating film can no longer separate the surfaces and surface-to-surface contact occurs. In the last stage, the load increases until a catastrophic failure occurs. This final failure is called “weld” and is characterized by increased noise, abrupt changes in friction signal, etc. Different formulations can be developed based on the characteristics of the lubricant in this test.

Four-ball wear test

The four-ball test can also be used to measure the wear characteristics of a lubricant. During the test, the top ball rotates relative to the rest of the fixed balls. The load is performed under fixed conditions (load, temperature, speed, etc.), as opposed to an extreme pressure test. After the test, the wear marks are measured using, for example, optical profilometry, and from these the wear characteristics of the lubricant can be judged. The frictional force is also measured during this test and therefore can also be analyzed.

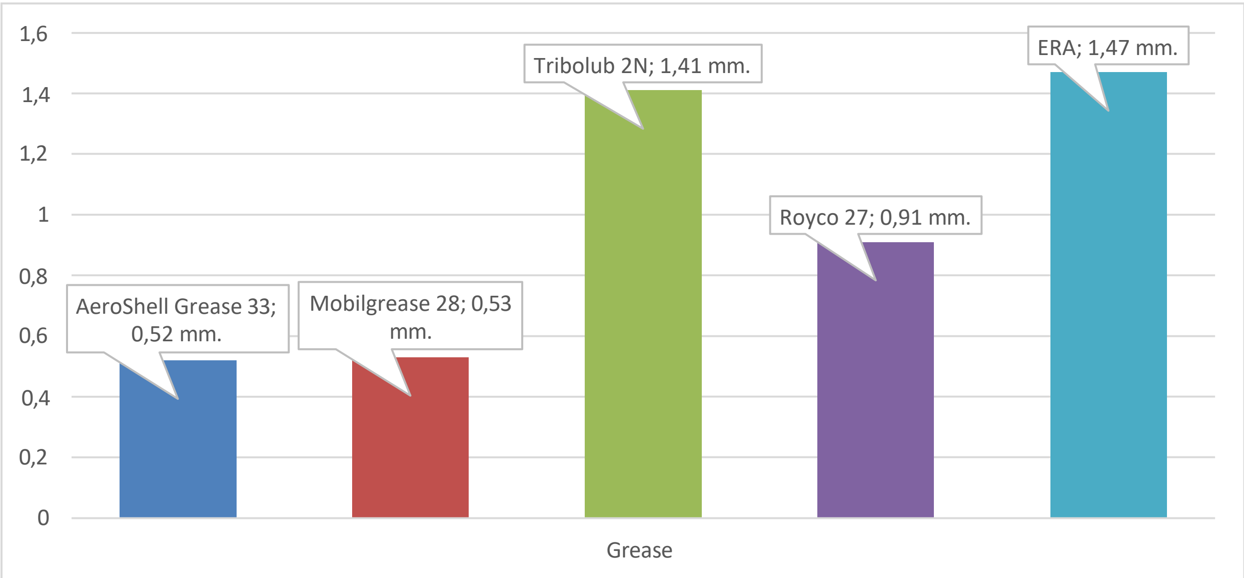


Figure 3.7 – Comparison of wear magnitude of different greases usig four ball wear test

3.2 Results.

Effect of the addition of nanoparticles, especially those based on ZrO_2, on the tribological properties of lubricants. A grease is a commonly used semi-solid lubricant consisting of a base oil, thickeners and possibly improvers. It is often used in roller bearing systems when it is difficult or even impossible to supply the required oil through a centralized lubrication system or when the lubricant must remain in a confined space. The presence of grease supports the sealing process of the bearings, since it is sealed, to some extent prevents corrosion of mating surfaces and requires simple maintenance.

The grease has a complex microstructure that breaks down with prolonged use. A lubricant is a thixotropic body, the properties of which change over time under the action of shear stresses, partially reversible. It was found that both the proportion of the thickener and the shear rate significantly affect the recovery of the microstructure of the lithium thickener after friction. Greases, especially lithium, are widely used for the lubrication of rolling bearings and moving joints in the automotive and other industries. However, such frictional joints can be heavily loaded if they operate at not very high sliding speed and temperature.

During the operation of rolling bearings installed in various mechanical devices, a process of mechanical degradation of lithium grease is usually observed as a result of a change in the bulk properties of the grease due to the shear stresses acting on it during friction. Two mechanisms of lubricant decomposition are described in the literature: physical decomposition and chemical. Physical degradation includes mechanical breakdown of the thickener structure due to shear stress, separation of base oil and thickener, evaporation of the base oil, and contamination of the lubricant with contaminants and debris.

Chemical degradation includes oxidation of both the base oil and the thickener and depletion of the improvers. When bearings are operated at higher temperatures, chemical decomposition predominates. Mechanical breakdown of the lubricant predominates when the bearing system is operating at high speeds. Most often, both chemical and physical degradation occurs due to changes in the operating conditions of rolling bearings, which largely depend on the chemical composition of the lubricant.

Very favorable conditions for degradation arise when different lubricants are mixed containing components that tend to react with each other. Lithium hydroxystearate grease can oxidize and thermally decompose. At elevated temperatures (150 ° C), lithium grease weakens even in the absence of oxygen. During aging of lithium grease at elevated temperatures, the effect of shear on viscosity loss was more pronounced. A twofold decrease in yield strength at a certain temperature rise for lithium and polyurea thickened greases was reported.

The activation energy based on Arrhenius's law is a suitable parameter for predicting the life of lithium greases. Mechanical destruction of the lubricant is caused by pressure and shear stresses.

The grease can soften with aging and leak out of bearing systems. The grease can also harden, resulting in a loss of oil drainage. This aging behavior of a lubricant depends on temperature, lubricant chemistry, and thickener microstructure. Elevated temperatures accelerate aging, as do the properties of the thickener. The mechanical aging of fibrous lubricants such as polyalpha-olefin lithium complex soap and an essential oil-based polyurea grease was studied. No oxygen-chemical reactions were reported.

It was found that shear decomposition of the lubricant accelerates with increasing temperature. They created a lubrication reference curve describing the effect of shear and temperature on mechanical aging of the test lubricant. If the operating temperature is much lower than the oxidation temperature and there is no contamination or evaporation of the grease, the life of the grease is determined by mechanical degradation.

Aggregation and agglomeration of nanoparticles dispersed in a lubricant. Aggregation and agglomeration are different concepts used to describe a collection of particles or nanoparticles in a material. Both concepts have different meanings. Clustering of particles due to aggregation is a reversible process, and clustering of particles due to agglomeration is an irreversible process. Both processes are easily distinguished using traditional methods such as dynamic light scattering, nanoparticle tracking analysis, or electron microscopy imaging. Such methods reveal large aggregates of particles in the test material only as a whole.

Aggregations and agglomerations of particles in the material sample were created by different mechanisms. One of these mechanisms consists of collisions and adhesion of particles as a result of their random Brownian motion (Brownian agglomerations). Another mechanism, called "gravitational agglomeration", is strictly dependent on the size of the particles and their final velocity. Slowly settling particles are captured by rapidly settling particles, which leads to the formation of particle clusters. Particle clustering affects acidity, pH, and ionic bond strength. Therefore, methods for correctly determining the degree of agglomeration and agglomeration of nanoparticles in a material sample are very important. The mechanisms of formation of secondary particles during non-aqueous synthesis affect the subsequent dispersion, functionalization or change in surface properties.

