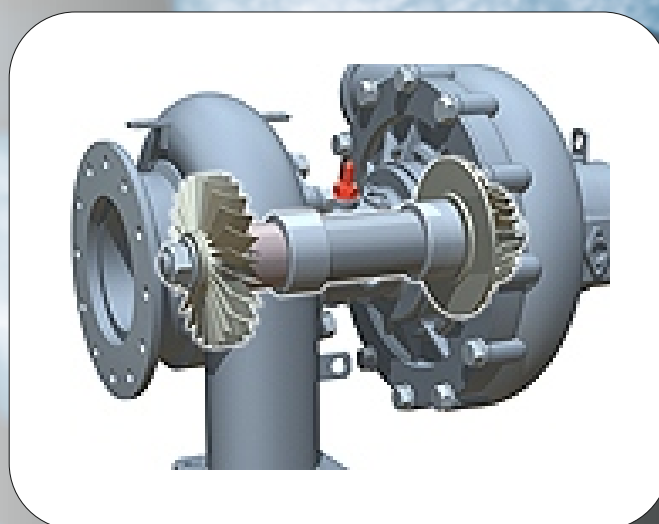


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DYNAMIC ANALYSIS OF BRIDGE CRANE WITH ONE MAIN GIRDER DURING TELPHER MOTION WITH FULL LOADING

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Abstract: This paper deals with dynamic analysis of bridge crane with one main girder during telpher motion in order to determine dynamic behavior and oscillations while carrying full load. During the telpher motion the main girders and side girders are heavily loaded parts while they undergo forces, moments and oscillations from lifting mechanism that carries workload. The method of analysis is the comparison of results gained through modeling and simulation and experimental measurements. The analysis will be concentrated in finding the nature of dynamic forces, moments and stresses that acts on main crane's parts and finding the extent and form of oscillations that can cause damage and failures. Also the interest is to study the effects of load swinging in crane's stability. Results will be shown in the form of diagrams as the solution results of the tested system. Crane is modeled from standard manufacturer, as a special type of Bridge Crane with one main girder and telpher. Conclusions of these analyses are useful for design considerations, dynamic behavior and safety.

Keywords: BRIDGE CRANE, TELPHER MOTION, MAIN GIRDER, DYNAMIC ANALYSIS, OSCILLATIONS, MODELING, SIMULATIONS

1. Introduction

Companies that work with Bridge cranes have difficulties dealing with oscillations and swinging of workload, which can lead to safety problems. Bridge crane taken for study is special type of overhead cranes with one main girder, mounted in factories and warehouses, and have three main working cycles: load lifting and lowering, telpher motion and crane travel. Usually they work with big and heavy loads, which are attached on the Hook. Telpher is mounted below the girder and connects with Hook through Pulley system, Lifting cables and Drum. In these cranes heavy oscillations are mainly caused due to load overloading, improper connection of load in cables, and inadequate speed of motion. These can lead to stability problems, break of parts, cables damage, etc.

This work is based in the theory of crane dynamics, multibody dynamics, systems design, modelling and simulations.

In Fig.1 and Fig.2 is represented Bridge crane taken for analysis from manufacturer *Prim Co Company*, Type JP100 [1]. Crane is mounted in rails on the walls of the factory. It has one main girder, and two side girders (left & right). Weight of workload & Pulley system is $Q = 5150 \text{ kg} = 50.5 \text{ kN}$. Elevated position of girders is $H = 6.5 \text{ m}$. Length of main girder is $L_m = 12 \text{ m}$. Mass of main girder is $m_m = 2000 \text{ kg}$. Velocity of telpher is $v_{te} = 0.33 \text{ m/s}$. Diameter of telpher wheels $D_v = 150 \text{ mm}$. Telpher is moving on 4 wheels, 2 per each side, mounted on main girder's edges (Fig.1).

In literature [3], [5], [6] it is estimated that the beginning of the telpher motion is the most difficult process concerning the dynamic behavior of crane.

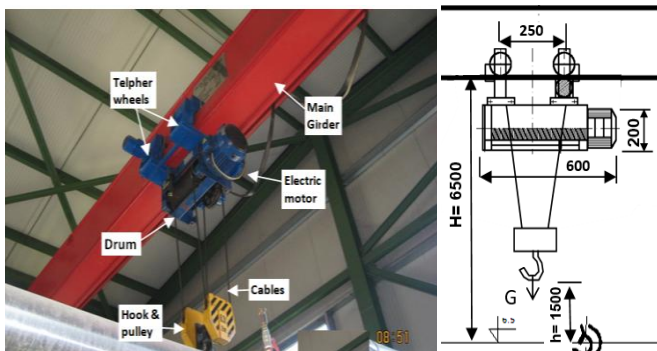


Fig.1. Telpher of crane and its dimensions [1]

2. Modelling and simulations of Bridge crane

In Fig.1 and Fig.2 is presented bridge crane in the working environment, which is also modeled in software (Fig.3) [2], [8]. Lifting mechanism is designed in the form of double pendulum. Working load has prismatic form with dimensions $1\text{ m} \times 1\text{ m} \times 1\text{ m}$, connected on 4 carrying cables with the Hook and Pulley.

Carrying cables are connected with the Hook and above with pulley system, that connects to Drum with 4 lifting cables. (Fig.1). Load height from basement is 1.5 m . It is positioned on the center of crane's main girder. We consider that best results will be achieved if the study is done with max carrying load $Q = 50.5 \text{ kN}$, as given by manufacturer [1], [5].

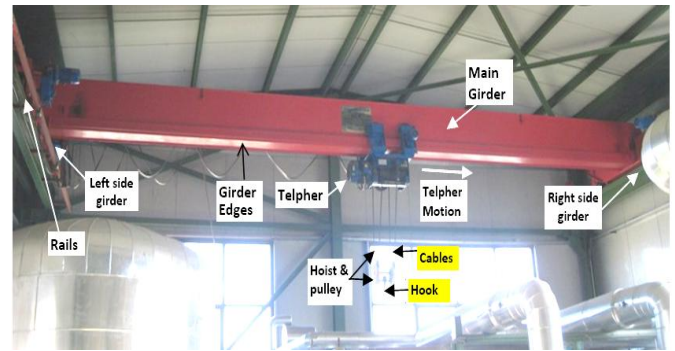


Fig.2. Bridge crane with parts in the working environment [1]

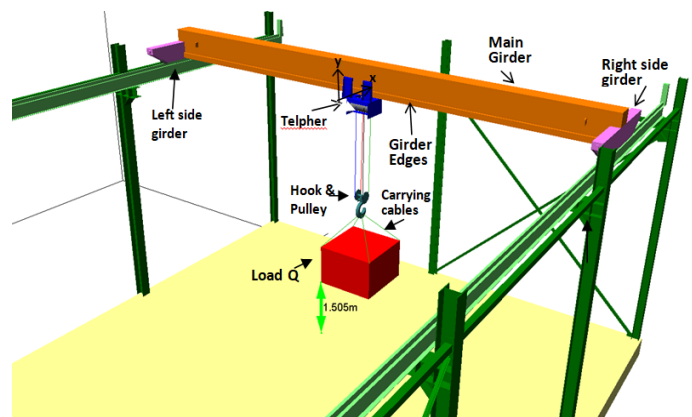


Fig.3. Model of bridge crane in the working environment created in the software SimWise 4d [2]

Before simulations with software, load Q is in the position of relative rest at the height $h = 1.5 \text{ m}$ from the basement. Simulation planning of telpher motion is close to real work which is important for achievement of reliable results. Telpher will move from center of Main girder towards right side Girder. Time of simulation will be $t = 11 \text{ s}$. Simulation has three phases [3],[13]:

First phase – initial position of relative rest with no motion of telpher. Load hangs on carrying cables. Starts at time $0 \text{ s} < t < 1 \text{ s}$.

Second phase – Is the process of motion of telpher with the speed $v_{te} = 0.33 \text{ m/s}$. Starts after first phase, between time $1 \text{ s} < t < 9 \text{ s}$. Length of telpher motion is $l = 2.7 \text{ m}$.

Third phase - motion stoppage. Telfer will stop moving, but load, pulley and hoist cables will continue to swing. Starts after second phase, between time sequence $9 \text{ s} < t < 11 \text{ s}$. Important for evaluation of the results after motion stop.

3. Experimental measurements

Measurements in crane are done in the place of work, where crane is mounted, in the factory of local company (Fig.1). They will be used for validation of results. Main measured parameter is tensile force in lifting cables – F_{ca} . In this crane there are 4 branches of lifting cables connected between drum and pulley system. This is the force on lifting cables resulting from weight of load and pulley system which hangs and swings during telfer motion. Lifting cables lifts up or lowers the load, but for the case of telfer motion they also carry the load (Fig.2 & Fig.3) [11].

Type of lifting cables are wire ropes type 6X37, with diameter $d_c = 19 \text{ mm}$ [1]. Other properties are: Modulus of elasticity: $E = 7.58 \cdot 10^{10} \text{ Pa}$, Minimum breaking strength $F_b = 212 \text{ kN}$, Safe Load $F_s = 42.3 \text{ kN}$ [1], [12]. Tensile force was measured with dynamometer type Dini Argeo attached to the Hook [10], during motion of crane (Fig.4). There were 6 measurements implemented. First measurement is done at first phase (relative rest), measurements 3,4,5, are done during telfer motion (second phase), measurement 6 is done after motion stoppage (third phase). Results are shown in Table.1.

Measurement No.	Time of telfer motion (s)	Tensile Force in all lifting cables - F_{ca} (N)	Force in each branch of lifting cables ($F_{ca}/4$) (N) (aprox.)
1	0	51050	12762
2	3	52200	13050
3	5	53150	13287
4	7	52600	13150
5	9	51530	12882
6	11	49850	12462

Table 1. Results of F_{ca} with dynamometer in hanging cables



Fig.4. Measurements with Dynamometer of tested load during the motion of telfer, and dynamometer used [10]

4. Results of force (tension) in lifting cables

In Fig. 5 is given the graph of Tensile Force in lifting cables - F_{ca} in one cable branch. It is a dynamic force which we will name it F_{cad} . It appears in cables while it comes from load swinging, pulley swinging and force in hanging cables. Diagram of other three cables is similar with this one, with minor changes.

Based on graph in Fig.5, we can conclude that dynamic tensile force F_{cad} in the lifting cables is close to experimental values (Table.1), which are shown with black dots. This validates results with simulations and makes them reliable and trustworthy. Force F_{cad} is dynamic in nature, with high frequencies up to $\nu = 19 \text{ Hz}$. Maximum value of force is achieved in time $t = 1.4 \text{ s}$, with the value $F_{cadmax} = 21800 \text{ N} = 21.8 \text{ [kN]}$.

Based on strength properties of cables, it can be concluded that $F_{cadmax} < F_s = 42.3 \text{ kN}$, meaning that lifting cables of crane can handle the dynamic tensile force without major deformations.

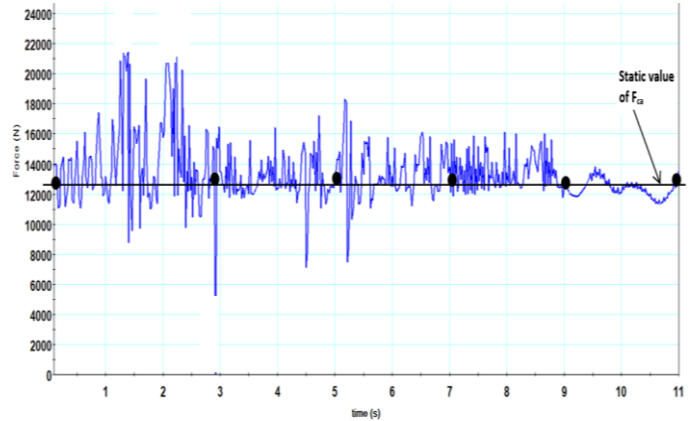


Fig. 5. Tensile force F_{ca} in one branch of lifting cable. Black dots are experimental values from Table 1.

Dynamic coefficient Ψ is the ratio between maximal dynamic force and static force [3],[6],[7]. Value of the coefficient is:

$$\Psi = \frac{F_{cadmax}}{F_{smax}} = \frac{21.8}{12.626} = 1.72 \quad (1.1)$$

Static force in lifting cables can be calculated by formulas [4]:

$$F_{smax} = \frac{F_0}{\eta_{ho}^l} = \frac{12.5}{0.99} = 12.626 \quad [\text{kN}] \quad (1.2)$$

Load in one branch of the cables in resting position is:

$$F_0 = \frac{Q}{m} = \frac{50}{4} = 12.5 \quad [\text{kN}] \quad (1.3)$$

$\eta_{ho}^l = 0.99$ - Working coefficient of hoist for lifting.

$m = 4$ – number of rope branches for weight lifting.

According to result of Ψ in (1.1), lifting cables undergoes 72% more dynamic forces compared to static forces. This value is high and a matter of concern, while it will weaken cables by time. Concerning the safety issues, this requires frequent control of lifting cables [14]. Conclusion is that lifting cables are heavily loaded with oscillations that have high amplitudes and high number of frequencies.

5. Resultant Force acting in telfer

Forces acting on telfer are passed from forces on drum and lifting cables that are connected with Hoist system, and they load the telfer while it moves (Fig.1). In Fig. 6 is given graph of Force in telfer - F_t . It is the Resultant force of all forces – tensile, bending and torsion components acting on telfer, and it is dynamic in occurrence. Maximal value of this dynamic Force is $F_{tmaxd} = 8.1 \cdot 10^4 \text{ Nm}$ and occurs in time $t \approx 4.5 \text{ s}$ (Fig.6). Based on graph, Static value of force is $F_{tst} \approx 5.25 \cdot 10^4 \text{ Nm}$. This concludes that the value of Dynamic Force is for 54% higher than the static force.

Static force is the Force in the condition when system is theoretically motionless, or in the situation of relative rest. It is the sum of weights of all devices acting below the telfer – Load Q, Cables, Hook, Hoist and Drum (Fig.1).

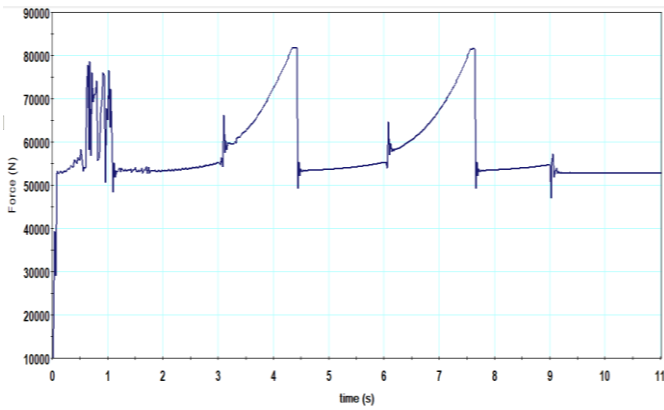


Fig. 6. Resultant Force acting on telpher

6. Results in main girder

Main girder is the most important and biggest part of Bridge crane. It has a cross section of Hollow Box Beam, with walls thickness of 1 cm [1], [11]. On the bottom side is mounted telpher that hangs in side extensions, where is also mounted hoisting mechanism with load Q (Fig.1 & Fig.3). Dynamics and oscillations from the hoisting mechanism and telpher are passed on girder.

Results will be achieved using Numerical methods (Kutta-Merson) and Finite Elements Method (FEM), supported by software, in order to achieve best results [2], [3].

Other properties of main girder are Elastic Modulus: $E=2 \cdot 10^{11}$ Pa, Yield Stress $\sigma_{yi} = 3.31 \cdot 10^8$ Pa ; Ultimate Tensile Stress $\sigma_{ut} = 4.48 \cdot 10^8$ Pa ; Poisson's Ratio $\nu = 0.29$.

Based on model created, results are achieved through simulations for main dynamic parameter – Stresses in main girder. [5], [9], [13]. Stress is the type Von Misses Stress. In Fig. 7 is shown discretization of girder in volume FEM Elements. Values of Stresses spread through girder volume and deforms the girder (Scaled by 6.274).

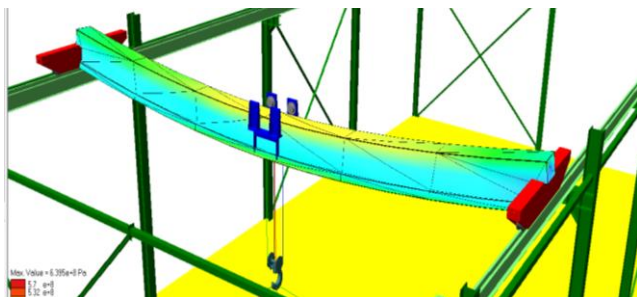


Fig.7. Deformation of main girder (Scaled by 6.274), and contour spread of Stress

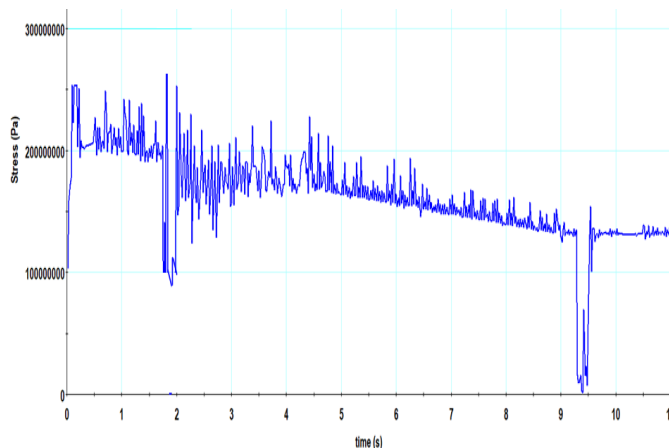


Fig.8. Stresses in main girder

Based on results from Fig.8, it can be conclude that main girder undergoes heavy dynamic stresses, with frequent oscillations, high

amplitudes and high frequencies. Max value of Von Misses stress occurs in time $t \approx 1.8$ s, and has the value $\sigma_{max} = 2.7 \cdot 10^8$ Pa.

