МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
АЕРОКОСМІЧНИЙ ФАКУЛЬТЕТ
КАФЕДРА ПІДТРИМАННЯ ЛЬОТНОЇ ПРИДАТНОСТІ ПОВІТРЯНИХ СУДЕН

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач кафедри
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«_____»_____________2021 р.

КВАЛІФІКАЦІЙНА РОБОТА
(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ЗДОБУВАЧА ОСВІТНЬОГО СТУПЕНЯ
«МАГІСТР»

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

Тема: «Підвищення ресурсу авіаційних деталей вакуумно-дуговими покриттями»

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Київ 2021

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE

NATIONAL AVIATION UNIVERSITY

AEROSPACE FACULTY

AIRCRAFT CONTINUING AIRWORTHINESS DEPARTMENT

PPERMISSION TO DEFEND
Head of the department
Ph. D., Assoc. Professor
_____________ O. V. Popov
«____”_______________ 2021

MASTER'S DEGREE THESIS

(EXPLANATORY NOTE)

GRADUATE OF EDUCATIONAL DEGREE

«MASTER»

FOR EDUCATIONAL-PROFESSIONAL PROGRAM
«MAINTENANCE AND REPAIR OF AIR VESSELS AND AVIATION ENGENS»

Topic: «Increasing the service life of aircraft parts with vacuum arc coatings»

Created by: ___________Y.V. Lukianenko

Supervisor: Ph. D., Assoc. Professor ___________A.M. Khimko

Advisers on Individual Sections:

Labour precaution: Ph. D., Assoc. Professor _____________V.V. Kovalenko

Environmental protection: Ed. D., Professor _____________T.V. Sayenko

Standards Inspector: ____________

Kyiv 2021

NATIONAL AVIATION UNIVERSITY

Faculty: Aerospace faculty
Aircraft Continuing Airworthiness Department
Educational and Qualifications level: «Master Degree»
The specialty: 272 «Aviation transport»
Educational-professional program «Maintenance and Repair of Aircraft and Engines»

APPROVED BY
Head of the department
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«____”______________ 2021

Graduate Student's Degree Work Assignment

LUKIANENKO YEVHENII VITOROVICH

1. The topic of the work: **«Increasing the service life of aircraft parts with vacuum arc coatings»** approved by the Rector's order of October 11, 2021 № 2196/ст.

2. The work fulfillment terms: since October 25, 2021 until December 31, 2021.

3. Initial data for the project (thesis): vacuum-arc coatings of solid and soft chromium, molybdenum and electroplated chromium coating, the conditions of the coatings work, base and counter-body material.

4. The content of the explanatory note: analysis of titanium alloys use in aircraft building and methods for improving wear resistance of titanium alloy details in fretting conditions, the study of vacuum arc and galvanic coatings deposited on titanium alloy parts wear in fretting conditions, development of measures for labor precaution and environmental protection and measures for improving of flight safety.

5. The list of mandatory graphic materials: pictures of titanium parts damage as a result of wear, the scheme of applying vacuum arc and galvanic coatings, diagram of linear wear relation of the surfaces at loading 20 MPa and 30 MPa, fractography pictures of samples surfaces.

6. Calendar schedule

Task	Fulfillment term	Completion mark
Literature review of materials for degree work	**25.10.2021-01.11.2021**	
Analysis of technological process of work fulfillment	**02.11.2021 – 09.11.2021**	
Preparation of necessary equipment for research carrying out	**10.11.2021 – 14.11.2021**	
Work on a special part of degree work	**15.11.2021 – 22.11.2021**	
Processing of research results	**23.11.2021 – 30.11.2021**	
Fulfillment of individual sections of degree work	**01.12.2021 – 09.12.2021**	
Processing of master's degree work	**10.12.2021 - 25.12.2021**	

7. Advisers on individual sections

Section	Adviser	Date, Signature	
		Assignment Delivered	Assignment Accepted
Labour precaution	Ph. D., Assoc. Prof. V. V. Kovalenko		
Environmental protection	Ed. D., Professo T.V. Sayenko		

8. Assignment issue date «_____»___________ 2021.

Degree work supervisor: ___________________ A.M. Khimko
(signature)

Assignment accepted for fulfillment ____________________ Y.V. Lukianenko
(signature)

ABSTRACT

The explanatory note to master's degree work « Increasing the service life of aircraft parts with vacuum arc coatings» contains:

104 pages, 38 figures, 4 tables, 33 literature sources.

Object of study is the different types of vacuum-arc and galvanic coatings and structural material BT-22, that are damaged by contact interaction in friction units.

The purpose of degree work is investigation of vacuum arc and galvanic coatings wear mechanism in fretting conditions and development of recommendations in improvement the wear resistance of high strength titanium alloy BT-22.

The scientific novelty of the work is that the author personally conducted experiments on the wear resistance of galvanic and vacuum-arc coatings and conducted comparative analyzes with other well-known gas-thermal coatings.

Research method - laboratory studies of the wear mechanisms of vacuum arc and galvanic coatings on the parts made of titanium alloy BT-22 in fretting conditions in the АМГ-10 medium and in dry conditions.

A complex analysis of the aircraft titanium alloys details operational fault probability and methods for their restoration was conducted. A complex study on qualitative and quantitative parameters of mating surfaces friction, on vacuum arc and galvanic coatings fretting resistance testing was conducted.

All these issues are described as fully as possible, thesis is completed in accordance with all requirements of the degree works fulfillment, the specifics of specialty is taken into account.

This degree work contains described measures in strengthening and further restoration of titanium aircraft details, it contains recommendations concerning the use of vacuum-arc and galvanic coatings for titanium alloy details restoration in order to enhance flight safety level, aircraft reliability and reduce environmental impact. This work was directed for solving these problems.

FRETTING, FRETTING CORROSION, WEAR, GALVANIC COATING, TITANIUM, RESTORATION

LIST OF ABBREVIATIONS

FC- fretting corrosion

GTE - gas turbine engine

MO – mineral oil

КП – cathodic amplifier

АП – anodic amplifier

РКТ – cathodic current regulator

РАТ – anodic current regulator

ЕК– electronic commutator

ПП– programming device

I_m - first value of operation for a turnaround flight time of the aircraft

I_{gon} - allowable response

I_{np} - limit operation

H_p - altitude

S - area of the rom

a - width

b - length

E_n - illumination

ρ_c - reflectance value of ceiling

ρ_w - reflectance value of walls

ρ_s - reflectance value of working surface

K - assurance factor

N - number of lamps

P - power of lamps

INTRODUCTION

Ensuring high levels of durability and wear resistance of friction parts is a decisive factor in improving reliability and service life of modern machines. Statistics shows that about 80% of faults in the machines are caused by wear and fracture of friction surfaces of machine parts. For aircraft the loss of details performance in the friction nodes is most often associated with the development of fretting.

The landing gear details are one the most critical details of modern passenger and cargo aircrafts. The analysis of landing gear materials revealed that such world famous companies as Boeing, Airbus, Antonov more often use titanium alloys for landing gear details production. These alloys meet the working conditions of the landing gear in terms of endurance, but they have low wear resistance.

With the help of coatings application many problems can be solved. Such as improving weather resistance and operational stability, grip strength, heat resistance, erosion resistance, protective properties and chemical resistance for a calendar resource.

Therefore it is necessary to choose the coating to apply it on the details friction surfaces which can not only increase the wear resistance of new components, but can be used during the restoration processes.

It should be noted that the possibilities of increasing wear resistance have their own limit and it is impossible to avoid wear completely. Therefore, it is important to develop technology for recovery of such items.

The aim of the degree work is to investigate the wear mechanism of vacuum arc and galvanic coatings in fretting conditions and to develop recommendations in improvement the wear resistance of high strength titanium alloy BT-22.

To achieve this goal we have solved the following problems:

1. To analyze the operational damageability of aircraft details produced from titanium alloys and their restoration methods.

2. To provide research of vacuum-arc and galvanic coatings wear resistance in the medium of liquid АМГ-10 and in dry conditions in a wide range of loads.

3. To carry out a set of comparative studies in selection the optimal vacuum arc and galvanic coatings for titanium aircraft parts.

4. To develop recommendations for the use of vacuum-arc coatings for strengthening and restoration of aircraft parts made of high strength titanium alloy BT-22.

Subject of research - to establish the regularities of interaction of vacuum-arc and galvanic coatings of titanium alloys parts and steel 95Х18Ш under fretting.

Object of research - the interaction of vacuum arc and galvanic coatings of titanium alloys parts and steel 95Х18Ш under fretting.

A complex analysis of the operational details of damageability of aircraft parts made from titanium alloys and the methods for their restoration were conducted.

It was determined for the first time, that the proposed vacuum-arc coatings have worse wear resistance than galvanic coatings. But in some cases (at a load of 20 MPa) solid chromium vacuum-arc coating has greater wear resistance characteristics than the galvanic one, but low bonding strength of hard chromium coatings leads to rapid destruction of the surface with increasing load.

It was found that if there is wear of the coating, the surface fracture increases dramatically due to the high propensity of titanium alloys to grip. In connection with this it was proposed to observe the work of the vacuum-arc and electroplated coatings on titanium alloy BT-22 when friction with the hydraulic fluid АМГ-10 and in dry conditions. The recommendations on the use of vacuum arc coatings for hardening and restoration of aircraft parts made of high strength titanium alloy BT-22 were proposed.

On the basis of these studies practical recommendations for the introduction of vacuum arc coatings in Antonov Conpany for the aircraft parts made of titanium alloy BT-22 were developed.

All the main results were obtained by the author in person or by his direct participation. The author was directly involved in preparing and conducting experiments, in determining the wear of the samples, conducting the surface factography and analyzing the results.

CONTENT

PART 1

ANALYSIS OF THE USE OF TITANIUM ALLOYS IN THE AIRCRAFT INDUSTRY

1.1 Titanium and its usage in aviation

Requirements of materials for aircraft:

1. small weight
2. high specific strength
3. heat resistance
4. fatigue load
5. crack resistance
6. corrossion resistance

In subsonic aircraft it is widely used aluminum. Aviation techniques of supersonic speeds faced with higher temperatures of the aircraft skin where aluminum can not be used because of the low heat resistance. So it was needed structural materials that can reliable operate in a complex combination of power and temperature fields under the influence of aggressive media, radiation and high pressures. Titanium and its alloys met all these requirements.

Today airplanes are becoming of greater amount of titanium. This is due to the fact that in the new airplanes it is increased share of the composite materials with which aluminum is actively engaged and corrode. Titanium is not subjected to these processes and increases the life of components.

Three major trends of titanium in aviation:

1. Fabrication of complex spatial form:

- Hatch and door edging, where it is possible accumulation of moisture (high corrosion resistance of titanium is used)
- Skins at which combustion engine product flow acts, fire extinguishing walls (it is used high temperature of melting and chemical inertness of titanium)
- Thin-walled pipelines of air system (using the minimum of all metals thermal expansion coefficient of titanium)
- Flooring of cargo compartment (of high strength and hardness)

2. For heavily responsible manufacturing components and assemblies

- Landing gear
- The power components (brackets) mechanization of the wing
- Hydrocylinders

3. Engine Parts Manufacturing

From titanium alloys in aircraft it can be manufactured: Ailerons, panels and rotary wing units, wall spars, brackets, wheels, air intake ducts, pipelines, frames, slats and flaps, hydraulic systems, hardware and some other parts of details. The percentage of titanium in aircraft [1]:

Boeing 707 - less than 0.5% , Ан-24 - 0.48 % , Ту-154 – 2 %, Boeing - 777 - 8.5 % , Ту- 334 - 8.7 % , Ан-148 - up to 10 % Ил- 76 and Ил -76Т – 12 % from aircraft weight. In the field of aircraft building and production of aircraft engines titanium is increasingly replace aluminum and stainless steel. With increasing of temperature, aluminum quickly loses its strength. On the other hand, titanium has a clear advantage in terms of strength at temperatures up to 430 °C and temperatures increasing of this order arise at high speeds due to aerodynamic heating.

The advantage of steel replacing in aviation is due to reduction of weight without sacrificing the strength. Overall weight with increased performance at elevated temperatures allows increasing the payload, range and maneuverability of aircraft. Due to this there are efforts aimed at expanding the use of titanium in the manufacture of aircraft engines, airframe construction, and manufacturing and even trim fasteners.

When building a jet engine the titanium is used for manufacture of compressor blades, turbine disks and many other molded parts. Titanium displaces stainless and heat- treated alloy steel. Saving of one kilogram in weight of engine allows saving up to 10 kg of the total weight of the aircraft by facilitating the fuselage.

In aircraft design titanium is widely used for parts of the fuselage that work at elevated operating temperatures. Titanium plates are used for production of all kinds of covers, protective cable sheath. From titanium sheets it can be produced various stiffeners, fuselage frames, ribs, etc.

Enclosures, flaps, sheaths for cables are made of unalloyed titanium. Doped titanium is used for production of fuselage frames, pipelines and fire partitions. Titanium becomes increasingly used in the construction of the F- 86 and F- 100. In the future, it will be made titanium landing gear doors, hydraulic lines, exhaust pipes and nozzles, spars, flaps, folding racks, etc.

Titanium can be used for the manufacture of armor plates, propeller blades and rocket boxes.

Currently, titanium is used in aircraft design of military aircraft Douglas X-3 for plating, Repablik F-84F, Curtiss - Wright J- 65 and the Boeing B -52.

Titanium is used in the construction of civil aircraft DC- 7. Firm "Douglas" by replacing aluminum alloys and stainless steel in the manufacture of titanium nacelle and fire partitions has already achieved savings in weight of the aircraft structure of about 90 kg. At the moment the weight of titanium parts in this plane is of 2 %, and this value is going to be changed up to 20 % of the total weight of the aircraft [2].

Application of titanium can also reduce weight of helicopters. Titanium plates are used for floors and doors. Significant reduction in the weight of a helicopter (about 30 kg) has been achieved by replacing steel with titanium alloy cladding its rotor blades. Consumption of titanium in civil aircraft also groves and it is clear why. Titanium combines the key performance parameters of the aircraft - the weight, reliability, maintenance cost and profit from exploitation. These are the main criteria for air carriers.

Currently, developers of aircraft overhaul the concept of building aircraft material actively involving and using composite materials that based on carbon fiber and titanium alloys. First replace aluminum and steel, the second corrosion resistance and extremely robust.

There are several reasons why it is necessary to use composite materials. First, there has been rapid growth in passenger and freight, the volume of which is forecast due to specialized analytical group Airline Monitor, in the period from 2008 to 2026 will be tripled, which would require to double the park mainline airliners. Second, due to high fuel prices companies have to develop and prepare the serial production of fuel-efficient models of airliners.

Since composites "gets" only with titanium the demand of civil aircraft for titanium semi products will increase by 2015 approximately doubled.

In " Dream Aircraft » Boeing 787 - the leader of a new generation of aircraft it is used a new high-strength titanium alloy VST 5553. The biggest punching landing gear beam of A380 weighing 3.5 tons is made of titanium. Manufactured stamping is made on modernized forging equipment, the most powerful in the world.

In ordering such aviation giants as Boeing, titanium share of 30 - 40 %, in the European company Airbus – 55 - 60 %, Brazil's Embraer – 90 % in the Canadian Goodrich - the world's largest manufacturer of landing gear – 90 %.

Titanium alloys are mainly used in a glider aircraft for such parts and structures as trim, power set, fastenings, landing gear, mechanization wing pylons, cylinders, multiple units, etc. Titanium alloys are used in helicopters mainly for parts of the rotor and the drive and control system. From titanium alloys are manufactured rotor head, tail rotor hub, trunnion bracket, housing axial joints, tips of the blades. Helicopter parts are done from titanium alloys BT 6, BT 5-1 and in future it will be tested the high-strength alloys BT22 [3].

Application of titanium in gas turbine engines, namely, turbofan engines

Titanium alloys are used in engines primarily for the manufacture of the fan and compressor components, i.e. discs, blades, guide vanes, intermediate rings, motor housing, various body parts, air intake, and some other details.

Decline in military and civil aviation industry has led to a decrease in consumption of titanium up to 53-56 tons in 1994-1995. Growth in demand for titanium in recent years due to the improvement of the situation of civil aircraft (each a Boeing - 747 and -777 spent more than 40 tons of titanium, titanium alloys details weight is 7 % of the weight of the aircraft), as well as increased demand from the producers of equipment for energy, sports equipment, coatings for roofs, their interior decoration. Currently in the western world it is consumed about 60 tons of titanium, in the USA - 32 - 33 tons, Japan - 18-20 thousand tons. In 1998 in the USA demand for titanium decreased to 9 % to 21.1 thousand tons [4].

In the western world in the aerospace industry uses 41 % of titanium (24.6 tons), including 33 % in the civil industry and 8 % in military industry, 47 % (28.2 tons) - in other industries (chemical , energy, desalination plants , etc.) and 12 % (7.2 tons) - in the newly emerging field (sporting goods - 8 %, and armor – 2 %, etc.).

In the USA in 1996, 45 % of titanium was consumed in civil aircraft, 15 % - in the military industry and 40 % - in other industries, including chemical, oil and gas, shipbuilding, medicine.

In Western European countries, the aerospace industry uses about 9 thousand tons of titanium, of which 8 tons - in civil aircraft, one thousand tons - in the military, and 5,000 tons used in engines, 3,500 tons - in airplanes, 500 tons - in rockets and satellites. Among used in Western Europe predominates alloys Alloy Ti-6A1-4V (80-85 %), followed Alloys Ti-10V-2Fe-3Al; Ti-6Al-2Sn-4Zr-2Mo-Si (including 10-15 %), and commercially pure titanium (4%), titanium aluminides are under investigation and testing as engine parts. It is projected that in the next 3-5 years, consumption of titanium in Western Europe will remain at the current high level and can be increased by 10 % mainly due to increased consumption of blanks for drives (up to 1600 t/year) and sheets of superplastic deformation. The leading countries of producers and consumers of titanium mill products – the USA, Japan.

Titanium has many benefits and only one drawback - the high cost. The last latter led to the fact that titanium, first began to use the strategic purposes. It was only much later titanium has found application in medicine and civil areas in the industry. Proportion of titanium is 4.505 grams per cubic centimeter. Compare with iron - 7.8 grams per cubic centimeter and aluminum - 2.7 grams. Thus the strength of titanium is twice higher than that of iron and nearly six times the strength of aluminum. The particularly important property of titanium is retaining of strength at high temperatures. This fact determined the widespread usage of titanium in aircraft and rocket. In modern aircraft, civil and military, the most loaded parts are made of titanium. This provides a significant gain in weight while maintaining the required strength characteristics.

Advantages:

• low density (4500 kg/m^3) helps to reduce weight of the material;

• high mechanical strength. It is necessary to note that at elevated temperatures (250-500 °C) titanium alloys are superior to high- strength alloys of aluminum and magnesium;

• high corrosion resistance due to the ability of titanium to form on the surface of thin (5-15 microns) solid oxide film TiO_2 strongly associated with the mass of metal;

• specific strength (ratio of strength and density) of the best titanium alloys is 30-35 or more, almost twice the specific strength alloy steels.

Disadvantages:

• the high cost of production. It is considerably more expensive than iron, aluminum, copper and magnesium;

• active reacting at high temperatures, especially in the liquid state, with all gases constituting the atmosphere, resulting in titanium and its alloys can be melted in a vacuum or in an inert gas;

• difficulties involved in the production of titanium waste;

• poor antifrictional properties due to titanium sticking on many materials, titanium paired with titanium can not work on friction;

• the high propensity of titanium and its alloys many to hydrogen embrittlement and salt corrosion;

• high chemical activity, tendency to grain growth at high temperature and phase transformations in welding cycle cause difficulties in welding titanium [5].

Modern parts of titanium

Titanium alloys are produced such important products as rotor head helicopters S- 65 landing gear shafts, etc. A very widely applied titanium alloys for the manufacture of the gas turbine engine compressor. Of alloys Ti- 6A1-4V, Ti-8A1-10V, Ti-8A1-1M-IV are produced discs and blades of low and high pressure compressors (at temperatures up to 400 °C). For higher temperatures, the high aluminum alloys are Ti-20A1-2V, as well as newly developed multicomponent alloys

Ti-6A -6V-2Sn-ICu-IFe-3Zr-IGr-IMo and the same alloy but without molybdenum and chromium. According to the company Pratt and Whitney, a compressor blade alloy Ti-6A1-4V had been operated for 7 years without a break. There is information on the manufacture of compressor blades of composite material in the form of a powder alloy Ti-6A1-4V, reinforced with molybdenum wire. The composite metal-ceramic materials are applied to the compressor blades may be created and the two titanium based alloys, for example on the basis of high-purity powders of Ti-6A1 ~ 4V (68 %) N 20 Ti-Nb-7, 5A1. After heat treatment, the material at 593 °C has a higher tensile strength than the alloy Ti-6A1-4V at 427 °C. To improve the temperature characteristics of the alloy there are used such alloys used as a coating consisting of 95 % silver and 5 % aluminum.

Modern industry needs a high strength lightweight alloy having good high-temperature mechanical properties. The main light metal alloys are aluminum, magnesium, titanium, and beryllium. However, the aluminum-based alloys and magnesium-based alloys can not be used under high temperature and corrosive environments. Titanium alloys are better than aluminum and magnesium in respect to the tensile strength and modulus of elasticity. Their density is greater than all other light alloys, but their specific strength is surpassed only by beryllium. At sufficiently low content of carbon, oxygen and nitrogen they are quite malleable. The electrical conductivity and the thermal conductivity of titanium alloys are rather small, they are resistant to abrasion and wear, and their fatigue strength is much higher than that of magnesium alloys. Creep certain titanium alloys with moderate voltages (in the order of 90 MPa) is satisfactory to about 600 °C, which is considerably higher than the temperature permissible for both aluminum and magnesium alloys. Titanium alloys are sufficiently resistant to the action of hydroxides, salt solutions, nitric acid and other acids the active but not very resistant to the action of hydrogen halide, sulfuric acid and phosphoric acid.

Titanium alloys are forgit at temperatures around 1150 °C. They allow the electric arc welding in an inert gas atmosphere (argon or helium), and a point or roller welding. They are not very amenable to machining (gripe cutting tool). Melting of titanium alloys should be performed in a vacuum or a controlled atmosphere to prevent contamination of oxygen or nitrogen impurities causing them to embrittlement. Titanium alloys are used in the aerospace industry for parts operating at high temperatures (150-430 °C), and some special-purpose chemical apparatuses. From titanium-vanadi alloys are manufactured the lightweight armor for combat aircraft cabins. Titaniym-aluminium-vanadi alloy is the main titanium alloy for jet engines and airframes.

Titanium alloys are absolute, and even more so for specific strength (strength divided by the density) are superior to most alloys based on other metals (e.g. , iron or nickel) at a temperature between-250 To 550 °C, and the corrosivity of a alloys are comparable to noble metals.