The formation of secondary particles during the non-aqueous synthesis of ZrO_2 and TiO_2 nanoparticles was investigated and the mechanisms governing agglomeration and agglomeration was studied (fig. 3.7). It was found that first densely packed aggregates were formed, consisting of primary nanoparticles, and then agglomerated into so-called "superstructures".

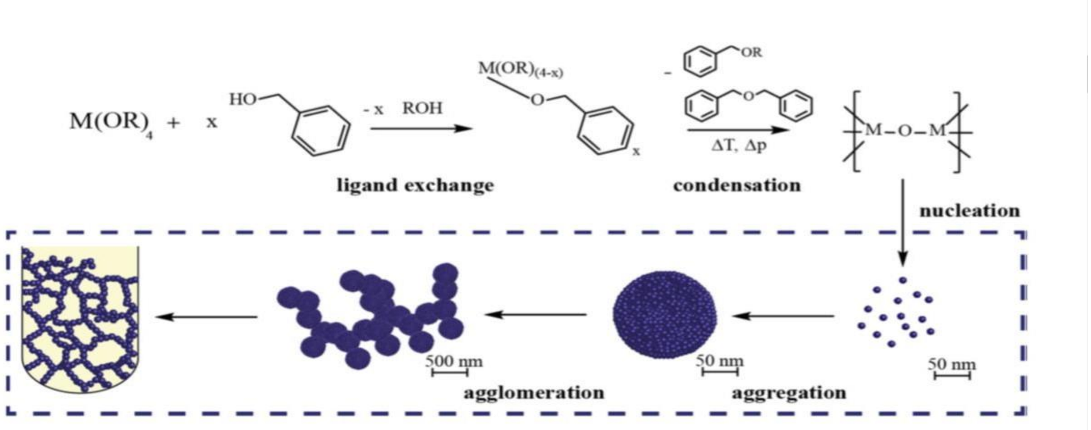


Figure 3.8 - Mechanisms of particle formation in non-aqueous synthesis with an emphasis on the processes of aggregation and agglomeration

The hydrothermal synthesis of zirconium dioxide nanoparticles was studied and the spherical aggregate structures consisting of 8 nm particles were observed. These structures were further agglomerated into superstructures. Nanoparticles added to an oil lubricant tend to agglomerate. After agglomeration, the particle size changes. In order to better estimate the nominal particle size in solution, the particle size distribution of dispersed nanoparticles in PAO must be measured using the dynamic light scattering (DLS) method.

The theory behind the measurements with this method is based on the influence of the Brownian motion of nanoparticles on the Rayleigh light scattering data. This makes it possible to determine the size of a particle or molecule in solution. The primary result obtained from a dynamic light scattering measurement is an intensity-weighted mean diameter obtained from cumulations. This diameter was very sensitive to the existence of agglomeration of nanoparticles due to their inherent weighting of intensity.

Agglomeration of nanoparticles can be undesirable not only in the preparation of nanolubotics, but also during sintering. Ggranulometry parameters such as the shape and size of particles and their agglomerates or aggregates, both the chemical and phase composition of the starting powders, and the type of agglomerate or aggregate affect the compaction level and the sintering process. The so-called "soft" agglomerates are characterized by weak van der Waals forces between particles, which can be easily separated in a liquid medium using ultrasonic treatment or the addition of dispersants. The so-called "hard" agglomerates are characterized by strong forces between particles due to high temperature calcination or inappropriate chemical additives.

ZrO_2 nanoparticles facilitate the sintering process. The ordered agglomeration of primary zirconium dioxide crystallites into secondary particles ensures their uniform packing. However, a decrease in the size of ZrO_2 nanoparticles also promotes undesirable disordered agglomeration. Collected crystallites obtained during ordered and disordered agglomeration subjected to intense electromagnetic radiation can agglomerate even more.

A preliminary analysis of the nanopowder market, especially in Poland, showed that zirconia nanopowders are available on the market and relatively cheap. The number of available publications on the use of ZrO_2 nanoparticles as an additive to lubricants is small; however, the results of preliminary studies indicated such nanoparticles as candidates for improving the tribological properties of certain lubricants (figure 3.8). It was noted that the problem of agglomeration can also arise in the preparation of nanolubricants with nanoparticles of zirconium dioxide.

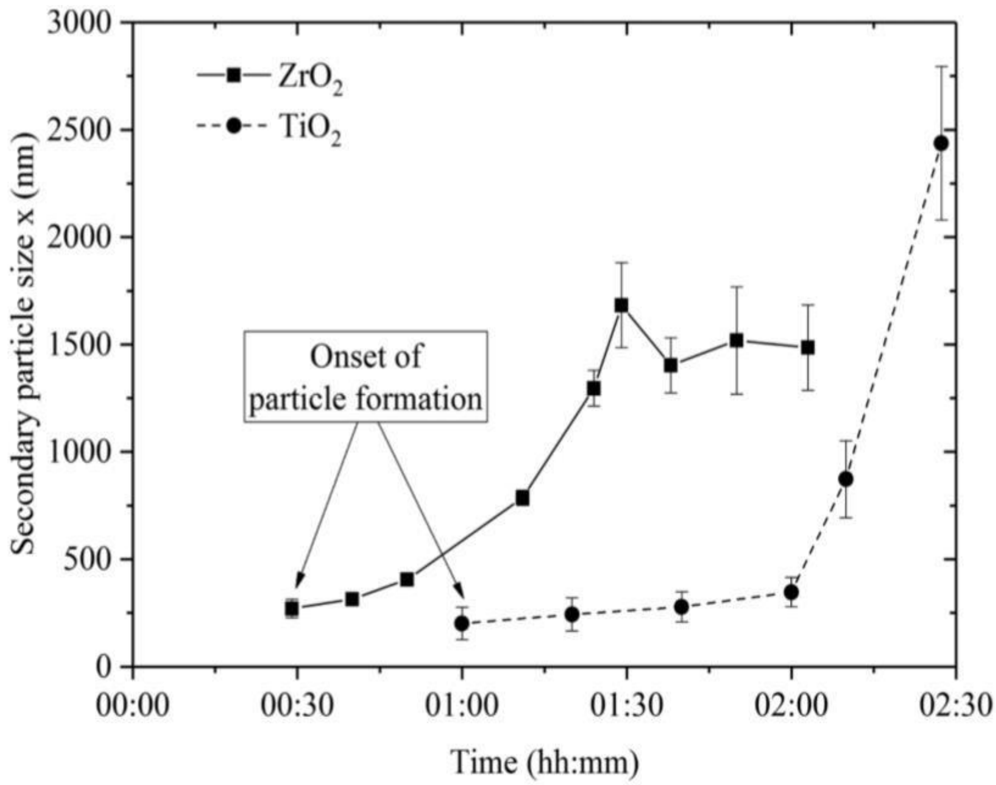


Figure 3.9 - Agglomeration in the synthesis of zirconium dioxide and titanium dioxide under standard conditions

Grease classifications and thickeners.

There are several classifications of greases. The greases can be classified by thickener composition and consistency according to the NLGI (National Lubricant Institute) classification. This classification is characterized by 9 gradations depending on the so-called working range of penetration. There are two main families of greases containing soap and non-soap thickeners. More than 90% of the thickeners used worldwide are soap based. There are three types of soap-based thickeners:

• Simple soap, made by the reaction of a fatty acid such as 12-hydroxystearic acid (12HSA) and a metal hydroxide such as lithium hydroxide. The thickener type is metal hydroxide fluorine. In the described case, the lubricant is called "simple lithium soap".