This value of stress is less then Yield stress $\sigma_{max} < \sigma_{yi} = 3.31 \cdot 10^8$ Pa of material given above. This concludes that structure of girder can handle the dynamic loads.

7. Moments and Forces in side girders

Side girders connect with main girder in one side, and wheels of crane in another side. Length of side girders is $L_s = 2$ m (Fig.1 & Fig.2). Mass of each of two side girders is $m_s = 400$ kg. In Fig.10 and Fig.11 are shown graphical results of moment (torque) and Resultant Force in Right Side Girder. They result from dynamic occurrence's in the main girder (Fig.9).

Values for left side girder are similar, therefore are not shown here. It can be concluded that side girders undergo heavy dynamic loading with high oscillation's and amplitudes.

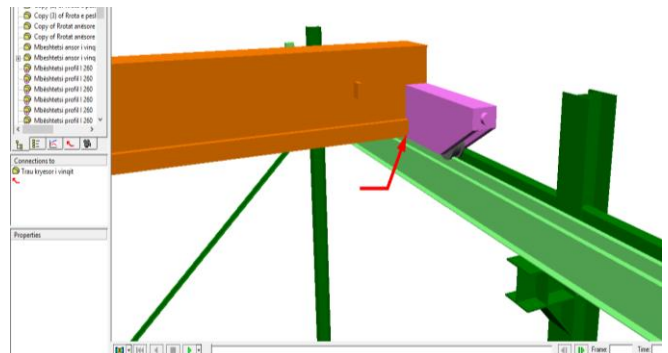


Fig.9. Position in Right Girder of measured Moments and Forces

Maximal value of Dynamic Moment (Torque) has the value $M_{maxd} = 6.3 \cdot 10^4$ Nm and occurs in time $t \approx 2.6$ s (Fig.10). Value of static moment is $M_{st} \approx 4.12 \cdot 10^4$ Nm. This concludes that the value of Dynamic Moment is for 53% higher, which is a matter of concern.

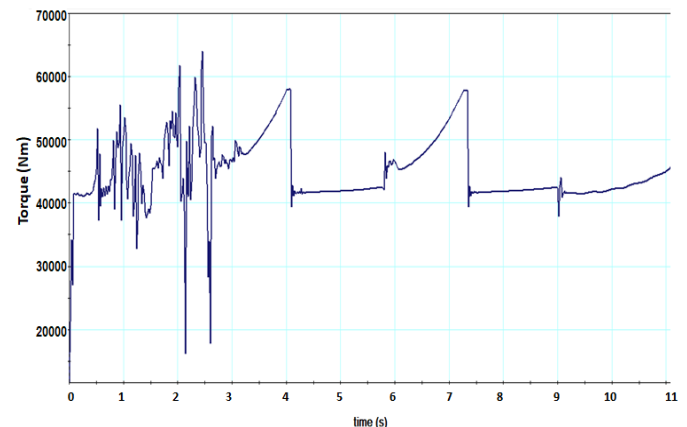


Fig.10. Moment (torque) in right side girder (Nm)

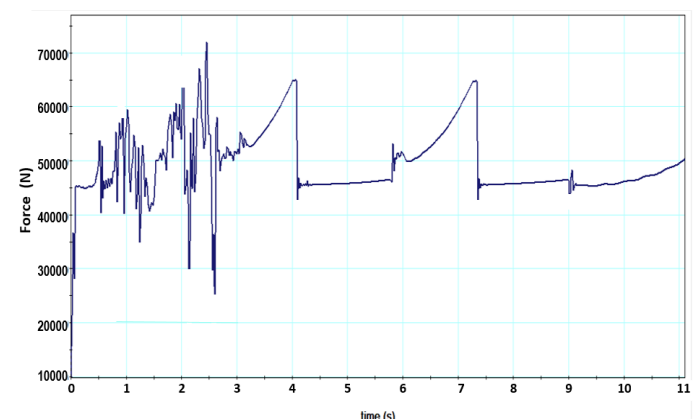


Fig.11. Resultant Force in right side girder (N)

Based on Fig.11, maximal value of Resultant Force has the value $F_{maxd} = 7.15 \cdot 10^4 \text{ N}$ and occurs in time $t \approx 2.6 \text{ s}$. Value of static force is $F_{st} \approx 4.5 \cdot 10^5 \text{ N}$. Value of dynamic Force is for 58% higher, which is also a matter of concern.

8. Conclusions

The main problem in bridge cranes during telfer motion are oscillations. It is important to identify and minimize them. To find this we created model of bridge crane and implemented simulations. Results are also compared with experimental measurements. Important part of analysis is finding proper simulations scenario that reflects real telfer motion. Results are gained for main parts of crane – lifting cables, telfer, main girder and right side girder. Based on the results, it can be concluded that analyzed parts of crane undergo oscillations that are heavy and mostly with irregular occurrence. They occur in different planes. They have negative effect which can cause damage. Values of dynamic forces, torques and stress are higher than corresponding static values, but analyzed crane parts can handle those dynamic loads. It is important to minimize oscillations in order to achieve minimal dynamic loads [5], [9]. Oscillations in cranes are difficult to measure with instruments, and they can cause parts failure, materials fatigue and stability problems. Therefore it is a good methodology to measure dynamic forces and oscillations with instruments where applicable, and other analysis to accomplish through modelling and simulations.

Another important conclusion is that oscillations occurring on Load Q and cables are passed in other parts of crane with similar form of curve, periods, and frequencies. Also, speed of telfer motion must remain in optimal value, as lower as possible to minimize negative effects of load swinging and oscillations in other parts.

Conclusions in this paper are important for safety and design considerations of these types of cranes [14]. It can be used also for analysis of other work processes, like load lifting or crane travel.

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AIRCRAFT REPAIR MAINTENANCE IN UKRAINE: ECONOMIC AND ORGANIZATIONAL PROBLEMS OF DEVELOPMENT AND INVESTMENT SUPPORT

Авиаремонтное обслуживание в Украине: экономико-организационные проблемы
развития и инвестиционного обеспечения

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Annotation. The article presents the structure of the aircraft repair industry in Ukraine. It is proved that the main customer of aircraft construction and aircraft repair enterprises are air carriers, which determine the demand for the services of aircraft repair enterprises. The features of aircraft repair enterprises and their economic and financial condition are considered. The problems, conditions and directions of development, as well as the prospects of the aircraft repair industry are clarified. The problems affecting the investment activity of the industry are identified. The investment directions for further development of aircraft repair enterprises are proposed.

KEYWORDS: REPAIR SERVICE, AIRCRAFT REPAIR ENTERPRISE, AIRCRAFT, INVESTMENT, DEVELOPMENT.

1. Introduction

Aircraft repair enterprises (AREs) in Ukraine are not going through the best times today, because the outdated material and technical base, focus on repairing airplanes manufactured in the USSR, the lack of innovation and international certification provoke loss of production and the hopelessness of development. In the process of management of the AREs, the problems of renewal of fixed assets, the development of international innovation technologies, the diversification of production (primarily, the development of repair of aircraft produced by foreign companies) are put forward.

Analysis of the structure, volume and dynamics of growth of world aviation market leads to active development of the aircraft maintenance market, with the annual growth rate of approximately 3-5%. The main indicators of the current state and the forecast of dynamics and structure of the world aircraft maintenance market by types of works are given in the Table 2.

Table 1 Dynamics and Structure of the World Market of Aircraft Maintenance Services [1]

Works related to maintenance	Years					
	2008		2013		2018	
	billion dollars	%	billion dollars	%	billion dollars	%
Linear forms of maintenance	8,1	17,96	9,9	17,68	12,1	17,64
Repair and restoration of aircraft assets	8,7	19,29	10,7	19,11	13,1	19,10
Severe forms of maintenance, repair and modification	9,6	21,29	11,9	21,25	14,1	20,55
Engine maintenance and repair	18,8	41,69	23,6	42,14	29,2	42,57
Total	45,1	100,00	56,0	100,00	68,6	100,00

In Ukraine, 78 aviation organizations engaged in transportation or aeronautical chemical works were registered in January 2017. Almost a third of carriers specialize exclusively in passenger transportation. According to experts, more than 85% of passenger traffic is carried out on regular flights and only 15% – on charter flights, with the freight traffic the opposite is the case – almost 90% is on charter flights.

There were 33 domestic airlines operated on the passenger and freight market in 2016. According to the statistics, during the year, 66,300 commercial flights were performed (by 2015 – 74.8 thousand). The number of passengers carried decreased by 2.7 percent compared to the previous year and amounted to 6302.7 thousand people. The volume of cargo and mail was 69.1 thousand tons (in 2015 – 78.7 thousand tons) [2].

Air carriers occupy a significant part of the aviation industry, which established international relations during the Ukrainian independence. They have access to foreign and domestic financial assets and competitive advantages in the Ukrainian market. Air carriers, as an institution that directly interacts with the population and has access to national savings, is the main customer of aviation and aircraft repair enterprises. It determines the demand for AREs services and is one of the factors of pricing in the market of aircraft repair services.

2. The Structure of the Aircraft Repair Industry in Ukraine

Historically, the AREs of Ukraine have highly skilled personnel, scientific and technical potential, with an expanded infrastructure. The Ukrainian aviation and repair industry includes 13 factories of industrial value today (Figure 1). Soviet-made aircraft and their repair technology are not only obsolete, but also physically unsuitable for use. This tendency reflects the dependence of the aircraft repair industry on state policy and the aviation-building industry.

Therefore, there is a need to find new customers and enter international markets, expand services, introduce innovative technologies for repair and modernization of aircraft.

Today 89 private enterprises have been certified by the Ministry of Transport and Communications of Ukraine for maintenance and repair of airplanes [3]. Mostly repair of aircraft such companies is their additional activities and production scale have no national significance. An example of private enterprises is the CJSC "Ukrainian Aviation and Technical Center" (JSC UATC).

A significant part of the industry is under the jurisdiction of the Ministry of Defense of Ukraine. According to studies conducted on the economic condition of military aircraft repair companies, they are not only profitable but also implement strategic modernization and development programs. This is due to significant state support, which is being implemented through government contracts, privileges and subsidies, certification for export services, as well as a significant volume of foreign orders (mostly from Asian countries that have Soviet-made aircraft).

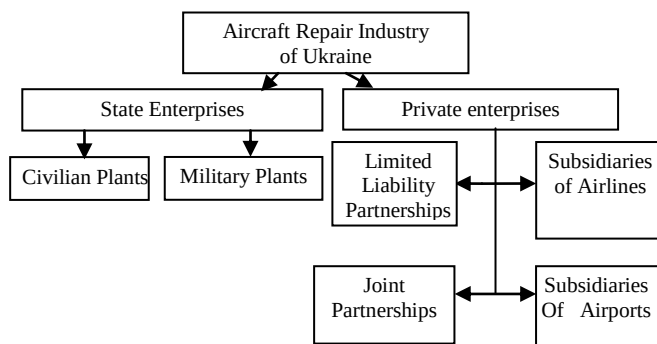


Figure 1 Structure of Aircraft Repair Industry of Ukraine

3. Financial and Economic Condition and Features of Aircraft Repair Enterprises

Civil aviation repair companies are in poor condition because they are state-owned and have no economic independence or proper funding. At the same time, the lack of orders for aircraft repair provokes an enforced idleness and unprofitable production.

However, the Strategy of the aviation industry development by 2020, worked out by the Government of Ukraine [4], can increase the potential of enterprises by:

- increasing financing;
- corporatization and establishment of associations on a corporate basis;
- the transition to mass production of airplanes and other aviation equipment with the creation of a wide range of their modifications, in particular, the aircraft Antonov An-3, An-32, An-38, An-140, An-74, An-148, An-124, An-70, which in the future will increase the production of AREs;
- privatization of aviation industry enterprises taking into account the specifics of the industry and preserving the state influence on making strategic decisions.

The main characteristic of the AREs is to provide and restore the airworthiness of fixed assets (in particular, aircraft) in the aviation industry, which is carried out by repair works or modernization of the aircrafts, and the development and production of facilities for the implementation of the main production

functions. We distinguish the following features of the AREs activity:

- focus on the restoration and modernization of existing aircraft;
- large scale production, the need for an expanded infrastructure;
- the long-term nature of the production cycle and investments;
- significant depreciation and, in addition, high level of wear and tear of fixed assets;
- a significant proportion of state-owned enterprises, which are an obstacle to private investment;
- dependence on national development and GDP;
- defined market niches of enterprises provoking low competition within the country and competitiveness in foreign markets;
- needs for innovative development, mastering of repairs and obtaining certificates for the repair of foreign aircrafts.

The need for AREs activity depends on the state of the aircraft and the financial capabilities of their owners. According to statistics, the general level of depreciation of fixed assets of the Ukrainian enterprises is 45-50%, and in the transport sector - 50-60% [5], while the tendency to increase the proportion of wear and tear remains. That is, the need for upgraded aircraft and their modernization is relevant to the aviation industry.

Another factor necessary for the development of the aircraft repair industry is a powerful production base, formed over the years of the USSR. By that time, a large proportion of the AREs of the USSR was in Ukraine, and they serviced the entire aviation industry of the USSR. After the collapse of the Soviet Union, the AREs failed to find a market corresponded to the existing production capacity. Today, the development of the aircraft industry and the policy of the Ukrainian government open up new perspectives to the AREs. Also, Ukraine is actively moving into international air transport markets, which provokes an increase in demand for aircraft repair services. In order to meet the demand of Ukrainian AREs, there is a lack of international certification for the repair of foreign-made aircraft. This direction of development is also promising, since most air transportation is carried out on foreign-made aircraft.

Table 2 Indicators of Financial and Economic Activity of Aircraft Repair Enterprises, Ukraine, 2016

№	Indicators	Units	SE "Konotop Aircraft Repair Plant "Aviakom"	SE "Chuguev Aircraft Repair Plant"	SE "Plant 410 CA"	SE "Zaporizhzhya State Aircraft Repair Plant "MiG repair"	SE "Lutsk Repair Plant "Motor"	SE "Lviv State Aircraft Repair Plant"	SE "Nikolaev Aircraft Repair Plant "Narp"	SE "Odessa Aircraft Plant"
1	The capital of the enterprise	thousand UAH	901243,0	58152,0	357282,0	290440,0	785597,0	289999,0	209964,0	205634,0
2	Production capacity of the enterprise	%	90,4	87,0	50,0	71,0	109,0	90,0	85,0	74,6
3	The average number of full-time employees	persons	927,0	288	1022,0	670,0	1093,0	904,0	611,0	777,0
4	The payroll of full-time employees actually	thousand UAH	119378,2	12213,2	86429,0	66841,7	131387,4	92562,0	50872,8	73449,1
5	The average monthly wage actually	UAH	10731,6	3533,9	7047,4	8313,6	10017,3	8532,6	6938,5	7877,4
6	Production volumes (rendered services) at current prices	thousand UAH	608092,0	67773,0	532809,0	272199,0	1058773,5	276720,0	340170,0	250101,0
7	Sales of products (goods, works, services) for the reporting period	thousand UAH	733756,0	61528,0	528542,0	286788,0	661633,0	348101,0	357295,0	240328,0
8	Net Sales of products (goods, works, services)	thousand UAH	733756,0	59400,0	500712,0	265531,0	636940,0	311777,0	348368,0	220089,0
9	Cost of Goods Sold	thousand UAH	428292,0	33277,0	199940,0	127395,0	199672,0	221415,0	130333,0	128915,0
10	Net Profits for the Reporting Period	thousand UAH	100335,0	8315,0	150208,0	65057,0	49985,0	13942,0	83582,0	6818,0

4. Terms of Aircraft Repair Enterprises Development in Ukraine

In general, the aviation industry in Ukraine has a great potential for development, which has been inherited since the Soviet Union. It consists not only of aircraft factories, but also of personnel and a highly developed scientific base for the industry. Involving and using them as effectively as possible is a goal that will help raise not only the industry, but also numerous research institutions, fundamental science. Today it is necessary to modernize the equipment, update the material and technical base, switch to energy-saving production, and improve existing methods of managing airlines.