The most common Ti alloy with 6 % of Al, 4 % of V is used in aviation, rocket and cryogenic engineering, shipbuilding, for the manufacture of chemical and metallurgical equipment, as prostheses in surgery, etc.

Titanium alloy BT3-1 relates to the system Ti-Al-Cr-Mo-Fe-Si. Alloy BT3-1 is among the most developed in the production of alloys. BT3-1 is designed for continuous operation at 400 - 450 °C, this is super alloy with relatively high long-term strength. From this alloy are made titanium bars, profiles, plates, forgings, and stampings (Figure 1.1- 1.3).

Figure 1.1 – Massive and very important parts of Ил-76 and modern landing gear of transport and passenger aircraft of Ilyushin constructional bureau made of titanium alloy BT22

Figure 1.2 – Nuts made from titanium

Figure 1.3 – Titanium details

1.2 Damages of titanium alloy parts

Practically any malfunction is the result of changes in the mechanical properties of the material, design and size of parts of their surface condition. In turn, the change in mechanical properties is due to changes in the composition and structure of the material components.Factors influencing the occurrence of such changes can be divided into 3 groups: design, technological and operational.

Design factors include factors that were taken into account at the design stage:

- Designs of parts and assembly units (shape, size, and gaps in the tighten coupling, roughness and hardness of surfaces, etc.);

- The estimated load speed relative movement, on which depends the choice of material details, type of heat treatment or chemical- heat treatment and overall dimensions;

- Operating conditions, type of lubrication and cooling of parts and assemblies.

Technological factors are factors that are found in the manufacturing stage. They are:

- Methods, accuracy and stability of the receipt of blanks;

- Types of machining and finish process of details;

- Strengthening treatment methods (thermal, chemical-thermal or plastic);

- Correctness of assembly, regulation and test assemblies, units and vehicles.

To operational factors include factors that are caused by the appointment of the machine and its loading and speed modes, intensity of use.

Regardless of the machine destination it must be carried out with operating conditions, the timeliness and completeness of the maintenance, preservation and transportation of accuracy and so on.

Typical failures of machine parts

Faults of machine parts can be divided into three groups: wear, mechanical damage and chemical-thermal damage.

Wear. According type of wear all wear parts can be divided into five groups.

The first group includes the details for which the main factor that determines their longevity is abrasive wear (undercarriage parts working in poor lubrication).

The second group includes wearing parts due to plastic deformation (gears, clutches, flywheels, etc.).

The third group includes parts that fail due to corrosion and mechanical wear (piston, piston ring, parts that operate in hostile environments).

The fourth group is the details durability of which is limited endurance limit (rods, springs, bolts, rods, parts operating under cycling loading) [6].

The fifth group is the details in which durability depends both on the wear resistance of friction surfaces and boundary endurance material parts (gears, gearboxes, transmissions, etc.).

Mechanical damage to the parts. Mechanical damage in detail there are exposed to in service loads that exceed allowable and due to fatigue of the material. To mechanical damage include: cracks, holes, fractures and deformation (bending, twisting, and bending).

The most dangerous at the same time there are cracks that can lead to serious damage.

Cracks can form as a result of shock loads and in the most loaded parts of the details (in the field of internal stress concentrations). It may also occur fatigue cracks due to prolonged exposure of alternating cyclic loads. Most often they appear in the detail frame, body, crank shafts, steering knuckle, leaf springs, and in many other details. Often fatigue cracks are developing in the stress concentration.

Cracks may be a thermal origin as a result of internal pressure, such as during welding of hot and cold cracks, or during quenching. Crack size to the width varies within wide limits, from the visible to the naked eye, to microscopic and they are detected by special instruments.

Deformations in detail occur as a result of dynamic loads and can be observed in such detail as crankshafts, connecting rods, shafts, front axle beams, frames and body parts and so on.

Twisting of details arise from the impact of large torque. Twisting is exposed to different shafts, etc.

Chemical and thermal damage. These injuries include: warping, corrosion, carbon deposits (scale), electro-destruction, etc. Warping can occur due to the high temperatures that lead to structural changes as a consequence of the emergence of significant internal stresses.

Corrosion is the destruction of metals due to chemical or electrochemical interaction with the environment. The results of corrosion appear as solid oxide films or as local damage (stains, pits and so on). Corrosion exposed to a lot of car parts.

Great danger presents the local (random) corrosion. To evaluate and predict the development of local corrosion processes is almost impossible, because in many cases it leads to a sudden failure of system design. Significantly reduces efficiency of welded construction intercrystalline corrosion on line fusing.

In most cases the process equipment exposed to both mechanical and chemical influences.

In the case of common influence of both mechanical and corrosive factors in the surface layers of the metal there can occur interrelated phenomena that contribute to activation of deformation, fracture, chemical and electrochemical reactions. Particularly intensive process of failure occurs in sliding in corrosive environments.

Changing of parts properties can occur as a result of heating in the process to the temperature that affect the heat treatment, and in result response surface layer, reinforced chemical methods - thermal treatment.

Elastic properties of parts are reduced due to fatigue of the material from which they are made. This defect often occurs in parts such as valve springs.

There are other types of wear such as:

- Waterjet wear that occurs due to exposure to the metal surface of solid abrasive particles consisting of process fluid;
- Erosion wear that occurs as a result of shock effects of turbulent jets;
- Cavitation wear that occurs due to exposure of microshock loads to the metal surface those results in the formation of cavities and bubbles;
- Electro-destruction that occurs as a result of exposure of spark discharges to the work piece surface. With this destruction electrons are emitted from the cathode, knock on the work piece surface (anode) metal particles that are dispersed in the environment. These injuries occur at the electrodes of spark.

Natural and accidental deterioration

Natural wear of mechanisms increases with the time of the arrangements. However, the gradual increase of the quantitative worn of metal to a certain boundary does not cause a qualitative change in the mechanism and, obviously, only to this boundary wear can be considered natural (normal). Disaster wear can be reached according to the specified limit.

Figure 1.4. It is represented a growth curve wear of a pair of working parts.

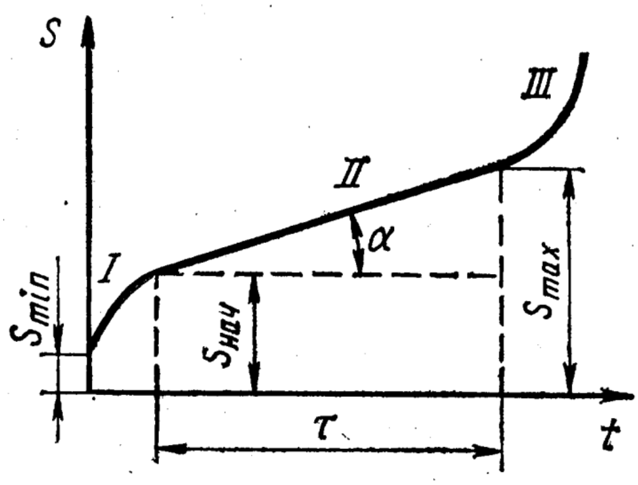


Figure 1.4 – The intensity of wear in time

The curve is valid for most satisfactorily constructed mobile connections operating in steady state. It has three explicit areas: primary and characterizing process of making new connection, the last III area, which corresponds to the period of destruction due to wear of connections over the permissible boundary (emergency wear), and an intermediate section II that is the largest in length and corresponds to the period of normal operation (natural wear and tear). In assessing the overhaul life connection sections I and III must be excluded because the beginning of normal operation is the moment of making ending, and the end is the achieving the maximum allowable wear.

In accordance with a present dependence the specified turnaround time of service connection may be provided as a result of measures that allow support where it is necessary within the meaning of the numerator and denominator. Support for some (not above normal) wear intensity is provided by technical supervision of the machine and support of some (not below normal) landing is provided during repair.

Indeed, if we adopt the same limits expansion of planting, the preservation of the angle of inclination of the curve straight section is the only way to ensure a given overhaul lifetime. You must use the proper oil, good operating supplies, proper regulation, rules that observe the start-up and management, etc. While repair it can influence by the amount of wear intensity only when modernizing (injected additional details) or changing the technology of parts (used durable coating).

The first period of work is characterized by intensive wear in a relatively short period of time - this time is the detaching of details. Wear in this period is largely dependent on the surface roughness, lubrication and load conditions.

The second period that is the largest in length corresponds to the normal operation of details. Wear intensity thus depends on the operating conditions, timely and qualitative service.

The third period is characterized by an intense increase in wear due to an increase in the coupling gap, accompanied by violation of lubrication, overheating, and increased noise. Details with marginal wear to work are permitted and must be replaced or repaired.

Marginal deterioration is called wear is corresponding to the boundary condition of products that wear out.

Permissible wear is called wear in which the product can remain operational during the overhaul period.

The question of the definition of acceptable wear parts during repairs is to find such its size, which ensures trouble-free operation of the car for the next race overhaul. Not the all-too large error, we can assume that the dependence of activation of parts of the operating time is linear (Figure 1.5).

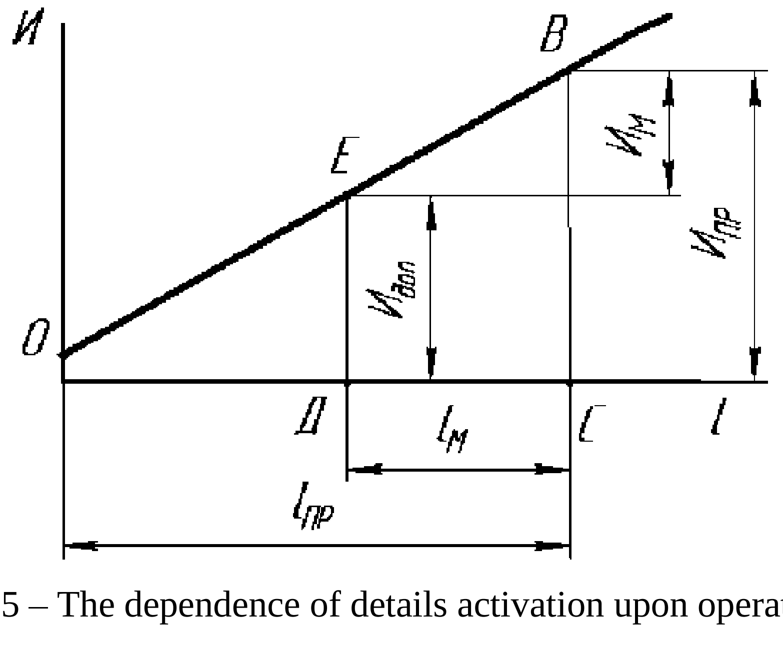


Figure 1.5 – The dependence of details activation upon operating time

Let the value of the limit operation is known and $BC = I_{пр}$. Aside from point C, which determines the details of developments to limit wear, the segment CD that is equal to overhaul the aircraft flying and then restoring the perpendicular from point D to the intersection with the direct agents, we obtain segment DE, the value of which will determine the allowable response $I_{доп}$ details.

Fig. 1.5 shows that the permissible operation.

$$I_{доп} = I_{пр} - I_{м}, \tag{1.1}$$

where:

- $I_{м}$ is the first value of operation details for a turnaround flight time of the aircraft.

The magnitude of response details for turnaround coating is determined as the arithmetic mean value by measuring a lot of pieces taken from planes that entered the repair.

The most common damages of working blades are (typical for most other types of engines).

In the fan:

- leading edge erosion - working blades (change of the radius of curvature front edge, reducing the length of the section chord);
- foreign object damage (significant distortion of the profile);
- end change in the form of blades;
- excessive surface roughness of the blades .

In low-pressure compressor:

- generation of outer ends during friction of the blades working body;
- leading edge erosion of working blades;
- foreign object damage of working blades (changing shape of the front and rear edges);
- pollution of working blades;
- significant increase of the surface roughness of the blades.

In high pressure compressor:

- erosion of working blades (decrease the chord length);
- distortion (sharpening) of the front and rear edges of the working blades;

- significant increase in surface roughness of the blades, pollution;
- increase of blades end gaps due to wear.

The turbine:

- erosion, pitting and burnout of working blades.

Let us consider the main issues of working blades damage and the impact of damage on some operational engine performance.

In operation except power factors that determine configuration of blades and external forces (static, gas-dynamic and vibration), the blades of a number of other factors associated with features influence on the environment in which the engine is operated: ingress of dirt, corrosion, temperature change, erosion, wear, fretting corrosion, etc.

To the greatest extent on the performance of the blades have an impact:

a) "normal" fatigue (alternating voltages associated with the vibrations ,exceed the fatigue strength of the material);

b) reduction of the fatigue strength of the material random nicks, caused by foreign objects (birds, hail, items left at the service particle surface, etc) damage (breaking the mold) due to the ingress of large foreign objects;

c) erosion fine particles (sand);

d) corrosion (mainly has an impact on resistance fatigue).

Comparison of sensitivity to damage of steel and titanium blades of one design shows that more susceptible to damage are titanium blades. The coefficient of reduction of long-term strength of the blades is proportional to the ratio of titanium alloys reduce long-term strength of steel blades with aspect ratio equal to the square root of the ratio of the elastic module of steel and titanium alloy.

It should be noted that a change in the relative depth of nick from 0 to 1 are more susceptible to blades damage made of alloy BT8 that are subjected to high-temperature thermo mechanical treatment and minimum sensitivity - BT9 alloy blade with the same treatment. At relative depth values of nick from 1 to 2 sensitivity to damage of titanium blades that are manufactured in various Technological Options regardless of the alloy type is aligned and relative depth of more than 2 nicks it asymptotically approaches to maximum value.

Mechanical damage of details

Mechanical damages in detail can exposed during operation when service loads exceed the allowable and due to fatigue of the material. Mechanical damage include: cracks, holes, fractures and deformation (bending, twisting).

The most dangerous at the same time there are cracks that can lead to serious damage (Figure 1.6) [7].

Figure 1.6 - Crack in pipelines

Cracks can form as a result of shock loads and in the most loaded parts of the details (in the field of internal stress concentrations). It may also occur fatigue cracks due to prolonged exposure of alternating cyclic loads. Most often they appear in the detail frame, body, crank shafts, steering knuckle, leaf springs, and in many other details. Often fatigue cracks are developing in the stress concentration.

Cracks may be a thermal origin as a result of internal pressure, such as during welding of hot and cold cracks, or during quenching. Crack size to the width varies within wide limits, from the visible to the naked eye, to microscopic and they are detected by special instruments.

Deformations in detail occur as a result of dynamic loads and can be observed in such detail as crankshafts, connecting rods, shafts, front axle beams, frames and body parts and so on.

Chemical and thermal damage

These damages include: warping, corrosion, carbon deposits (scale), electro-destruction, etc. Warping can occur due to the high temperatures that lead to structural changes as a consequence of the emergence of significant internal stresses (Figure 1.7 – 1.8).

Figure 1.7 – Scale on the detail of cylinder piston group

Corrosion is the destruction of metals due to chemical or electrochemical interaction with the environment. The results of corrosion appear as solid oxide films or as local damage (stains, shells, etc.).

Figure 1.8 – Corrosion in the connection bolt-nut

1.3 Friction as a way of damaging details

By nature of the relative motion we can distinguish rolling friction and sliding friction. Simultaneously emit rolling friction with sliding.

Friction is the resistance with relative movement of one body on the surface of another under the influence of an external force that is tangentially directed to the common boundary between the two bodies.

Depending on the availability of lubricant friction we can distinguish the following modes :

- Friction without lubricant;
- Friction with lubricants;
- Friction provided with the help of marginal lubrication [8].

Theory of friction and wear

The most widely used are three theories of friction.

First - **molecular mechanical or adhesive and deformation**. According to this theory, the surface layers of the body friction occurs by two processes: repeated deformation of the surface layers of the contacting surfaces and the formation and rupture of molecular interaction forces in areas of actual contact with their relative sliding. For molecular-mechanical theory, friction and energy dissipation quantitatively dependent on the physical and mechanical properties of detail parts, size and spatial configuration of roughness parameters, the activity of molecular interactions in frictional contact. Under the surface roughness it means a series of microscopic relatively small steps that form surface relief and is considered within the area, the length of which is equal to the base length l. Microscopic step varies from 2 to 800 microns and of height from 0.01 to 400 microns. A necessary condition for the external friction in this case –is the existence of discretion.

Mechanic chemical theory considers friction as the formation and destruction of secondary structures on the working surface. It limits the action of molecular-mechanical theory of domain about abnormal shape wear. Under this approach, the friction force is the sum of the derivatives of the energy dissipation components. It is shown that the amount of heat arising is 70 - 100 % of the mechanical energy spent on friction.

Atomic-molecular friction hypothesis considers this process as sliding of two surface layers of molecules. Because the molecular roughness of sliding surfaces in the direction of the relative velocity vector is accompanied by vibration motion of bodies in a direction perpendicular to this vector.

Friction without lubricant

Friction without lubricant and with no contamination between surfaces is friction in the brakes, friction gears, the friction of textile machinery, food processing and chemical industries, where the use of lubricants due to possible damage to the product or on safety is unacceptable.

According to the molecular-mechanical theory, in actual contact platforms there are forces of molecular attraction, which appear in the distance, which is ten times greater than the interatomic distance in the crystal lattice and increases with increasing of temperature. Molecular forces causes adhesion at sites of contact.

A strong display of molecular forces is setting of surfaces. Friction in this case depends on the zone setting and the resistance of the gap.

Friction without lubricant is accompanied by step like sliding surfaces. So, for example, there is a vibration in industrial equipment ready for use like braking, vibration cutter when cutting.

Friction in the condition of boundary lubrication

During friction, in the condition of boundary surface lubrication the joint bodies are divided by lubricant layer of very small thickness (from thickness of one molecule up to 0.1 microns). The presence of the boundary layer or boundary film reduces the friction strength compared to friction without lubricant in 2-10 times and reduces the wear of conjugated surfaces in hundreds times.

All oils are able to adsorb on the metal surface. The strength of the film depends on the activity of molecules, their quantity and quality. Mineral oil is a mechanical mixture of inactive carbohydrates and includes organic acids, resins and other surfactants.

Almost all of the mineral oil form on metal surfaces the limiting phase of quasi-crystalline structure with thickness up to 0.1 mm, which has quite strong bond with the surface and longitudinal cohesion.

Lubricant molecules are perpendicularly oriented to the solid surface, which allows imagining the boundary film like a pile (Figure 1.9).

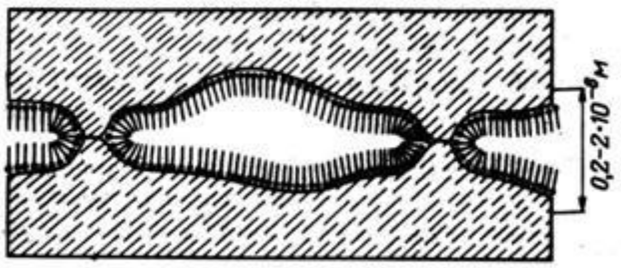


Figure 1.9 – Scheme of rough surfaces boundary lubrication

Mineral oil in the boundary layer is anisotropic. For normal to the solid surface the film has a high resistance to compression, and its bearing capacity is counted in tens of thousands of pounds to 1 cm^2.

Consider the mechanism of friction at the boundary painting. Under the influence of load there occurs elastic and elastoplastic deformation on planes of the most fitting surfaces coated with a film of lubricant limit. At such contact it may occur relative implementation of surfaces without destroying the integrity lubricant film. The resistance movement during sliding consists of the shear resistance made up of the boundary layer and slip resistance surfaces.

Mineral oil molecules are constantly moving. Due to their mobility on friction surfaces the adsorption occurs much faster, allowing the film «to self treat." This feature prevents a process of continuous seizure.

Liquid, contact- hydrodynamic, semi liquid lubrication

Liquid lubrication is characterized by the fact that the surface friction layers are separated by liquid lubricant, which is under pressure. Pressure of MO is equilibrated under the external load. The oil layer is called the carrier. By increasing its thickness decreases the degree of influence of solid surfaces on the oil molecules that are far from it. During liquid painting the resistance movement is determined by oil viscosity. This regime is characterized by a low coefficient of friction.

Contact-hydrodynamic lubrication occurs when rolling friction or rolling friction with sliding. In this case, the oil is drawn into the contact area of contacting surfaces that move. Increasing of pressure and temperature reduces the viscosity of the oil.

Friction in semi painting is possible in the presence of both liquid lubrication and boundary lubrication. Normal load in the case of friction during semi liquid painting balances the normal component of the interaction forces on plane surfaces of contact forces and hydrodynamic pressure in the lubricant layer. The relative share of each reaction depends on the load, speed, relative movement of surfaces and their roughness, quantity and viscosity of mineral oil. Friction force is composed of the tangent component of surface interaction forces and viscous shear resistance. Hydrodynamic friction can occur in two cases:

- Micro geometry of contacting surfaces forming the gap that is narrowing;
- Inequality between the contact planes that form the relative movement of parts space narrowing or expanding in height [9].

The mechanism of friction pairs wear

The destruction of the solid surface that appears to change its size or shape is called wear. Deterioration is the result of wear and tear, expressed in units of length, volume or weight [10].

The intensity of wear - wear relation to way of friction or volume of done work.

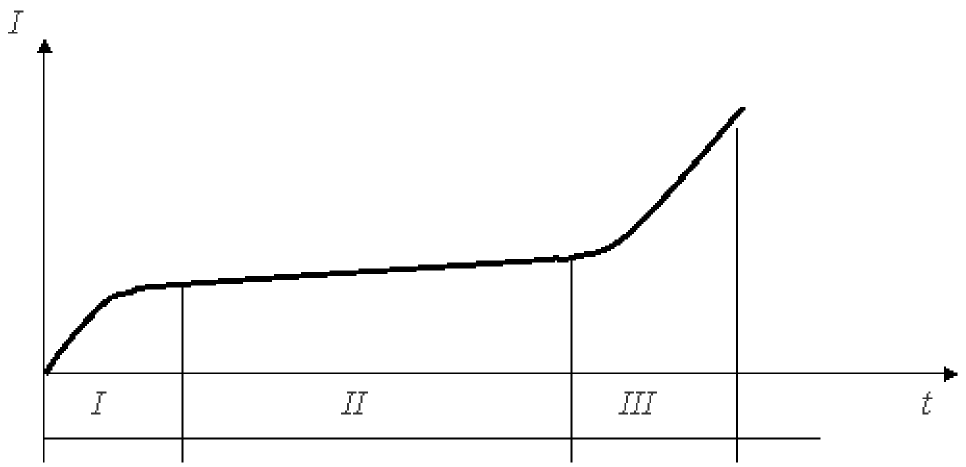
Light wear - wear ratio of the time during which there was deterioration.