• Mixed soap - obtained by the interaction of fatty acids with metal hydroxides. For example, if 12 HSA reacted with lithium and calcium hydroxide, this resulted in a Ca/Li mixed soap.

• Complex Soap - Produced by the reaction of a fatty acid such as 12 HSA with a short chain complexing acid such as azelaic, resulting in a complex soap. If you use lithium hydroxide, you get a lithium complex grease. This type of thickener has much better heat resistant properties than a simple soap thickener.

The most widely used are complex lithium soaps and simple lithium soaps (their share in the world market exceeds 60%). The category of Soap Greases includes: soap grease (calcium stearate or hydroxystearate), soap grease with aluminum, soap grease (stearate or hydroxystearate) lithium, soap grease with calcium complex, soap grease with aluminum complex and soap grease with lithium complex. The soap-free grease category includes: urea and polyurea grease, bentonite grease and other non-soap greases such as sodium terephthalamate grease, copper phthalocyanine grease, mica grease, and silicon gel.

Characteristics of lithium grease.

A very important feature of lithium grease is its load-carrying capacity. Lithium grease with the addition of CaF_2 has a bearing capacity of up to 48% more than base lithium grease. The addition of nano-calcium borate to the helium grease resulted in greater load-carrying capacity compared to plain lithium grease. Pure lithium grease did not provide effective lubrication at loads exceeding 300 N. In contrast, a grease with 6 wt% nano-calcium borate performed well at loads up to 600 N.

This was also found in the study. Lithium grease with the addition of CeF_3 nanoclusters coated with oleic acid, that its bearing capacity was higher than that of simple lithium. The oleic acid - CeF_3 nanoclusters in the head improve wear resistance and extreme stress pressure of synthetic lithium grease. However, oleic acid - CeF_3 nanoclusters have no effect on reducing the friction of the lithium grease.

Grease Additives.

Lithium complex greases are generally stable and resistant to water and high temperatures. Correctly such additives can also improve performance such as extreme pressure, antiwear, rusty and corrosive. These greases also meet the NLGI GC-LB specification (where GC is a wheel grease performance class selected from existing GA, GB and GCones, and LB is a chassis lubricant performance class selected from existing LA and LB ones).

Lithium complex greases require significant amounts of zinc-antimony or other types of additives to provide extreme pressure resistance and wear properties. In addition, rust inhibiting additives should be added to lithium complex greases. To improve water resistance, lithium complex greases generally require tackifying agents that are quickly depleted in the presence of water.

Common grease additives include antioxidants, antiwear agents, corrosion inhibitors, extreme pressure agents, friction modifiers, and metal deactivators, among others. The additives improve lubricant performance and protect grease and lubricated surfaces when it is composed of mineral oil mixed with a soap thickener. Greases cannot meet the requirements for high-performance lubricants without the use of modern additives such as corrosion inhibitors, as well as additives that increase wear resistance (so-called antiwear agents) and extreme pressure (so-called extreme pressure agents). Some corrosion inhibitors are applied to lithium grease:

• neutral calcium sulfonates, characterized by high thermal stability and the ability to inhibit galvanic corrosion,

• medium calcium sulfonates with total base mass in oil. range (40–50), especially useful as a universal corrosion inhibitor for lithium greases, new MoS_2. They can neutralize organic and inorganic acids.

• ethylenediamide sulfonate, which in lithium grease can reach 2 weight percent.

Basic calcium sulfonate, neutral calcium sulfonate and alkoxylated amine particles are reported as corrosion inhibitors in lithium products.

The role of nanoparticles as additives to Lubricants.

There are various aspects of using nanoparticles as additives and creating a so-called nanoparticle. Nano-lubricants improve tribological properties, increase load-carrying capacity and reduce wear compared to base oil-based lubricants. The improved performance of nanoscale lubricants is due (among other things) to their increased surface area to volume ratio. The mechanism underlying the formation of the structure of the dispersed phase of greases was described using the chemical principle of modifying a complex calcium sulfonate grease by adding nanocalcite particles.

A calcium grease with different ratios of TiO_2 particles and TiO_2 / CNT carbon nanotubes (0.5,1,2,3.4 weight percent) was prepared for the experiments. The tribological and rheological characteristics of nanoscale lubricants was studied at different temperatures. The addition of TiO_2 / CNT in an optimal ratio of 3 weight percent helped to reduce wear rate and friction coefficient values by 73% and 60%, respectively, compared to those for simple lubrication. The apparent viscosity and shear stress increased by 48% and 74%, respectively.

Nanoparticles as an additive to lithium grease Recently, there have been reports of some studies on the effect of adding various nanoparticles to lithium grease on its tribological properties. We used SiO_2, ZrO_2 and TiO_2 nanoparticles. A lithium grease without SiO_2 nanoparticles and with a certain amount of SiO_2 nanoparticles was studied using a four-ball tribotester. For a grease with 0.3 weight percent SiO_2 nanoparticles, the friction coefficient was reduced by 26–39% compared to the base grease, depending on the loads in the contact zone.

Methods for preparing ZrO_2 nanoparticles There are three thermodynamically stable crystalline phases of ZrO_2 at atmospheric pressure: monoclinic, tetragonal, and cubic. Among all these crystalline phases, the cubic phase has good thermal, mechanical and electrical properties.

Agglomeration of ZrO_2 nanoparticles and methods for its prevention. The degree of agglomeration depends on the properties of the nanoparticle surface, the type of dispersant, and other conditions. Some reports indicate that deposition methods with microwave drying, pulsed magnetic field treatment and ultrasonic treatment of Zr hydroxide lead to the formation of "soft" agglomerates of Zr hydroxide of small size. Subsequent calcination processes at low temperatures made it possible to obtain ZrO_2 nanoparticles with a given particle size of a narrow distribution and “soft” agglomerates. The effect of difluoro surfactants (Trilon B, polyammonium acrylate, and neonol) and mineralizers (HCl, KOH, CH_3COOH, etc.) on the degree of agglomeration of ZrO_2 was studied.

Nanopowders. Zirconium dioxide nanopowders of various phase composition, particle size, and degree of agglomeration were obtained by adding surfactants and mineralizers. An increase in specific surface area did not always lead to a decrease in particle size. The addition of KOH and KNO_3 led to an increase in particle size and specific surface area simultaneously. This was influenced by a decrease in the degree of agglomeration of nanoparticles due to changes in the forces of interaction between particles under the action of surfactants and mineralizers. Low calcination temperatures (less than 700 ° C) resulted in the formation of cylindrical zirconia particles. The addition of KNO_3 led to the formation of non-agglomerated cylindrical zirconia particles with a diameter of about 12 nm and a length of about 2-3 nm.

Materials and methods of tribological research. Preparation of Samples for Tribological Tests During friction tests, a polished steel ball with a diameter of 18 mm rotated at a constant speed relative to a fixed counterpart. The ball mates with a polyethylene counterpart with an inner diameter of 30 mm and is fixed in a steel ring. The contact zone was loaded with a constant force and lubricated with lithium grease without or with 1 weight percent ZrO_2 nanoparticles 10–20 nm in size.