Consequently, the main possibilities (Figure 2) that will ensure the development of the AREs in Ukraine are:

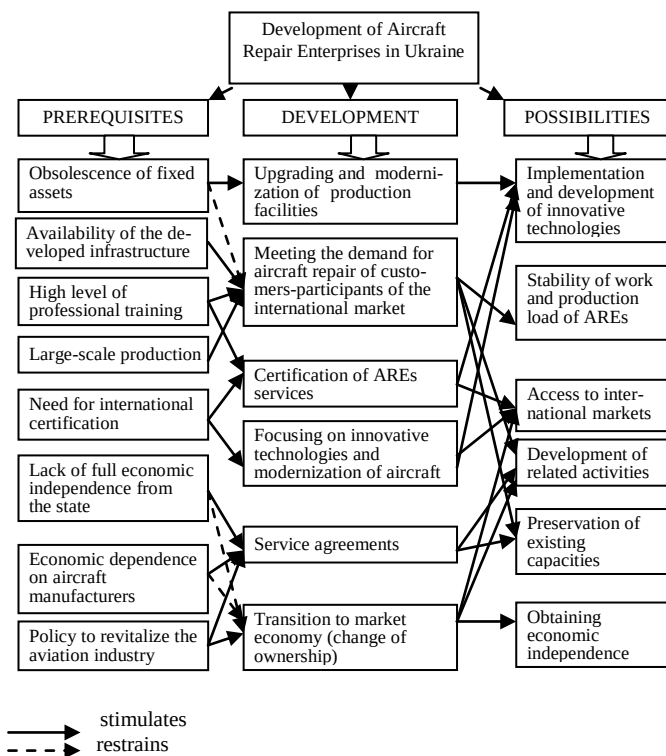


Figure 2 Conditions for Development of Aircraft Repair Enterprises in Ukraine [6]

1. Updating and modernizing the existing production base.
2. The preservation of AREs infrastructure, formed in the USSR, and its modernization.
3. Economic interdependence with aircraft manufacturers will reduce the cost of certification and will ensure the stability of the AREs.
4. Passage of international certification, which will allow repairing aircraft of foreign production.
5. The policy of activating the production of Ukrainian aircraft.
6. Production of Ukrainian equipment and components to ensure the production process and reduce its cost.
7. Use of international experience in the management of enterprises.

5. The Main Problems of Investing in Aircraft Repair Companies

To determine trends in investment activity, the AREs will investigate the factors that affect it. The first step is to analyze the investment climate, in which AREs function. Investment climate in

Ukraine cannot be called favorable. It is characterized by general instability of legislation, underdevelopment of the banking system and the stock market, etc. In order to assess the current innovative climate in Ukraine, it is necessary to take into account the international business rankings and competitiveness of the national economy of our country by the main indicators [7].

The main problems of investing in modern market conditions and proposed ways to solve them are given in Table 3.

The conducted research on the investment market of aviation repair industry showed that the level of general economic development and the state of the political and legislative climate had the greatest impact on the development of investment activity. The factors contributing to overcoming or reducing the risks for investors in Ukraine include [8]:

- the level of development of productive forces and the state of the investment market;
- legislative framework; political will of all branches of government;
- state of the financial and credit system of the country;
- the status of a foreign investor and the investment activity of the population.

Under conditions of economic instability, state support for the implementation of investment projects for the development of priority industries (industrial policy) is important, as well as the introduction of economic regulators to intensify domestic investment activity.

Table 3 Problems and Prospects of Investing in the Aircraft Repair Industry

Existing Problems	Proposed Activities to Address Problems	Prospects for Development
Narrow range of investment projects	Financing of scientific and technical developments	Enhancing capacity of aviation industry
	Legal protection of intellectual property	
	Product differentiation	
Partner search problem	Entering the international market	Development of domestic aviation market
	International certification and compliance with international market conditions	
	Participation in international exhibitions and forums	
Lack of adequate funding	Providing economic independence	Growing financial capacity
	Implementation of public credit system	
	Opening access of private investors and creditors to participate in financing of enterprises	
	Government funding and development programs	

Investment expectations are conditioned by the understanding of the urgent need for expanding production volumes, updating the existing material and technical base, innovation development, implementation of long-term programs with long payback periods.

The volume of attracted investments is one of the main characteristics of economic activity as separate economic entities and the state as a whole, taking into account that the investment climate is determined primarily by the political and economic situation in the country.

The described situation defines the main ways for the development of investment activity of the AREs, which include:

- growth of foreign investors' activity and increase of the share of their investments in aviation sphere;
- growth of investment activity of domestic AREs, provoked by the needs for the physical and moral renewal of fixed assets;
- development of the financial and credit system and private lending;

- activation of insurance relations, which positively influence the development of investment attractiveness of Ukrainian AREs, minimizing investment risks.

In general, today there are negative trends in the investment sphere of Ukraine's economy due to military actions in the East of the country and the instability of the national economy, which led to decrease in production volumes, instability and riskiness of the currency and financial markets, rising unemployment and fall in household incomes. However, the market demand for AREs services requires finding ways out of a crisis and opens prospects for the industry.

The study of the resource availability of APEs in Ukraine and their structure (by classifying the resources that can participate in investment activities) shows that enterprises have significant material resources. The amount of resources that AREs can use in investing activities are determined by the following factors:

1. Need for resources, determined by the investment strategy of the enterprise.

2. The amount of funding that affects the attraction of a resource to the investment process.

3. Availability of substitute resources, which allows for the formulation of alternative projects or identifies the alternative cost of the project.

Therefore, the investment resources of the AREs include all non-financial resources of the enterprise, and some of financial resources – net profit and depreciation fund (internal resources), as well as available borrowed and attracted funds (external resources). The basis of AREs investment resources is financial resources, while enterprises use their own funds.

6. Conclusions

Insufficient state support is a major factor among the political factors. There is no basic state policy for Ukrainian airlines in a difficult competitive environment. The weak point is also a discrepancy legislation of Ukraine in the field of air transport to international and European standards, including the International Civil Aviation Organization (ICAO), the European Union, the European Civil Aviation Conference (ECAC), and the European Organization for the Safety of Air Navigation (EUROCONTROL). Gradual displacement of a domestic air carrier to foreigners is due to weak state regulation of competition in the aviation market.

The research of investment strategies of the Ukrainian AREs showed their focus on upgrading production capacities. This tendency is caused by a high level of depreciation of fixed assets. In this case, the AREs cannot independently ensure the introduction of innovative technologies. The authors propose to work out the following directions for investment development of enterprises:

1. Diversification of production (necessarily - development of repair of foreign manufactured aircraft and development of technologies for the modernization of domestically manufactured aircraft).

2. Implementation of energy and resource-saving technologies.

3. International certification programs.

4. Development of international methods of economic management and analysis.

For each of these directions, it is expedient to justify an investment project based on efficiency, compliance with the investment strategy and the level of the investment potential use, which in turn will ensure the intensive development of the AREs.

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THE BLOWING PROCESS OF A PET BOTTLES

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Abstract: The article presents the process of blowing out PET bottles. PET is processed for various applications due to its very good physical properties. In the packaging industry it is used for the production of PET bottles. The concepts of Blow molding is a process used to produce hollow objects from thermoplastic. The basic blow molding process has two fundamental phases. The first phase of the device's operation consists in heating preforms. The second phase consists in the mechanical extension of the preforms on the axes and on the extension by means of pre-blowing and then blowing the preforms. The discussion was prepared on the basis of the collected literature data.

Keywords: INDUSTRIAL COMMODITIES, WASTES, PLASTICS, PET PACKAGING, WASTE MANAGEMENT

1. Introduction

Plastics are an inseparable element of modern human life.

In 2014, 311 million tons of plastics were produced in the world, which is twenty times more than in 1964. The forecast of plastics production assumes that this number will double by 2036 and will increase fourfold by 2050. Demand for plastics in Europe in 2015 amounted to 49 million tons, of which almost 40% was the raw material used for packaging production. Currently, we distinguish over 1,000 types of plastics, 90% of which comes from primary fossil fuels. In Europe, post-production waste plastics are developed by incineration with energy recovery at 39%, they are deposited in landfills in an amount of 31% or derived from recycling of 30%.

The potential and benefits of plastic products refer to low manufacturing costs, high durability and versatility in use. A large number of positive features also reflects the broadly understood production problems that have a negative impact on the natural environment, climate and human life and health [3].

In 2015, the European Union Commission recognized plastics as one of the priority areas for economic activities. It assumes that the production of plastics takes place in a closed circuit, by reusing the packaging waste, which gives the possibility to reduce the amount of waste to a minimum. The change of the plastics strategy in the presented chain would improve the recycling process, promote re-use and redesign the product in terms of the whole life cycle.

The presented changes give the opportunity to increase the security of supply, simulate the growth of economic benefits and reduce the pressure associated with care for the protection of the natural environment. Before implementing the changes, the challenge for entrepreneurs is the lack of adequate economic support, technical and financial constraints [3,10].

2. Characteristics of the PET bottle production process

Polyethylene terephthalate in short PET is a thermoplastic polymer from the group of polyesters. Used for the production of synthetic fibers and bottles for non-alcoholic beverages with structural structure [5].

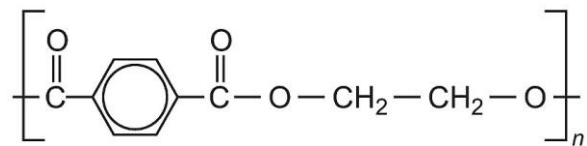


Fig. 1. Polyethylene terephthalate

The PET bottle is made using a semi-finished product preform. PET preforms are produced in various variants, colors and types. Parameters such as the type of thread, weight, wall thickness and length define the PET preform. It is thanks to them that you can determine what capacity the preform bottle can be blown. A view of an exemplary PET preform is shown in Figure 2 [2,4].



Fig. 2. PET bottle preforms

The blasting machine is designed for the production of PET bottles, stretched in two axes. The principle of operation of the device consists in heating preforms, removing the preforms on the axes mechanically and pulling them out by pre-blowing and then blowing the preforms.

The initial dimensions of the preform depend on the expected stretch ratio to obtain the characteristics of the finished bottle. The degree of stretching is determined by the stretching factor on the two axes, which takes into account the orthotropic development of the preform and, consequently, preferential stretching of the material.

Depending on the capacity and use of the bottle, different stretching factors are defined after two axes [4,7].

Table 1: Stretching factor

	Carbonated drinks / still drinks	HR
Longitudinal stretching factor	2.8 ÷ 3.1	2.6 ÷ 23.9
Diameter stretching factor	3.5 ÷ 4.2	3.3 ÷ 3.6
Stretching on two axes	9.8 ÷ 13.5	8.6 ÷ 10.5

The stretching process of the PET preform

The greater the order in the material structure, the better the mechanical properties of the processed object. In the process of stretching during the production of the bodies, the preforms are reduced by cold blowing with a reduced size in relation to the final shape of the finished product. The stretching takes place along the axes and radially leading to stretching the material along two axes in parallel, so-called two-dimensional pulling.

Figure 2 presents a two-stage process of blowing out a PET bottle [4,10].

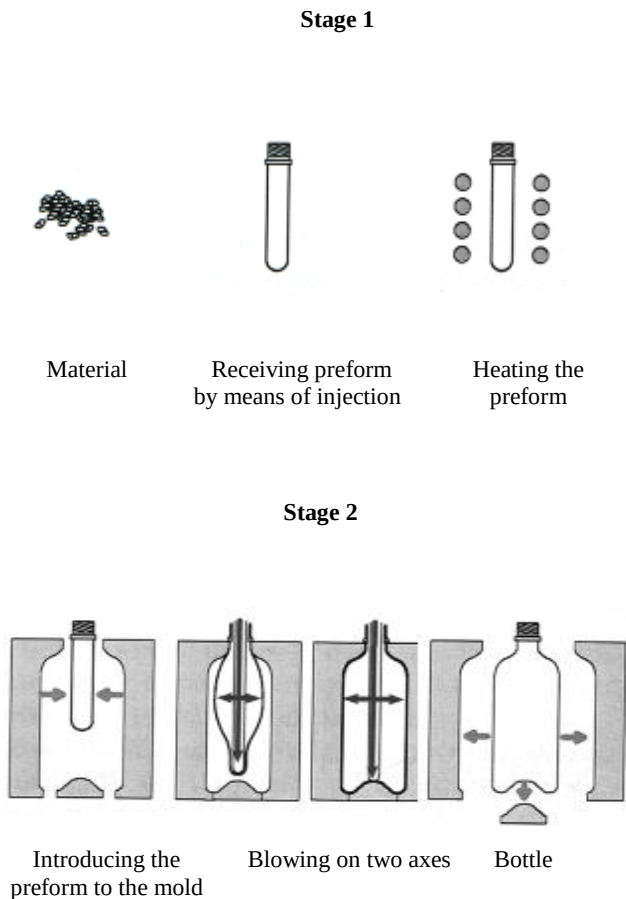


Fig. 3. A two-stage process of blowing out PET bottles

A two-stage stretching process means an internal change in the structure of the material. After completion of the heating process used preform it takes the form of a rubber in the form of liquid rubber.

Then, during the stretching step after two axes, the material changes state, where at the end of the blowing process the material takes on a more stable state. Such a change in the state of aggregation is characterized by the "strain hardening" parameter, beyond which the solid state behavior is obtained.

Natural stretch ratio λ_N . It specifies that during the free blowing of preforms, the drawing coefficient decreases with the increase of

temperature and increases with the decrease of the viscosities of the boundary lines 2 and 3.

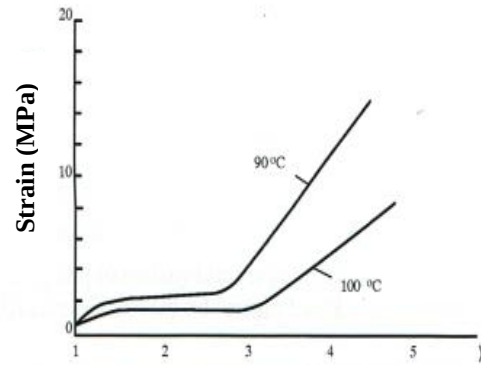


Fig. 4. Stresses depending on the stretching factor

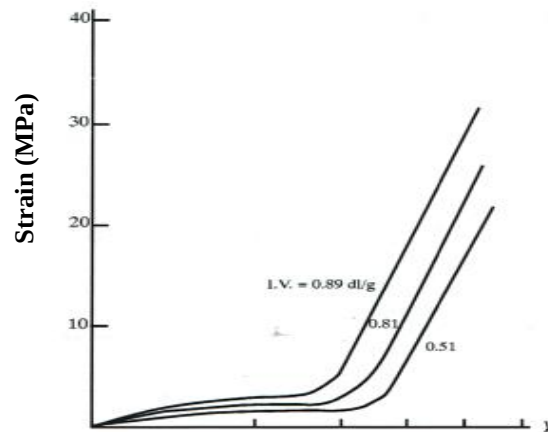


Fig. 5. Stress depending on the stretching factor for different limiting viscosities (temperature 95 °C)

The choice of intrinsic viscosity depends on the final use of the product. In order to obtain proper mechanical properties in the production of food packaging for carbonated drinks, strong degrees of intrinsic viscosity are assumed. In the case of still drinks in order to obtain the desired degree of mechanical strength, a weak degree of intrinsic viscosity is enough [10,11].

In the initial process of deformation under the influence of elongation of the tibia and blowing the preform mechanically weakest parts are deformed first.

The weakest parts are elements having a higher temperature obtained during the heating of the preform. If the mechanical properties of the deformed zone exceed the properties of non-deformed zones, then they deform and develop the bubble.

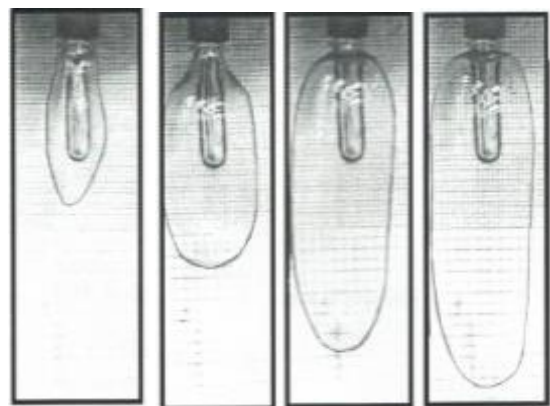


Fig. 6. Blowing bottles

The process of molecular stretching after two axes is the result of double stretching of the plastic under specific conditions. Providing the appropriate thermal conditions allows to obtain the desired strength properties of the finished product. In the case of a PET bottle, the temperature of the double orientation is in the range of $90 \div 120$ °C.

According to the definition of the tensile factor up to two axes, the temperature of the double orientation depends on the product and the final application. In the case of hot filling, one should strive to achieve the natural draw ratio while maintaining the temperature range in the upper range between 110 °C and 120 °C. In the case of "soft drinks" increase the stresses induced in the lower temperature range from 90 °C to 100 °C.

After the blow-out process is completed, the process of stretching to the finished bottles forms. In order to prevent disorientation of the polymer that can cause product defects, an appropriate speed should be maintained for drawing ready bottles. Depending on the batch of bottles produced, the bottle withdrawal speed is from 500 to 1 500 mm / s.

After the bottle extrusion process is complete, the cooling process takes place. Cooling conditions vary with each other depending on the intended uses of the finished product. In the case of "soft drinks" applications, after cooling, the cooling is below the glass transition temperature (below 800C). If the filling process was hot after taking out, the temperature should be maintained above 800C. The behavior of the process conditions allows stabilizing the construction of the finished product [6, 9, 10].

The second type of maintaining the right conditions are the geometric features of the bottle. Geometric features are understood as a type of preform, its dimensions and application. The kind of preform depends on the intrinsic viscosity. It is characterized by a stretching factor on two axes depending on the expected mechanical properties. Exceeding natural coefficients causes internal stresses that may hinder the extrusion process.

For products filled cold, to prevent swelling occurring as a result of the internal pressure must be increased. On the contrary, in the case of hot-filling of a non-carbonated beverage so as not to increase distortion due to the vacuum during cooling, the pressure should be reduced.

The concept and design of a PET bottle project depends primarily on the expectations of the manufacturer. Depending on the processing technology used, the product manufactured, or the type of conditioning, the obtained technical and mechanical conditions depend on the finished packaging [1,8].