Durability is estimated inverse intensity or rate of deterioration.

Marginal wear is called wear, where further operation becomes impossible due to the release of details of the system, uneconomical or unsafe due to lower reliability mechanism.

Interaction surfaces can be mechanical and molecular. Mechanical interaction is expressed in mutual introduction and grip surface roughness. Molecular interaction manifests as adhesion and seizure. Seizure is characteristic of metal surfaces and unlike adhesion has stronger ties. Molecular interaction is only possible in areas of mutual introduction surfaces. It must occur in the destruction of the oil film.

There are three stages of friction pairs wear (Figure 1.10).



I - the initial stage of wear, II - stage of wear established,III - stage of catastrophic wear

Figure 1.10 – Stages of friction pairs wear

Details after picking are conjugated in projections and in other kinds of uneven surfaces that are rapidly sliding during wear out (Figure 1.10, I). After smoothing the microscopic and surface waviness, increased their load-bearing capacity and wear intensity decreases (Figure 1.10, II). Micro relief of surface micro hardness thus stabilizes regardless of their initial states. The process of deterioration that has been established consists in deformation, fracture and continuous formation in some areas of the surface layer of the secondary structures of stable properties. Wear parts thus can significantly change the properties of interface. The gap in the coupling violates the terms of liquid lubrication and can cause a dynamic factor. Change of micro geometry worsens the conditions of friction and eventually causes a sharp increase in the rate of wear, corresponding to the stage of catastrophic wear (Figure 1.10, III).

Types of working surfaces wear

Formation of wearing surface is a result of summation of different intensity elementary acts of destruction and changes in mechanical, physical and chemical properties of the material under the influence of external factors (environment, temperature, pressure, type of friction, etc). The combination of factors in the process of friction determines the type of wear and its intensity. Type of wear in the first approximation can be detected on the outer surface of the friction type. Full confirmation can be obtained by analysis of the physical and mechanical properties of thin surface layers.

The destruction of the working parts of machines and surfaces of friction associated with the process are classified (Figure 1.11- 1.14):

- Hydrogen wear.
- Abrasive wear.
- Oxidative deterioration.
- Wear under plastic deformation.
- Deterioration due to dispersion.
- Corrosion.
- Erosion.
- Cavitation wear.
- Wear during fretting – corrosion.
- Surface cracking.
- Selective transfer.
- Wear with fretting corrosion.

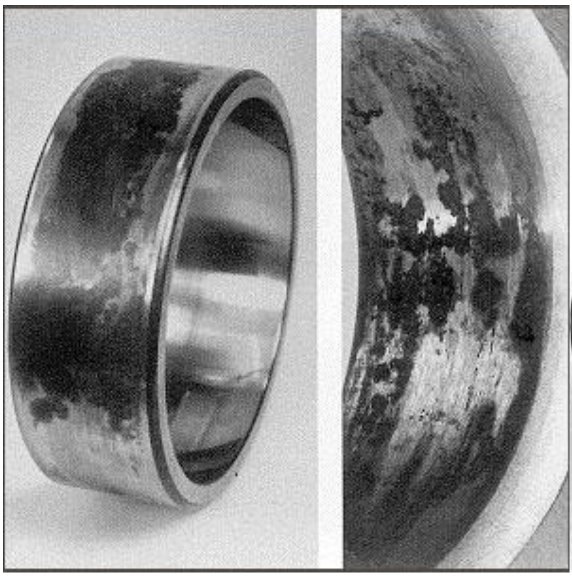


Figure 1.11 – Wear during fretting corrosion

Figure 1.12 – Cavitation wear

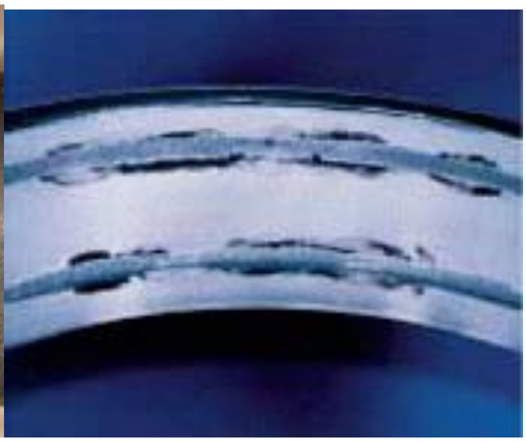


Figure 1.13 – Erosion wear

Figure 1.14 - Abrasive wear

Fretting corrosion - is the process of destruction of tightly contacting surfaces of pairs of metal-metal or metal- non-metal in their oscillatory movements. For excitation of fretting corrosion it is necessary surface displacement with amplitude of 0.025 mm. Destruction is the formation of conjugate surfaces in small holes and corrosion products in the form of stains and powder. To this type of wear carbon and corrosion resistant steel are exposed.

Because of small amplitude of conjugated surface displacements damages accumulate in small areas of real contact. Products deterioration can not get out of the contact area, which results in high pressure and increases their abrasive effect on the base metal.

During fretting corrosion the relative velocity of the conjugate surfaces is small. Thus, in the case of harmonic oscillations with amplitude of 0.025 m and a frequency of 50 s -1 the maximum speed - 7.5 mm/s, and average - 2.5 mm/s.

Fretting corrosion occurs in a vacuum, in oxygen environment, the environment of nitrogen and helium. The intensity of wear in fretting corrosion in air is greater than in a vacuum and in a nitrogen environment and oxygen is greater than that of helium. Thus, fretting corrosion is a type of fracture of metals and alloys in low-and non-aggressive corrosive environments, while the influence of mechanical and chemical factors.

This type of wear is typical for parts of aircraft (joints blades of gas turbine engines, engine mount, prop shafts, rods components, steering parts, etc.), internal bearing rings, winches, screw, and slotted connections.

Damage fretting - corrosion surface details can be stress concentrators, leading to the emergence of cracks and fracture of fatigue details. In places of forging shaft landings the fretting -corrosion leads to scroll bearings (bushings) on the shafts.

Most of the details of the mechanism and control of aircraft gas turbine engines, which occur during fretting– corrosion is made from high-strength titanium alloys (BT3 -1, BT -22). Their lack of stability in terms of FC can not significantly improve turnaround service life of individual components and mechanisms in general. To strengthen titanium alloys are widely used chemical and heat treatment, electroplating coatings, surface plastic deformation, thermal and vacuum-condensation coating methods. In recent years, the increasing spread of acquired thermal methods (plasma, detonation), the advantage of a broad class of materials used for coating , low temperature heating parts (200 °C) , high performance, and others.

Taking into account the development of aviation and space technics, the development of various technologies and materials for strengthening of the working surfaces of parts made of titanium alloys, operating under fretting-corrosion is a problem to be solved and future directions.

To fretting corrosion are prone bolted connections, landing surface bearing (liberty) the rolling, leaf springs, gears, clutches, etc. (Figure 1.15-1.16).

Figure1.15 – Fretting-corrosion of the bearing

Figure 1.16 – Fretting-corrosion of the pipel.

1.4 Methods of recovery

To restore worn parts or worn coupling means to restore the original (or close to it) geometric, physical, mechanical, physical, chemical, and their other characteristics (properties) that eliminate operational defects, restore size, geometric shape, structure and physic-mechanical properties according to specifications.

Restoration of parts and conjugations is the most important task of the repair production. Investigations have shown that the efficiency and life of restored parts are 60...80 % of these new indicators. But now it is known technological methods (electromechanical, electrical, etc.) for which you can completely restore the original life of parts or even increase it.

Organization of restoration parts can save a significant amount of scarce materials also in 2...3 times extend the service life of parts and reduce the production of commodity parts to manufacturing plants and reduce the cost of machinesrepair and equipment. Implementation of centralized restoration parts, widely used production lines, automation processes of repair parts will further improve the efficiency replacement of production.

Recovery manufacturing uses a large number of parts labor, materials and energy required for the application of coatings, thermal and mechanical cultivation details. Therefore, cost optimization of these resources by best usage of them with timely execution of production tasks and ensuring regulatory quality indicators is the actual problem [11].

The general renovation technology (Figure 1.17-1.19) consists of a number of methods each of which has both advantages and disadvantages. The main disadvantages that have a negative impact on the end result or significantly increase the cost of repairs are:

- Appearance of leashes.
- Poor adhesion of the applied layer of foundation.
- The presence of pores, cracks and slag inclusions.
- Reduction of fatigue strength.
- Increased environmental risk.

Table 1.1- Compensation technologies for worn layer of metal parts

Method	Advantages	Disadvantages
Surfacing	Increase of hardness and wear resistance, possibility for unlimited increase of worn surface	Crack appearance, high porosity, the presence of slag inclusions, reduction of fatigue strength, warping, increased environmental danger
	Keeps the structure of details, high wear resistance and surface hardness	Low wetting of lubricant reduction of fatigue strength, low adhesion, increased environmental danger
Metallization	The mechanical properties of the material details are not change and detail defies hogging, high wear resistance	The high porosity (10 %), reduction of fatigue strength, low adhesion, increased environmental danger
Plastic deformation	Improves firmness, reduces roughness, increases the strength	Low productivity, can deform surface up to 5-10 mcm and more, there may occur uniform metal flows with thickness of 0.03-0.3 mm
Electro erosiondoping	Local treatment of the surface-doping can be done in some areas of several mm and no longer protecting the rest of the surface; a strong connection of suffering and base metal; lack of detail heat in the overall processing, the ability to use as arable material: pure metals, alloys, ceramic compositions, melting of connections, increase hardness, heat-, wear-and corrosion stability; absence of surface preparation	Increased roughness, occurrence in surface layer the stretching residual stresses, reduction of fatigue strength
Polymeric coatings	Unlimited increase of worn surface, deformation characteristics are close to the metal, high adhesion	The need for special surface preparation, also formation of surface roughness; limited use because of relatively low hardness

Figure1.17 – Gas thermal spraying

Figure 1.18 – Electric arc metallization

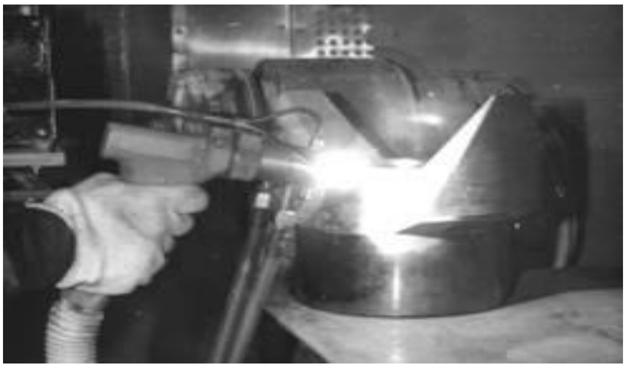


Figure 1.19 – Plasma spraying

In repair production the finished detail is obtained by mechanical machining of billet repair.

To get the repair timber it must be performed two groups of manufacturing operations:

The first group is surface preparation to recovery, including metalwork processing, machine cutting tools or electric physical chemical processing.

The second group includes direct transaction of recovery [12].

Details restoration with the help of galvanic methods

Restoration technology of worn parts by electroplating method is based on the deposition of metals by electrolysis of water solutions of metal salts or acids (chrome).

To the part (cathode) it is brought the negative potential power. Like anode it is used the metal plate that needs to be put on a piece or plate of insoluble metal such as lead (with chrome plating). To the plates there is added positive potential power.

Electrochemical equivalent depends on the type of metal it takes to cover, current density, electrolyte temperature, current electrolysis waveform and other parameters.

Before the galvanic extension details have special treatment. They are sanded, washed, degreased, pickled in solutions of sulfuric, phosphoric or chromic acid, washed again, and then suspended in an electrolytic bath and added to the negative electrode power source. In place of detail with unenforceable escalating metal can be applied insulating materials.

To obtain high-quality metal with the help of metal extension there are used different methods of polarity changing and shape current electrolysis:

a) automatic reverse current, periodic change in polarity of the voltage at the details from negative to positive and vice versa. Lengths of details stay under negative voltage - an order of magnitude more than the positive voltage;

b) the usage of asymmetric current that is rectified current with different coefficients of straightening.

Universal power adapter for the electrolytic bath power is developed.

Source allows prosecuting the process of metal exposure to build single-phase asymmetric and three-phase rectified current with the ability to switch from one mode to another without interruption of power and precision stabilization and regulation components of current.

Metal deposition process is divided into several cycles. After parts immersion in a bath and connecting of electrodes the software unit is switched on and that after a certain time delay set to establish the details of the current density on the half-wave line (cathode/k) and the return on the half-wave (anode/well). After time that is equal to about 1 minute, software relay gradually for 3 min. reduces the current density to zero. After this time there is gradual increase in the density of the rectified current to the cathodic limit. The current density and time are selected and adjusted depending on the set parameters of microhardness, connection and thickness of coatings, as well as temperature, pH and concentration of electrolytes [13].

Maturing of details without power for 10…60 seconds is necessary to equalize the temperature of the electrolyte and components that provides the best coupling of first coating layer with detail.

Low current density (< 300 A/m^2) and the presence of the anode current offer soft under layer of iron deposition with small internal stress. The use of asymmetric power increases the productivity of the process in 2...3.5 times and improves clutch cover with the base and allows obtaining coverage with a given micro hardness.

With the help of software device it can be automatically controlled the processing modes, namely the stabilization of electrolyte temperature, current density, acidity of the solution and the exposure time of parts in a tub that provides a given thickness of coatings. Program device has appropriate regulators.

Automatic temperature control is especially important in chrome plating, chemical nickel plating. In these processes, variations in temperature of the electrolyte should not exceed ± 2 °. For small bathrooms double position regulators are used for large bathrooms are used regulators with proportional- integral steps that control the electric heater solution.

Automatic control of acidity provides receiving of quality metal precipitates in detail. With the help of meters we can measure the acidity of pH, and adjust it by adding alkali or acid electrolyte.

Automatic adjustment of the desired thickness of the coating is carried out either by the meter of ampere -hours, or by using the timer.

Electroplating shops are equipped with production lines, in which the work piece is transported to the curricula. The program provides the necessary movement sequence and exposure time in the baths of parts in degreasing, washing, electroplating, drying and other operations. Galvanic production lines are equipped with manipulators that move parts of the bath in the bathroom under a given process.

Automation galvanic coating process improves quality and reduces the cost of treatment, reduces the volume of work and consumption of chemicals, improves working conditions and speeds up the repair process.

Restoration of details with the help of vacuum-arc coatings

Vacuum arc coating is a physical method of coating (thin film) in a vacuum, by condensation on the substrate (product detail) material of plasma flows that are generated at the cathode target in the cathode spot of high-current vacuum arc of low-voltage discharge that is exclusively developing in material parts of the electrode.

The method is used for the application of metal, ceramic and composite films for various products [14].

Vacuum arc evaporation process begins with ignition of vacuum arc (characterized by high current and low voltage) that forms on the cathode surface (target) one or more point (ranging in size from several microns to tens of microns) emission zones (so-called " cathode spots ") in which all power of discharge is concentrated. Local temperature of the cathode spot is extremely high (about 15,000 °C), which causes intense evaporation and ionization of cathode material and appearance of high-speed (up to 10 km/s) plasma flows propagating from the cathode spots in the surrounding area. Separate cathode spot exists only for a very short time (microseconds), leaving on the cathode surface the characteristic microcraters, then it happens self-extinction and self-initiation of a new cathode spot in the new field at the cathode, close to the previous crater. Visually, this is perceived as a moving arc over the surface of the cathode.

Since the arc is substantially a current conductor, it is possible to influence on it with the help of superposition of the electromagnetic field which is used in practice to control the movement of the arc on the cathode surface, to ensure its uniform erosion.

In the vacuum arc cathode spots it is focused extremely high density power, resulting in a high level of ionization (30-100 %) which results in generated plasma flows, consisting of multiply charged ions, neutral particles, clusters (particulate drops). When during the evaporation process the vacuum chamber is introduced with reactive gas by reaction with the plasma stream it can be its dissociation, ionization and excitation, followed by passage of the plasma-chemical reactions with the formation of new chemical compounds and their deposition in the form of a film (coating) [15].

Appreciable difficulty during vacuum arc evaporation process is that if the cathode spot is at the point of evaporation for too long, it emits a large amount of particulate or droplet phase. These macro inclusions reduce coating characteristics, as they have poor adhesion to the substrate and can exceed the size of the coating thickness. Even worse, if the target cathode material has a low melting point (e.g. , aluminum): in this case the target under the cathode spot can be melted throughout, in result of which cathode evaporator holder material can start to evaporate or cathode cooling water starts flowing into the vacuum chamber, giving rise to the emergency.

To resolve this problem, make one way or another continuous movement of the cathode spot on the bigger and bulkier cathode having sufficiently large linear dimensions. Basically, as mentioned above, for a controlled movement of cathode spots on the cathode surface it is used the magnetic field. For the same purpose, when applying cylindrical cathodes during operation (evaporation) it can be informed their rotational movement. Not allowing the cathode spot to stay in one place too long, you can use the cathodes of fusible metals, and thus reduce the amount of junk droplet phase.

Some companies also use the so-called filtered arc (born filtered arcs), which macro inclusions are separated from the plasma flow by magnetic fields.

Cathodic arc source of Sablev construction (most common in the West) consists of a short massive cathode target cylindrical shape made of an electrically conductive material, and open with a (working) end. This is surrounded by a cathode located at a floating potential ring (screen), which serves to protect the non-working surfaces from exposure to arc. Anode for the system can be either wall of the vacuum chamber, or separate the anode. The cathode spots are initiated by ignition of the arc by a mechanical trigger (igniter device) at the open end of the cathode through the circuit short between the cathode and the anode. When arc cathode spots move spontaneously chaotically on the open end of the cathode or their movement is defined by the external magnetic field.

There are also designs multicathodic constructions of cathodic arc sources, allowing a single technological cycle apply combined multilayer coatings and / or coating of the chemical compounds of complex composition wherein each cathode is responsible for drawing its material or a compound thereof.

Due to the fact that the cathode target is experiencing active ion bombardment, breaking its surface, then in general the plasma flow of cathodic arc source includes not only individual atoms or molecules, but they are quite large clusters (called particulates) that in some cases, without any filtering prevent its effective use. There are many different designs of filters (separators) particulates, the most studied of which is a structure with a curved plasma duct (channel), based on the work of Ivan Aksenov and published in the 70 -ies of XX century. It is a quarter-toroidal channel, where using the principles of the plasma (ion) plasma optical flow takes place at an angle of 90 ° to the plasma source, resulting in neutral or weakly ionized particles, and particulate deposited on its walls before reaching the work piece [16].

There are also other interesting designs of filters, such as straight channel design with built-in cathode in the form of a truncated cone proposed by D.A. Karpov in 90-ies of XX century. This design is still quite popular among companies producing thin-film deposition of wear-resistant coatings, and among researchers in the former Soviet Union. There is also a cathode arc source with long cylindrical and rectangular cathodes, but they are less popular (Figure 1.20-1.21).

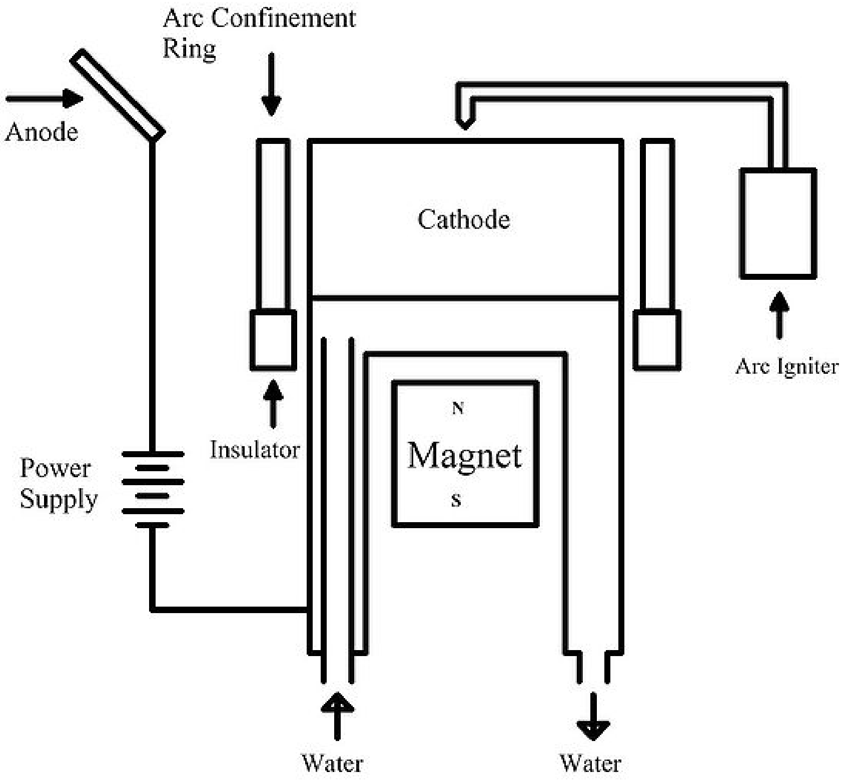


Figure 1.20 – The cathodic arc source of Sablevs' construction with a magnet to control the movement of the cathode spot

Cathodic arc deposition is widely used for the synthesis on the surface of the cutting tool that is very hard wearing and protective coatings, significantly prolonging its life. Among others, for example, titanium nitride is also popular as a decorative coating resistant "golden". With this technology can be synthesized by a wide range and superhard nanocomposite coatings, including TiN, TiAlN, CrN, ZrN, AlCrTiN and TiAlSiN.

This technology is widely used for the deposition of diamond-like carbon films. Since this type of coating is particularly sensitive to parasitic inclusions (particulates) in equipment for the technology it is necessarily to apply filtering of the plasma beam. Diamond-like carbon film of filtered vacuum arc contains a very high percentage of sp3 diamond structure and is known as tetragonal amorphous carbon or ta-C.

Filtered vacuum arc can be also used as a source of metal ion / plasma ion implantation or combined plasma immersion ion implantation with the deposition of coatings.