The lithium grease was mixed with ZrO_2 nanoparticles using a THINKY SR-5000 high-speed planetary mixer, followed by treatment with a GT Sonic VGT-800 ultrasonic cleaner for about 120 seconds to avoid agglomeration or structural destruction of the nanoparticles. To indicate the occurrence of agglomeration of ZrO_2 nanoparticles, a lithium grease with 1 weight percent ZrO_2

nanoparticles was left for two weeks from preparation to the start of testing in a closed container at 20 ° C (figure 3.9).

Investigation of the friction coefficient Friction in the contact zone of a steel ball with a polymer insert lubricated with lithium grease without or with ZrO_2 nanoparticles was investigated using a tribotester. The tribotester made it possible to obtain the values of the friction torque in the contact zone of the ball with its copy. The measurements were carried out at a constant ball speed of 36 rpm and a constant load in the contact zone, which increased in steps from 7.2 to 27.2 N.

The friction coefficient values were recalculated using the measured values of the friction moment, the diameter of the contact zone and the average back pressure between the ball and the contact area. The average contact pressure and the diameter of the contact zone were estimated using the FEM model of such a zone. The values of the contact pressure did not exceed 38 MPa.

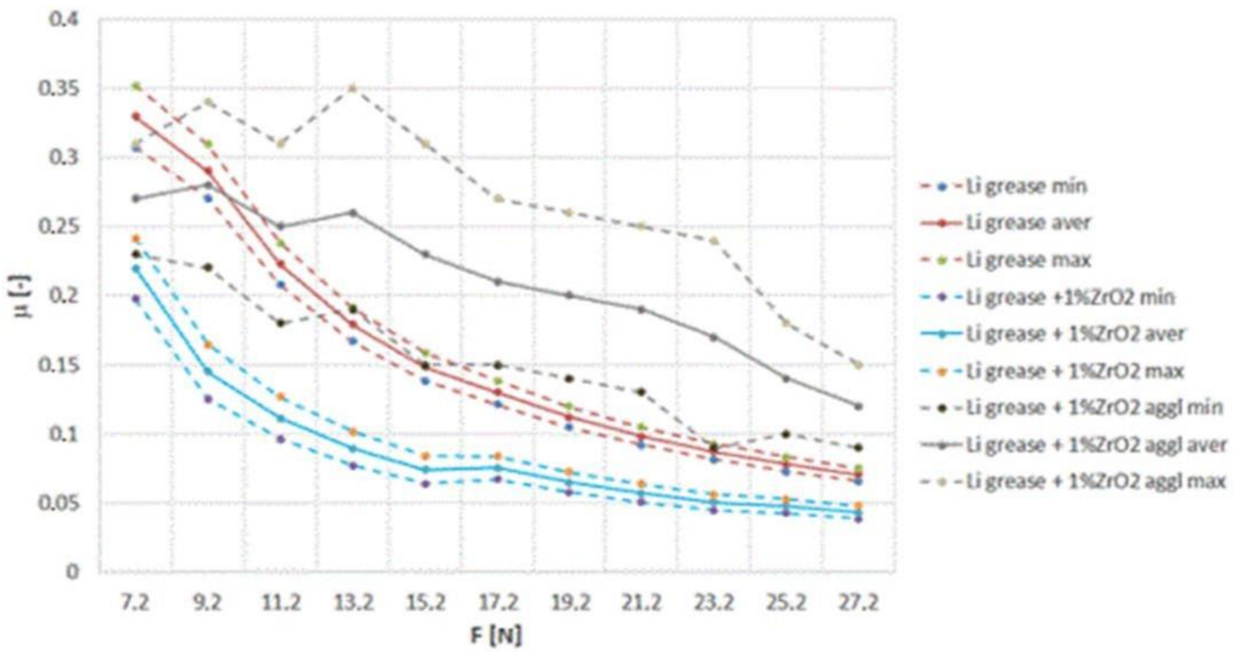


Figure 3.10 - Friction coefficients comparing to load in the contact zone between the steel ball and the inner sphere of the polyamide for three different lubrication systems

Results. The resulting graphs of the dependence of the coefficient of friction on the load in the contact zone between the steel ball and the inner sphere of polyamide are shown in figure 3.8 for 3 different lubrication systems: with clean lithium grease, with fresh lithium grease containing 1 weight percent ZrO_2 nanoparticles as an additive without agglomerations of ZrO_2 nanoparticles and with lithium lubricant with 1 weight percent ZrO_2 nanoparticles left alone for two weeks from preparation to the start of testing in a closed container at 20 ° C, which provoked the appearance of agglomerations of ZrO_2 nanoparticles.

Down below you can see the comparison of four ball wear test for AeroShell Grease 33 with different additives, e.g. Carbon (C), Molibdenum Disulfide (MoS_2) and Zirconium Dioxide (ZrO_2). The weight percent of additives is 2 percent. According to these results, the following conclusions must be made:

1. Performance of AeroShell Grease 33 is significantly improved with any of the three additives.
2. The optimal weight percent of additives is on the appropriate level.
3. Among all additives, Zirconium Dioxide (ZrO_2) shows much better results then the other two and far better then the pure AeroShell Grease 33 with no additives (by 20 percent).

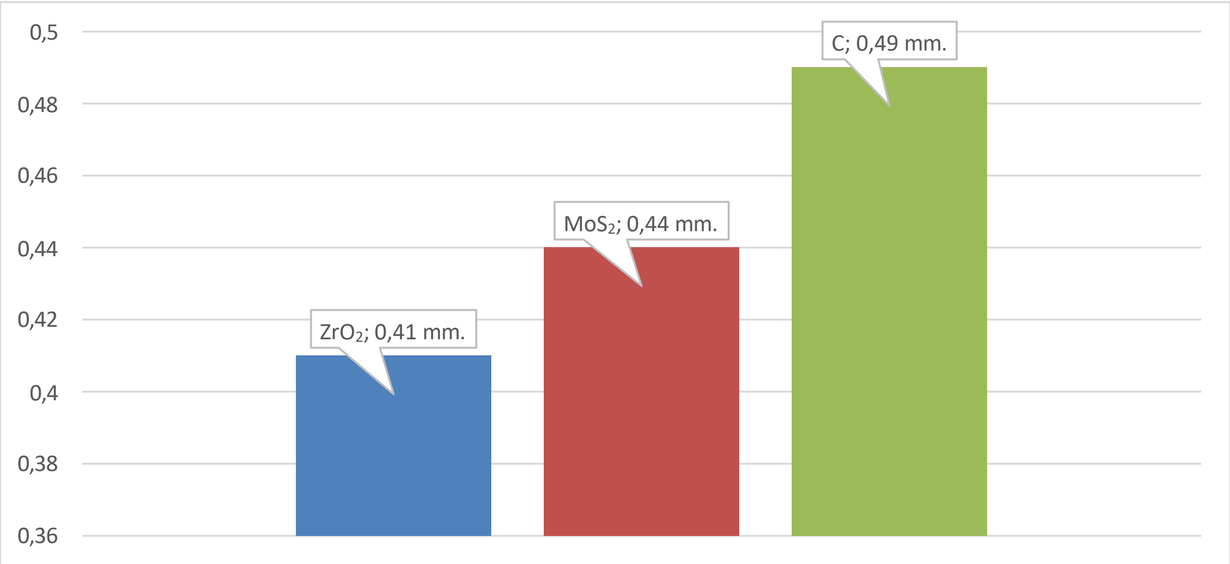


Figure 3.11 – Comparison of grease AeroShell 33 with different additives in four ball wear test

Conclusions to the part 3

This follows from the study of the properties of lithium grease and additives important for it, in particular nanoparticles based on ZrO_2, for the tribological properties of the grease. Agglomeration of such nanoparticles is an undesirable phenomenon not only during the preparation of a lubricant, but also during the subsequent sintering process of ZrO_2 nanoparticles. There are several methods for the preparation of ZrO_2 nanoparticles, however, in addition to them, the agglomeration of nanoparticles cannot be prevented.