3. Conclusions

Properly completed bottle blowing process allows further continuation of the manufacturing process of the finished product. The presented blowing technology positively influences the limitation of the type of bottle produced. Thus, it prevents the use of mold blanks or the need to locate the extraction process that may adversely affect the mechanical properties of the finished product.

The end of the blown bottles process includes the recoil phase of preforms and bottles. The occurrence of an incorrect preform or bottle is automatically signaled by the device.

The reasons for the defects of PET bottles are very diverse and depend on many factors. During the process of forming a PET bottle, defects are very often observed. Defects observed in the process could be in different forms. Types of Defects in PET bottle production processes: short shot, flash on thread, parting line flash, long gate, gate pin hole, gate stringing, gate crystallization, moisture marks, air bubbles, hazy preform, scratches [10].

Due to the dominant share of materials, the plastics industry aims to reduce the share of raw materials

throughout the production cycle. An important factor related to the change in production parameters is the preservation of aesthetic values and the maintenance of an appropriate level of quality indicators. The basic condition for maintaining the correctness of the production process is the complete education of the PET preform to the required sizes [10,11].

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SYSTEM FOR SENTIMENT ANALYSIS OF BIG TEXT DATA

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Abstract: The importance of Big Data and Big Data Mining is growing significantly in recent years. Different kind of e-sources as social networks, e-commerce sites, e-mails, sensors, etc. are generating large amount of structured and unstructured numerical and text data. This data provides valuable information about customer's preferences or ratings of products or commodities. This information is essential for making predictions on the base of the sentiment analysis of this data. The sentiment analysis of large amount of text data requires specific big data and machine learning /ML/ libraries. In this paper the implementation of a system for big data sentiment analysis using ML algorithms is proposed. It is based on Naïve Bayes and Support Vector Machines /SVM/ classification ML algorithms for text analysis. The system is implemented in Java and uses Apache Spark ML libraries which are very flexible, fast and scalable. The system is tested with well known Amazon dataset and its performance is measured in form of accuracy. The obtained results approve the effectiveness of big data sentiment analysis algorithms. The System can be applied for recommendation of products and services or predictions of customers' needs.

Keywords: BIG DATA; MACHINE LEARNING; SENTIMENT ANALYSIS; NAÏVE BAES; SVM

1. Introduction

Big Data is a new term used to identify the data sets that are of large size and have greater complexity [1]. Big data is defined as a large amount of data which requires new technologies and architectures to make possible to extract value from it by capturing and analysis process [2]. The Big data is very important for business and society purposes. The data came from different sources like sensors used to accumulate climate information, available data on the social media websites, video movie audio and so on. This series of data are known as Big Data [3]. They are in form of structured, semi-structured or unstructured data and can be used for Sentiment Analysis [4].

Sentiment Analysis /SA/, also known as opinion mining, is defined as the task of finding the opinions of authors about specific entities [5]. Sentimental analysis is used in various places: to analyze the reviews of a product whether they are positive or negative, to check if a political party campaign was successful or not, to analyze the reviews of a movie and to analyze the content of tweets or information on other social media [6]. Social media monitoring applications and companies depend on sentiment analysis and machine learning to assist them in gaining insights about mentions, brands, and products [7].

Machine learning /ML/ is a branch of artificial intelligence [8]. ML is the science of training a system to learn from data and act. [10]. ML computations aim to derive predictive models from current and historical data. The inherent premise is that a learned algorithm will improve with more training or experience, and in particular, ML algorithms can achieve extremely effective results for specific domains using models trained from large datasets [11]. Machine learning is used for a variety of tasks in different fields, as well for Sentiment Analysis. The ML tasks can be broadly grouped into Classification, Regression, Clustering, Anomaly detection, Recommendation, and Dimensionality reduction [10].

2. Machine Learning Algorithms

Machine learning algorithms are generally grouped into two categories (Fig. 1): supervised and unsupervised learning [9].

2.1. Supervised Machine Learning Algorithms

Supervised machine learning refers to working with a set of labelled training data to learn [8], which means, they can be used only with labelled training datasets. Each observation in the training dataset has a set of features and a label. A supervised machine learning algorithm learns from data to estimate or approximate the relationship between a response variable (label) and one or more predictor variables (features). The labels in a training dataset may be generated manually or provided from another system [10]. Supervised machine learning algorithms can be grouped into Recommendation Engines, Regression and Classification algorithms [12]. The commonly used supervised algorithms for

regression tasks are Linear Regression, Decision Trees, and Ensembles of Trees. The classification tasks are related to Logistic Regression, Support Vector Machines /SVM/, Naïve Bayes, and different types of Artificial Neural Networks. The Recommendation includes Collaborative filtering with Alternating Least Squares [10].

Machine Learning Algorithms	
Supervised Machine Learning	Unsupervised Machine Learning
Regression	Clustering
Classification	Anomaly detection
Recommendation	Dimensionality reduction

Fig. 1: Machine learning algorithms

2.2. Unsupervised Machine Learning Algorithms

Unsupervised machine learning is related to cases when the model does not require labelled data. These types of models try to learn or discovering hidden structures in unlabeled data or reduce the data down to its most important features [12]. With unsupervised learning there is no right or wrong answer [8]. They are generally used for clustering, anomaly detection, and dimensionality reduction. The list of commonly used unsupervised algorithms includes k-means, Principal Component Analysis, and Singular Value Decomposition.

2.3. Sentiment Analysis

Sentiment Analysis refers to the use of Natural Language Processing /NLP/, text analysis and computational linguistics to identify and an extract subjective information from source materials [7]. SA is a process of exploring product reviews on the internet [14] to determine the complete opinion. SA can be considered as a classification task as it sorts the location of a text into either positive or negative. ML is one of the widely used approaches towards sentiment classification. Sentiment analysis has been applied to the broader area of research including consumer product reviews and services [5]. One of the forms of text analysis is SA. So to understand what kind of emotion (love, hate, positive, negative, and so on) contains certain text, the techniques of SA are required [6].

2.4. Natural Language Processing (NLP)

Some techniques and concepts from NLP will be used working on sentimental analysis problems. Some of them are given below:

- **Features:** A feature represents an attribute or a property of an observation. It is also called a variable. A feature represents an independent variable. In a tabular dataset, a row represents an observation and column represents a feature. For example, consider a tabular dataset containing user profiles, which includes fields such as age, gender, profession, city, and so on. Each field in this dataset is a feature in the context of machine learning. Each row containing a user profile is an observation.

- **Feature Extractors:** Term frequency-inverse document frequency /TF-IDF/ is a feature vectorization method widely used in text mining to reflect the importance of words to a document in the amount.

Bag-of-Words /BoW/ is a representation of text that describes the occurrence of words within a document. In this method, each word count can be considering as a feature. Because ML algorithms cannot work with raw text data directly, the text must be converted into numbers. Exactly, vectors of numbers [15].

Feature Transformers

Tokenization is a transformer that converts an input string (text) to lowercase and splits it into words using whitespaces as a separator. A simple Tokenizer provides this functionality and splits sentences into sequences of words.

Stop Words Remover - stop words are words which should be excluded from the input because the words appear frequently and don't carry as much meaning. Stop Words Remover takes as input a sequence of strings (output of a Tokenizer) and drops all the stop words from the input sequences [13].

2.5. Naïve Bayes Classification Algorithm

The Bayesian Classification represents a supervised learning method as well as statistical methods for classification. It can solve diagnostic and predictive problems. Naïve Bayes is a simple multiclass classification algorithm based on the application of Bayes' theorem "The Bayes theorem is based on the concept of learning from experience that is, using a sequence of steps to come to a prediction. It is the calculation of probability based on prior knowledge of occurrences that might have led to the event" [6]. Naïve Bayes is a probabilistic model that makes predictions by computing the probability of a data point that goes to a given class [12]. Initially, the conditional probability distribution of each feature given class is computed, and then Bayes' theorem is applied to predict the class label of an instance [16]. Naive Bayes is used in a lot of practical real-life applications such as it is used in the sentimental analysis of text to classify the emotion of a particular piece of text, whether it is a positive sentiment or a negative one. This algorithm is fast to train and test; hence it is used in real-time prediction scenarios to make fast predictions on events based data that is generated in real time. It is used in many recommendation systems to give useful suggestions of content to the users [6].

2.6. Support Vector Machine (SVM) Algorithm

Support Vector Machine is another popular algorithm of the supervised machine learning algorithms that are used in many real life applications like text categorization, image classification, sentiment analysis and handwritten digit recognition. SVM is a powerful and popular technique for regression and classification. Unlike Naïve Bayes, it is not a probabilistic model but predicts classes based on whether the model evaluation is positive or negative [12]. SVM is used to classify the texts as positives or negatives. It works well for text classification due to its advantages such as its potential to handle large features [5].

3. Used Big Data Machine Learning Libraries

From the machine learning point of view, there is a fundamental difference in algorithm implementation to process the data in memory or from distributed storage. In case the processed data cannot be stored in the memory, then a big data machine learning library [9] is required. There are a lot of Big Data Machine Learning Libraries developed on programming languages as Python, C#, C++, but here the focus is on the Apache Spark Learning Libraries for Java, because the proposed in the paper system is developed using Java.

3.1 Apache Spark

Apache Spark is a fast and general engine for large-scale data processing. Spark supports main-memory caching and possesses a loop-aware scheduler. Spark is fully compatible with Java-based applications. Its own programming language Scala fully supports a Java Virtual Machine and allows easier integration with Java [13]. Spark provides two machine learning libraries: - MLlib and Spark ML (also known as the Pipelines API). Spark MLlib is Spark's implementation of the machine learning algorithms based on the RDD format. Resilient Distributed Datasets (RDDs) is a distributed main-memory abstraction that enables users to perform in-memory

computations on large systems. MLlib is the first machine learning library that is shipped with Spark. It is much faster and scalable than single node machine learning libraries. Spark ML is based on datasets and allows usage of Spark SQL along with them. Feature extraction and feature manipulation tasks become very easy because they can be handled using Spark SQL queries. Spark ML is provided with an advanced feature - Pipeline. Plain data is usually in an extremely raw format and this data goes through a cycle or workflow where it gets cleaned, mutated, and transformed before it is used for processing and training of machine learning models. This entire workflow of data and its stages are very well encapsulated in the new Pipeline of the Spark ML library [6]. In addition, since Spark allows an application to cache a dataset in memory, machine learning applications built with Spark ML or MLlib are fast [10]. Spark ML help users to create and tune practical machine learning pipelines [11]. Spark ML libraries contain implementations of many algorithms and utilities that can be used for common machine learning tasks such as Regression and Classification, Clustering, Dimensionality Reduction, Feature Extraction and Transformation, Frequent pattern mining, and Recommendation [10]. Spark ML supports the implementation of multinomial Naïve Bayesian and Bernoulli Naïve Bayes, as well linear SVM algorithms [13].

3.2 ML Pipelines

In machine learning, it is common to run a sequence of algorithms to process and learn from data. For example, a simple text document processing workflow might include several stages as splitting document's text into words, converting each document's words into a numerical feature vector; learning a prediction model using the feature vectors and labels. MLlib represents such a workflow as a Pipeline, which consists of a sequence of Pipeline Stages (Transformers and Estimators) to make it easier to combine multiple algorithms into a single pipeline, or workflow, to be run in a specific order. ML Pipelines provide a uniform set of high-level APIs built on top of Data Frames that help users create and tune practical machine learning pipeline [13].

4. System for Sentiment Analysis

The developed System for Big Data Sentiment Analysis, object of this paper, is based on machine learning classification algorithms for text analysis. The goal of the system is to train a predictive model that predicts whether a sentence has a positive or negative sentiment. As given in Fig. 2 the system takes Big Data sets as input, and then performs the sentiment analysis for selected data set by using provided by the Spark ML library Naïve Bayes and SVM classification algorithms for text analysis.

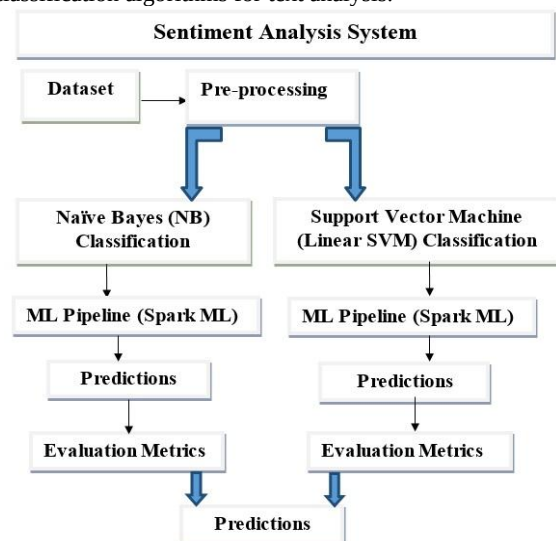


Fig. 2: Sentiment Analysis Algorithms for analyzing big data and generating predictions

The results were measured using Accuracy, for evaluating the effectiveness of the proposed methods. The system is implemented

using Java programming language and mentioned above Spark ML library. It is trained and evaluates multiclass classifiers using the labelled dataset from the amazon_cell_labelled.txt.

The alorytm of developed system is described in the pseudo code below. It includes following steps:

First (step 1), the dataset is loaded as input to the system and (step 2) the data sparse is performed. After caching (step 3 and 4) the dataset into the system, before applying and evaluating models the dataset is split into 80 % train dataset and 20 % test dataset randomly (step 5 and 6). Then the pre-processed steps (step 7, 8 and 9) will start on the training dataset using some concepts of NLP for sentiment analysis such as Feature Extractors and Feature Transformers.

Steps 10 to 21 are the same and are applied in parallel for both Naïve Bayes and Linear SVM models. The parallel implementation is performed using the Spark ML Pipeline (steps 11 and 12) for training both models. Getting the predictions (step 13) and estimation of the average accuracy (steps 14 to 20) and test error (step 21) is done in the remaining steps. Finally, in step 22 the total prediction is produced.

procedure Naïve Bayes and Linear SVM using Spark ML

Input: (Labelled-dataset.txt) [sentence, label], From local file system.

Output: label, text, words, updateWords, rawFeature, features, probability, prediction.

1. Load the data from Labelled-dataset.txt into an RDD.
dataset1 ← (labelled-dataset.txt).
2. Sparse the data for that: Split the data based on the tab ('t') and return reviewsRdd ← dataset1.map(strRow → [] rowArr
← strRow.split("\t"),
rowText ← rowArr[0]
realText ← rowText.replaceAll(", ", "").replaceAll("\n", "").replaceAll("\t", "").replaceAll("\r", "").trim();
return (setText(realText) and
setLabel(Double.parseDouble(rowArr[1])))
3. Then returns Dataset of Review class objects productsDs ← spark.createDataFrame(reviewsRdd.rdd(), Review.class);
4. Store the productsDs data in memory using cache() , or productsDs.createOrReplaceTempView("Review");
5. compute K iteration for get average performance evaluation accuracy based on K-fold Cross-validation idea:
k=5; double accuracyArr[] =new double[k];
for (i =1 to k) (repeat k iteration)
6. randomSplit() the Dataset (productsDs) into trainingDataset (80%) and tesDataset (20%).
7. perform Tokenizer to convert texts to words tokenizer ← newTokenizer().setInputCol("text").setOutputCol("words");
8. perform StopWordsRemover to remove stop words stopWordRem ← newStopWordsRemover().setInputCol("words").setOutputCol("updatedWords");
9. perform TF-IDF and numFeatures ← 20000;
hashingTF ← newHashingTF().setInputCol("updatedWords").setOutputCol("rawFeatures").setNumFeatures(numFeatures);
idf ← newIDF().setInputCol("rawFeatures").setOutputCol("features");
10. perform NaiveBayes / LinearSVM algorithms
NB ← new NaiveBayes().setFeaturesCol("features").setPredictionCol("predictions");
LinearSVM ← newLinearSVC().setFeaturesCol("features").setPredictionCol("predictions");
11. perform Pipeline for combining all methods together
pipe ← pipe.setStages(new PipelineStage[] { tokenizer, stopWrdRem, hashingTF, idf, NB/ LinearSVM });
12. Fit the pipeline to training data using PipelineModel
pipemodel ← pipe.fit(trainingDs);
13. getting predictions via testdataset, predicts ← model.transform(testDataset)
14. perform Multiclass Classification Evaluator
evaluator ← calculate (Accuracy metrics) on predicts
15. accuracyArr[i] ← accuracy; // for storing all k accuracy
16. end for
17. define and declaration double SumAccuracy=0 , AverageAccuracy=0;
18. for (m=1 to accuracyArr.length)
SumAccuracy ← SumAccuracy + accuracyArr[m];
19. end for
20. return AverageAccuracy ← SumAccuracy/accuracyArr.length;
21. return Test Error ← (1.0 - AverageAccuracy);

22. return predicts.show(false) to show all fields from predict dataset (label, text, words, updateWords, rawFeature, features, probability, prediction).

end procedure

Dataset used for evaluating the system

The sentiments labelled sentences datasets are available at <https://archive.ics.uci.edu/ml/datasets/>. For current system tests the Amazon cell phone reviews dataset (amazon_cell_labelled.txt) is used. It includes randomly selected 500 positives and 500 negatives reviews. A review with negative sentiment is labelled 0 and with positive review is labelled 1. A review is separated from its label by the tab character. On Fig. 3, is given the sample of the content of Amazon dataset with its schema (label/text review).

label	text
0.0	[So there is no way for me to plug it in here in the US unless I go by a converter
1.0	[Good case Excellent value
1.0	[Great for the jawbone
0.0	[Tied to charger for conversations lasting more than 45 minutesMAJOR PROBLEMS!!
1.0	[The mic is great
0.0	[I have to jiggle the plug to get it to line up right to get decent volume
0.0	[If you have several dozen or several hundred contacts then imagine the fun of sending each of them one by one
1.0	[If you are Razr owner you must have this!
0.0	[Needless to say I wasted my money
0.0	[What a waste of money and time!
1.0	[And the sound quality is great

Fig. 3 Amazon dataset content with its Schema

Train and Test Datasets

In order to estimate the generalization error the input data set is splitted into two datasets randomly: training dataset and testing dataset [9]. First one contains 80% from the original dataset and second one 20%. First one is used of building models, which is used for training the models to get predictions / recommendations. The second one is used for testing and finding the performance evaluating metrics such as accuracy and error and for evaluating the quality of the training models.