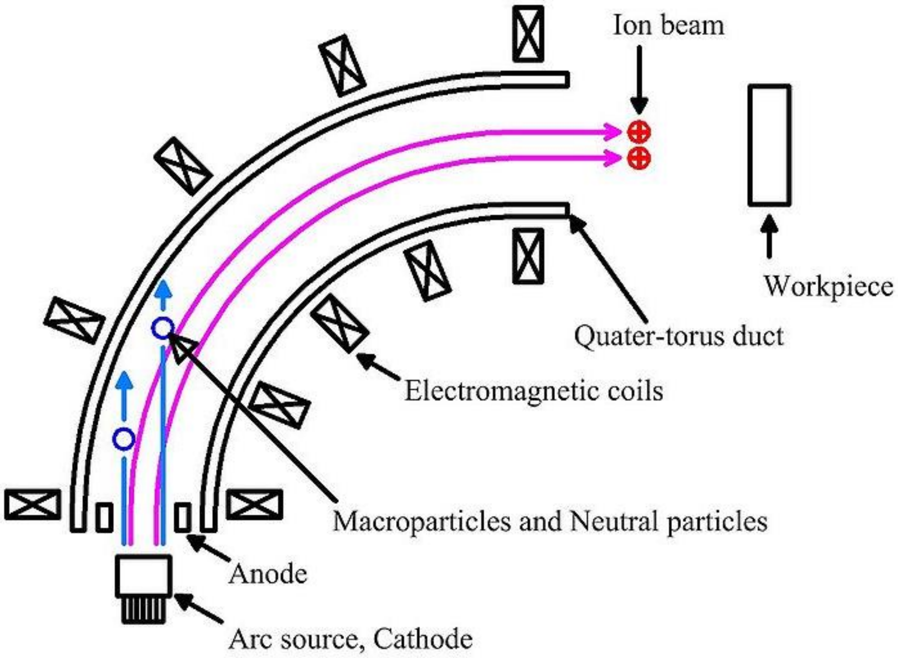


Figure 1.21 – Curve quarter-torus filter (separator) of Aksenovs' particulate structure that is based on plasma-optical principles developed by Morozov

Conclusion to chapter 1

The aviation industry was the first consumer of titanium. Low specific weight and high strength (especially at elevated temperatures) of titanium and its alloys make them very valuable aeronautical materials. In the field of aircraft and aircraft engines titanium is increasingly replacing aluminum and stainless steel. The advantage of replacing steel with titanium in aircraft is to reduce weight without sacrificing strength. Overall weight with increased performance at elevated temperatures allows increasing payload, range and maneuverability of aircraft. Hence the efforts aimed at expanding the use of titanium in the manufacture of aircraft engines, airframe construction, and manufacturing and even trim fasteners.

Details made from titanium alloys can be damaged during operation. The most common is the mechanical damage. They occur when detail is exposed to stress during operation exceeding the allowable and due to fatigue of the material. Mechanical damages include: cracks, holes, fractures and deformation (bending, twisting, and bending). The most dangerous at the same time there are cracks that can lead to serious damage.

During operation, friction plays a significant role, since it is due to friction there is a great part of wear details, which ultimately leads to negative consequences such as fretting corrosion.

Fretting corrosion is the corrosion cracking at the interface of two bodies in contact with each other. These surfaces under the influence of a corrosive environment move (slide) relative to each other. So fretting corrosion is corrosion by friction.

Fretting can appear: at clasped to each other details that affect the vibrational, rotational stresses. These include bolt, drills, riveting, spline joints, the contact portions of bearings, metal rope contacting moving shafts and more.

When the flow of fretting corrosion of the metal surface is discolored, and when it is exposed to vibrational stress ulcers are formed, in which the fatigue cracks are generated subsequently. During friction of the metal the heating occurs, which further enhances the fretting corrosion, particularly in the absence of surface grease.

There are many ways to restore parts. The most common methods of recovery are restoration with the help of galvanic coatings. Electroplating industry is able to perform many different kinds of surfaces, including chrome plating. Chrome cover for their functional use is one of the most versatile. They help to increase the surface hardness and wear resistance of products, tools, restore worn parts. This is due to the presence on the surface the oxide film that is very dense nature and that can be easily restored. It is widely used for corrosion protection and to the decorative surface treatment products. Depending on the mode of the process we can get different coating.

PART 2
RESEARCH METHODOLOGY

2.1 Methods of preparing the surface of metal parts before coating

Surface preparation is the essential first stage treatment of a substrate before the application of any coating. The performance of a coating is significantly influenced by its ability to adhere properly to the substrate material. It is generally well established that correct surface preparation is the most important factor affecting the total success of surface treatment. The presence of even small amounts of surface contaminants, oil, grease, oxides etc. can physically impair and reduce coating adhesion to the substrate.

Chemical contaminants that are not readily visible, such as chlorides and sulphates, attract moisture through coating systems resulting in premature failure. In summary, the importance of a chemically clean substrate to provide the best possible contact surface for the applied coating cannot be over-emphasised.

All the technological operations, which the details prior to coating application are exposed to, leave traces on the details surface in the form of pollution. Every product, however it may seem clear at the outer rough inspection, it almost always contains on a surface some pollution, which violates the process of normal coating obtaining.

Contamination on the metal surface may be different in their nature and properties. The most common on the metal surface pollution in their nature are divided into three main types [17]:

- thermal scale, corrosion products, sulfide or oxide films and other chemical compounds;
- fats, ois and other organic matter;
- foreign rigid particles from various sources.

Chemical compounds that are on the parts surface are usually strongly linked with the metal surface. The composition of oxide films is not uniform over the cross section. Usually closer to the boundary metal - oxide are located lower oxides, and at the oxide - the external environment boundary are higher oxides.

For newly manufactured metal products are distinguished two levels of contamination with fats and oils. The surfaces on which a thin layer of mineral oil mixed with dust, grease, and coolant can refer to the first group, the second group includes the surfaces with thick layers of conservation-based lubricants, oils and hard dirt.

The solid particles get onto the surface of metal during polishing and grinding with abrasives, as well as lubricants and coolants at machining. These particles are usually graphite, dust, surface inclusions of mechanically adhering particles of other metals, etc. The developed surface of fine particulate matter causes strong adsorption of the particles among themselves and with the surface details of the formation of stable conglomerates. In addition, solid particles fill cracks, crevices on the surface, blind holes, from where they are most difficult to be removed.

Foreign layer in thousandths of a micron rapidly reduces the adhesion strength of coating with the base metal. With the thickness increase of a foreign layer the adhesion strength of coating to the base metal decreases almost exponentially. The quality of coatings in a great measure depends on the quality of surface cleaning. A long-term verification galvanic coatings defect proves that 70 % of all defects are associated with poor quality of surface preparation before coating [18].

Optimal adhesion to the base material can be achieved if we can add to the crystal structure of the base metal the coating structure in such a way as to form an internal communication in a common crystal structure. To fulfill this condition, preparing to coating application operations is the foundation that determines the quality of details protection.

The choice of a surface cleaning method depends on many factors, primarily on the nature of contamination and cleanliness requirements of the surface. Therefore the choice of treatment method is determined by the type of contamination, material items, the required degree of purification and the cost of the process. All cleaning methods can be divided into two groups [19]:

- methods of pre-treatment;
- methods of vacuum cleaning.

In the first case, the most serious "macroscopic" pollution is removed, i.e. surface irregularities caused by technological processes of manufacture of the samples. The biggest drawback of pre-treatment methods is that in the process of cleaning the surface from some substances, we pollute it with others. For example, the surface skimmed with the solvent is simultaneously contaminated with molecules with dissolved substances contained in the solvent. Acid etching causes physical heterogeneity (after etching the surface remains rough).

Group of vacuum techniques is an essential tool for obtaining a clean surface. These methods are implemented in a high vacuum (10^{-6} Pa and below). Likelihood of re-contamination of the surface in high vacuum is significantly reduced.

Methods for pretreatment of the surface are the following

1. Mechanical methods.

This is a blast, abrasive, blasting and brushing treatment, as well as surfaces cleaning in solutions when exposed to ultrasound.

Surface cleaning by hand tools such as scrapers and wirebrushes is relatively ineffective in removing mill scale or adherent rust. Power tools offer a slight improvement over manual methods and these methods can be approximately 30% to 50 % effective but are not usually utilised for new steel work fabrications.

2. Chemical methods.

Steels are mainly etched in acid solutions - sulfuric or hydrochloric. Other etching methods - electrochemical, alkaline, etc. are applied with restrictions. The chemical methods of cleaning include methods for degreasing in various solvents and alkaline solutions.

3. Plasma methods.

These are new and improved methods of surface cleaning. The metal surface is treated with directional flow of ionized particles (plasma), at temperatures of about 10000 °C. A disadvantage is the complexity and high cost of equipment for the process (including the creation of a special gas environment). At the same time, the methods are versatile and of high performance, and easily combined with the further application of quality coatings.

Vacuum-cleaning of the surface can be realized through the following methods:

- the method of thermal desorption;
- ion etching (ion spray);
- the method for obtaining a clean surface by spraying;
- cleaning method using catalytic reactions;
- the method of cleavage in a vacuum.

The most effective technology for surface preparation of parts, machining of the past, is a chemical pretreatment followed by vacuum cleaning by ion spraying on the surface.

Surface of the metal parts are cleaned from oxides by etching in acid and alkaline solutions. Etching of parts - is the dissolution of oxides in acid or alkali. The choice of correct material depends on the etching properties of metal. Ferrous metals are etched mainly in sulfuric acid or hydrochloric acid [20]. Sulfuric acid - the most common etching agent, because of its cheapness compared with other acids.

Iron oxides Fe_2O_3 and Fe_3O_4 are porly soluble in acid, and etching is mainly due to dissolution of the base metal, followed by loosening of the oxides. If the oxide layer is uneven in thickness, some areas may be over etched. This leads to an increase in surface roughness, which may be unsuitable for coating. To avoid over etching of bases inhibitors are introduced into solution - substances that are adsorbed on the cleaned metal surface to form a film that prevents metal etching. The concentration of sulfuric acid is maintained in the range 150 - 250 kg/m^3, and then the etching rate is maximum. Increasing the etching rate is achieved by increasing the temperature to 40 - 80 ºC.

Oxides dissolve better in hydrochloric acid than in sulfuric acid, so there is less danger of over etching. However, hydrochloric acid can be heated to a temperature not exceeding 40 ºC because of its high volatility and the solutions must often be corrected. For etching hydrochloric acid is used in the same concentrations as sulfuric acid (150 - 250 kg/m^3).

For etching the steels alloyed with nickel, chromium, titanium and other elements, apply a mixture of acids, for example, a mixture of sulfuric, hydrochloric and nitric acid or nitric and hydrofluoric acids. The choice of a mixture depends on the grade of steel, or more precisely the nature of the alloying metals.

2.2 The equipment used and methodology of coating application

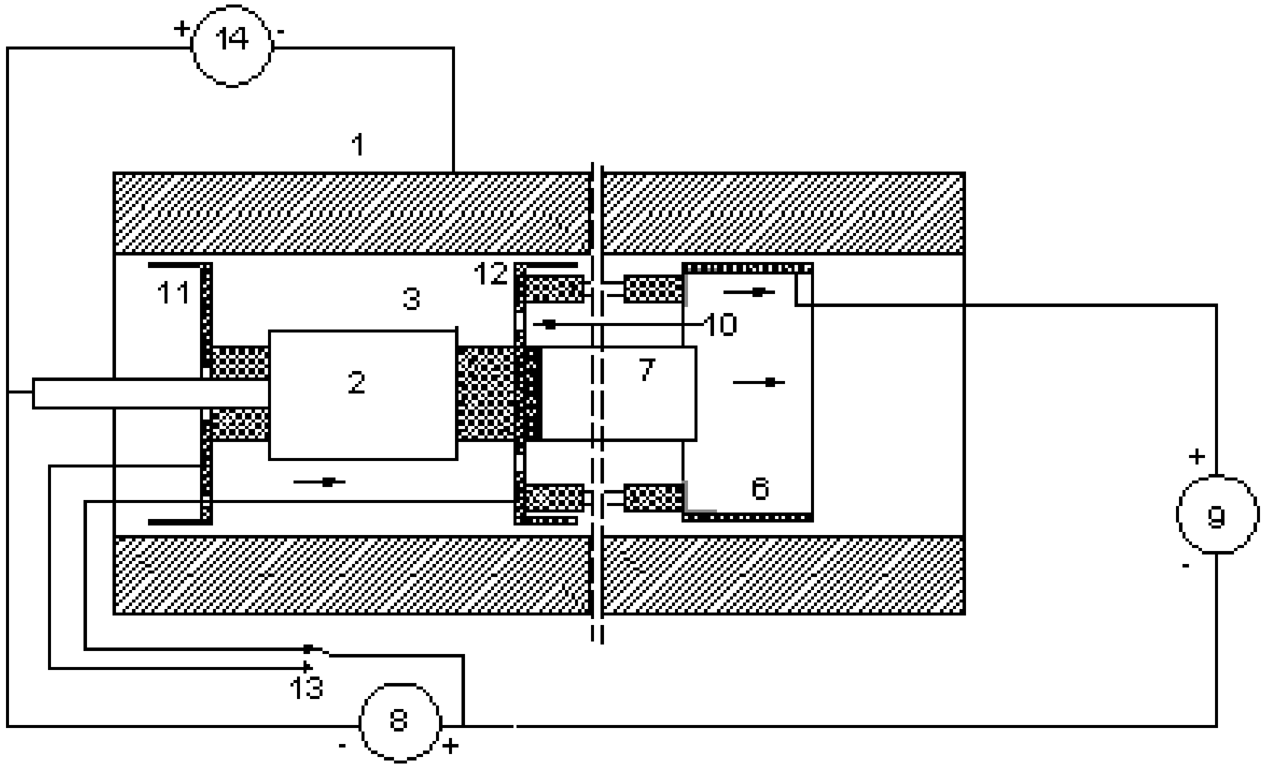
Creation of equipment for coating application by vacuum arc deposition on the inner surface of items requires the solution of two mмin tasks: to develop an effective system of cleaning the surface to be coated, and the development of electric-arc evaporator of metals of high reliability, capable of operating over tens of hours without maintenance [21].

The traditional method of products surface ion cleaning before applying the coatings is cathode sputtering in a glow discharge. The effectiveness of cathodic sputtering depends on the working gas pressure, the maximum it falls on the pressure range of several mm m. c. In this pressure range the electric vaporizer does not work, because on the surface of the anode there are slow-moving anodic spots with a high concentration of electrical power. The disadvantages of the evaporator should include low efficiency of ion cleaning the inside surface of the product during the coating process. This is due to the fact that cleaning the surface with accelerated ions of the metal is provided only within the region, commensurate with the length of the cylindrical cathode. At sites near the inner surface of the peripheral regions of the cathode ion flux density decreases. At the same time the flux density of a neutral pair in these areas remains high enough to form a metal film on the surface of the workpiece. Because of the low density of ion flux in these areas, the rate of sputtering products with visiting on its surface oxide films is not enough. In addition, a metal film formed by condensation of a neutral pair, has a weak grip the workpiece. This leads to the flaking of the coating in these areas for loading the product with the coating. We propose to use arc evaporator of metals with two anodes located near the ends of the cathode. With this arrangement, the anodes may control the position of cathode spots on the cathode surface by switching the power supply current leads. Azimuthal motion of the cathode spot is due to the axial magnetic field permanent magnet node spot can cause melt the anode material. It is therefore necessary to create this kind of level that would ensure a high ion current density at relatively low working gas pressures. The most suitable is the use of two-stage vacuum-arc discharge. The two-stage vacuum-arc discharge cathode is vacuum-arc metal plasma source. Cathode from the anode is separated by a partition, which provides optical opacity of the cathode relative to the anode. Design of partitioning must be such that the anode electric field penetrates the metal-gas plasma. Under the influence of an electric field of anode, electrons from the metal-gas plasma region penetrate near the anode region and ionize the gas in it. When the negative potential is applied to the work piece the accelerated ions of the working gas are sprayed on contaminated surface layer of metal.

In earlier works arc evaporator of metals with the control of cathode spots with a magnetic field and the anode in the form of a squirrel wheel was used. This provided the opportunity to feed on the treated tube high voltage during ion cleaning of the pipe.

The disadvantages of the evaporator are low efficiency of ion cleaning the inside surface of the product during the coating process. This is due to the fact that cleaning of the surface with accelerated ions of the metal is provided only within the region, commensurate with the length of the cylindrical cathode. Ion flux density decreases on the sections of the inner surface near the peripheral regions of the cathode. At the same time the flux density of a neutral pair in these areas remains high enough to form a metal film on the surface of the workpiece. Because of the low density of ion flux in these areas, the rate of sputtering products with visiting on its surface oxide films is not enough. In addition, a metal film formed by condensation of a neutral pair, has a weak grip with the surface of treated detail. This leads to the flaking of the coating in these areas for loading the product with the coating. The arc evaporator of metals with two anodes located near the ends of the cathode can be used. With this arrangement, the anodes may control the position of cathode spots on the cathode surface by switching the power supply current leads. Azimuthal motion of the cathode spot is due to the axial magnetic field of the permanent magnet.

Figure 2.1 shows a schematic diagram of electric-arc evaporator of metals and ionic gas purification system. Inside the workpiece, 1 is located a cathode 2. The anode consists of two parts 11 and 12, each of which is located from one end of the cathode 2. In part 12 of the anode, which is located after the cathode 2 in the direction of movement there are holes 10. Power supply arc 8 is connected to parts 11 and 12 of the anode via a switch 13. Additional electrode 6 mounted coaxially with the cathode 2 in front part of the anode 12, located after the cathode 2 in the direction of travel, is coupled with the positive pole of an additional source of supply 9 arc. The device includes a second auxiliary power supply 14 arc discharge, the negative pole of which is connected with the product 1. Between the additional electrode 6 and part 12 of anode, installed after the cathode 2, the screen 7 is insulated from the part of the anode.



1 – workpiece, 2 – cathode, 3, 4 – working surfac, 5, 6 – additional electrode,
7 – screen, 8 – source; 9 – additional source of supply, 10 – holes, 11, 12 – anode,
13 – switch, 14 – second auxiliary power supply

Figure 2.1 – Schematic diagram of the metals arc evaporator and ionic gas purification system

Part of the anode 12 within the spaace of the workpiece is divided into two zones, providing in the process of coating various functions. In the first zone elong the displacement components of the device cleaning the product surface with accelerated ions of argon takes place. Argon into the space inside the product is fed through gas inlet and has a pirtial pressure of about 0.1-1.0 Pa. In the second zone (zone of the coating) is the cathode arc evaporator. In this zone of already pre-cleared of contamination of internal surface area product is provided coating deposition. When operating in electric-arc evaporator zone coating plasma containing metal ions and the working gas is formed. Metal ions deposited on the surface of the product contained between the cathode and the screen, form a cover. Electrons of the metal-gas plasma under the influence of an electric field an additional anode pass through the holes in the screen or the gap between the screen and the inner surface of the product and ionize the gas contained in a zone of clearing, forming plasma of argon in it.

Device at the initial moment of process technology installed so that the cathode 2 was out of the workpiece 1, and the initial portion of the product was part of the anode 12 and all elements of the device to the right of it. With the help of a working gas supply system produce overlap of the working gas to a pressure of 0.1-1.0 Pa. When you turn on the DC source 8 between the working surface 3 of the cathode 2 and anode 11, 12 electric arc is energized. When turned on the DC source 9, then between cathode 2 and the additional electrode 6 is also excited the arc discharge. Electrons of the metal-gas plasma under the influence of an electric field generated by an additional electrode 6 penetrate the zone of the coating in the area of cleaning. These electrons are accelerated by the field of additional electrode 6 and produce ionization of the working gas. Product in the area of treatment is at a negative potential relative to plasma potential in this area. Under the influence of this potential, the ions of the working gas are accelerated and bombard the surface of the pipe located within a zone of clearing. The accelerated ions cause cathode sputtering on the inner walls of pipes, removing from the surface all pollution. During axial movement of the device cathode enters the inner cavity of the product and the coating is carried out on a clean surface that promotes high adhesion of the coating with the inner surface of the product.

2.3 Methods of testing materials and coatings of fretting

The research performance on fretting differs with different methods used, the scheme of loading and type of contact, and in the evaluation of surface damage. The method is chosen according to the two basic requirements [22]:

- imitation of fretting in the laboratory should maximally approach the conditions of this type of surface damage in real structures;
- the selected method should be such that you can compare obtained results with data from other works.

The followings requirements are set to test the devices in connection with the specifics of fretting:

- backlash-free mounting of samples in clamping devices;
- torsional rigidity and low deforming of device;
- availability of vibration skidding movement of controlled frequency and amplitude;
- availability of controlled normal force to create the necessary pressure in contact;
- possibility to supply lubricant or other medium.

The choice of a flat circular contact and swing-rotation movement of contact surfaces is stipulated by the necessity of control of normal load and elimination of edge effect.

The basis of the accepted methods of work contains a comprehensive study of qualitative parameters of friction pares. Scheme of the contact plane-plane type used on installation by ГОСТ 23.211-80, the general view is shown on Figure 2.2.

The main advantages of this method are:

- quick assessment of durability of materials and coatings under fretting;
- satisfactory reproducibility of test results with a minimum number of test samples;
- simplicity of the method and corresponding equipment;
- possibility of smooth control of the frequency and ampliiude of normal load micro shifts;
- tests using plastic and liquid lubricants;

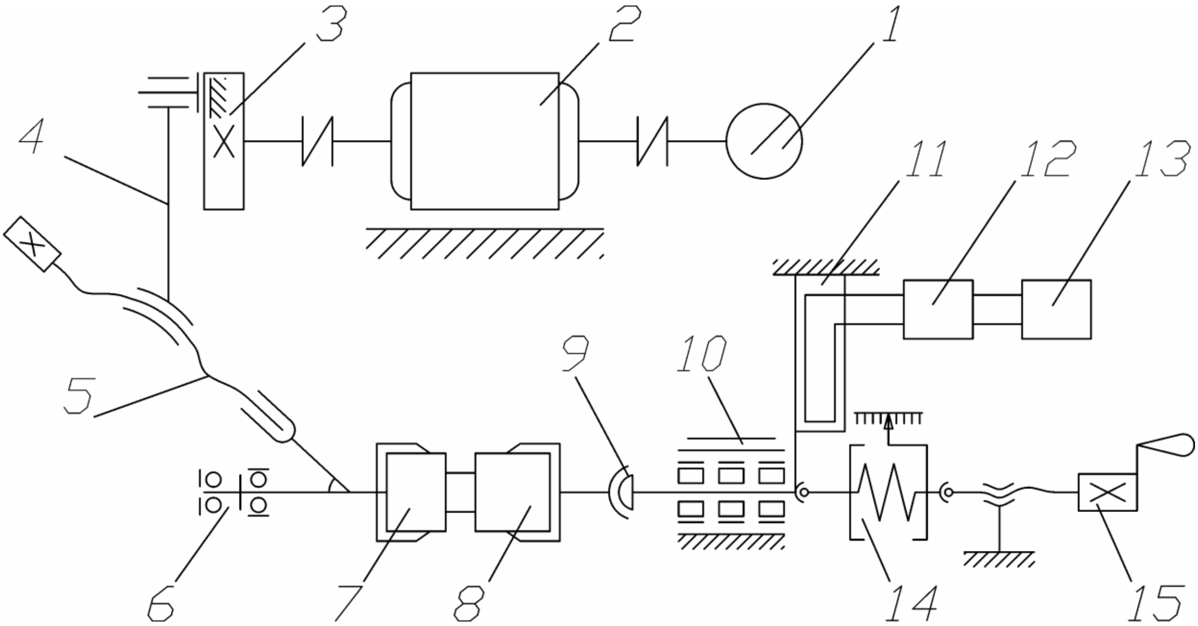
- registration of friction during testing.