For example, a commonly used precipitation method results in aggregated ZrO_2 nanoparticles, which are then disaggregated using a ball mill. In this context, the method based on washing off ZrO_2 nanopowder with water and ethanol, followed by centrifugation with the possibility of deagglomeration using ultrasonic treatment of microtips, looks interesting. The stability of the dispersion of ZrO_2 nanoparticles in oil or grease can be improved either by modifying the surface of such nanoparticles or by using surfactants. The choice of a surface modification method or surfactant application is difficult, and further research is needed for ZrO_2 nanopowders.

There is a clear relationship between the tribological properties of lubricants containing nanoparticles and the agglomeration of such nanoparticles. The addition of 1 weight percent ZrO_2 nanoparticles to pure lithium grease reduced the friction coefficient value to 50 percent, especially at lower loadings in the contact zone. The presence of agglomerations of ZrO_2 nanoparticles in lithium grease doubled the friction coefficient value as compared to pure grease. Moreover, the standard deviations of friction coefficient values are significantly higher than that of a lithium grease without agglomerated nanoparticles.

Part 4. Occupatioal Safety

4.1Analysis of harmful and dangerous production factors.

Harmful and dangerous production factors for aircraft technician:

1) Physical;

a) moving machines and mechanisms; moving parts of production equipment; moving products;
b) the increased dustiness and gassiness of air of a working zone;
c) increased or decreased temperature of surfaces of equipment, materials;
d) increased or decreased air temperature of the working area;
e) increased noise in the workplace;
f) increased vibration level;
g) increased voltage in the electrical circuit, the short circuit of which can occur through the human body;
h) increased level of static electricity;
i) lack or absence of natural light;
j) insufficient lighting of the working area;
k) sharp edges, burrs and roughness on the surfaces of workpieces, tools and equipment;
l) location of the workplace at a significant height relative to the ground (floor);

1) Chemical;

a) toxic;
b) annoying;
c) by penetration into the human body through:
- respiratory organs;
- skin and mucous membranes.

2) Psychophysiological.

a) physical overload;

- static;
- dynamic.

b) neuropsychiatric overload.

- analyser overvoltage;
- monotony of work;
- emotional overload.

Aircraft technician working conditions:

PHYSICAL WORKING CONDITIONS

Often exposed to hazardous equipment. There is some potential for moderate injury from the equipment. Wear protective equipment such as gloves or earmuffs regularly (figure 4.1). Motors are subject to noise and vibration when checked weekly.

Figure 4.1 - Aircraft mechanics draining hydraulic fluid from aircraft

Mostly they work in hangars or other premises. They can work outdoors, sometimes in hot or cold weather. Exposed weekly to contaminants. Sometimes exposed to hazardous conditions, such as standing on scaffolding. Sometimes they are exposed to dangerous situations. There is a possibility that they could cut themselves or burn themselves. However, the extent of the injury will be minor. From time to time they find themselves in cramped workplaces where they need to take an uncomfortable position. Can work next to other people, for example, within a few feet.

LABOR PRODUCTIVITY

It is necessary to make sure that all details of the work are completed and performed accurately. Mistakes can seriously harm the aircraft or passengers. Repeat the same physical and mental tasks. Make regular decisions that affect your colleagues, their employer, and passengers. Make decisions often without first consulting with anyone. For complex tasks, they can consult with others. Can set most of the tasks and goals for himself without checking with the boss. Work in a moderately competitive environment where daily and weekly hazards must be met.

WORKING TIME

Often they work more than 40 hours a week because overtime is common. May work in the evenings or at night because shifts work around the clock. Usually they work according to the established schedule.

4.2 Measures to reduce the impact of harmful and dangerous production factors.

To determine the required air flow, we need to calculate two values of air exchange: the number of people and the multiplicity and then choose the larger of these two values:

Calculation of air exchange by number of people:

L = N * Lnorm, where

L - required capacity of supply ventilation, m^3 / h;

N - number of people;

Lnorm - air consumption rate per person:

at rest (sleep) - 30 m^3 / h;

typical value (according to SNiP) - 60 m^3 / h;

Calculation of air exchange by multiplicity:

L = n * S * H, where

L - required capacity of supply ventilation, m^3 / h;

n is the normalized multiplicity of air exchange:

for living quarters - from 1 to 2, for offices - from 2 to 3;

S - area of the room, m^2;

H - height of the room, m;

Calculation of the sizes of air ducts

The estimated cross-sectional area of the duct is determined by the formula:

Sc = L * 2,778 / V, where

Sc - calculated cross-sectional area of the duct, cm^2;

L - air flow through the duct, m^3 / h;

V - air velocity in the duct, m / s;

2,778 - coefficient for coordination of various dimensions (hours and seconds, meters and centimeters).

We get the final result in square centimeters, because in such units it is more convenient to perceive.

The actual cross-sectional area of the duct is determined by the formula:

$S = \pi * D^2 / 400$ - for round air ducts,

S = A * B / 100 - for rectangular air ducts, where

S is the actual cross-sectional area of the duct, cm^2;

D is the diameter of the round duct, mm;

A and B are the width and height of the rectangular duct, mm.

Heater power.

Heater power is calculated by the formula:

$P = \Delta T * L * Cv / 1000$, where

P - heater power, kW;

ΔT is the difference between the air temperatures at the outlet and inlet of the heater, ° C.

L - ventilation capacity, m^3 / h.

Cv is the volumetric heat capacity of air equal to 0.336 W · h / m^3 / ° C.

The maximum current consumed by the heater can be calculated by the formula:

I = P / U, where

I is the maximum current consumption, A;

P - heater power, W;

U - supply voltage:

220V - for single-phase power supply;

660V (3 × 220V) - for three-phase power supply (when connecting heaters "star" between 0 and phase)

Calculation of productivity (air exchange) and air supply network.

Air network parameters

Main air duct

Type of main air duct: Round rigid

Length of the main air duct, m: 10

Number of 90 ° turns on the duct: 3

Air speed in the main air duct, m / s: 4

Additional air filter: No.

Branches from the master. air duct

Type of air ducts - branches: Round rigid

Length of the longest branch, m: 50

Number of 90 ° turns on the branch: 2

Air velocity in air ducts - branches, m / s: 3

Noise level on internal grilles: 25 dB (A), quiet

1.2. Calculation of productivity on rooms

Number of rooms: 1

Room №1

Calculation by number of people

Maximum number of people: 50

Consumption rate per person, m^3 / h: 60

Productivity on people: 720 m^3 / h

Calculation of the multiplicity of air exchange

Multiplicity of air exchange: 1.5

Room area, m2: 500

Ceiling height, m: 20

Multiplicity productivity: 3000 m³ / h

Productivity for the room №1: 3000 m³ / h

Duct cross-sectional area: 2778 cm²

1.3. Calculation of total network performance and resistance

Total productivity: 3000 m³ / h

The cross-sectional area of the main air duct: 2084 cm²

Resistance of an air supply network: 54 Pa

5 Calculation of heater power

With a capacity of 3000 m³ / h (2001 m³ / h for the ventilation system) and air heating at 44 ° C (-26 ° C to + 18 ° C).