Cross-validation

Cross validation splits the input dataset into k sets of almost the same size, for example, to five sets as shown in Fig 4. First, sets 2-5 will be used for training and set 1 for testing. Then the procedure is repeated five times, leaving out one set at a time for testing, and average the error over the five repetitions [9].

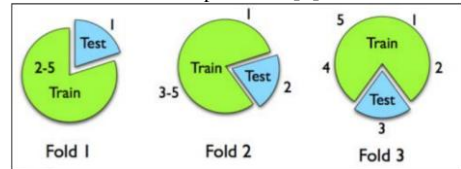


Fig. 4 Cross-validation K- Fold

Pre-processed datasets

The pre-processing or cleaning the datasets is performed via NLP concepts (Features Transformers and Extractors), to convert an input string to lowercase and to split it into words (tokens) using whitespaces as a separator, and eliminate not need tokens.

label	text	words	updatedWords	rawFeatures	features
0.0	[Drinks took clos...	[drinks, took, c...	[drinks, took, c...	(20000,[419,2044,...	(20000,[419,2044,...
0.0	[2 times - Very Ba...	[2, times, -, ver...	[2, times, -, bad...	(20000,[1413,5499,...	(20000,[1413,5499,...
0.0	[Although I very m...	[although, i, ver...	[although, much, ...	(20000,[2745,7190,...	(20000,[2745,7190,...
0.0	[And it was way to...	[and, it, was, wa...	[way, expensive]	(20000,[5062,1915,...	(20000,[5062,1915,...
0.0	[Any grandmother c...	[any, grandmother...	[grandmother, mak...	(20000,[941,2044,...	(20000,[941,2044,...
0.0	[As much as I'd li...	[as, much, as, i'...	[much, like, go, ...	(20000,[3330,8430,...	(20000,[3330,8430,...
0.0	[But I don't like it...	[but, i, don't, l...	[like]	(20000,[3330],[1,0])	(20000,[3330],[1,0])
0.0	[Coming here is li...	[coming, here, is...	[coming, like, ex...	(20000,[3330,7909,...	(20000,[3330,7909,...
0.0	[Del Taco is prett...	[del, taco, is, p...	[del, taco, prett...	(20000,[2061,3075,...	(20000,[2061,3075,...
0.0	[Disappointing exp...	[disappointing, e...	[disappointing, e...	(20000,[2745,7190,...	(20000,[2745,7190,...
0.0	[Don't waste your ...	[don't, waste, yo...	[waste, time]	(20000,[15066,181,...	(20000,[15066,181,...
0.0	[Food is way overp...	[food, is, way, o...	[food, way, overp...	(20000,[1742,8653,...	(20000,[1742,8653,...
0.0	[Gave up trying to...	[gave, up, trying...	[gave, trying, ea...	(20000,[213,1800,...	(20000,[213,1800,...
0.0	[He was extremely ...	[he, was, extreme...	[extremely, rude...	(20000,[8463,1131,...	(20000,[8463,1131,...
0.0	[Hell no will I go...	[hell, no, will, ...	[hell, go, back]	(20000,[1617,8430,...	(20000,[1617,8430,...

Fig. 5 Pre-processed steps results for Amazon Dataset

To prepare data in a format that can be used in machine learning algorithms a feature Vector for each sentence in the dataset must be created. For that the TF-IDF is applied to get a bag of words. Then the Sentimental analysis algorithms can be applied using a bag of words. Figure 5 shows a sample of the results of the pre-processed steps of the selected dataset.

Results

The results of both machine learning algorithms for text analysis on the Amazon_cell_labelled dataset are shown in Fig. 6 and Fig.7. These results are the final results of testing the training models by test dataset, after performing the training models on train dataset. The Naïve Bayes model produces the probabilities and predictions from the features, but the Linear SVM model produces

only the predictions and their results easily can be compared with the base value of labels.

[label]	features	rawPrediction	probability	predictions
0.0	[20000, [19637], [5...]	[-40.198273587791...	[0.99999962538923...	0.0
0.0	[20000, [941, 2745, ...]	[-210.19583354933...	[0.99999981652783...	0.0
0.0	[20000, [2044, 3208, ...]	[-554.98779945383...	[0.99996119971449...	0.0
0.0	[20000, [1624, 4034, ...]	[-332.79628117605...	[0.99999997767548...	0.0
0.0	[20000, [505, 2277, ...]	[-128.90480026635...	[0.9999999893763...	0.0
0.0	[20000, [1955, 2177, ...]	[-347.08097989511...	[0.01932759708368...	1.0
0.0	[20000, [1868, 1924, ...]	[-301.97116641090...	[0.00678859272681...	1.0
0.0	[20000, [4511, 8103, ...]	[-112.75167131188...	[0.99999999999998...	0.0
0.0	[20000, [17086, 192, ...]	[-58.228223650788...	[0.99999817092654...	0.0
0.0	[20000, [2404, 1237, ...]	[-52.79739411466...	[0.02759563603203...	1.0
0.0	[20000, [8297, 1238, ...]	[-68.913703017755...	[0.97675709312516...	0.0
0.0	[20000, [16213], [4, ...]	[-28.086391713991...	[0.85120876645934...	0.0
0.0	[20000, [15984, 162, ...]	[-47.195515557507...	[0.65350430047939...	0.0
0.0	[20000, [1413, 5499, ...]	[-105.49344847043...	[0.99818726296542...	0.0
0.0	[20000, [13337, 135, ...]	[-72.095790908299...	[0.99999999976954...	0.0

Fig. 6 Sentiment Analysis Results by using Naïve Bayes

[label]	features	rawPrediction	predictions
0.0	[20000, [645, 3866, ...]	[-0.5475272933290...	1.0
0.0	[20000, [941, 2745, ...]	[0.15520851708257...	0.0
0.0	[20000, [2044, 3208, ...]	[1.53501873581684...	0.0
0.0	[20000, [8418, 9694, ...]	[-0.4611041347706...	1.0
0.0	[20000, [15984, 190, ...]	[-1.1296972759785...	1.0
0.0	[20000, [4511, 8103, ...]	[1.09560932818885...	0.0
0.0	[20000, [4366, 1159, ...]	[0.97878584992358...	0.0

Fig. 7 Sentiment Analysis Results by using Linear SVM

Model Evaluations

Accuracy is a simple model evaluation metric. It is used as the evaluation metric of the different algorithms. It is defined as the percentage of the labels correctly predicted by a model. For example, if test dataset contains 100 observations and a model correctly predicts the labels for 85 observations, then its accuracy is 85 %. To evaluate how the generated model performs on both the training and test datasets, first the predictions is get for each observation in the training and test datasets. Second, the models are evaluated by using accuracy measure to the test datasets. To improve the accuracy evaluation performance results are used in the K-fold cross-validation idea with k=5 iterations.

Table 1: Techniques Evaluation Metrics Results

Techniques with Evaluation Metrics	Naïve Bayes	Linear SVM
Accuracy Evaluation Metrics1	0.8	0.79803
Accuracy Evaluation Metrics2	0.78421	0.7973
Accuracy Evaluation Metrics3	0.77941	0.83333
Accuracy Evaluation Metrics4	0.77251	0.80729
Accuracy Evaluation Metrics5	0.80303	0.8
Average Accuracy	0.78783	0.80719
Test Error	0.21217	0.19281

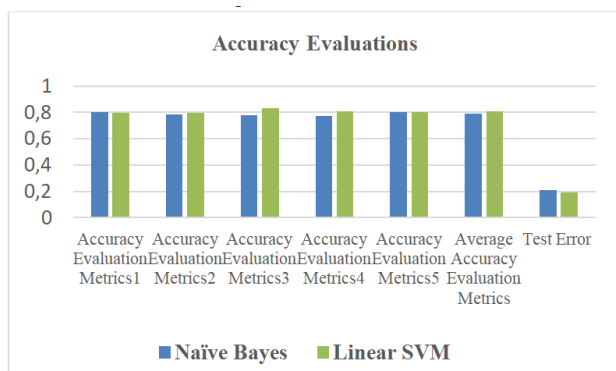


Fig. 8 Evaluation Metrics Results

The results are presented in Table 1 and Fig. 8. The Average accuracy evaluation metrics detects that the Linear SVM model is better than Naïve Bayes model using the test datasets to evaluate of this dataset. Because the accuracy score will be between 0 and 1, and high Accuracy score is better, it means that has less error.

5. Conclusion

Big data sentiment analysis is one of the most interesting techniques to find out the users opinion of products. The system

proposed in this paper is able to perform the text reviews sentiment analysis over the large amount of data with high speed near to real-time. The system uses Apache Spark ML libraries to implement big data sentiment processing on the base of Naïve Bayes and SVM models which classify the reviews in positive and negative sentiments. The work of proposed models implements several stages: pre-processing stage, features generation stage, classifiers learning stage, and Pipeline stage. The analytical evaluation of proposed model is done by accuracy evaluation measure. It is shown through experiments that the performance of the system is increased by obtaining the average evaluation accuracy metrics, based on the cross-validation idea. The comparison analysis in the proposed system shows that Linear SVM is better than Naïve Bayes in term of average accuracy metrics. The main focus of current research was to perform the Sentiment Analysis faster and Big Data sets to be handled efficiently. At the moment the system is implemented on a single node PC configuration. Next steps in the future will be to run the system in a multi-node configuration and to increase its performance, as well to test it with larger data sets.

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MODELLING, SIMULATION AND IMPLEMENTATION OF AUTONOMOUS UNMANNED QUADROTOR

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Abstract: This research proposes modelling, simulation and implementation of autonomous unmanned quadrotor prototype based on Matlab Simulink software, and Mission Planner for communicating with APM control board of the quadrotor. The goal is to Control attitude and altitude over a desired trajectory of the Quadrotor using PID control, with high precision and reliability. The mathematical model used for simulation takes into account all differential equations of motion of the quadrotor. A full quadrotor prototype was assembled for real experiments to do a comparison between real and simulated data. This comparison reveals the reliability and the accuracy of the PID controller and the mathematical model used in Matlab.

KEYWORDS: QUADROTOR, UAV, SIMULATION, PID CONTROL, TRAJECTORY TRACKING.

1. Introduction

The Unmanned Aerial Vehicles (UAVs), particularly the Vertical Take-Off and Landing (VTOL) Quadrotors, are flying robots without pilot which are able to conduct missions in hostile and disturbed environments[1]. The rotors are directed upwards and they are placed in a square formation with equal distance from the center of mass of the quadrotor. The quadrotor is controlled by adjusting the angular velocities of the rotors which are spun by electric motors. Quadrotor is a typical design for small unmanned aerial vehicles (UAV) as shown in Figure 1. And because of the simple structure, Quadrotors are used in surveillance, search and rescue, construction inspections and several other applications.

Quadrotor has received a big attention from researchers as this new technology has generated several areas of interest. The basic dynamical model of the quadrotor is the starting point for all of the studies. Different control methods have been investigated, including PID controllers [2]–[5], Backstepping control method [6], [7], [8], LQR controllers [5], nonlinear H_∞ control and nonlinear controllers with nested saturations [9], [10]. but more complex aerodynamic properties has been introduced as well [11], [12]. Control methods require accurate measurement from the position and attitude sensors represented in a gyroscope, an accelerometer, and other measurement devices, such as GPS, sonar and laser sensors [13], [14].



Figure 1: Aeryon Skyranger Quadrotor.

The purpose of this research is to present the basics of quadrotor modelling and control as to form a basis for further research and development in the area. This is pursued with the first aim to study the mathematical model of the quadrotor dynamics and modelling it in Matlab to develop proper methods for trajectory tracking control of the quadrotor. The challenge in controlling a quadrotor is that the quadrotor has six degrees of freedom but there are only four control inputs which means an under-actuated system.

In this literature review we will show the differential equations of motion for a quadrotor, which could be derived from Newton-Euler and Euler-Lagrange equations. The behavior of the model is examined by simulating the flight of the quadrotor. Stabilization of the quadrotor is conducted by utilizing a PID controller. The PID control method is easy to implement and to be used for the quadrotor control.

2. Dynamic System Model

The quadrotor structure is presented in Figure 2 including the corresponding angular velocities, torques and forces created by the four rotors (numbered from 1 to 4).

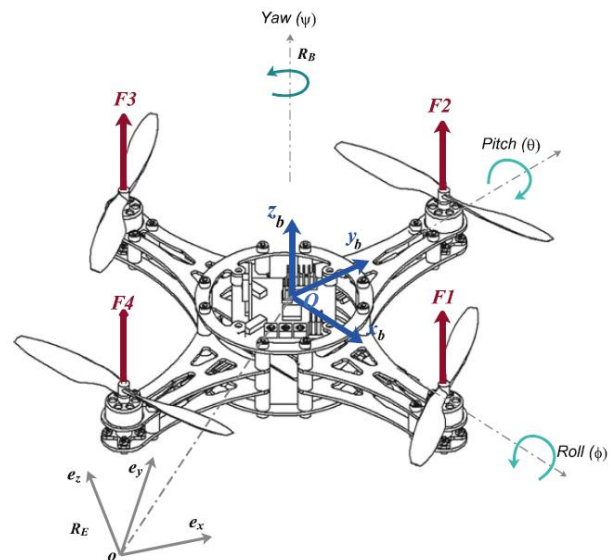


Figure 2: The inertial and body frames of a quadrotor.

The absolute linear position of the quadrotor is defined in the inertial frame x, y, z axes with ξ . The attitude, i.e. the angular position, is defined in the inertial frame with three

Euler angles η . Pitch angle θ determines the rotation of the quadrotor around the y-axis. Roll angle ϕ determines the rotation around the x-axis and yaw angle ψ around the z-axis. Vector q contains the linear and angular position vectors:

$$\xi = \begin{bmatrix} x \\ y \\ z \end{bmatrix}, \quad \eta = \begin{bmatrix} \theta \\ \phi \\ \psi \end{bmatrix}, \quad q = \begin{bmatrix} \xi \\ \eta \end{bmatrix} \quad (1)$$

The origin of the body frame is in the center of mass of the quadrotor. The linear velocities in the body frame are determined by V_B and the angular velocities by v :

$$V_B = \begin{bmatrix} v_{x,B} \\ v_{y,B} \\ v_{z,B} \end{bmatrix}, \quad v = \begin{bmatrix} p \\ q \\ r \end{bmatrix} \quad (2)$$

The rotation matrix from the body frame to the inertial frame is:

$$R = \begin{bmatrix} C_\psi C_\theta & C_\psi S_\theta S_\phi - S_\psi C_\phi & C_\psi S_\theta C_\phi + S_\psi S_\phi \\ S_\psi C_\theta & S_\psi S_\theta S_\phi + C_\psi C_\phi & S_\psi S_\theta C_\phi - C_\psi S_\phi \\ -S_\theta & C_\theta S_\phi & C_\theta C_\phi \end{bmatrix} \quad (3)$$

In which $S_x = \sin(x)$ and $C_x = \cos(x)$. The rotation matrix R is orthogonal thus $R^{-1} = R^T$ which is the rotation matrix from the inertial frame to the body frame.

The transformation matrix for angular velocities from the inertial frame to the body frame is W_η , and from the body frame to the inertial frame is W_η^{-1} , is as shown:

$$\dot{\eta} = W_\eta^{-1} v, \quad \begin{bmatrix} \dot{\theta} \\ \dot{\phi} \\ \dot{\psi} \end{bmatrix} = \begin{bmatrix} 1 & S_\phi T_\theta & C_\phi T_\theta \\ 0 & C_\phi & -S_\phi \\ 0 & S_\phi / C_\theta & C_\phi / C_\theta \end{bmatrix} \begin{bmatrix} p \\ q \\ r \end{bmatrix},$$

$$v = W_\eta \dot{\eta}, \quad \begin{bmatrix} p \\ q \\ r \end{bmatrix} = \begin{bmatrix} 1 & 0 & -S_\theta \\ 0 & C_\phi & C_\theta S_\phi \\ 0 & -S_\phi & C_\theta C_\phi \end{bmatrix} \begin{bmatrix} \dot{\theta} \\ \dot{\phi} \\ \dot{\psi} \end{bmatrix} \quad (4)$$

In which $T_x = \tan(x)$. The matrix W_η is invertible if $\theta \neq (2k-1)\pi/2$, ($k \in \mathbb{Z}$).