Description of the method is that the rolling cylindrical sample (control sample), adjacent by edge with immovable cylindrical sample at a given pressure is driven to swivel-rotary motion with given amplitude and frequency. Measured wear of stationary sample for a given number of cycles is determined by the value of durability of the investigated material. Plant layout is shown on Figure 2.3.

Figure 2.2 – General view of installation for testing the fretting

Installation works as follows: motor 2 transmits rotational motion to eccentric 3 of adjustable eccentricity. Rotational frequency and the number of revolutions are recorded by instrument 1. Eccentric 3 through rod 4 is related to the crank 6 of drive 7 axis 6 of control sample 8swing-rotation motion. Amplitude of control sample 8 displacement and is regulated by an eccentric device 5. Fixed sample 9 is fixed in the centered collet 10 installed on the shaft of the moving stock 11. Samples are loaded by the dynamometer 14 and loading device 15. Size of axial load on the specimens recorded by dynamometer ЗІП 02-79 type ДОСМ-3-0,2 (ГОСТ 2283-79) with the boundary measurements from 0.2 to 2 kN. Friction registration is done by device НО71.5М *13* through amplifier 8-АНЧ-7М *12* with the help of tenzobeam 11.

Number of test cycles has to be controlled by the counter located on the front panel of the aggregate.



1 – revolution counter, 2 – motor, 3 - eeccentric, 4 – vertical rod, 5 – adjusting device, 6 – horizontal rod, 7 – moving sample, 8 – fixed sample; 9 – self orienting collet, 10 – moving stock of 11 – tenzo beam 12 - amplifier, 13 – registering apparatus 14 – dynamometer, 15 – loading device

Figure 2.3 – МФК-1 installation layout

Vibration amplitude is governed by the change of eccentric eccentricity (roughly) and by change of the length of the horizontal rod length (exactly). Rough amplitude regulation allows changing its size from 10 to 1000 microns, exact - from 5 to 15 microns. The amplitude of relative displacement is defined as the oscillation difference of movable and fixed samples. Measuring the amplitude is held directly on the samples using an optical binocular microscope МБС-2 (with an increase in from 8 to 56 times) using strobe effect (stroboscope ТСТ-100).

Samples for testing are shown in Figure 2.4. Contact of test samples is performed on the surface, which is a closed loop with the nominal contact area 0.5 cm^2, 11 mm inner diameter and an outer diameter of 13.6 mm.

Samples should be washed and dried before and after the eчperiment. For washing are used liquids: gasoline ГОСТ 443-76, acetone ГОСТ 2603-79, ethyl

ГОСТ 18300-72. Before the test the measuring and recording equipment should be checked and marked.

Installation allows testing at next parameters [23]:

- loading of samples in axial direction by 200 - 1000 N;

- swivel-rotary motion of control sample to sample with a frequency of 10 - 30 Hz and amplitude 10 - 1000 microns;

- measuring system settings during testing provides continuous registration of number of cycles of control sample swivel-rotation with an error less than 50 cycles.

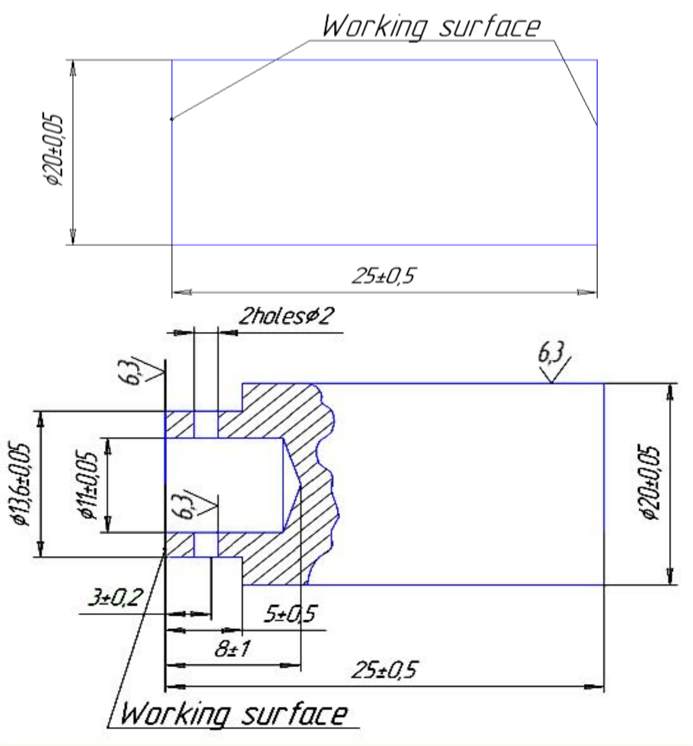


Figure 2.4 – Samples for fretting testing

For the materials testing in liquid environments the special heating chamber is used that provides the possibility of supply and withholding liquid environments in the contact area of the specimens.

The specimens for tests fastened in the unit collets, set in the round openings of chamber, provided with the sealing, manufactured from heat-resistant rubber. The leakage of working environment from a chamber is prevented with a help of sealing regulators.

The control of the temperature of working environment is provided by a thermocouple and pointer of temperature with accuracy ±2 °C, working range of temperatures of chamber 0…200 °C. The set temperature of tests is achieved with the help of a heating element and temperature regulator.

A chamber allows carrying out the experiments in oils and plastic greasings at the temperature from 0 to 200 degrees. Heating is carried out by the increase of tension on latra and heating of nichrome coil. The control of temperature of the liquid environment is carried out through the temperature sensor and milliammeter. The impermeability of the chamber internal cavity is carried out with the help of two rubber temperature and oil resistant sealings.

Measuring of the sample and coating wear have carried out using profilometer depth recorder Калібр-201 of model ГОСТ 19300–86 up to 10 microns and the vertical type optimeter ІКВ more than 10 microns, by taking profilograms of eight equidistant sections of the working surface of the sample in the radial direction.

Thus, the unique unit for materials wear resistance testing at fretting conditions is developed. The unit enables to carry out the comparative tests of fretting of steels, alloys, coverings and composite materials in different liquid and gas environment. Using the standard specimens for fretting - ГОСТ 23.211-80 the unit allows providing tests in the range of loading from 1 to 40 MPa and in the wide range of sliding speeds.

An important advantage of determining the linear depreciation method [24] is that the magnitude of wear does not depend on the ratio of material and possible changes in supply patterns.

Metallography

Metallography is study of the structure of metals and alloys, particularly using microscopic (optical and electron) and X-ray diffraction techniques.

Metal surfaces and fractures examined with the unaided eye or with a magnifying glass or metallurgical or binocular microscope at magnifications less than 10 diameters can reveal valuable information as to the crystalline, chemical, and mechanical heterogeneity. Crystalline heterogeneity is known metallographically as grain. Chemical heterogeneity arises from impurities, segregation of chemical elements, and nonmetallic inclusions. Mechanical heterogeneity consists of local deformations of structure, elongation or distortion of nonmetallic inclusions, and regions of chemical segregation, resulting from cold fabrication processes.

Microscopic examination of polished or etched surfaces at magnifications ranging from about 100 to 1,500 diameters can reveal such information as size and shape of grains, distribution of structural phases and nonmetallic inclusions, microsegregation, and other structural conditions. Metallographic etching—that is, subjecting the polished surface to the action of a corrosive reagent—can reveal the structure by a selective and controlled solution or can unbuild the metal inwardly from the surface. This successive destruction occurs because of the different rates of dissolution of the structural components under the attack of the etching agent. Polarized light is useful to reveal grain structure, detect preferred orientation, examine oxide surface films, and identify phases of different composition [25].

In electron microscopes a beam of electrons instead of a beam of light is directed onto the specimen; because only a highly energetic electron beam will pass through metal films thicker than about 0.05 micron (1 micron equals 0.001 millimetre), a microscope specimen replica of the surface is ordinarily made. To do this a plastic solution is poured over the etched surface; the hardened solution contains on one side a reverse impression of the surface contours of the specimen. The development of transmission electron microscopes, in which the electrons are accelerated to 100 kiloelectron volts or more, has made it possible to examine internal details of thin foils of metals.

X-ray diffraction techniques involve the impingement of a beam of X-rays on the metal specimen and the subsequent diffraction of the beam from regularly spaced planes of atoms; usually, the diffracted rays are recorded on photographic film. The technique is used to study phenomena related to the grouping of the atoms themselves. By measuring the lines or spots on the diffraction pattern and by analysis of the intensity of the deflected rays, information can be obtained about the positionsof the atoms of the specimen and hence the crystallography of the phases, the presence of internal strains, and the presence of solute atoms in solid solutions.

Fractography

Fractography is the study of fracture surfaces of materials. Fractographic methods are routinely used to determine the cause of failure in engineering structures, especially in product failure and the practice of forensic engineering or failure analysis. In material science research, fractography is used to develop and evaluate theoretical models of crack growth behavior.

One of the aims of fractographic examination is to determine the cause of failure by studying the characteristics of a fracture surface. Different types of crack growth (e.g. fatigue, stress corrosion cracking, hydrogen embrittlement) produce characteristic features on the surface, which can be used to help identify the failure mode. The overall pattern of cracking can be more important than a single crack, however, especially in the case of brittle materials like ceramics and glasses [26].

An important aim of fractography is to establish and examine the origin of cracking, as examination at the origin may reveal the cause of crack initiation. Initial fractographic examination is commonly carried out on a macro scale utilising low power optical microscopy and oblique lighting techniques to identify the extent of cracking, possible modes and likely origins. Optical microscopy or macrophotography are often enough to pinpoint the nature of the failure and the causes of crack initiation and growth if the loading pattern is known.

Common features that may cause crack initiation are inclusions, voids or empty holes in the material, contamination, and stress concentrations. "Hachures", are the lines on fracture surfaces which show crack direction. The broken crankshaft shown at right failed from a surface defect near the bulb at lower centre, the single brittle crack growing up into the bulk material by small steps, a problem known as fatigue. The crankshaft also shows hachures which point back to the origin of the fracture. Some modes of crack growth can leave characteristic marks on the surface that identify the mode of crack growth and origin on a macro scale e.g. beachmarks or striations on fatigue cracks. The areas of the product can also be very revealing, especially if there are traces of sub-critical cracks, or cracks which have not grown to completion. They can indicate that the material was faulty when loaded, or alternatively, that the sample was overloaded at the time of failure.

Fractography is a widely used technique in forensic engineering, forensic materials engineering and fracture mechanics to understand the causes of failures and also to verify theoretical failure predictions with real life failures. It is of use in forensic science for analysing broken products which have been used as weapons, such as broken bottles for example. Thus a defendant might claim that a bottle was faulty and broke accidentally when it impacted a victim of an assault. Fractography could show the allegation to be false, and that considerable force was needed to smash the bottle before using the broken end as a weapon to deliberately attack the victim. Bullet holes in glass windscreens or windows can also indicate the direction of impact and the energy of the projectile. In these cases, the overall pattern of cracking is vital to reconstructing the sequence of events, rather than the specific characteristics of a single crack. Fractography can determine whether a cause of train derailment was a faulty rail, or if a wing of a plane had fatigue cracks before a crash.

Fractography is used also in materials research, since fracture properties can correlate with other properties and with structure of materials [27].

Conclusions to chapter 2

All the technological operations to which the details are exposed prior to coating application, leave traces on the details surface in the form of pollution. So prior to coating application it is necessary to clean the detail surface. The choice of a surface cleaning method depends on many factors, primarily on the nature of contamination and cleanliness requirements of the surface. In this chapter different methods of preparing metal part before coating application were considered. We have proposed the electric-arc evaporator of metals and ionic gas purification system developed by specialists of the National Science Center "Kharkov Physical-Technical Institute".

The basis of the methods chosen for work contains a study of qualitative parameters of friction pares. Scheme of the contact plane-plane type is used on installation МФК – 1. The main advantages of this method are: quick assessment of durability of materials and coatings under fretting, satisfactory reproducibility of test results with a minimum number of test samples, simplicity of the method and corresponding equipment, possibility of smooth control of the frequency and amplitude of normal load micro shifts, tests using plastic and liquid lubricants, registration of friction during testing.

Currently, the aviation industry widely uses solid chrome plating, primarily to improve the durability and corrosion resistance. With regard to internal surfaces, chrome is often used to increase wear and corrosion resistance of the surface of the hydraulic cylinders of aircraft landing gear. With the above described methods for surface cleaning and deposition of coatings on it coatings of vacuum-arc method can be tight vacuum-arc coating thickness to 200 microns with a hardness of from 170 to 700 kg/mm^2. Different structure of the coatings (both columnar and fine-grained) can be obtained.

With regard to environmentally unsound method of galvanic current the actual is the replacement of chromium electroplating with other refractory coatings applied by environmentally clear methods.

PART 3
SCIENTIFIC RESEARCH PART

3.1 Conditions of an experiment

Tests on fretting were conducted at an installation МФК-1 that simulates the vibration on the scheme plane to plane contact. The essence of the method is that the movable cylindrical sample, which faces an end face of the real cylindrical sample at a given load, is driven to back-rotating motion with given amplitude and frequency.

Investigation was performed at constant load, corresponding 20 and 30 MPa. Research in studying the changes of the intensity of linear wear and wear coatings was conducted in the hydraulic liquid АМГ-10 and in dry environment.

For the research the grinded samples of titanium alloy ВТ-22, after ion cleaning of various regimes and after deposition of chromium and molybdenum coatings in various modes were used.

For the study conduction there were selected four kinds of coatings on the alloy ВТ-22. Three of the four coatings were deposited by vacuum-arc method: solid chromium (Cr_{sol}), chromium soft (C_s) and Mo. Electrolytic coating method was applied only for chromium (Cr_{gv}). Vacuum arc coatings were deposited by Research Production Enterprise "Tekhnoinvest-start", Dnepropetrovsk, and galvanic coatings were deposited on Antonov Company. Before coating applying the surface was treated by the preparatory operations: grinding and vacuum cleaning.

After coating application the samples were subjected to grinding to smooth the surface on a flat grinding machine ШПХ 40.61.

Samples were washed and dried before and after the experiment. Liquids that were used for flushing are: gasoline ГОСТ 443-76, ГОСТ 2603-79 acetone, ethyl ГОСТ 18300-72.

With the help of an electromagnetic defectoscope by the method of non-destructive testing thickness of the coating was measured. The measurement results are listed in Table 3.1

Table 3.1 – Thickness of coatings which are under the research

Base material	Vacuum-arc coatings			Galvanic chromium
	Solid chromium	Soft chromium	Molybdenum	
BT-22	95-220 micron	115-205 micron	70 micron	12-24 micron

After processing the samples were installed into МФК-1 installation, the necessary parameters for the experiment were calculated and adjusted.

3.2 Research results

The test results of vacuum-arc and electrolytic coatings fretting resistance are shown in Table 3.2, Table 3.3.

Table 3.2 – Linear wear of coatings in terms of fretting corrosion in dry environment

Material	Loading, MPa	Sample wear, micron
BT22	20	47,3
	30	84,6
Cr solid	20	1,72
	30	4,23
Cr soft	20	1,8
	30	5,87
Mo	20	5,48
	30	9,21
Cr gal	20	1,24
	30	2,15

Table 3.3 – Linear wear of coatings in terms of fretting corrosion in hydraulic liquid АМГ-10

Material	Loading, MPa	Sample wear, micron
BT22	20	15,10
	30	22,9
Cr solid	20	0,1
	30	1,4
Cr soft	20	2,5
	30	6,7
Mo	20	4,8
	30	6,5
Cr gal	20	0,3
	30	4,1

Durability histograms of vacuum-arc and galvanic coatings in the conditions of АМГ-10 and in dry conditions are represented in Figures 3.4 and Figure 3.5.

Analyzing histograms we can say that durability of all tested materials and pure Ti alloy BT-22 is analogical in АМГ-10 conditions and in dry conditions.

Durability data of vacuum-arc and galvanic coatings are proportional to durability of Ti alloy BT-22 during testing in АМГ-10 conditions and in dry conditions. We can make the conclusion that for coating durability determination we can make researches either in АМГ-10 conditions or in dry conditions. During this the durability tendency of different types of materials are equivalent between themselves.

It is necessary to mention that that durability of all tested materials in the condition of АМГ-10 is higher than in dry condition. But such coatings as soft chromium and galvanic chromium during the resting without lubricant at loads of 30MPa showed greater durability than without the lubricant АМГ-10. That is because during fretting-corrosion testing in soft chromium we can see the layer oxidation and also oxidation of the sample 95X18 with appearance of fine-dispersed oxides from black to red colors (Fe_2O_3) that appeared like roller bearings for the friction pair.

All in all it is necessary to say that during testing the greatest durability showed such materials as solid vacuum-arc chromium and galvanic coatings of chromium. Vacuum-arc soft chromium and molybdenum showed the worst results both in АМГ-10 condition and without it. Also we can mention that durability of galvanic chromium during testing in АМГ-10 condition at loads of 30 MPa is worse in comparison with loads of 20 MPa. Its durability increases in 12 times. It can be connected with the fact that the lubricant condition does not undergo the sample pressure and the gripe appears. As a result of which it can be seen the dug on the chromium surface of the sample.

The most acceptable from all coatings are the vacuum-arc chromium and solid chromium. Its durability is commensurated with galvanic chromium durability and in some cases it is even greater. So, during testing of vacuum-arc solid chromium in the condition of АМГ-10 at loads of 20 MPa practically has not got the wear.

Ti alloy BT-22 during testing in the conditions of АМГ-10 and without it showed the classical durability results. Usage of the АМГ-10 condition decreases the durability of Ti alloy in 3 times. It is connected with the fact that Ti alloy BT-22 is very inclined to grip. In the process of testing the condition АМГ-10 does not allow the surface to oxide. Thereby there is the lubrication of Ti alloy specimen surface and the friction Ti to Ti appears. So, the effect of selective transfer appears.

Analyzing the durability of material BT-22 and coatings in fretting condition in the environment of the hydraulic fluid АМГ-10, we can say that galvanic chromium coating with a thickness of 12-24 microns has shown the most wear resistant characteristics as in the tests at 20 MPa and 30 MPa. Friction tracks of this coating remained practically smooth along all the control sample contact. Only just at loads of 30 MPa tears of electroplated chromium coating appeared in some places of the contact as a result of seizure with counterbody 95X18.

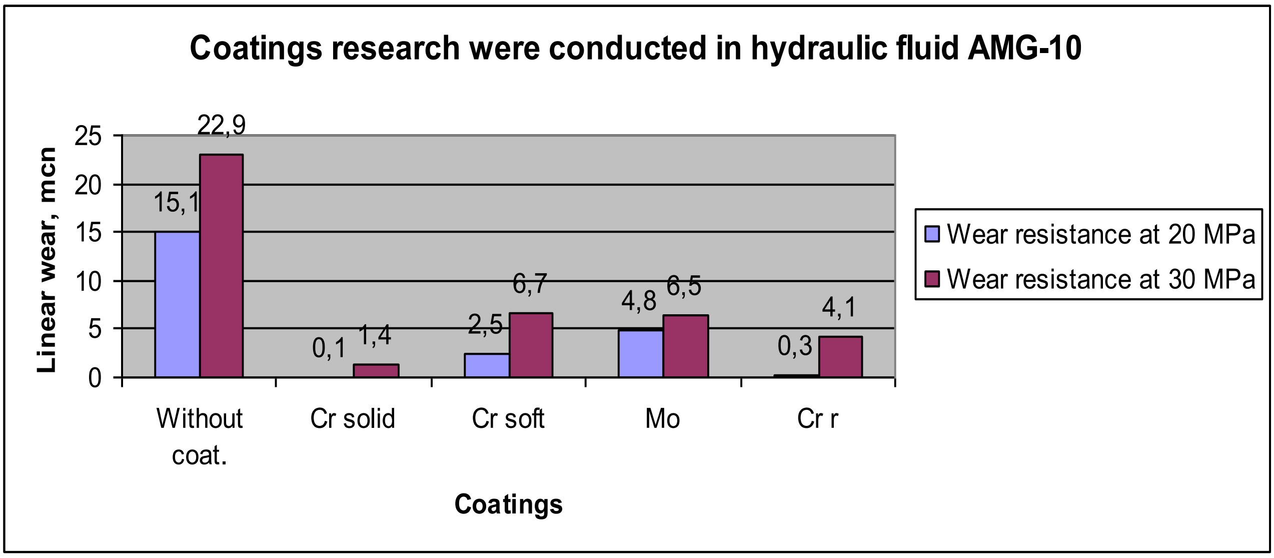


Figure 3.4 – Dependence of linear wear of the vacuum-arc coatings under load of 20 MPa and 30 MPa in hydraulic fluid АМГ-10

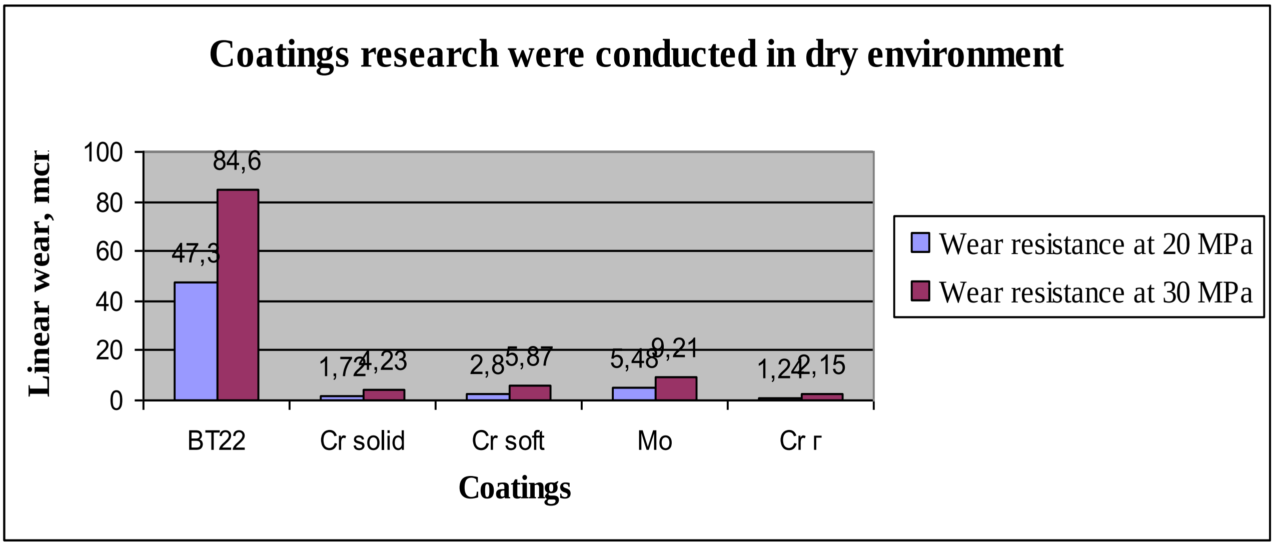


Figure 3.5 – Dependence of linear wear of the vacuum-arc coatings under load of 20 MPa and 30 MPa in dry environment

When wear of galvanized chrome coating on titanium alloy BT-22 takes place, and then intensity of wear sharply increases due to increased influence of titanium alloy to seizure with control sample.