Use calculated performance values

Productivity of system of ventilation, m³ / h: 3000

Outdoor air temperature, ° C: -26

Supply air temperature, ° C: +18

4.3 **Occupational Safety Instruction.**

1. General provisions

1.1. Instruction on labor protection when performing work at height is developed in accordance with the Law of Ukraine "On labor protection" (Resolution of the Verkhovna Rada of Ukraine from 14.10.1992 № 2694-XII) as amended on 20.01.2018, based on "Regulations on the development of instructions on labor protection », Approved by the Order of the Committee on Labor Protection Supervision of the Ministry of Labor and Social Policy of Ukraine dated January 29, 1998 № 9 as amended on September 1, 2017, taking into account the Rules of labor protection during work at height (NPAOP 0.00-1.15-07) approved by the order of the State Committee of Ukraine for Industrial Safety, Labor Protection and Mining Supervision on March 27, 2007 № 62.

1.2. This instruction on labor protection when performing work at height applies to all employees of the educational institution when performing work at height in order to ensure the safety of employees engaged in work at height and persons in the immediate area of these works.

1.3. Employees who perform work at height are obliged to:

know and comply with the requirements of the Rules of labor protection when performing work at height, other regulations and this instruction on labor protection when performing work at height; take care of personal safety, as well as the safety of others while performing any work; perform work with the use of helmets, seat belts, other means of individual and collective protection; undergo a medical examination in the prescribed manner.

1.4. Work at height is considered to be work in which the worker is at a height of 1.3 m or more from the surface of the ground, floor or work surface and at a distance of less than 2 m from the limit of the difference in height.

1.5. Work performed at a height of more than 5 m from the ground, floor or work floor is considered climbing. These works are carried out directly from structures or equipment during their installation or repair, and the main means of protecting the worker from falling is a seat belt.

1.6. The main danger when performing work at height is the location of the workplace at a significant height relative to the ground (floor). In this regard, there is a high risk of the worker falling from a height or falling objects on workers who are at the bottom in the immediate vicinity.

2. Safety requirements before starting work

2.1. The control over the condition of the ladders in the educational institution is carried out by the head of the farm, who is responsible for the safe performance of work related to the ascent and height.

2.2. Lifting equipment should be inspected before starting work. Inspection of ladders immediately before their use should be performed without entries in the logbook and inspection of rigging tools, mechanisms and devices. In case of doubt in their serviceability, the person responsible for labor protection should be involved.

2.3. The use of means intended for lifting to a height, not for its intended purpose is prohibited. If it is necessary to perform such actions after their implementation, unscheduled tests of lifting equipment must be organized with an entry in the logbook of inspection and inspection of rigging equipment, mechanisms and devices.

2.4. Before starting work, make sure that the lifting device is stable, make sure by inspection and testing that the ladder or ladder cannot slip or be accidentally moved.

2.5. When installing additional stairs in such conditions, when there may be cases of displacement of their upper end, the upper part of the stairs must be securely fastened to the stable structural elements.

2.6. Work by workers who do not have proper personal protective equipment or with faulty personal protective equipment is prohibited (figure 4.4).

2.7. In case of detection of malfunctions of equipment and means of collective protection, notify the person responsible for carrying out this work and do not start work until the identified malfunctions are eliminated.

3. Safety requirements when working at height

3.1. Work at height can be started only after the completion of all preparatory work and activities with the permission of the person responsible for work at height.

3.2. Depending on the type of work performed at height, the employee must comply with the requirements of the rules for the use of personal protective equipment and the equipment and tools used.

3.3. When working at height, you should follow the regime of work and rest, established by the rules of internal labor regulations.

3.4. When working at height, the following requirements must be observed:

- not to arrange a ladder on steps of a stairwell;

- not to arrange additional support structures from boxes, barrels, etc. in case of insufficient length of a ladder;

- do not work from the two upper steps of the ladder, which have no railings or stops;

- not to be on the steps of the ladder more than one person;

- do not raise, lower the load on the ladder and do not leave the tool on it;

- not to work near and over rotating mechanisms, working machines, conveyors, etc.

- do not perform gas-electric welding works;

- do not perform work on pulling wires, do not support heavy parts, etc .;

- do not perform work using electric and pneumatic tools.

3.5. Works on cleaning of windows, plafonds, lamps, light lanterns, etc., performed at height, are works with increased danger and must be provided:

- the choice of detergent;

- method of cleaning (dry, semi-dry, wet);

- the choice of methods of protection of glasses from aggressive pollution;

- choice of cleaning method (manual, mechanized);

- the choice of means and methods of access to glazing (scaffolding, scaffolding, ladders with a work platform);

- workplace organization;

- choice of overalls, footwear and other personal protective equipment.

3.6. When wiping the glass at height, it is necessary to comply with the requirements contained in this instruction on labor protection when working at height, modes of operation in the cold season when working outdoors, established by the rules of internal labor regulations. Wiping windows at height is allowed in daylight. The main dangerous factors when performing work at a height of glass cleaning are [59]:

- the possibility of injury when falling from a height;
- the danger of getting cuts on the sharp edges of window frames and glazing defects (cracked and loose glass);
- influence of adverse meteorological factors during work (wind loadings,
- influence of negative temperatures);

- influence of noise, vibration.

3.7. When wiping windows at height, the employee must:

- perform only the work that was entrusted to him;
- to start work after checking the serviceability of lifting equipment and work at height, as well as making sure by external inspection of the serviceability of personal protective equipment and safety devices;
- in case of threat to life and health, work should be stopped immediately;
- immediately report to the organizer of works or the direct supervisor about the threats or accidents which have arisen in the course of work;
- fastening of a safety belt should be carried out only for elements of designs in the places specified by the organizer of work;
- if possible, supplement and strengthen personal protective equipment or insurance if the protection kit used under the previous work plan is insufficient;
- during performance of work to observe requirements of the instruction on fire safety of establishment.

3.8. When cleaning and wiping the glass at height, the employee is prohibited from:

- perform work simultaneously on two levels in order to avoid the fall of the means of performing work;
- drop objects from a height;
- wipe the outer planes of the glass protruding from the open windows and transoms;
- get up on the window sills;
- touch the external wiring with your hands or means of work;
- wipe the glass with a sharp local pressure on the glass or shocks;
- use detergents to wipe the glass in violation of the instructions on fire safety and industrial sanitation.

3.9. When performing other work at height, the same safety requirements should be observed when organizing and performing work as for work when wiping glass.

3.10. Work at height, which is carried out outdoors, must be stopped in winds of more than 6 points, heavy ice and snow. It is not allowed to perform work at height in open places at wind speeds of 13 m / s and more, in ice, thunderstorms or fog.

3.11. If malfunctions are detected during work at the workplace, in equipment and means of collective protection, stop work, switch off equipment and devices. Notify the supervisor and do not resume work without instructions.

4. Safety requirements after work

4.1. Remove the means of work, fences and lifting equipment to the places provided for their storage.

4.2. Remove personal protective equipment and auxiliary tools.

4.3. Wash your hands thoroughly.

4.4. If deficiencies in the operation of equipment and means of collective protection are detected, notify the immediate supervisor or another official.

5. Safety requirements in emergency situations

5.1. At detection of malfunctions of the applied tool and the equipment or creation of an emergency situation at performance of works it is necessary [61]:

- stop work immediately;
- warn others of the danger;
- immediately inform the manager about what happened, help eliminate the emergency situation;
- provide first aid to the victim, call an ambulance or take measures to deliver him to a medical institution.