The quadrotor is assumed to have symmetric structure with the four arms aligned with the body x- and y-axes. Thus, the inertia matrix is diagonal matrix I in which $I_{xx} = I_{yy}$

$$I = \begin{bmatrix} I_{xx} & 0 & 0 \\ 0 & I_{yy} & 0 \\ 0 & 0 & I_{zz} \end{bmatrix} \quad (5)$$

The angular velocity of rotor i , denoted with ω_i , creates force f_i in the direction of the rotor axis. The angular velocity and acceleration of the rotor also create torque τ_{Mi} around the rotor axis

$$f_i = k\omega_i^2, \quad \tau_{Mi} = b\omega_i^2 + I_M \dot{\omega}_i, \quad (6)$$

Here is the lift constant k , the drag constant b and the inertia moment of the rotor is I_M . generally, the effect of $\dot{\omega}_i$ is considered small, so it is omitted.

The combined forces of rotors create thrust force T in the direction of the body z-axis. Torque τ_B consists of the torques τ_ϕ , τ_θ and τ_ψ in the direction of the corresponding body frame angles

$$T = \sum_{i=1}^4 f_i = k \sum_{i=1}^4 \omega_i^2, \quad T^B = \begin{bmatrix} 0 \\ 0 \\ T \end{bmatrix} \quad (7)$$

$$T_B = \begin{bmatrix} T_\phi \\ T_\theta \\ T_\psi \end{bmatrix} = \begin{bmatrix} lk(-\omega_2^2 + \omega_4^2) \\ lk(-\omega_1^2 + \omega_3^2) \\ k \sum_{i=1}^4 \tau_{Mi} \end{bmatrix} \quad (8)$$

Here l is the distance between the rotor center and the center of mass of the quadrotor. Thus, the roll movement is acquired by decreasing the 2nd rotor velocity and increasing the 4th rotor velocity. In the same way, the pitch movement is acquired by decreasing the 1st rotor velocity and increasing the 3rd rotor velocity. Yaw movement is acquired by increasing the angular velocities of two opposite rotors and decreasing the velocities of the other two.

3. Euler-Lagrange equations of motion:

The Lagrangian L is the sum of the translational E_{trans} and rotational E_{rot} energies minus potential energy E_{pot}

$$\mathcal{L}(q, \dot{q}) = E_{trans} + E_{rot} - E_{pot} \\ = (m/2) \dot{\xi}^T \dot{\xi} + (1/2) v^T I v - mgz. \quad (9)$$

Equations of external forces and torques are:

$$\begin{bmatrix} f \\ \tau \end{bmatrix} = \frac{d}{dt} \left(\frac{\partial \mathcal{L}}{\partial \dot{q}} \right) - \frac{\partial \mathcal{L}}{\partial q} \quad (10)$$

The linear and angular components do not depend on each other thus they can be studied separately. The linear external force is the total thrust of the rotors. The linear Euler-Lagrange equations are

$$f = RT_B = m\ddot{\xi} + mg \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}, \quad (11)$$

$$\begin{bmatrix} \ddot{x} \\ \ddot{y} \\ \ddot{z} \end{bmatrix} = -g \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} + \frac{T}{m} \begin{bmatrix} C_\psi S_\theta C_\phi + S_\psi S_\phi \\ S_\psi S_\theta C_\phi - C_\psi S_\phi \\ C_\theta C_\phi \end{bmatrix}$$

$$\ddot{x} = \frac{1}{m} (c\phi c\psi s\theta + s\phi s\psi) u_1$$

$$\ddot{y} = \frac{1}{m} (c\phi s\psi s\theta - s\phi c\psi) u_1$$

$$\ddot{z} = \frac{1}{m} c\phi c\theta u_1 - g$$

The Jacobian matrix $J(\eta)$ [15] from v to $\dot{\eta}$ is:

$$J(\eta) = J = W_\eta^T I W_\eta, \quad (12)$$

$$J(\eta) = \begin{bmatrix} I_{xx} & 0 & -I_{xx} S_\theta \\ 0 & I_{yy} C_\phi^2 + I_{zz} S_\phi^2 & (I_{yy} - I_{zz}) C_\phi S_\phi C_\theta \\ -I_{xx} S_\theta & (I_{yy} - I_{zz}) C_\phi S_\phi C_\theta & I_{xx} S_\theta^2 + I_{yy} S_\phi^2 C_\theta^2 + I_{zz} C_\phi^2 C_\theta^2 \end{bmatrix}$$

Thus, the rotational energy E_{rot} can be expressed in the inertial frame as:

$$E_{rot} = (1/2) v^T I v = (1/2) \dot{\eta}^T J \dot{\eta} \quad (13)$$

The external angular force is the torques of the rotors [16]. The angular Euler-Lagrange equations are

$$\tau = \tau_B = J\ddot{\eta} + \frac{d}{dt} (J)\dot{\eta} - \frac{1}{2} \frac{\partial}{\partial \eta} (\dot{\eta}^T J \dot{\eta}) = J\ddot{\eta} + C(\eta, \dot{\eta}) \dot{\eta} \quad (14)$$

in which the matrix $C(\eta, \dot{\eta})$ is the Coriolis term, containing the gyroscopic and centripetal terms. The matrix $C(\eta, \dot{\eta})$ has the form, as shown in [8],

$$C(\eta, \dot{\eta}) = \begin{bmatrix} C_{11} & C_{12} & C_{13} \\ C_{21} & C_{22} & C_{23} \\ C_{31} & C_{32} & C_{33} \end{bmatrix}$$

$$C_{11} = 0$$

$$C_{12} = (I_{yy} - I_{zz})(\dot{\theta}C_{\phi}C_{\theta} + \dot{\psi}S_{\phi}^2C_{\theta}) + (I_{zz} - I_{yy})\dot{\psi}C_{\phi}^2C_{\theta} - I_{xy}\dot{\psi}C_{\theta}$$

$$C_{13} = (I_{zz} - I_{yy})\dot{\psi}C_{\phi}S_{\theta}C_{\theta}^2$$

$$C_{21} = (I_{zz} - I_{yy})(\dot{\theta}C_{\phi}S_{\theta} + \dot{\psi}S_{\phi}C_{\theta}) + (I_{yy} - I_{zz})\dot{\psi}C_{\phi}^2C_{\theta} + I_{xx}\dot{\psi}C_{\theta}$$

$$C_{22} = (I_{zz} - I_{yy})\dot{\phi}C_{\phi}S_{\theta}$$

$$C_{23} = -I_{xx}\dot{\psi}S_{\theta}C_{\theta} + I_{yy}\dot{\psi}S_{\phi}^2S_{\theta}C_{\theta} + I_{zz}\dot{\psi}C_{\phi}^2S_{\theta}C_{\theta}$$

$$C_{31} = (I_{yy} - I_{zz})\dot{\psi}C_{\theta}^2S_{\phi}C_{\theta} - I_{xx}\dot{\theta}C_{\theta}$$

$$C_{32} = (I_{zz} - I_{yy})(\dot{\theta}C_{\phi}S_{\theta}S_{\theta} + \dot{\phi}S_{\phi}^2C_{\theta}) + (I_{yy} - I_{zz})\dot{\phi}C_{\phi}^2C_{\theta}$$

$$+ I_{xx}\dot{\psi}S_{\theta}C_{\theta} - I_{yy}\dot{\psi}S_{\phi}^2S_{\theta}C_{\theta} - I_{zz}\dot{\psi}C_{\phi}^2S_{\theta}C_{\theta}$$

$$C_{33} = (I_{yy} - I_{zz})\dot{\phi}C_{\phi}S_{\theta}C_{\theta}^2 - I_{yy}\dot{\theta}S_{\phi}^2C_{\theta}S_{\theta} - I_{zz}\dot{\theta}C_{\phi}^2C_{\theta}S_{\theta} + I_{xx}\dot{\theta}C_{\theta}S_{\theta}$$

(15)

Equation (14) leads to the differential equations for the angular accelerations:

$$\ddot{\eta} = J^{-1}(\tau_B - C(\eta, \dot{\eta})\dot{\eta}) \quad (16)$$

$$\ddot{\phi} = \frac{I_y - I_z}{I_x}\dot{\theta}\dot{\psi} - \frac{J_r}{I_x}\Omega_r\dot{\theta} + \frac{1}{I_x}u_2$$

$$\ddot{\theta} = \frac{I_z - I_x}{I_y}\dot{\phi}\dot{\psi} - \frac{J_r}{I_y}\Omega_r\dot{\theta} + \frac{1}{I_y}u_3$$

$$\ddot{\psi} = \frac{I_x - I_y}{I_z}\dot{\phi}\dot{\theta} + \frac{1}{I_z}u_4$$

From (15) and (16) we can find the equations of motion for translational and rotational movement of the quadrotor system.

The influence of aerodynamical effects are complicated and difficult to model. Also it has significant effect only in high velocities. Thus, these effects are excluded from the model and a simplified model is used.

4. Controller Design:

To stabilize the quadrotor, a PID controller is utilized. Advantages of the PID controller are easy implementation and tuning of the controller. The known form of the PID controller is as follows:

$$e(t) = x_d(t) - x(t)$$

$$u(t) = K_P e(t) + K_I \int_0^t e(\tau) d\tau + K_D \frac{de(t)}{dt} \quad (17)$$

in which $u(t)$ is the control input, $e(t)$ is the difference between the desired state $x_d(t)$ and the present state $x(t)$, and K_P , K_I and K_D are the parameters for the proportional, integral and derivative elements of the PID controller.

In a quadrotor, there are six states, positions ξ and angles η , but only four control inputs, the angular velocities of the four rotors ω_i . The interactions between the states and the total thrust T and the torques τ created by the rotors are clear as we can see in the dynamical equations of motion. The total thrust T affects the acceleration in the direction of the z-axis and holds the quadrotor in the air. Torque τ_{ϕ} has an effect on the acceleration of angle ϕ , torque τ_{θ} affects the acceleration

of angle θ , and torque τ_{ψ} contributes in the acceleration of angle ψ .

The role of the PID controller is to adjust the speed of the four motors thus propellers such that a desired quadrotor orientation is achieved. The Quadrotor is controlled by independently varying the speed of the four rotors. Hence, these control inputs $u_{1,2,3,4}$ are defined as follows:

$$u = \begin{bmatrix} u_1 \\ u_2 \\ u_3 \\ u_4 \end{bmatrix} = \begin{bmatrix} F \\ \tau_{\phi} \\ \tau_{\theta} \\ \tau_{\psi} \end{bmatrix} = \begin{bmatrix} b & b & b & b \\ 0 & -lb & 0 & lb \\ -lb & 0 & lb & 0 \\ d & -d & d & -d \end{bmatrix} \begin{bmatrix} \omega_1^2 \\ \omega_2^2 \\ \omega_3^2 \\ \omega_4^2 \end{bmatrix} \quad (18)$$

$$\begin{pmatrix} u_1 \\ u_2 \\ u_3 \\ u_4 \end{pmatrix} = \begin{pmatrix} b(\omega_1^2 + \omega_2^2 + \omega_3^2 + \omega_4^2) \\ b(-\omega_2^2 + \omega_4^2) \\ b(\omega_1^2 - \omega_3^2) \\ d(\omega_1^2 - \omega_2^2 + \omega_3^2 - \omega_4^2) \end{pmatrix} \quad (19)$$

$$\omega_1^2 = \frac{u_1}{4b} - \frac{u_3}{2lb} + \frac{u_4}{4d}$$

$$\omega_2^2 = \frac{u_1}{4b} + \frac{u_3}{2lb} - \frac{u_4}{4d}$$

$$\omega_3^2 = \frac{u_1}{4b} + \frac{u_3}{2lb} + \frac{u_4}{4d}$$

$$\omega_4^2 = \frac{u_1}{4b} - \frac{u_3}{2lb} - \frac{u_4}{4d}$$

(20)

4.1 Description of the Simulation Tool:

We built the Simulink block diagram for the quadrotor dynamics as shown in Figure 3. Which represent the translational and rotational system dynamics, also we can see special block for motor speed calculation.

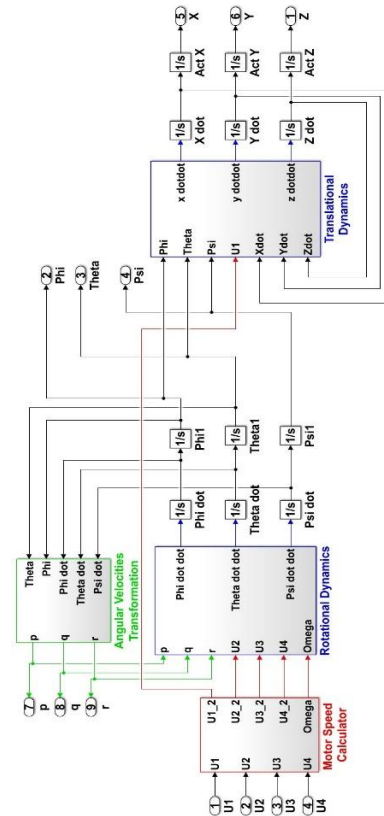


Figure 3: Quadrotor Dynamics diagram in Simulink

The Full system with controller and trajectory generator can be seen in Figure 4.

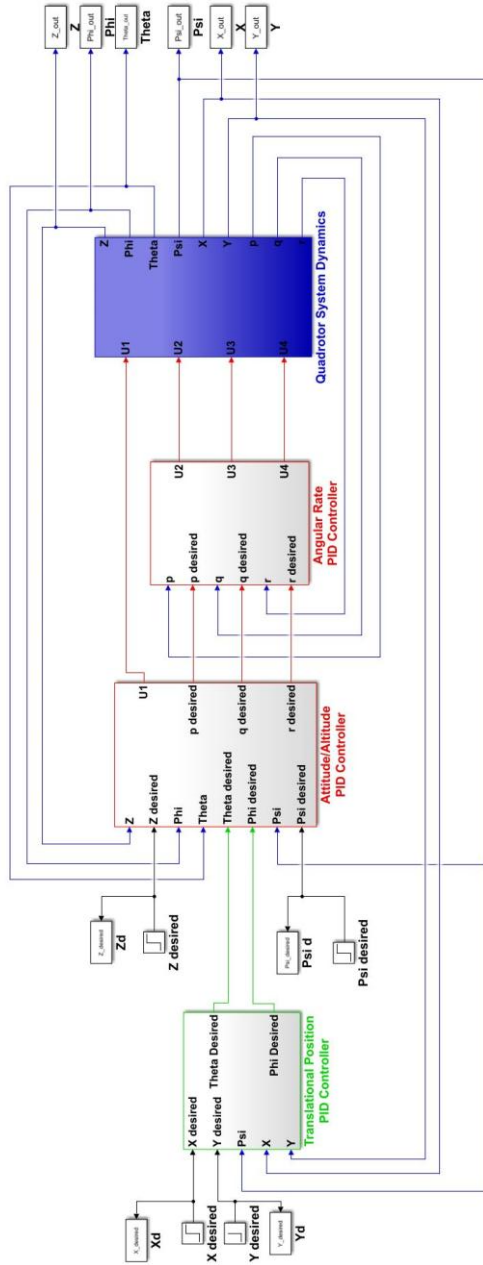


Figure 4: Simulink Diagram with PID controllers

Quadrotor controller is implemented using nested control loops. The inner most loop controls the angular velocities of the quadrotor. This loop needs to run at a high frequency due to the fast dynamics of the quadrotor. The next highest loop controls the attitude and altitude of the quadrotor. Small attitude changes are directly related to translational acceleration. This means small attitude errors can cause large and unwanted translational displacements very quickly.

Small attitude angles will result in translational movement or drifting of the quadrotor. In order to prevent this translational drifting behavior, a position controller is implemented.

5. Implementation and Design:

Quadrotor implementation and selecting the correct parts is a very important step. Because we should calculate the total weight of the quadrotor and according to that the suitable parts will be selected. Our quadrotor weight is 1.3 kg. we used APM 2.6 ArduPilot Mega 2.6 Flight Control Board as shown in Figure 5. The Ardupilot is connected to ESCs for

controlling the four motors speed. We selected DJI F450 frame and 10 inch propellers. FlySky 9 channels remote control is used for sending control signals and communicating with APM control board.

On the ground station we used Ardupilot mission planner software and by using 900 MHz telemetry device we could communicate with quadrotor. Figure 5 shows Communication process between the different parts of the quadrotor.



Figure 5: Communication process between quadrotor different parts.

After that we built the real model of the quadrotor by assembling all the parts together in one unit. Then we uploaded the open source of the ArduPilot to the control card, and by finishing the motor tests and ESCs calibrations we could make the real flight experiments.

We can see the full model of the quadrotor in Figure 6 whereas the upper black part is the GPS device used for locating the position. While the IMU (Inertial measurement unit) is used for measuring angular speeds and acceleration of the quadrotor.



Figure 6: Quadrotor Full Model Assembly.

The flight experiments were done at Istanbul university campus. We made manual and autonomous flight tests, and we could send the trajectories from the ground station to the control board over the quadrotor to be tracked automatically.

The manual tests done to assure the consistency and compatibility of the quadrotor parts with each other. Some photos were taken while doing tests as shown in figure 7.



Figure 7: Trajectory tracking and Flight test at Istanbul university campus.

6. Simulation Results:

The model was verified by simulating the flight of a quadrotor within Matlab. Blocks that representing all external forces, torques and loads acting on the model have been integrated into the block diagrams model. Then we generated the desired 3D trajectories to follow it using the Mission Planner open source software. This simulator is able to predict the latitude and altitude on the desired trajectory in order to represent real model with high reliability as shown in Figure 8 and Figure 9.