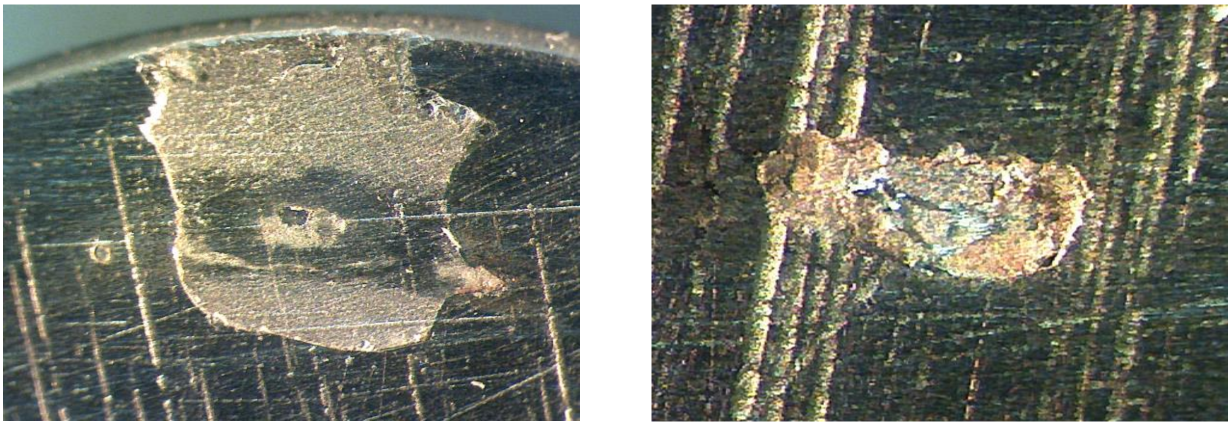


Figure 3.6 – Tears on the solid vacuum-arc coating of chromium at friction in pair with 95X18, the load - 20 MPa (x56)

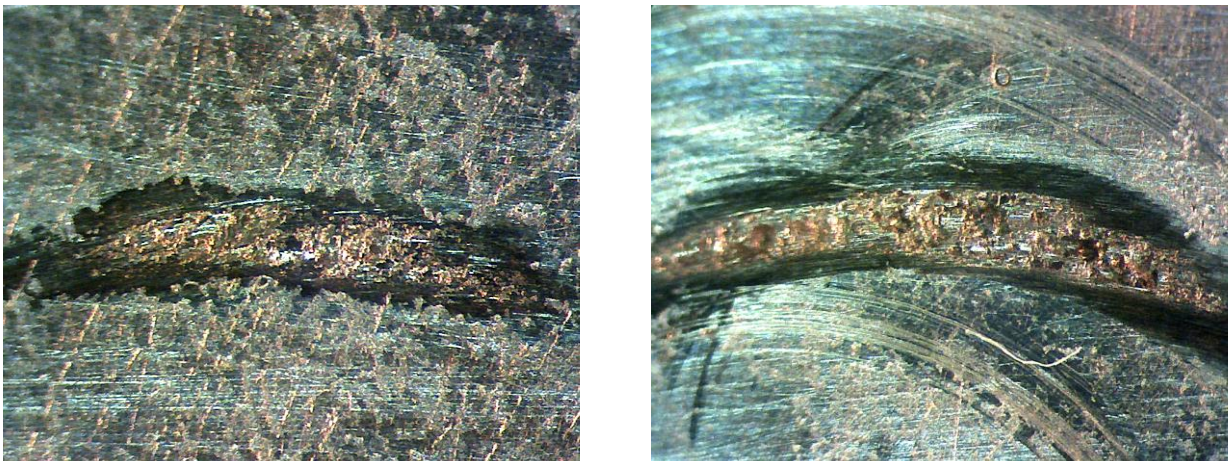


Figure 3.7 – Places of wear of solid vacuum-arc coating of chromium, formed as a result of the seizure with steel 95X18 (x56), load-30 MPa

Next coating that has showed some of the best characteristics for durability in fretting conditions was a solid vacuum-arc coating of chromium. At loads of 20 MPa, the coating in some cases even exceeded by fretting resistance the galvanic chromium coating (see Figure 3.6). When increasing the load to 30 MPa, vacuum-arc coating has wear resistance characteristics comparable to galvanized coatings.

At the load of 20 MPa surface friction of solid vacuum-arc chrome on titanium alloy BT-22 was not worn completely - linear wear was practically equal to zero. Only in some places bedding of coating and steel 95X18 is barely noticeable.

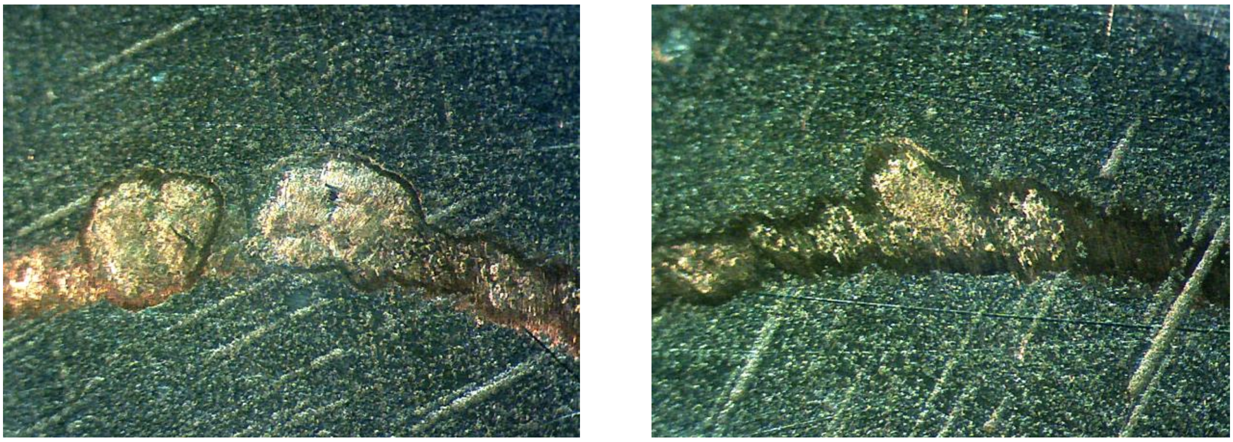


Figure 3.8 – The friction surface of the soft vacuum-arc coating chrome alloy on BT-22 at friction with 95X18, the load - 30 MPa (x56)

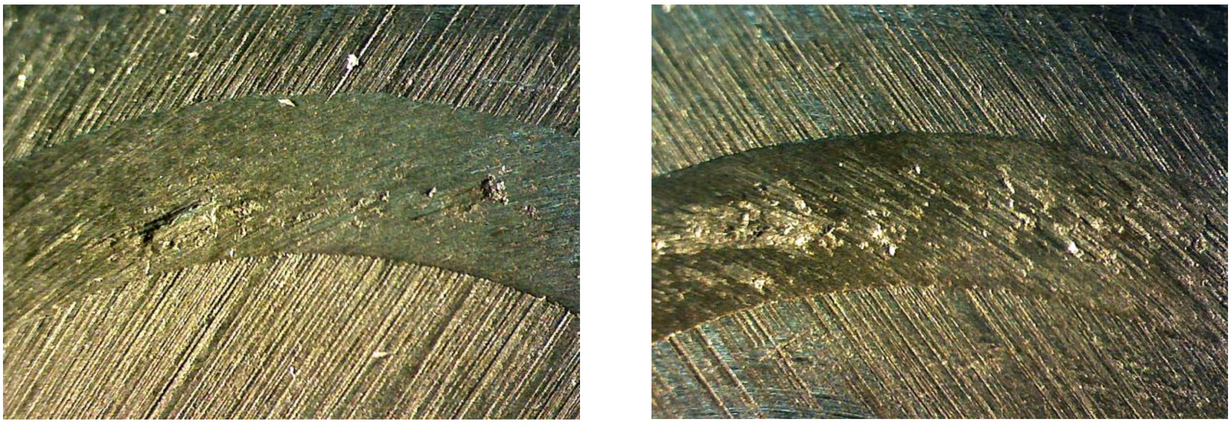


Figure 3.9 – The friction surface of titanium alloy BT-22 at friction with 95X18 at a load of 20 MPa (x56)

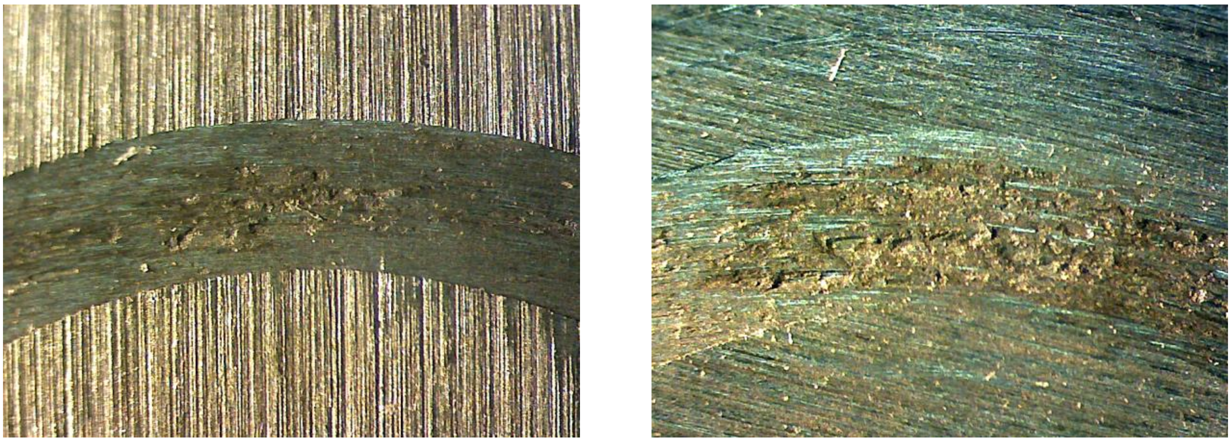


Figure 3.10 – The friction surface of titanium alloy BT-22 at friction with 95X18 at a load of 30 MPa (x56)

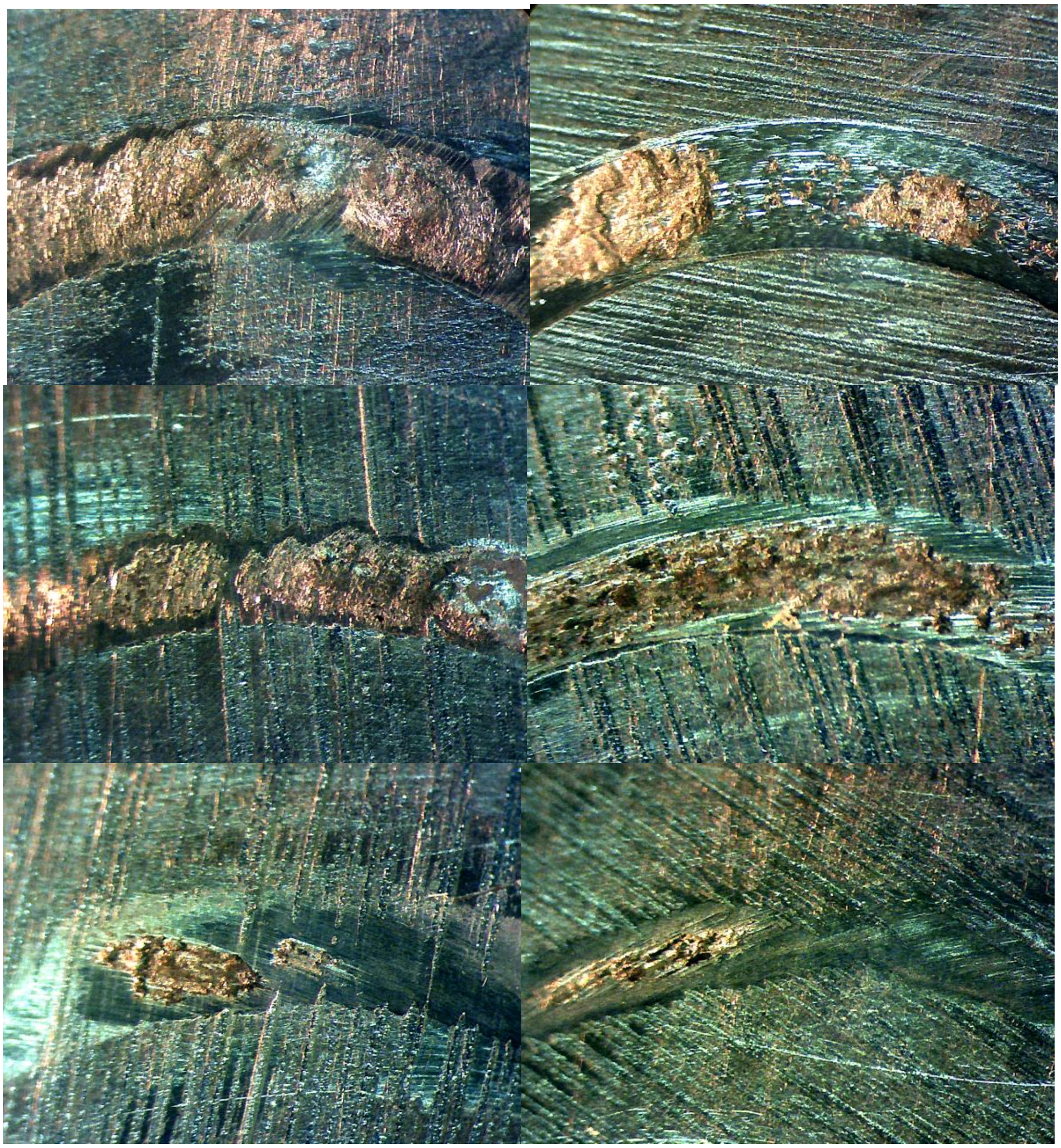
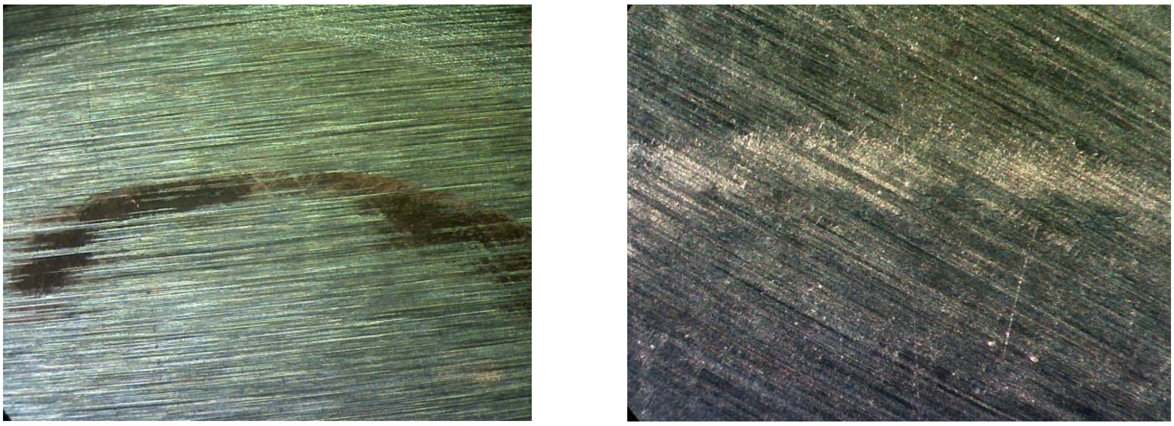


Figure 3.11 – Adhesion places of friction surfaces of vacuum-arc coating of molybdenum with BT-22 alloy at friction with 95X18 (x56)

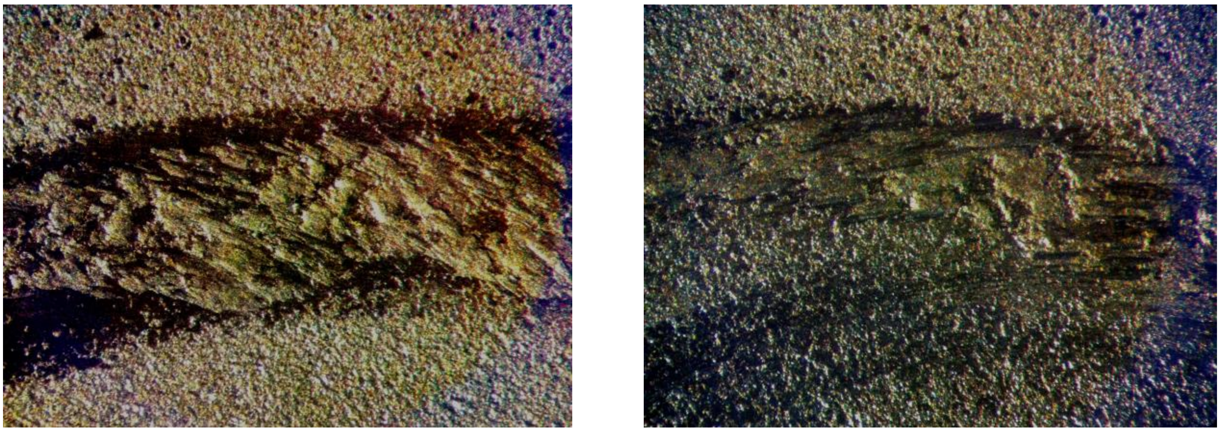
At loading 30 MPa wear resistance of solid vacuum-arc coating chrome on alloy BT-22 is considerably greater.A serious drawback of solid vacuum-arc coating of chromium is a high hardness of the coating. At testing in some places of seizure, there was tearing of this coverage and transfer it on the control sample material that proves insufficient adhesion strength of solid vacuum-arc chrome coating with the base surface. Also on the friction surface the coating wear was observed in some places as a result of seizure with control sample.



a) b)

a) – at 30 MPa; b) – at 20 MPa

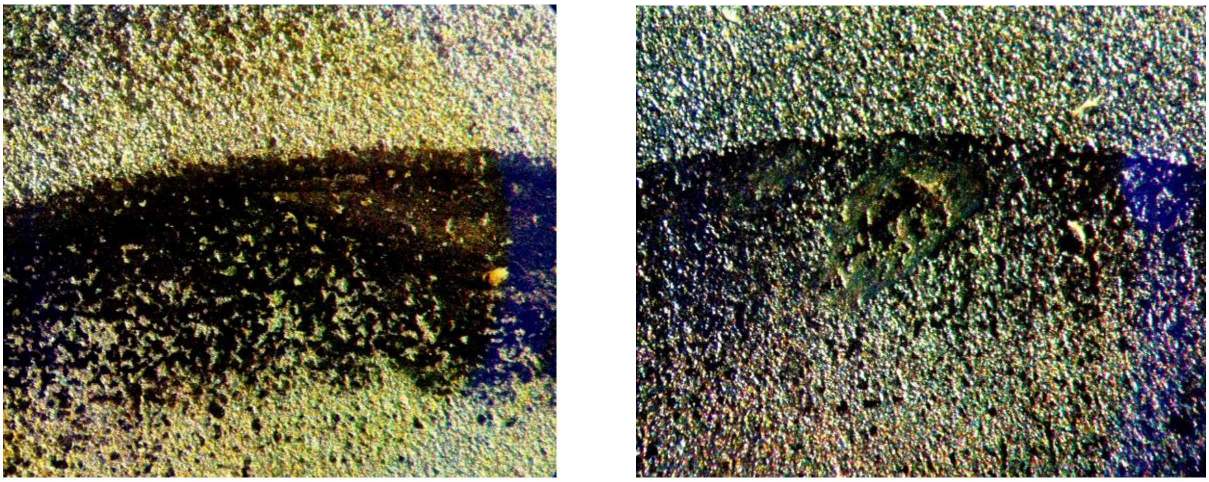
Figure 3.12 – Friction tracks of electroplated chromium in a pair with steel 95X18 under loads of 20 MPa and 30 MPa (x28)



a) b)

a) – at 30 MPa; b) – at 20 MPa

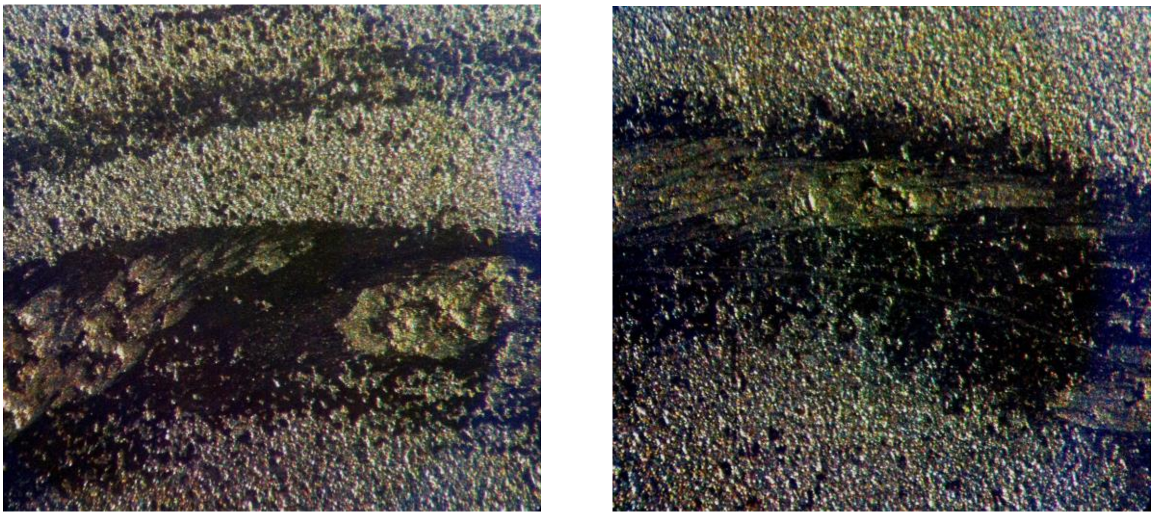
Figure 3.13 – Topography of the Mo surface wear formed as a result of the seizure with steel 95X18 (x56)



a) b)

a) – at 30 MPa; b) – at 20 MPa

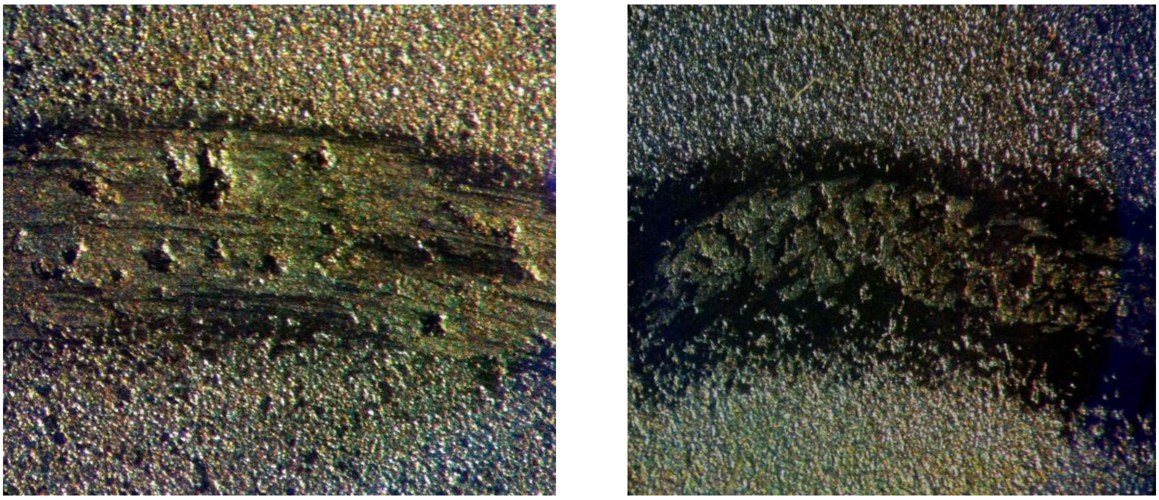
Figure 3.14 – Places of wear of galvanic vacuum-arc coating of chromium, formed as a result of the seizure with steel 95X18 (x56) a-at 30 MPa; b-at 20 MPa



a) b)

a) – at 30 MPa; b) – at 20 MPa

Figure 3.15-Tears on the solid vacuum-arc coating of chromium at friction in pair with 95X18 a-30 MPa; b-20MPa.



a) b)

a) – at 30 MPa; b) – at 20 MPa

Figure 3.16 Topography of the chromium soft surface wear formed as a result of the seizure with steel 95X18 (x56) a-at 30 MPa; b-at 20 MPa

Topography of vacuum-arc and galvanic chromium and molybdenum surfaces are represented on Figures 3.13-3.16.