5.2. In the event of a fire, immediately start extinguishing with fire extinguishers and notify the fire brigade by phone 101.

Conclusion to the part 4

Aircraft technician is often exposed to hazardous equipment. There is some potential for moderate injury from the equipment. Wear protective equipment such as gloves or earmuffs regularly. Motors are subject to noise and vibration when checked weekly. It is necessary to make sure that all details of the work are completed and performed accurately. Mistakes can seriously harm the aircraft or passengers.

Often they work more than 40 hours a week because overtime is common. May work in the evenings or at night because shifts work around the clock. Usually they work according to the established schedule.

In order to reduce the negative factors the Occupational Safety Instruction is given. It consists of five main chapters and includes all the necessary information for safe work performance at high altitude.

5. Environment protection

5.1. Analysis of the impact on the environment during the production, operation and disposal of rubber products.

IMPACT OF THE RUBBER INDUSTRY ON ENVIRONMENT

In recent decades, there has been a clear tendency to increase environmental pollution due to intensive technogenic human activities. Petrochemical enterprises, especially production of rubber products are a source of dust. Its particles havetangible negative effects on the human body and often cause serious health problems. In addition, contaminants in the composition ventilation emissions enter the natural environment and harm organisms in the environment.

Worn tires are a very harmful tool for the environment (figure 5.1). This is due to the peculiarity of their production and the properties from which they are made. It is the tires that make up most of the rubber waste. To a lesser extent, rubber tubes, gaskets, belts, rugs and the like are formed.

Figure 5.1 – Environment pollution by rubber produts

A tire is made up of different layers and materials, each with a different function. Rubber - mechanical and synthetic, all components are selected in such a way as to provide maximum service life and the greatest resistance to mechanical damage and environmental influences. On the one hand, this allows the tires to last for years. Tires contain a variety of synthetic chemicals that are extremely harmful to the environment. Burning tires does not solve the problem of recycling. As a result of the compound, toxic substances are released into the atmosphere, which poison the air, harming not only the environment, but also human health. Old tires are often scattered around yards, on the side of the road, and many of them are thrown in forests or other inappropriate places.

Few people ask themselves what happens to waste and how it affects the environment. It turns out that tires degrade very slowly, a consequence of properties required for strength and durability in service. Because of this, the negative impact of tires for a long time - more than 100 years. Used tires are one of the main types of industrial waste. Despite the fact that car enthusiasts still tend to discard tires like regular rubbish, car companies are legally required to hand them over for recycling.

This is absolutely correct, because the number of vehicles is constantly growing, which increases the amount of car waste. The prices for the disposal of tires and tires differ significantly, but now more and more organizations are appearing that offer the disposal of tires, tires, used oil, batteries and other waste. It seems that in a few years, motorists will be obliged to hand over hazardous waste for recycling.

The positive quality of recycling old tires is that as a result of their recycling, products can be obtained that are useful in many industries, for example, in construction, in the laying of roads, etc. In particular, used tire crumbs are injected into the asphalt mixture for road surfaces, which increases the grip of the tires on the track surface. The work of enterprises of the rubber industry, which includes the production of tires, rubber products, household and medical products, accompanied by release of significant amounts of various volatile substances into the air.

Among the latter are also substances of varying degrees of danger. Compared to metallurgical and chemical plants, and in cities - and vehicles, quantitative air pollution by rubber industry significantly less, but qualitatively it is so diverse that neglect they can't. In chemical plants that produce rubber products, the smell very harmful. Often, special masks and ventilation systems do not save from it. Air. Everyone knows that rubber has a peculiar smell, which is given by chemical connections. For example, car or bicycle tires contain about fifteen names of harmful chemical compounds, and research by scientists for observation of the health of workers in tire factories makes it possible to assert that workers in such industries are more likely than others to be susceptible to various diseases respiratory tract, circulatory system, cancer. Also it was noted that children whose parents work at chemical enterprises for production of rubber products, often suffer from allergic diseases.

Therefore it can be argued that the toxicity of rubber tires is very high. Problems of environmental safety of materials used for the manufacture of rubber products is given increased importance, since the production of rubber products and carbon black has very harmful effect on the environment (figure 5.2), and petroleum resins, unrefined or incompletely refined mineral oils, bitumens, some N-nitroso compounds, styrene, 1,3-butadiene, etc. Therefore, the study of toxic and carcinogenic properties of raw materials and materials, used for the manufacture of tires, and the search for alternative environmentally friendly materials attract close attention of specialists.

Figure 5.2 – Negative influence of rubber production on the environment

The development of the modern rubber industry is characterized by the following main features: the expansion of the fields of application and assortment of rubber products; toughening of operating conditions of products (temperatures, loads, speeds, aggressive media, etc.); desire to use the cheapest and most affordable reinforcing materials, rubbers and ingredients for impossibility of unlimited increase in their assortment; the need to reduce material consumption of products and labor intensity of their manufacture; security requirements health and environmental protection.

Saving raw materials and materials, development of waste-free technologies, extension of the life of products. The production of rubber products entails the emergence of various adverse consequences, one of which is environmental pollution. Therefore, the main goal of enterprises producing rubber products is the search for ways to minimize the negative impact on the environment becomes. Prevention of possible emergency situations associated with exposure to the environment and readiness to eliminate their consequences is ensured by:

- identification of possible emergency situations and assessment of potential environmental risks;
- compliance with the requirements of the legislation on industrial safety, labor and environmental protection;
- development of plans for response and liquidation of possible emergency situations;
- maintaining the readiness of forces and means to implement liquidation plans emergency situations;
- checking the readiness of forces and means for emergency situations.

5.2. Measures to reduce the negative impact of certain factors on the environment.

Disposal of old rubber. Recycling tires, like other rubber goods, is a very profitable business. The rubber from which they are made has a high content of valuable synthetic rubber - a substance from which fuel can be produced, as well as many other useful things, without leaving any waste. Mechanical processing of tires and rubber goods into crumb. The most common form of used tires is crumb rubber. This is a relatively simple and costly affair.To produce such a crumb from tires, you need: ll metal elements (cords, landing rings) must be separated from the rubber of the tires; this is done by magnetic and cyclonic separators; using a shredder, a roller crusher and a water sieve, the rubber is cleaned and crushed to microscopic 30-50 mm; then separated into separate fractions of different sizes (figure 5.3).

Figure 5.3 – Rubber crumb

The price of crumb rubber also varies depending on the fraction and quality. In addition to the standard above-described method of processing tires into crumb, some others are increasingly used: tires are pulverized with ozone; shock wave. In the process of blowing with ozone, the tires completely crumble and turn into crumbs. The shockwave also has a similar effect.

Useful crumb products. Crumb rubber lasts a long time. It is very durable and resistant to external influences. The baby is not harmed by severe frosts, blows, or flammable substances. It is also easy to paint and separate into parts. This is why this material is a good choice for decorative coatings. Crumbs are used to cover various surfaces.

There are many products which can be made out of rubber crumb: floors of car repair shops, car washes, chemical laboratories and factory workshops and warehouses, as well as other surfaces in which strength and shock resistance are very important (car bumpers, berth fenders, etc.); a variety of surfaces, in which the main thing is softness, good adhesion to the sole of the shoe and durability (sports tracks and grounds, the surface of tennis courts, sidewalk tiles, entrance steps of buildings); garden and park paths, terraces and summer cottages.