Stabilization of attitude of the quadrotor was done by utilizing a PID controller. The simulation proved the presented mathematical model to be realistic in modelling the position and attitude of the quadrotor.

Finally, the required control inputs were solved from the total thrust and the torques. The simulation results indicated that the quadrotor could be controlled accurately with the control inputs given from the computer throw telemetry to the quadrotor.

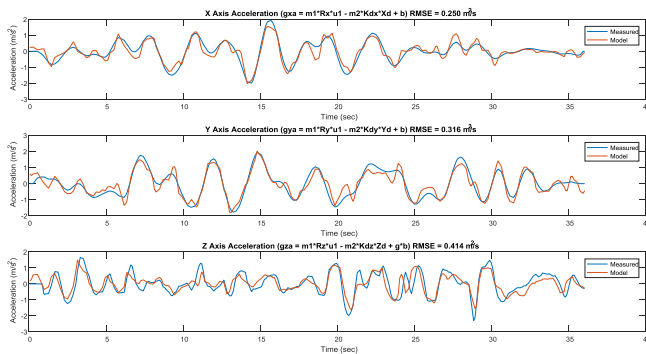


Figure 8: Measured and modeled acceleration control Plots.

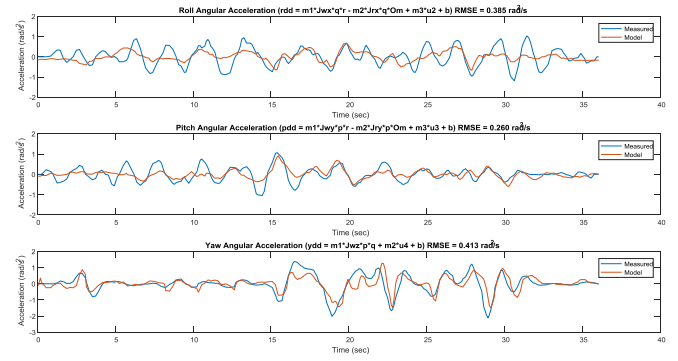


Figure 9: Measured and modeled roll control plots.

For 10 seconds period of simulation time we can see the measured and desired Roll angle in figure 10. Also measured accelerations over x, y and z could be seen in figure 11.

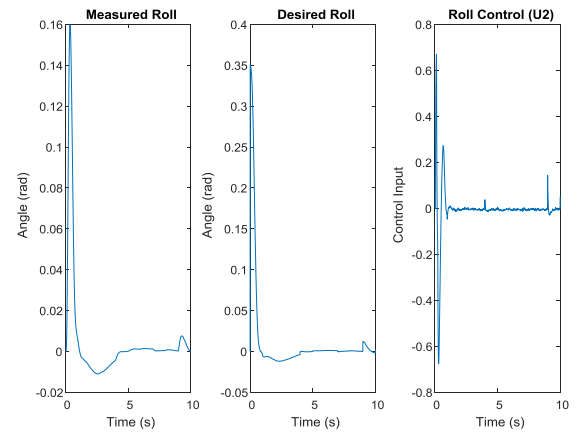


Figure 10: Roll Control plots.

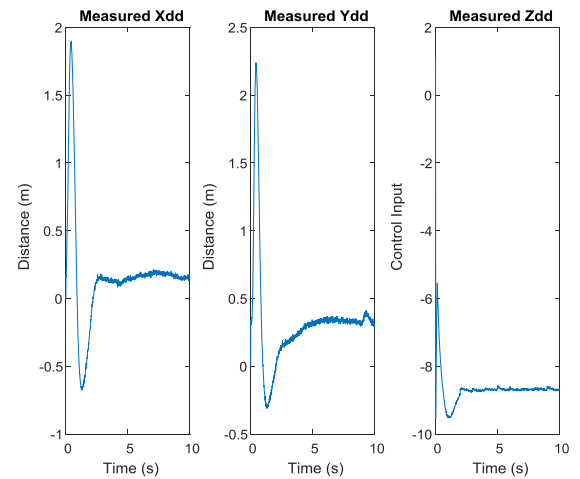


Figure 11: Acceleration Control Plots.

7. Conclusion

This research studied mathematical modelling and control of a quadrotor system as well as the implementation of the Quadrotor real model using Simulink® for mathematical modelling and simulation of the differential equations of motion of a quadrotor. The mathematical model of quadrotor dynamics was presented and the differential equations of motion were derived from the Euler-Lagrange equations.

The presented mathematical model only consists of the basic structures of the quadrotor dynamics. Several aero dynamical

effects were excluded which can lead to unrealizable behavior. The position and attitude information was assumed to be accurate in the model and the simulations. However, the measuring devices in real life are not perfectly accurate as random variations and errors occur. Hence, the effects of imprecise information to the flight of the quadrotor should be studied as well. Also there are methods to enhance the accuracy of the measurements which should be researched and implemented to improve all aspects required for robust quadrotor maneuvers.

The presented model and control methods were tested both in simulations and Real experimental prototype of a quadrotor that constructed to achieve more realistic and reliable results. With a real prototype, the theoretical framework and the simulation results could be compared to real-life measurements.

Finally, simulation results indicate that the applied PID controller over ArduPilot control board can follow the desired trajectory with high precision. Block parameters used for defining the model can be easily modified to be adapted to other assembly models. Moreover, the model can be used to simulate any other quadrotor with different parameters and to predict the resultant errors.

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THE USE OF GLOBAL BEST PRACTICES OF EFFECTIVE MANAGEMENT OF THE COMPANY ARCELORMITTAL TEMIRTAU JSC

ИСПОЛЬЗОВАНИЕ ЛУЧШИХ МИРОВЫХ ПРАКТИК ЭФФЕКТИВНОГО УПРАВЛЕНИЯ КОМПАНИЕЙ АО «АРСЕЛОРМИТАЛЛ ТЕМИРТАУ»

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Abstract. The article is devoted to the study of the complex of modern management tools aimed at improving the efficiency of enterprise management. According to the results of the study, the directions of the company's development based on the application of the best practices of company management were determined. From the modern point of view, the approaches to enterprise management are systematized and refined. The developed recommendations for improving management are brought to concrete proposals, the implementation of which will improve the stability of the enterprise.

KEYWORDS: CUSTOMER FOCUS, MANAGEMENT TOOLS, KEY COMPETENCE, TARGET CUSTOMER.

1. Introduction

Changes in the economy in recent decades: increased competition, increased costs of storage and transportation of products make enterprises look for new ways to increase competitive advantage, that is, the abilities and competencies that are characterized by sustainability and non-copyability, allowing to develop and provide the market with a product with high added value. The growing struggle between production, trade and service enterprises has led to the need to find new methods of work, change the structures of enterprises, finding internal reserves to improve the competitiveness of ArcelorMittal Temirtau JSC, by providing the best consumer offer, which will allow this company to develop systematically and steadily, as well as to receive benefits not available to competitors.

ArcelorMittal Temirtau JSC today is the largest metallurgical enterprise in Kazakhstan with a full metallurgical cycle and a design

capacity of 4.5 million tons of rolled products per year, covering an area of more than 5,000 hectares.

ArcelorMittal Temirtau JSC is one of the largest enterprises of ArcelorMittal group of companies – the number one steel producer in the world. ArcelorMittal has a leading position in major global markets, including the automotive and construction markets, as well as the home appliance and packaging markets. The company is a leader in research and development of innovative technologies. It has its own extensive raw material base and operates a network of global distribution of raw materials and products.

The planned increase in the volume of steel at ArcelorMittal Temirtau JSC, possibly through the introduction of the best global practices of management of the new Millennium. The group of the best tools to work with customers, include customer focus. The meaning of customer focus is that it is a tool for customer relationship management, aimed at achieving sustainable profits in the long term and based on three criteria, which is presented in Fig.1.[1]

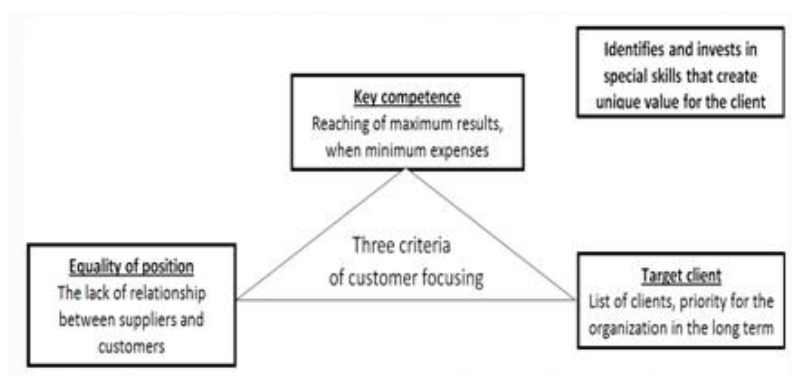


Figure.1 The criteria of customer focus

Client-oriented approach, acting as a tool, is a means to adapt to changing environmental conditions, the main task of which is to exclude from the environment the influence of uncertainty and create conditions of certainty, stability and repeatability [8].

2. Client relationship management tools

One of the best practices with a high rating in the management of the company is the key competence. The essence of which is to allocate and invest in special skills or technologies that create unique value for the client. And, as a result, to achieve maximum results with minimum costs.

To determine the priority (target) customers for the organization in the long term, it is necessary to solve two problems:

1. To collect and process information for better understanding of customers, in order to retain and grow the most profitable of them.

2. To collect information from the client to measure their satisfaction level, identify basic needs and form proposals on this basis [2-5].

The activity of the target customer is based on equality of positions, that is, the exclusion of dominance between suppliers and customers, the regulatory document is the "standard of service", the key words of which are "good customer" and "good supplier".

Customer focus can be understood as the self-restraint of an organization rewarded by its customers. The company does not go beyond its competence and does not try to satisfy all the needs of all its customers, instead focusing on its core competence for a limited target group, which is capable of establishing partnerships.

Thus, it is possible to determine the following mandatory conditions for the organization that claims to be customer-oriented: the presence of conscious and purposefully developed key competencies and the absence of declarative core competencies of a General nature; the unambiguous definition of target groups and the

identification of their unique needs. Willingness to refuse non-target customer for priority service; priority of long-term profit over short-term benefit.

One of the best tools in the management of the company is a key competence – competence, providing a competitive advantage.

[6] when ranking key competencies by priority, it was found that end users give priority to product quality and price as shown in the figure. 2.

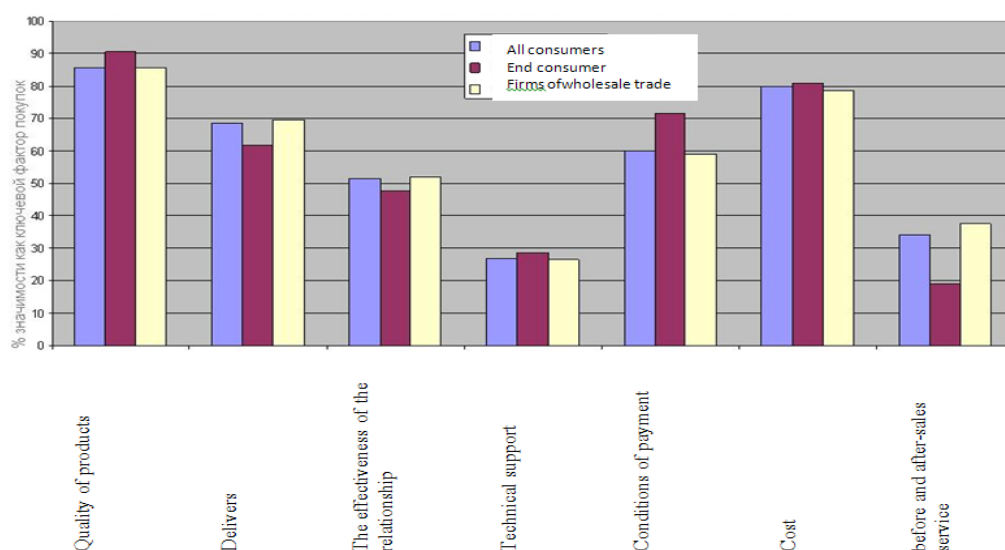


Figure 2. Key factors from a consumer perspective

The measure of quality is the degree of customer satisfaction, determined by the ratio of value and cost. Based on this approach, three situations should be considered: $V=C$ is a neutral position. The expectations of the consumer were confirmed, and the manufacturer paid back its costs and received the planned profit. $V > C$ - customer is satisfied. At the same time, the manufacturer is interested in making more profit by increasing the cost of sales. $V < C$ - the customer is not satisfied and most likely the purchase will not be realized. The manufacturer starts to lose acquired consumers.

One of the best modern practices of effective management of the company is segmentation. Segmentation is a grouping of consumers on any grounds, which is carried out in order to create a special offer or marketing program, in terms of deeply personalized marketing. [7]

The main consumers of ArcelorMittal Temirtau JSC were European and East Asian regions, they accounted for 80% of the total supply.

Currently, the situation has changed, a large proportion of target consumers are the CIS countries. Why this happened? Consumers have become more demanding, as evidenced by the survey questionnaire "Requirements for products". In addition to the basic requirements, consumers pay special attention to mechanical properties, such as: yield strength, tensile strength, adhesion strength, formability and weld ability, etc.

In order to improve the quality and attract the European market, and in order for the company to remain effective in a highly competitive environment, it is necessary to comply with European standards. The comparative analysis of 17T1C steel (GOST 19281-2014) with S355J2 steel (EN10025-2), which is a foreign analogue (see table 1).

Table 1. The requirements of Eurocode

Indicator	17T1C steel	S355J2 steel (1.0577)
Standard	GOST 19281 - 2014 rolled steel with increased strength. General specifications ST RK 23118-2002 steel construction Designs. General specifications	EN 10025-2 hot rolled products of structural steels. Part 2: Technical delivery conditions for non-alloy structural steels
Classification	Structure alloy carbon	Structure alloy
Application	Specially designed for welded structures. Welded parts work under high pressure. Large temperature range from -40 °C to +475 °C	Hot rolled products
Chemical composition	C – 0,17 % Fe – about 96 % Mn – 1,6 % Si – 0,6 % S – 0,04 % P – 0,035 % Cu, Cr, Ni – no more than 0,3 %	C – 0,2 % Fe – about 96 % Mn – 1,6 % Si – 0,55 % S – 0,025 % P – 0,025 % Cu – 0,55 %
Technological properties	Weld ability without limits	Weld ability without restrictions, according to ISO / TR 20172 gr. 1.1
Impact tests	A sample of the type U	A sample of the type V
Yield strength $\sigma_{0,2}$, MPa	295	355
Tensile strength σ_B , MPa	510	510
Brinell hardness, HB	---	104-154
Method of deoxidation	still	FF – completely deoxidized
Inquality	Normal quality	Normal quality

The quality of steel by EN is higher and is achieved by increasing the purity of the chemical composition, resulting in pulverized grain, relieves internal stress, increases ductility and strength. Deoxidation by EN is provided by a higher content of silicon, manganese, vanadium, molybdenum and aluminum (0.2%) due to this, a more fine-grained structure less prone to grain growth is obtained.

Thus, the end-user strategy involves some changes in the current sales management, namely:

- on an ongoing basis to identify markets / consumers for stable strategy;
- development of steel grades with higher added value for identified segments / markets and replacement of commercial / base grades with the same added value;
- global reorganization of the structure of the plant.

Based on the above, we offer the main directions of the company's development based on the application of best practices, namely:

- * continuous improvement of production technology and product quality for maximum customer satisfaction;
- * by means of market segmentation to continue to allocate target clients (key-customers) for the subsequent full implementation of factors of the best tools and the most successful cooperation with each of clients.

3. Conclusions

Thus, the application of the best tools should demonstrate leadership and commitment to key clients by ensuring that:

1. Customer requirements as well as applicable regulatory and legal requirements are defined and met;
2. Risks and opportunities that may affect product compliance and the ability to increase customer satisfaction are also identified and addressed;
3. The focus is on increasing customer satisfaction.

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INVESTIGATION OF ELECTRICAL CONDUCTIVITY AND HYDROPHOBIC/HYDROPHILIC INTERACTION OF PAN + PMMA COMPOSITE NANOFIBERS WITH AG NANOWIRE PRODUCED BY ELECTROSPINNING METHOD

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Abstract: In this study, the electrical conductivities and hydrophobic/hydrophilic properties of Polyacrylonitrile (PAN) + Polymethyl methacrylate (PMMA) composite nanofibers reinforced with nanowires were investigated. The nanofibers are produced by the electrospinning method. Their electrical conductivities and their hydrophobic/hydrophilic properties were examined. The maximum electrical conductivity value is 0.00298 S/cm at PAN + PMMA composite nanofibers with Ag nanowires (5 wt. %). The biggest static contact angle occurred in PAN+PMMA composite nanofibers with 1 wt. % Ag nanowire. The static contact angles of all PAN + PMMA composite nanofibers with Ag nanowire were found to be bigger than those of PAN + PMMA composite nanofibers.

KEYWORDS: ELECTRICAL CONDUCTIVITY, ELECTROSPINNING, HYDROPHOBIC/HYDROPHILIC, NANOFIBERS

1. Introduction

Nanotechnology is science, engineering, and technology conducted at the nanoscale, which is about 1 to 100 nanometers. Nanoscience and nanotechnology are the study and application of extremely small things and can be used across all the other science fields, such as chemistry, biology, physics, materials science, and engineering [1]. A nanofiber is a fiber with a diameter of 100 nanometers or less. The properties of nanofibers have caused researchers and companies to consider using this material in several fields. A survey of the applications of nanofibers: Researchers are using nanofibers to capture individual cancer cells circulating in the blood stream. They use nanofibers coated with antibodies that bind to cancer cells, trapping the cancer cell for analysis. Nanofibers can stimulate the production of cartilage in damaged joints [2].