Analyzing the friction surface topography we can make the conclusion that in all cases there were the mechanical and chemical wear. Friction surface of molybdenum and vacuum-arc soft chromium have numerous places of material grip transfer on the other specimen and smearing of this material. Especially good it can be seen on soft chromium coating. Topography of vacuum-arc solid chromium practically has not got the places of grip. The surface is uniform without dugs and cankers.

Conclusions to chapter 3

The most wearability showed vaccum-arc Cr solid. Its wearability is commensurated with Cr gal but vacuum-arc Cr solid has in 2 times gerater wear than Cr gal.

During friction without the lubricant the wearability of some coatings is less than during testing without the lubricant АМГ-10. It can be explained by the fact that during soft friction the surfaces intensively oxidizes and the corrosion products appear like the intermediate layer between friction pairs.

During friction in АМГ-10 it can often be grip and diggings of the coating that lead to great wear.

The wearability of coatings durinf friction without the lubricant is equidistant to friction in hydraulic liquid АМГ-10.

Vaccu,-arc coatings of Cr soft and Mo showed practically the same bad wear results in conditions of fretting-corrosion. It is necessary to eliminate the usage of these coatings for details that work in conditions of АМГ-10 at fretting-corrosion.

It is necessary to pay special attention at work of vacuum-arc and galvanic coatings on titanium alloy ВТ-22 in the process of friction with hydraulic fluid АМГ-10. If we can see the coating wear, so due to titanium susceptibility to grip the catastrophic wear of coating appears.

PART 4
ENVIRONMENTAL PROTECTION

4.1 The requirements of the laws of Ukraine in ensuring environmental protection

Environmental protection, rational use of natural resources, environmental safety of human life - is an essential condition for sustainable economic and social development of Ukraine.

For this purpose Ukraine carries on its territory environmental policy aimed at preserving for the existence of living and inanimate nature safe environment, for protection the lives and health from the negative impact caused by environmental pollution, achieving harmonious interaction between nature and society, protection, rational use and reproduction of natural resources.

In the Law of Ukraine on economic independence among the main objectives of achieving economic independence are listed security achievements, creating healthy and safe living and working conditions.

The Law of Ukraine on Environmental Protection defines the main principles of environmental protection:

- priority of environmental safety requirements, mandatory compliance with environmental standards, norms and limits of natural resources use;
- ensure environmental security for life and health;
- ecological material production based on complex issues of environmental protection.

The purposes of environmental assessment are:

- identification of environmental dangers of economic and other activities that may directly affect the future state of the environment;
- ascertain the projects compliance to legislative requirements;
- assessment of completeness and validity of the measures envisaged concerning environmental protection.

Positive findings of environmental assessment are the basis for funding the opening of the object. To provide programs and projects without this is prohibited.

Galvanic manufacture as a source of environmental pollution

In diploma work the two methods of coating application on the surface of aircraft parts are concerned- galvanic and vacuum-arc.

Almost all technological processes of metal platings are sources of harmful chemicals discharge into the air. State of hazardous substances (in the form of gases, vapors, dust) and their quantitative characteristics depends on the conditions of technology, in some cases, of respect for the work.

For example, in electroplating processes the unreasonable increase in current density, solution concentration and electrolyte temperature increase leads to the rapid evolution of hydrogen and oxygen with the removal in air the environment fog and electrolyte decomposition products.

At high temperature of galvanic solution it evaporates vigorously, polluting the air. The greatest danger is in the air discharge cyanide compounds (hydrogen cyanide vapor, solution Ksn, NaSN) with silver cyanide , zinc plating, cadmium plating in alkaline cyanide baths. The reasons for the secretion of cyanide in air are the possible changes in the pH of the electrolyte strongly alkaline to acidic. Under normal circumstances the theoretically acidic environment is created by three effects on air CO2 solution and the possible dissociation of water under the influence of an electric current to the ions H + and OH -.

These conditions, however, in practice, do not entail massive emissions of hydrogen cyanide, as the environment is alkaline. However, in emergency situations (falling of acids in cyanide baths, combining of ventilation air flows or wastewater from cyanide and acid pickling baths) can happen the hydrogen cyanide allocation in dangerous concentrations. During the process of digestion there are secretions of sulfur dioxide, nitrogen oxides, hydrogen chloride (as in the application of sulfuric, nitric, hydrochloric acid). And now they are rarely determined in the air of industrial facilities through the implementation of effective technological and sanitary measures [28].

However, in some emergency cases, their income in the air of working area can take place. In addition to air pollution by harmful chemical substances, the electrolyte has a negative impact and direct effect on skin and mucous membrane (in electroplating), degreasing and etching solutions, alkalis and acids during oxidation, etc.

Up to 10 % of working electroplating plants and other metal plating plants are occupied by dosing, preparation and mixing of granular components of electrolytes solutions. This staff is sometimes exposed to dry powdery substances or concentrated (to dilution or reconstitution) of toxic substances such as cyanide salts, acid).

Plating plants air environment may be contaminated with substances that are deliberately displacing toxic or that are playing a supporting role in the processes of cover. Couples of molten metal in some of the above processes (lead, zinc) can cause a number of specific pathological changes.

Organic solvents, chlorinated hydrocarbons, which are part of degreasing solutions with constant inhalation, may also cause some professional poisoning.

The great importance in the practice of electroplating has an impact on the working of chromic anhydride, which may manifest as lesions of the nasal mucosa. Depending upon the chromic anhydride concentration in the air, the symptoms are different: at low concentrations there was runny nose, irritation of the nose, minor nosebleeds.

At higher concentrations, there were areas of mucosal necrosis, ulceration until the breakthrough of the nasal septum.

Secretion of acids and alkalis vapor into the air gives irritating effect on the mucous membranes of the respiratory tract, eyes, also destroy tooth enamel. In the electrolytic areas the most unfavorable influence is because of nickel and chromium salts, which have sensitizing effect. Their influence is especially pronounced after prior contact with decreased alkalis and organic solvents.

The clinical picture of skin professional diseases from exposure to nickel salts is similar to eczema that is localized in the flexor surface of the forearm due to action of chromium salts and there was found eczema and dermatitis. These diseases are easily recurring with resumption of contact sensitizers. Acids and alkalis in contact with skin cause the characteristic burn. Solvents and chlorinated hydrocarbons irritate and cause chronic eczema, dermatitis, dry skin, cracked.

Sometimes skin blows from exposure of chemically active substances are found in persons to whom details are received in subsequent manufacturing processes and operations (collections). This is due to the presence on the surface the certain number of parts acid or chromic anhydride.

In electroplating plants the sources of danger are processes of surface preparation, preparation of solutions and electrolyte coating. Methods for surfaces cleaning are characterized by increased dust, noise and vibration. Used for preparation solutions of alkali, acids, salts when exposed to the body can cause poisoning or professional disease. Using manual vibro instrument for surfaces grinding could cause vibro diseases. Work with ultrasonic cleaning baths is associated with exposure to working sonic and ultrasonic vibrations. In addition, a large number of wash tubs in the room creates higher humidity. Normal conditions are created with the help of good lighting, ventilation system and maintaining the proper temperature in plant [29].

The most hazardous substances in circulation are:

Sodium hydroxide (NaOH)

When injected solution or dust is formed on skin the soft crust is appeared. There can be ulcers, eczema, especially in the folds of the fingers joint. It is very dangerous when even the smallest amounts of NaOH hit the eye. Not only the cornea is affected, but also in consequence of the NaOH rapid penetration the deep parts of eye can alsp suffer. The result can be blindness. If it hits the skin you should wash the affected area of running water for 10 minutes, then use the lotion with 5 % acetic or citric acid. In case of contact with eyes you should immediately flush it with water or saline for 10 - min.

Personal protection equipment: overalls of thick cloth, rubber gloves, sleeves, apron, shoes.

Soda ash ($Na_2 CO_4$)

When using soda ash there is detection of mucosal congestion there, and just the same you can see during the action of chromium compounds. Inhalation of dust may cause respiratory tract irritation, conjunctivitis. During prolonged usage of solutions the next deseases are possible: eczema, skin irritation. Concentrated solution of $Na_2\ CO_4$ causes burns, necrosis, and further clouding of the cornea.

Personal protection equipment: overalls of thick cloth, rubber gloves, sleeves, apron, shoes.

Hydrochloric acid (HCL)

At high concentrations there can be irritation of mucous membranes, especially of the nose, conjunctivitis , corneal opacity , tingling in the chest , runny nose , cough, chronic poisoning causes catarrh of the respiratory tract , tooth decay , changes in the nasal mucosa, gastrointestinal disturbances, possible inflammatory skin disease. Certainly the cause of poisoning is not gaseous HCL, but fog HCL, which is formed by the interaction of gas with water evaporation of air.

If poisoning, it is necessary immediately to bring the victim to fresh air, and make him free from hindering breathing clothes, also make inhalation of oxygen, rinsing the eyes, nose, and rinse 2% of sodium carbonate solution. If there is any damage of eyes after their flushing it is necessary to drop 1 drop of 2% solution of Novocain. After contact with strong acids on the skin you should immediately wash it with water for 5 - minutes.

Personal protection: filter respirator, protective airtight goggles. Working clothes must be done from acid resistant fabric. Mittens, gloves also should be made from resistant rubber. Boots must be done from rubber anti-acid.

Hydrocyanic acid (HCN)

Poisoning with cyanide and its compounds are possible in the processing of ore (cyanidation), electroplating of metals and during disinfestation of facilities , etc. Once in the body through the respiratory tract, at least - through the skin, hydrocyanic acid blocks the respiratory enzyme cytochrome oxidase and causes tissue anoxia. During acute poisoning it is observed the irritation of mucous membranes, weakness, dizziness, nausea, vomiting, then dominated by respiratory disorders - a rare deep breathing, shortness of breath painful, coming slow and stop breathing. In chronic cyanide poisoning bother headache, fatigue, marked low blood pressure, electrocardiogram changes in blood - sugar lowering and increased hemoglobin, lactic acid, etc. The action of cyanide of potassium and sodium on the skin can cause cracking, development of eczema.

Personal protection: industrial filter respirator, protective airtight goggles, working clothes done from acid resistant fabric, mittens, gloves from resistant rubber, boots done from rubber anti-acid.

Ammonia (NH 3)

Ammonia vapors strongly irritate the mucous membranes of the eyes, respiratory system and skin. This we take as a pungent smell. Ammonia vapors cause excessive tearing, eye pain, chemical burn conjunctiva and cornea, loss of vision, seizures, coughing, redness and itching. The collision of liquid ammonia and its solutions with skin cause chemical burns with blisters, ulcers. Besides this liquid ammonia during evaporation absorbs heat and in contact with skin occurs varying degrees of frostbite [30].

Producing of noise and vibration

High levels of noise and vibration that are accompanied during operation of equipment in all areas of production (machinery, building, agriculture, etc.), results in decreased productivity, deterioration in the quality of products and well-being of employees. Moreover, when there is large proportion of heavy and unskilled work of these factors (noise and vibration) can cause occupational diseases.

A great attention is received to the problem of high level vibration in electroplating plants. It is connected with particularly dangerous influence on human body, and also with the fact that the noise and vibration in the workplace is growing due to the consolidation of production, usage of equipment and mechanisms with more power.

The noise in the plant is the result of engines, pumps, mixers. Noise and vibration have harmful effect on human body. Prolonged exposure to noise not only reduces hearing acuity, but changes blood pressure, diminishes attention, deteriorates vision. With simultaneous operation of motors, pumps, mixers do not exceed the permissible sound level in the workplace 80 dB, according to CH 3223-85, so there is no need to apply measures for sound insulation. To weaken the propagation of vibration in the building design that is caused by the operation of fans and pumps at their base lay resilient materials.

Ventilation of galvanic plants

There are standards of maximum permissible concentration of MPC pollutants in the air of working places. These standards include a lot of substances released in the process of electroplating equipment (splash and dust chemicals, dust, abrasives, solvents, steam, etc.). For their concentration not to exceed the allowable limit there are different events. The most common and most effective of these is the equipment shop ventilation system , the purpose of which is to due to the exchange of air that is contaminated suction and supply fresh, keep harmful substances in the air electroplating shop at a level not to exceed the requirements [31].

Ventilation of air can occur due to the difference of its temperature inside and outside the room through the open window, random cracks, even through walls when they are relatively porous, but this so-called natural ventilation is not productive, and the direction and velocity of air is exposed to bad governance. Much more efficient is the industrial ventilation in which air is sucked or filed with the fan power drive. Forced air supply allows air to suck the desired intensity directly from the harmful emissions and give fresh air efficiently distributing it around the room.

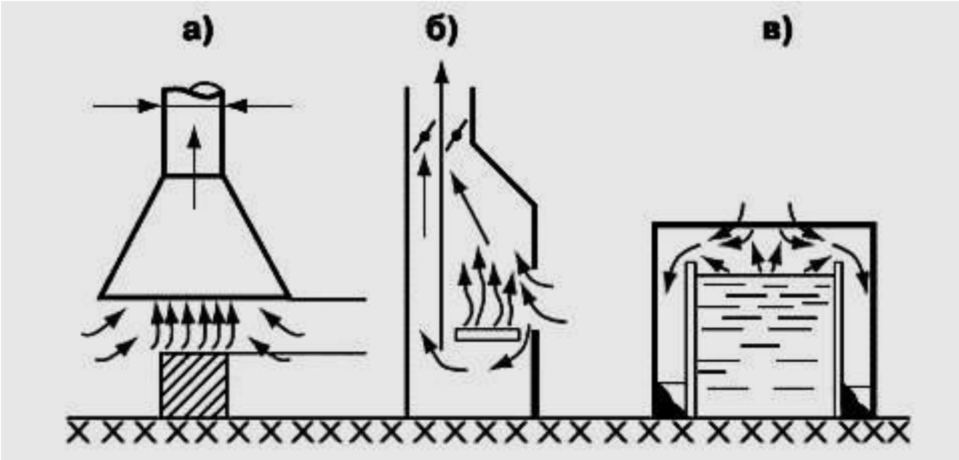
All supply - exhaust ventilation system of galvanic production is a single unit in which all movement of air in the pipes and in the indoor are interconnected.

Production and processing of ventilation should be performed only by qualified experts, as well as ventilation punctuality is the matter of health and even lives of workers in the galvanic plant.

Suction electroplating equipment

The design of suction affects not only the efficiency of ventilation, but also on the convenience of electroplating, and, consequently, on its performance.

Ventilation systems used in electroplating plants are: hoods, inside which there is a set of equipment, exhaust chimney (caps) that are installed above the equipment, suction play that is located to the non-working side of the equipment, suction side, installed at the upper edge of plating baths and handling of surfaces. These systems are shown in Figure 1.



a) – Exhaust umbrella, b) – fume hood, c) – suction

Figure 4.1 – Arrangement of Local Exhaust Systems

Sewage cleaning of galvanic plants

The purpose of treatment facilities is to clean waste water (acid- alkali, cyanide, fluoride) after washing operations in the electroplating industry up to maximum permissible concentration level of harmful substances by heavy metals and drop of clean water in the sewer system or return to reuse in the loop water recycling company. Wastewater from electroplating plant is gravity coming for separate pipelines for each type of pollution. Mixing different types of waste water is not allowed. Runoff containing cyanide, valent chromium , acids, alkalis and salts of heavy metals (nickel, zinc, iron) , whose content in discharges into municipal sewers are limited by sanitary standards. Waste water after electrochemical etching degreasing baths and after electroplating bath, contaminated with acids, alkalis and salts of heavy metals are chemically treated at wastewater treatment plants. This method of acid- alkaline treatment takes into account the possible presence of acid - alkaline effluent of heavy metal impurities.

General preventive measures

Metal platings plant lodging should preferably be located in one-story houses. In case of multistoried building the plants are located in the I floor building, and some sanitary units (air ducts, sewage, warehouses, etc.) are preferably to place in the basement. The room syllables dosage compartment, plots for electrolyte surface preparation (etching) must be isolated from each other and provided with the necessary ventilation devices.

The premises are provided with special acid-resistant floor asphalt, wall cladding to a height of 1.5 m above the floor acid resistant ceramic tile on special acid resistant mastic. In the floor there must be drains. Location of plating baths using cyanide salts should be provided at the largest distance from the bath with acidic solutions.

Equipment should not occupy more than 20 % of the plant, necessary device for passes and passages. From sanitary and technical devices the most effective is local exhaust ventilation that provides capture of the harmful emissions at the site of their formation. A number of plating processes is carried out in baths without the need of local exhaust ventilation. These include: copper plating bath and galvanizing in an acidic electrolyte bath chemical neutralization (sodium), Deca- citation ' washing in hot and cold water and lighting. However, the vast majority of galvanic baths and other units for metal platings should be provided with shelter for exhaust ventilation or suction board.

The amount of air that is removed with airborne suction and minimum air velocity over the bath, depending upon the process nature is shown in CH 245-71 that is a special sanitary regulation. Depending on the width of the bath there can be used one side extraction (width 700 mm) or double side (width 700-2000 mm) or one side with blowing (over 2000 mm).

To prevent the release of harmful gases and vapors from the surface of the electrolyte there are used different additives. A number of acid corrosion inhibitors are used for electroplating and etching baths.

Mechanization and automation of the metal platings eliminate manual operations and eliminates contact with harmful substances. Very important is the replacement of electrolytes and less toxic formulations if it is allowed by technology.

To protect the skin from exposure of corrosive substances the electroplating workers are provided with gloves, aprons, boots that do not miss moisture and stainless. And workers in other parts of metal platings if it is necessary are provided with glasses and filter masks. After work it is necessary to lubricate the skin with different creams. In determining workers hypersensitivity to nickel or chromium using skin tests or during medical examinations they should be transferred to another job [32].

When working with cyanide and chromium compounds, special attention should be paid to the immediate processing of micro-and macro skin damages (antiseptic solution and adhesive bandage). Electroplating workers should be well briefed about safety because of the presence of an electric current and they should be taught with first aid measures with shock and electrolyte solution in contact with eyes. Workers and employees plant engineering industry should have1 preliminary and periodic medical examinations in every 24 months.

Conclusion to chapter 4

According to the Law of Ukraine on Environmental Protection the degree work has been complied with all requirements summarized above and proposals concerning reduction of hazardous influence of galvanic production for the ecosystem have been presented.

As can be seen from the above, most galvanic production stations have an allocation of liquid, gaseous and particulate aerosols in the working area of the air. One of the most unfavorable factors of galvanic production is pollution of the air on the territory and domestic territories with metal compounds, various toxic vapors and acid emissions.

To avoid unpleasant emergencies it is necessary to carry out inspection of work equipment, air security systems and other equipment. Also it is necessary to conduct routine preventive work and constantly observe precautions and safety rules.

PART 5
LABOUR PRECAUTION

5.1 Legislation and normative acts of Ukraine on labour precaution

Labour precaution – is one of multiple socio-economic factors, affecting the labour productivity, quality and quantity of occupational diseases, injuries at work, as well as the number and results of accidents.

Basic principles of State policy in labour precaution

Labour precaution is based on following foundation-stone of State policy:

- priority of life and health of the workers in relation to results of their occupational activity at enterprise, total responsibility of the proprietor for creation of safe and non-hazard working conditions;
- social protection of the workers, full compensation of harm to persons, which suffered from accidents on production and occupational diseases;
- establishment of single standards in labour precaution for all of enterprises, irrespectively of property forms and appearances of their activity;
- use of economic management methods in labour precaution, taking of policy of preferential taxing, that contributes to creation of safe and harmless conditions of work, State participation in financing of arrangements in labour precaution;
- teaching of the population, their professional preparation and upgrading in labour precaution questions.

Legislation on labour precaution of Ukraine consists of the Laws: “About labour precaution”, “Labour Code of Ukraine” and other normative acts, which regulate the mutual relations between different subjects of the right in sphere of labour precaution.

Ukrainian Law About Labour Precaution defines a regulation for realization of constitutional right of the citizens on protection of their life and health during labour activity, regulates in participation of appropriate State organs the relationships between enterprise proprietor, establishment and organizations or its representative organ and worker in safety questions, working hygiene and occupational environment and installs single organization order of labour precaution in Ukraine.