The crumb is a good insulating material. It produces: he soles of rubber boots, boots and other footwear; various fillers: crumbs are especially often used to make fillers for sports equipment; thermal and moisture insulating materials for the protection and insulation of various buildings.

Processing into fuel by pyrolysis. Pyrolysis is an opportunity to create fuel with good heat output (high calorific value) from tire rubber and other rubber goods and leave no waste. Using a special installation rubber: tightly packed and sent to a retort; the retort is placed in a special pyrolysis vacuum oven; there the rubber is heated to very high temperatures (more than +500 Celsius degrees) so that it decomposes and turns into a combustible high-calorie substance – pyrocarbon (figure 5.4).

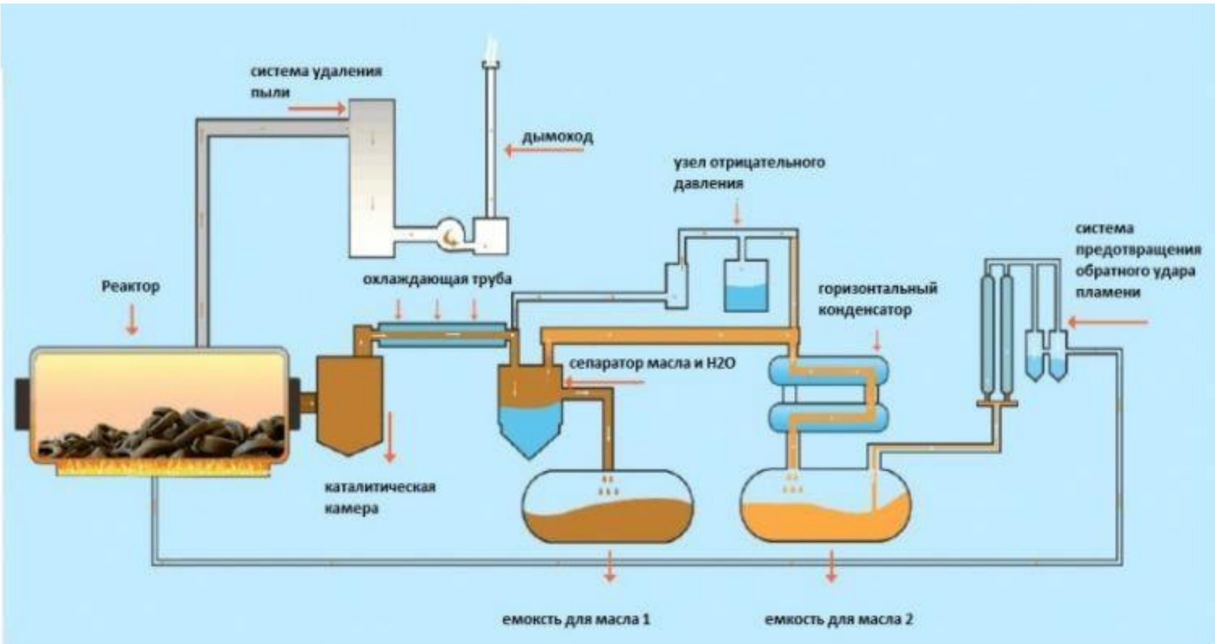


Figure 5.4 – Process of rubber tires recycling into pyrocarbon

Pyrocarbon (after additional purification) can be used to produce synthetic oil, thermolysis gas and carbon black:

1. Thermolysis gas differs little from ordinary natural gas in its properties and heat transfer. It can be used in small boiler rooms.

2. Synthetic oil is almost indistinguishable from conventional fossil oil. From such fuel (but only after distillation), you can create real gasoline and fuel oil. Also, synthetic oil can be used to heat various large rooms. This is why it is used in North American pulp and paper mills and cement factories.

3. Carbon black. This substance is used to make:

- mastic bases, as well as various pigments;
- fillers for a variety of rubber products;
- conveyor belts;
- sidewalk coverings;
- sorbents.

Conclusion to the part 5

Disposal of waste tires is one of the most painful environmental the problems of our time. Burning tires produces a wide range of toxic connections. In addition, harmful substances such as carbon monoxide and carbon dioxide, sulfur oxides and soot are formed. Tires thrown into landfills or buried under natural conditions decompose for at least a hundred years. Contact of tires with rainfall and soil water leads to the leaching of a number of toxic organic compounds: diphenylamine, dibutyl phthalate, phenanthrene and other carcinogenic compounds.

Of the multimillion-dollar number of used tires, only 23% of tires find the use of combustion for the purpose of obtaining energy, mechanical grinding for road cover and so on. The remaining 77% of used tires are not recycled due to the lack of a cost-effective disposal method. Worn tires are formed and accumulate in motor vehicles, industrial enterprises, tire fitting and car service enterprises, as well as in the private sector. In many industrialized countries have methods and programs to supp’ort collection and recycling of used tires. In most cases, the fact itself is paid for recycling of car tires at the rate of 50 - 400 EUR per ton.

Recycling of rubber, including tires, has been engaged since the moment we started it use in industry. In 1910, natural rubber stalls the same how much silver, which contributed to the repeated use of this material in new products. At that time, the content of recycled rubber in rubber products accounted for more than 50%. In the 60s, the content of recycled rubber in industrial products decreased to 20%. In the last decade, cheap oil imports contributed to the widespread distribution of inexpensive synthetic rubbers. Also all steel radial ply tires have become more widespread.

Both of these circumstances have led to a decrease in the level of tire restyling. It should be noted that the cushioned tire is a valuable secondary raw material containing rubber, carbon black and high quality metal. Cost effective recycling tires will not only solve environmental problems, but also ensure high profitability of processing industries.

General Conclusion and Recommendations

Nowadays modern aviation has a vital part in all apheres of our society. It has dramatically changed such industrial branches as civil transportation, cargo transfer, agricultural development, weather monitoring, military activity and many others. It is impossible to imagine twenty first century without aircraft.

One of the vital systems of aircraft is Landing Gear. It supports the whole fuselage when aircraft is on the ground. And what is even more importantly, the landing gear absorbs the shocks and forces during landing. Therefore, this system must be of incredible quality and durability.

One of the main Landing gear assemblies is main landing gear trunnion pin. Basicaly, this unit is responsible for attaching the whole landing gear shock strut to the aircraft body. It is obvious that this part is subjected to the incredible loads during aircraft landing. And this is why the above mentioned part can damaged or even destructed during lading. This may happen because of variable factors. One of which is lubricating materials the quality of which decreases after some time.

Taking that information into account, the thorough and detailed survey of aircraft greases has been carried out. The studies have shown that the most widely used aircraft greases are Aeroshell Grease 33, Mobill grease 28, Tribolub 2N, Royco and ERA. After studying the results of four ball wear tests, it has became understood that Aeroshell Grease 33 has the best performance among the others.

It was decide to find the way of improvent of Aeroshell Grease 33 lubricating qualities. The most rational was to do this is implementation of grease additives. After studying the properties of the selected grease with such additives as Carbon (C), Molibdenum Disulfide (MoS_2) and Zirconium Dioxide (ZrO_2), it was found out that the additive Zirconium Dioxide (ZrO_2) has the best results in wear resistance test.

Considering the information given above, we come to a conclusion that Aeroshell Grease 33 with Zirconium Dioxide additive is best recommended solution for the represented problem.

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