Legislation on labour precaution considers the general questions of organization of labour precaution on production, such as: proprietor duties in managements by labour precaution on enterprise; facing out of requirements of normative acts on labour precaution by workers, medical examinations, learning and financing of labour precaution; establishment of labour precaution service on enterprise; labour precaution at projecting, building and reconstruction of enterprises, objects and production means; workers rights on labour precaution during enter into a labour pact, work time at enterprise, social security from accidents and occupational diseases; workers rights on tax benefits and compensations for heavy and harmful conditions of work, and also for the overalls, other means of individual protection, washing off and rendering innocuous means; proprietor obligations for compensation of harm to workers in case of their health damage; labour safety of the women, under-aged and invalids.

Labour precaution is managed by great number of State, interbranch and branch normative acts.

State, interbranch and branch normative acts on labour precaution – are the rules, standards, norms, regulations, circulars and other documents, which allotted a validity of legal norms, binding effect.

The State, interbranch and branch normative acts on labour precaution are reviews for implementation of science and engineering achievements, that contribute to improvement of safety, labour hygiene and occupational environment, but not less than once on ten years.

Standards, technical conditions and other normatively-technical documents on labour means and technological process are ought to include the requirements for labour precaution and to be affirmed by organs of State supervision for labour precaution.

State, interbranch and branch normative acts on labour precaution are binding effect in production workshops, laboratories, divisions and in other places of labored and vocational training of young people, appointed in schools, interschool groups of enterprises, colleges, higher and middle special teaching establishments, houses of technical amateurs, etc.

For violation of legislative and other normative acts on labour precaution, creation of barriers for activity of official persons of the organs of State supervision for labour precaution and spokesmen of professional associations guilty workers are dragged to disciplinary, administrative, material, criminal responsibility, in obedience to legislation [33].

Dangerous and harmful production factors of occupational environment influence on human health and capacity. In particular conditions they may cause traumas.

Let's introduce general characteristics of developed topic concerning labour precaution, mainly dangerous and harmful production factors.

Speaking about regulations it s necessary to mention the next one:

Works at electroplating stations belong to work with hazardous substances and high risk according to НПАОП 0.00-8.24-05 "List of works with high-risk", approved by the State Committee of Ukraine for supervision of works from 26.01.05 № 15.

The НПАОП 5.1.30-1.02-83 Safety and health regulations for aviation chemical works.

The НПАОП 24.1-7.30-76 Installation of air separators. General safety requirements for operation.

The НПАОП 24.14-7.53-84 Collection, storage, destruction and regeneration of waste flammable liquids. General requirements for safety.

The НПАОП 24.4-3.38-80 Typical industrial norms of free issue of special clothing, footwear and other personal protective equipment for workers and employees of the microbiological industry.

5.2 Dangerous production factors during application of coatings on aircraft details

Application of coatings on aircraft titanium details is usually provided in laboratories. So, the subject of labor precaution is a man, who makes experiments and with the help special equipment applies appropriate coatings on details, simply speaking the mechanic. The laboratory is chosen as the object of labour precaution.

All dangerous and harmful production factors are subdivided on: physical, chemical, biological and psycho-physiological.

Physical factors - moving machinery, noise and vibration, electromagnetic and ionizing radiation, low lighting, heightened level of static electricity, high voltage in an electrical circuit, and others.

Chemical factors - substances and compounds, which vary by states of aggregation and have toxic, irritant, carcinogenic and mutagenic effects on the human body and affecting its reproductive function.

Biological factors - pathogens (bacteria, viruses, rickettsia, spirochetes) and their metabolic products, and also animals and plants.

Psycho-physiological factors – the factors of the labor process. These include physical (static and dynamic overloading) and neuropsychiatric overloading (mental tension, overexertion analyzers, monotony of work, emotional overloading).

During application of coatings the following dangerous harmful production factors can influence the mechanic: moving hardware, work pieces and materials; unprotected mobile elements of machines, mechanisms and production equipment; flying away smithereens, elements, details of production equipment; raised dust and air contaminants in the laboratory room; raised noise level, vibration, ultra- and infra-sound; raised electric voltage, shorting of chain can happen over man body; raised static electricity; raised laser radiation in working area; raised ionizing radiation in working area; sharp edges and roughness of surfaces of equipment and tool; absence or lack of natural light; insufficient illumination of working zone; lowered contrast range of the objects upon the background; raised luminosity; raised level of ultraviolet and infrared radiation; chemical matters, included in composition of applied materials, fuels, special liquids; physical overloads (static and dynamic) and nervously-psychic overloads (emotional, overstrain of analyzers).

Insufficient illumination of working zone affects the functional of visual apparatus, which determines the visual performance, psyche and emotional state; it also causes the fatigue of the central nervous system. It was determined that light except providing visual perception also effects on nervous fiber-vegetative system, the formation of immune protection, growth and development of the body and effects on many others basic processes.

Raised noise level of working zone leads to the hearing disorder, cardiovascular diseases, and influences on the psyche and appearing of the chronicle stress, also low tone and immunity of human body. It is obligatory to have a consultation of different doctors to prevent such kind of diseases.

5.3 To carry out methods for reducing influence of harmful and dangerous factors of subject of labour

5.3.1 Calculation of lightning of working environment for works conduction in the laboratory rooms

In the working area depending on condition of exerted work the illumination standard for application of luminescent lamps with degree I is E_n = 400 l_x. The line voltage is 220 V. It is supposed to establish lamp appliances such as ODOR-2 with light sources LBR2-40 Wt hanged at altitude H_p = 2.5 m. The area of the room S = a·b = (6·8) m^2. Reflectance values of ceiling ρ_c = 0.5, walls ρ_w=0.3, working surface ρ_s = 0.1. The assurance factor K = 1.8. Calculate the power of the lighting installation and the number of lamp appliance.

While solving the problem we use the specific power computation method. From the special table we discover specific power of a lighting installation for voltage 220 V and K_1 = 1.5: W = 17.6 Wt/m^2.

We make allowance for the given assurance factor K=1.8:

$$W_s = W\frac{K}{K_1}\left[\frac{Wt}{m^2}\right]. \tag{5.1}$$

$$W_s = 17.6\frac{1.8}{1.5} = 21.12\ (Wt/m^2).$$

Let us find the power of a lighting installation.

$$W_{li} = P_A S \quad [Wt]. \tag{5.2}$$

W_{li}=21,12·48=1014(W_t)

The number of required lamp appliances

$$n = \frac{W_{li}}{NP_1} \,, \tag{5.3}$$

$$n = \frac{1014}{2 * 40} = 12{,}7 = 13$$

where N – number of lamps in a lamp appliance ODOR 2,

2 pieces;

P_1 – power of a lamp LB, Wt.

Approximating to an integer we find the number of a lamp appliances *n=13* pieces. This number of lamp appliances is enough for providing of labor precaution in coating application laboratory, regarding sufficient illumination of working zone.

5.4 Fire and explosive safety

Fire safety – is a state of the object, at which with established probability a possibility of beginning and conflagration development and influence on people of dangerous conflagration factors is excluded, and protection of material valuables is provided also.

People safety at the beginning of conflagration is ought to be realized in any place of production building or enterprise territory. Fire safety is provided by prevention systems of conflagration and fire protection.

A conflagration prevention system is a complex of organizational arrangements and technical methods, directed on exclusion of possibility of conflagration beginning. Organizational and technical arrangements for prevention of conflagration are already realized on stage of projection of separate objects laboratories. For that the peculiarities of technological processes and objects are learned in advance, first of all possible causes and sources of conflagration beginning.

For the situation considered in the diploma work, the next safety measures should be taken to eliminate fire and explosion in the laboratory:

There is a person responsible for fire safety in the laboratory room. Employees must know the fire hazard of substances and materials used in the laboratory and comply with fire safety measures when working with them. Before starting work on a new theme manager must conduct unscheduled instruction on fire safety, fixed in the Instruction Journal.

To prevent fire and explosion are conducted organizational, operational, technical and secure works, namely: fire safety training of workers; instructions, lectures; correct operation of machines, internal transport, equipment, buildings and territories; observance of fire regulations and standards during installation of heating and ventilation devices; banning of smoking in prohibited places, welding and other hot work in fire zones.

In the laboratory rooms computers are usually used for different works conduction, for processing the experiments results. And during computer work there are possible the following emergencies:

- short circuits;
- overloads;
- transient resistance increasing in electrical contacts;
- overvoltage;
- leakage current appearance.

In case of emergency, there is a sharp separation of heat which can cause a fire. The statistics says that 20 % of fires are fires in electric installations.

In order to prevent fires and explosion in laboratory, to save property from destruction by fire or explosion and to save the lives of people in the laboratory room it is forbidden:

- perform work associated with the release of toxic substances, explosive fumes or gases in the defective fume hoods;

- block walk ways, exits and approaches to the primary means of fighting with various combustible materials and equipment, as well as to arrange the passages between the equipment width of less than 1 meter;

- clean floors and equipment with kerosene, gasoline and other flammable liquids and materials;
- dry flammable items on the heating devices;
- clean up spilled flammable liquids when the burners are lighted, and electric heaters turned on;
- pour liquid waste down the drain;
- store flammable and combustible liquids in quantities exceeding the replacement demand;
- leave oily rags and paper at the workplace;
- store in working rooms any substance with unknown properties of fire;
- smoking in the workplace;
- left unattended workplace, lighted burners, and other heating devices;
- carry out work in a fume hood, if it contains materials and equipment not related to the operation being performed;
- to heat frozen pipes, equipment and engineering services with the help of blowtorch and other ways with the use an open flame;
- to left unattended energized TV sets, radios and tape recorders;
- to apply for heating non-standard (homemade) heaters - electric furnaceand electric bulbs;
- laboratory equipment should be installed so that it does not prevent the evacuation. Minimum allowable width of passages between the equipment should not be less than 1 m;
- in laboratory rooms petroleum products, flammable solvents and other flammable liquids should be stored in metal boxes located on the opposite with respect to the room exit side. The maximum allowable number of these fluids should be written down in the instruction.

At the end of the working day the responsible employee must check all the instruments and equipment, gas and water valves, turn off the general electrical switch and ventilation, and remove from laboratory room remains of combustible and flammable liquids, substances and chemicals, waste liquids, waste, garbage and rags, after that to mark this in a special journal.

In the case of a fire in a laboratory room it is necessary to notify immediately the fire department by telephone "101 " indicating the exact address of the object where is the fire, the name of the sender, to organize fire-fighting with available means, evacuate people and property, as well as to organize a meeting of fire departments.

Explosion – is a fast exothermal chemical transformation of explosive environment that is attended with extraction of energy and formation of constricted gases, capable to execute the work.

As the consequence of explosion a matter is gasified with strongly heating, filling in a volume with huge pressure. Explosion is possible only at certain concentration of air-gas. The concentration limits of airgas, at which an explosion takes place, are called by concentration inflammation limits of matter.

To prevent the beginning of explosion is possible by exclusion of possibility of formation of explosive environment and beginning of explosion initiation source.

Prevention of formation of explosion initiation source must be provided:

- by application of explosion-proofed equipment;
- by application of fast-acting methods of protective cutting off of possible electric sources of explosion initiation;
- by limitation of power of electromagnetic and other thermal radiation.

Laboratory rooms should be provided with primary fire extinguishing means.

All laboratory workers must know the location of fire extinguishers and know how to use them.

One of the most effective primary means of extinguishing is a fire extinguisher.

Extinguishers, as a primary means of fire fighting, take one of the main places in the system of fire protection. On the effectiveness and reliability of fire extinguishers, as well as their skillful use depends not only the nature of the further development of the fire, the amount of damages that they can cause, but also people's lives. Fire statistics show that most fires are usually extinguished before the arrival of fire brigade units.

Fire extinguishers:

ОХП-10, ОП-М, ОП-9ММ - Hand chemical foam fire extinguishers;

ОВП-10 та ОВП-5 - hand air-foam fire extinguishers;

ОУ-2, ОУ-5 і ОУ-8 - hand carbon dioxide fire extinguisher;

ОУБ-3 і ОУБ-7 - Hand ethyl bromide, carbon-dioxide fire extinguishers are designed to extinguish small sources of fire of fuel materials.

Fire equipment - covered with combustible insulation cloth, fabric or wool, boxes with sand, water barrels, fire buckets, scoops;

Fire tools (hooks, crow-bar, axes, etc.).

Primary means of extinguishing fire may be placed on boards.

Manual fire tool on the boards should be periodically cleaned from dust, dirt and traces of corrosion and repair needs sharpening angles and painting tool for use after fire or during practice.

Conclusions to chapter 5

In the given chapter of degree work different harmful and dangerous production factors for the mechanic in the laboratory room were identified and described. The measures of fire and explosion safety in laboratory room were considered. Also calculations of lightning of working environment for works conduction were carried out.

On the basis of carried out analysis of dangerous and harmful production factors that can take place during application of coatings on aircraft details in laboratory room the measures are developed for increasing the labor safety during work in laboratory room.

GENERAL CONCLUSIONS AND RECOMMENDATIONS

While performing the degree work the key issues were considered and important problems were solved in the project and special parts, namely:

- We have analysed the topicality usage of titanium in aircraft manufacture instead of all other materials;

- we have analyzed the operational damageability of aircraft details produced from titanium alloys and their restoration methods;

- we have provided research of vacuum-arc and galvanic coatings wear resistance in the medium of liquid АМГ-10 and in dry conditions in a wide range of loads;

- we have carried out a set of comparative studies in selection the optimal vacuum arc and galvanic coatings for titanium aircraft parts;

- we have analyzed the environmentally best method for details parts restoration;

- recommendations for the use of vacuum-arc coatings for strengthening and restoration of aircraft parts made of high strength titanium alloy BT-22 were developed.

The analytical part of the work revealed that titanium alloy details have definite advantages, such as:

1. low density (4500 kg/m^3) helps to reduce weight of the material;
2. high mechanical strength. It is necessary to note that at elevated temperatures (250-500 °C) titanium alloys are superior to high- strength alloys of aluminum and magnesium;
3. high corrosion resistance due to the ability of titanium to form on the surface of thin (5-15 microns) solid oxide film TiO_2 strongly associated with the mass of metal;
4. specific strength (ratio of strength and density) of the best titanium alloys is 30-35 or more, almost twice the specific strength alloy steels.

As the result of solution of the main assigned tasks in the scientific-research part it was revealed that among the tested materials the most wear-resistant coatings appeared to be vacuum arc coating of chromium and chromium galvanic coating. In some cases the solid vacuum-arc chromium coating exceeds galvanic chromium coating in wear resistance but low bonding strength of hard chromium coatings leads to rapid destruction of the surface with increasing load. But galvanic manufacture is one of the most dangerous sources of environmental pollution that is why the vacuum arc coatings are considered as perspective coatings.

In the degree work the issues of labour precaution, flight safety and environmental protection were described.

The section of flight safety highlights the question how to increase the safety level using the coatings applied on aircraft details.

The major issues on labour precaution make it possible to obtain the necessary and sufficient information for decision making.

Section of environmental protection reveals hazards of electroplating industry on the environment. Also in this section, methods of reducing adverse impacts on the environment electroplating are described.

The following recommendations were developed:

1. It is reasonable to use a vacuum arc coating of hard chromium coating instead of electroplated chrome on the aircraft parts that are made from titanium alloys. The wear resistance of these materials is practically identical, but the galvanic coatings have still a negative impact on the environment.

2. Soft vacuum-arc coatings of chromium and molybdenum showed almost identical results in poor wear resistance under conditions of fretting corrosion. The use of these types of coatings for parts operating in the hydraulic liquid АМГ-10 and in dry conditions, under fretting corrosion and frictional sliding should be limited.

3. The work of the vacuum-arc and electroplated coatings on titanium alloy ВТ-22 at friction in the hydraulic liquid АМГ-10 and in dry conditions should be more carefully monitored. If the coating wear takes place, the fracture surface increases dramatically due to the high propensity of titanium alloys to seizure.

Thus, the tasks that were posed for the degree work were fulfilled in a full size.

References

1. Білоусова Н.А. Поляризаційні методи визначення швидкості корозії металів та їх метрологічна оцінка: Автореф. Дис.канд. техн. наук: 05.17.14. / НАН України. Національний технічний ун-т України «Київський політехнічний ін-т». – К., 2005. – 22 с.

2. Теплофизические свойства титана и его сплавов: Справочник / В.Э. Пелецкий, В.Я. Чеховский, Э.А. Белецкая; Под. Ред. Акад. А.Е. Шейндлина и др. – М.: Металлургия, 1985, – 104 с.

3. Титан. Металловедение и технология. Тр. III Международная конференция по титану М. ВИЛС, – 1978, т.1. – 485с., т.2. – 738с., т.3. – 602 с.

4. Курсовое проектирование по восстановлению деталей. Улашкин А.П. Тузов Н.С. ХГТУ, 2000. – 140 с.

5. Нержавеющие и легированные стали и сплавы. Марки. Сортимент. Справочник снабженца. – М.: Торговый Дом Металлов, – 2005. – 589 с.

6. Бібліотека українських підручників (pidruchniki.website), 2010 – 2014 http://pidruchniki.ws/14210923/menedzhment/nespravnosti_vidmovi_mashin

7. Закалов О. В. Основи тертя і зношування в машинах: Навчальний посібник / О. В. Закалов, І. О. Закалов. – Тернопіль: Видавництво ТНТУ ім. І.Пулюя, 2011. – 322 с http://uk.wikipedia.org/wiki/Тертя

8. Анализ типовых соединений авиационных конструкций, у которых возможно разрушение от усталости вследствие развития фреттинг-коррозии в процессе эксплуатации, с целью установления путей повышения их срока службы. Отчет.

9. Закалов, О.В. Триботехніка і підвищення надійності машин: О.В.Закалов. –Тернопіль: ТДТУ, 2000. – 354 с.

10. Зносостійкість сплавів, відновлення та зміцнення деталей машин: Навчальний посібник. За ред. Попова В. С. — Запоріжжя: Мотор Січ, 2006 — 420 с

11. Харламов Ю.О., Будагьянц Н.А. Основы технологии восстановления и упрочнения деталей машин. Учебное пособие в 2т. – Луганск: изд-во Восточно–укр. Национ. ун-та им. В. Даля. 2003

12. Кондрачук М. В. Трибологія / М. В. Кондрачук, В. Ф. Хабутель М. І., Пашечко Є. В. Корбут. – К.: Вид-во Національного Авіаційного університету «НАУ-друк», 2009. — 232 с

13. Надежность и ремонт машин. Под редакцией В.В. Курчаткина. – М., „Колос”. 2000.– 776 с.

14. Навчальний посібник Автоматизація технологічних процесів і систем автоматичного керування (частина 4) Карпов Д. А. Катодно-дуговые источники и фильтры макрочастиц. // Surface and Coatings technology 96, 1997. с. 22-33

15. Гура Г. С. Качение тел с трением. Фреттинг. Сочи: ООО «Полиграфический центр "Дория"», 2009. 295 с

16. І. І. Аксьонов, В. А. Білоус Вакуумно-дугове обладнання для іонно-плазмового осадження покриттів (огляд) (укр.) // «Вопросы Атомной Науки и Техники» (ВАНТ) : Журнал. — Харьков: Национальный научный центр "Харьковский физико-технический институт", 2000. — № 4. — С. 153—157.

17. Харламов Ю.О., Будагьянц Н.А. Основы технологии восстановления и упрочнения деталей машин. Учебное пособие в 2т. – Луганск: изд-во Восточно–укр. Национ. ун-та им. В. Даля. 2003.

18. Орехова В. В., Байрачный Б. И. Теоретические основы гальваностегических процессов. К.: Выща шк., 1988. – 208 с.

19. Charles Sexton. Fundamentals of Aqueous Cleaning: Materials, Equipment, and Waste Treatment; June, 1996.

20. С. Я. Грилихес Обезжиривание, травление и полирование металлов. Издательство Машиностроение. Л. 1983 г. 101 с.

21. Шаронов Е.А., Ванновский В.В., Алексеев С.В. Вакуумно-дуговое напыление меди на порошок керамики SiO2 – FeOn // Труды 6-й междунар. Конференции «Пленки и покрытия – 2001». — СПб: Изд. СПбГТУ. — 2001. — С.146–149.

22. Селиверстов И.А. Анализ процесса вакуумной металлизации порошковых материалов в виброкипящем слое / И.А.Селиверстов, С.А. Русанов, И.В. Смирнов, В.И.Копылов // Вестник національного технического

университета Украины „ Киевский политехнческий інститут” / Машиностроение. —2009. — № 57. — С 50 — 56.

23. А. А. Андреев, В. Г. Василина, В. И. Зайцев, Г. Н. Картмазов, В. Н. Надтока, И. М. Неклюдов, Л. П. Саблев, Р. И. Ступак. «Устройство для ионно-плазменного нанесения покрытий на внутреннюю поверхность труб» - Пат. Украины № 76344, 01.11.04, опубл. 17.07.2006, Бюл. № 7.

24. O. Protoiereiskiy. Labour protection: Manual for practical classes for all specialities – Kyiv: NAU – 2001. 164 p.

25. Григорьев С.Н. Вакуумно-дуговые устройства и покрытия – Харьков: ННЦ «ХФТИ», 2005. – 235 с.Lewis, Peter Rhys, Reynolds, K, and Gagg, C, Forensic Materials Engineering: Case studies, CRC Press (2004).

26. Mills, Kathleen Fractography, American Society of Metals (ASM) handbook, volume 12 (1991)

27. Ажипа Я. И. Медико-биологические аспекты применения метода электронного парамагнитного резонанса. М: Наука.-1983. -528с.

28. Береснев В.М., Перлов Д.Л., Федоренко А.И. Экологически безопасные вакуумно-плазменное оборудование и технологии нанесения покрытий. – Харьков: ХИСПИ, 2003. – 292 с.Доклад «О состоянии и об охране окружающей природной среды Ивановской области в 2001 году». Иваново: Office-club, 2002. 154 с.

29. Ю. П. Хранилов. Экология и гальванотехника.: учеб.пособие.-Киров: ВятГТУ, 2000.- 97 с.

30. Климов Е.С., Эврюкова М.Е., Колганова Н.С., Варламова С.И., Борисова В.В. ЭКОЛОГИЧЕСКИЕ ПРОБЛЕМЫ ГАЛЬВАНИЧЕСКИХ ПРОИЗВОДСТВ // Успехи современного естествознания. – 2004

31. С.С. Виноградов. Экологически безопасное гальваническое производство. – М.: Глобус, 1998. – 302 с.

32. O. S. Protoiereiskiy, O. I. Zaporozhets. Basics of labour precaution: Education manual – K: NAU, 2002. – 524 p.

33. Жидецький В. Ц. Основи охорони праці: підруч. / В. Ц. Жидецький. — 3-тє вид., перероб. і доп. — Львів : Укр. акад. друкарства, 2006. — 336 с