Electrospinning is most widely chosen tool for synthesizing one-dimensional (1D) nanostructures which include ribbons, fibers, filled and hollow tubes from the fact that it's quite simple, easy to use and relatively inexpensive technique. The unique features of such as-spun nanofibers are one-dimensional morphology, extraordinary length, large surface area and highly porous structures [3, 4, 5]. Electrospin production of polymer composite nanofibers is a remarkable work in recent years. The superior properties exhibited by polymer nanofibers make them suitable for many applications. Some of the studies on nanofibers have been presented below.

Bahrambeygi et al. investigated the sound absorption behavior of PAN nanofibers, nano clay, multi-walled carbon nanotubes and polyurethane combination. Bahrambeygi et al. Reported that the nanoparticle provided a significant improvement in sound absorption and had more positive results in multi-walled carbon nanotubes [6]. Piperno et al. [7] produced nanofibers with various percentages of PMMA. They have characterized the morphological structure and chemical composition of the nanofibers they have produced. Ozek et al. (2015) produced nanofibers with polyacrylonitrile (PAN) polymers using the electrospinning method, the most common method of obtaining nanofibers. They have found that nanoclay-doped PAN nanofibers can be used as an alternative adsorbent [8].

In this study, the electrical conductivities and hydrophobic / hydrophilic properties of (PAN + PMMA) / (PAN + PMMA + Ag nano wire) composite nanofibers were investigated. First, 8% by weight of a solution consisting of PAN + PMMA + DMF was prepared. Pure PAN + PMMA composite nanofiber was produced from this solution. After various proportions (1%, 3% and 5%) of silver nanowires + PAN + PMMA + in solution of DMF was

prepared. PAN + PMMA composite nanofibers, which have been reinforced with nanoparticles, have been produced. Pure PAN + PMMA composite nanofiber and Ag nano wire PAN + PMMA the electrical conductivity and hydrophobic / hydrophilic properties of the composite nanofiber were investigated.

2. Material and Method

In this study, PAN, PMMA, DMF, Ag nano wire were used. A PAN with an average molecular weight (Mw) of 150,000 g/mol, A PMMA with an average molecular weight (Mw) of 350,000 and N, N-Dimethylformamide anhydrous, 99.8% were purchased from the Sigma Aldrich Co.

Polyacrylonitrile: PAN molecule has strong polar nitrile groups. It is relatively insoluble in nature. PAN based carbon fibers possess very high strength compared to other polymeric precursors. When subjected to heat treatment, it can produce high carbon yield giving rise to thermally stable, highly oriented, graphite like molecular structure. Generating carbon-fiber from PAN based fiber is a combination of three processes-- namely stabilization, carbonization and graphitization [9].

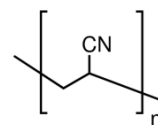


Fig.1. Skeletal formula of the PAN

Poly(methyl methacrylate) : PMMA, also known as acrylic or acrylic glass as well as by the trade names Crylux, Plexiglas, Acrylite, Lucite, and Perspex among several others, is a transparent thermoplastic often used in sheet form as a lightweight or shatter-resistant alternative to glass. The same material can be used as a casting resin, in inks and coatings, and has many other uses. PMMA is a strong, tough, and lightweight material. It also has good impact strength, higher than both glass and polystyrene; however, PMMA's impact strength is still significantly lower than polycarbonate and some engineered polymers [10, 11, 12].

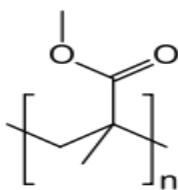


Fig.2. Skeletal formula of the PMMA

N,N-Dimethylformamide anhydrous, 99.8% : N,N-Dimethylformamide (DMF) is the commonly employed solvent for chemical reactions. DMF is a useful solvent employed for the isolation of chlorophyll from plant tissues. It is widely employed reagent in organic synthesis. It plays multiple roles in various reactions such as solvent, dehydrating agent, reducing agent as well as catalyst. N,N-Dimethylformamide is a polar solvent commonly used in organic synthesis. It also acts as a multipurpose precursor for formylation, amination, aminocarbonylation, amidation and cyanation reactions [13].

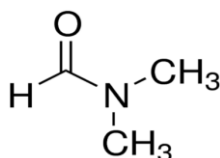


Fig.3. Chemical formula of N,N-Dimethylformamide anhydrous, 99.8%

Ag nano wire : Silver nanowires are useful in a wide variety of conductive, optical and anti-microbial applications such as touchscreen displays, medical imaging and sterile clothing [14].

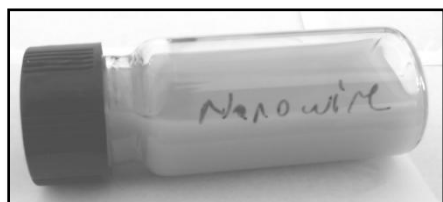


Fig. 4. The nanowires used in this study

2.1.Fabrication of PAN + PMMA Composite Nanofibers/ PAN + PMMA Composite Nanofibers with Ag nanowires

In this study, four types of solutions were prepared. These are pure PAN+PMMA composite nanofibers 8 % and PAN+PMMA composite nanofibers 8 % with Ag nano wires (1 %, 3 %, 5 %) by weight. The pure PAN+PMMA composite nanofibers and PAN+PMMA composite nanofibers with Ag nanowires were fabricated by electrospinning technique. The procedure for preparing pure PAN + PMMA and PAN+PMMA with Ag nano wires electrospinning solution is described below.

Fabrication of pure PAN+PMMA composite nanofibers : Firstly, PAN+PMMA/ DMF solution with polymer content of 8 wt % by mass were prepared. In order to prepare the electrospinning solutions, the PAN+PMMA sample was dissolved in its DMF

solvent. Then, solution was stirred using a magnetic stirrer device at 70°C and 500 rpm for three hours so as to obtain a homogeneous electrospinning solution. Once the homogenization process ended, the solution samples were waiting to the room temperature. In order to proceed with the electrospinning setup, the solution sample was poured into syringe of 2.5 mL and 0.8 mm as inner diameter. Then, the electrospinning process was carried out. The applied voltage was 20 kV. The needle to the collector distance was 12 cm. The solution flow rate maintained at 2 mL/h. Rotating speed was 112.5 rpm (Fig.5).

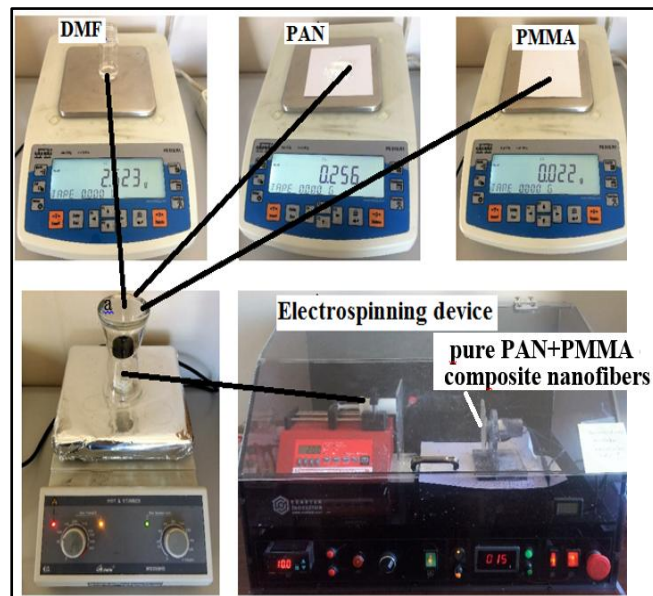


Fig.5. Electrospinning experimental setup

Fabrication of PAN+PMMA/Ag nanowires composite nanofibers : In the same fashion, three samples of solution containing 8 wt. % of PAN+PMMA and % 92 of DMF as solvent were prepared under the same conditions and stirred in the similar conditions as it was done for each previous solution. Ag nanowires were added in the (PAN+PMMA)/DMF electrospinning solution at different rates (1, 3, 5 wt. %) (Fig. 6).

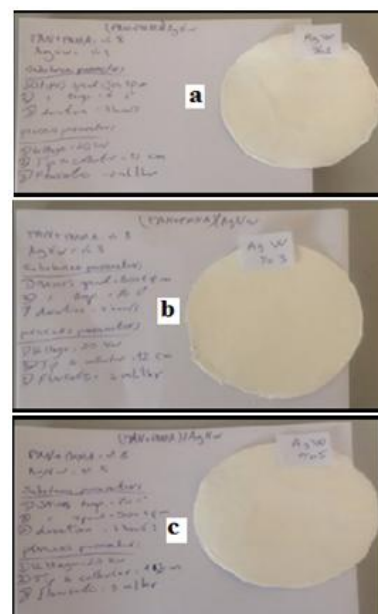


Fig. 6. Pictures of PAN+PMMA/Ag nanowires composite nanofibers. (a) 1 wt. % Ag nanowires (b) 3 wt. % Ag nanowires, (c) 5wt. % Ag nanowires

2.2. Determination of Electrical Conductivity for PAN+PMMA Composite Nanofibers/ PAN+PMMA Composite Nanofibers with Ag nanowires

It is well known that one of the subatomic particles of an atom is the electron. The electrons carry a negative electrostatic charge and under certain conditions can move from atom to atom. The direction of movement between atoms is random unless a force causes the electrons to move in one direction. This directional movement of electrons due to an electromotive force is what is known as electricity. Electrical conductivity is a measure of how well a material accommodates the movement of an electric charge. It is the ratio of the current density to the electric field strength. Electrical conductivity is a very useful property since values are affected by such things as a substances chemical composition and the stress state of crystalline structures [15, 16].

A four-point probe device (ENTEK Elk. FPP-460 with Pt probes) was used to measure the electrical conductivity of nanofibers at room temperature. The used four point probe device is illustrated in Fig. 6 [17]

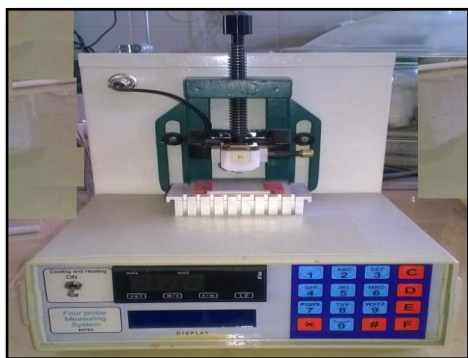


Fig. 6. Four-point probe device (ENTEK Elk. FPP-460)

The results on electrical conductivity of pure PAN + PMMA composite nanofibers and PAN + PMMA composite nanofibers with Ag nanowires (1, 3, 5 wt. %) are compared in Fig 7.

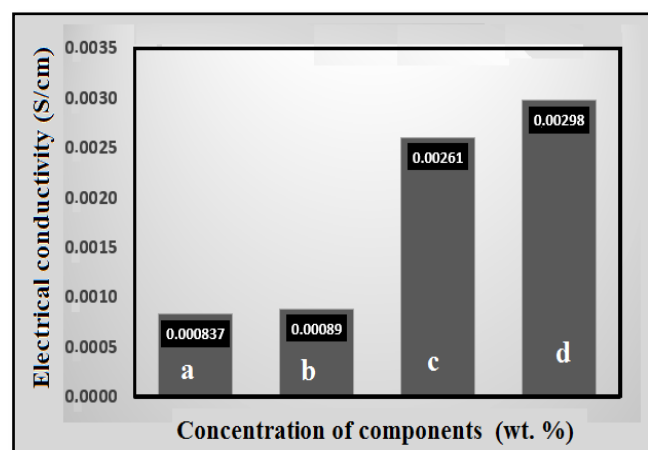


Fig. 7. Comparison of electrical conductivity of nanofibers.

(a) Pure PAN+PMMA composite nanofiber, (b) PAN+PMMA composite nanofibers with 1 wt. % Ag nanowire, (c) PAN+PMMA composite nanofibers with 3 wt. % Ag nanowire (d) PAN+PMMA composite nanofibers with 5 wt. % Ag nanowire

Electrical conductivity values found from the four-point probe technique were 0.000837 S/cm for pure PAN+PMMA nanofibers and 0.00089, 0.00261 and 0.00298 S/cm for PAN + PMMA

composite nanofibers with Ag nanowires, respectively. As can be seen from the Fig. 7 higher electrical conductivity were obtained at high Ag nanowires contents (5wt. %).

2.3. Determination of Hydrophobic/Hydrophilic Interaction for PAN+PMMA Composite Nanofibers/ PAN+PMMA Composite Nanofibers with Ag nanowires

Nonpolar molecules that repel the water molecules are said to be hydrophobic; molecules forming ionic or a hydrogen bond with the water molecule are said to be hydrophilic. This property of water was important for the evolution of life. Hydrophobic interaction plays the most critical roles in the formation of the lipid bilayer of the cell membrane and the folding of proteins and nucleic acids; therefore, hydrophobic interaction is the foundation for the existence of life [18]. The contact angle (θ) is the angle, conventionally measured through the liquid, where a liquid-vapor interface meets a solid surface [19].

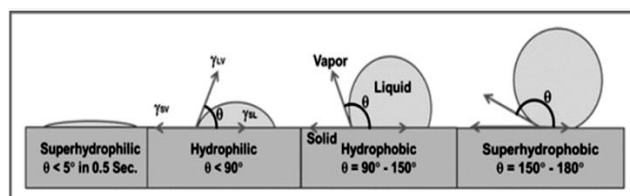


Fig. 8. The contact angle for hydrophobic/hydrophilic [20]

The hydrophobic/hydrophilic of PAN+PMMA composite nanofibers/ PAN+PMMA composite nanofibers with Ag nanowires were investigated using the contact angle measurement device (Dataphysics instruments GmbH, model OCA15EC, version 1.3).



Fig. 9. OCA15EC with single-direct dosing system [21]

Fig. 10. shows the average static contact angles of pure PAN + PMMA composite nanofibers and PAN + PMMA composite nanofibers with Ag nanowires (1, 3, 5 wt. %) for left and right side. It has been found that all PAN + PMMA composite nanofibers with Ag nanowire have bigger static contact angles. The biggest static contact angle (θ) occurred in PAN+PMMA composite nanofibers with 1 wt. % Ag nanowire (θ is 132.14° for left and right side).

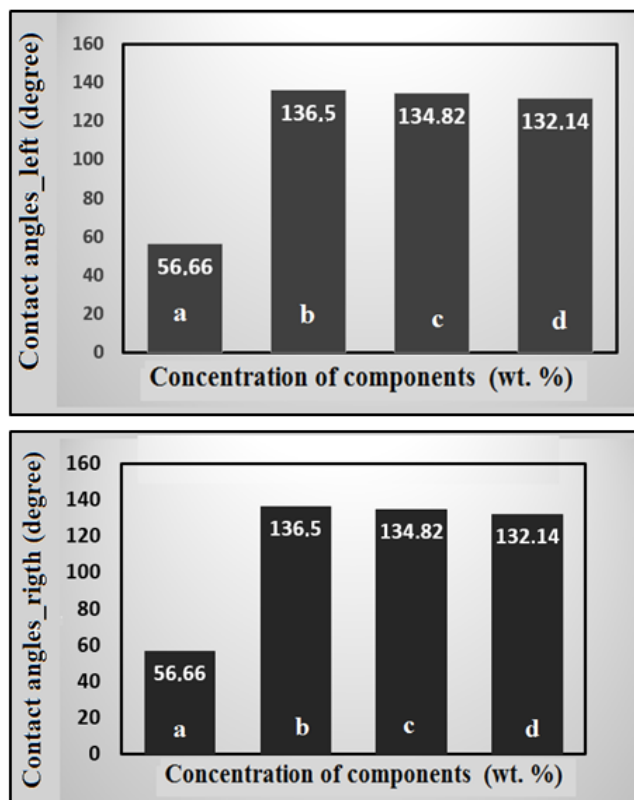


Fig. 10. Comparison of the average static contact angles for left and right side. (a) Pure PAN+PMMA composite nanofiber, (b) PAN+PMMA composite nanofibers with 1 wt. % Ag nanowire, (c) PAN+PMMA composite nanofibers with 3 wt. % Ag nanowire, (d) PAN+PMMA composite nanofibers with 5 wt. % Ag nanowire

3. Conclusions

In this study, the electrical conductivities and hydrophobic/hydrophilic properties of PAN + PMMA composite nanofibers/ PAN + PMMA composite nanofibers with nanowires were investigated. The maximum the electrical conductivity value is 0.00298 S/cm at PAN + PMMA composite nanofibers with Ag nanowires (5 wt. %). The the biggest static contact angle occurred in PAN+PMMA composite nanofibers with 1 wt. % Ag nanowire.

Acknowledgments

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NEW METHODS FOR MEASURING THE PROPERTIES OF ANTIBIOGENIC COATINGS OF MEDICAL TITANIUM IMPLANTS FOR TRAUMATOLOGY AND ORTHOPEDICS

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Abstract: The work is a part of researches of the technical characteristics of 20 types of medical titanium implants for traumatology and orthopedics with antibiogenic coating of titanium and hafnium nitrides in accordance with technical conditions of the manufacturer of the implants – JSC "Medmash", Russia. Based on a titanium alloy the implant with antibiogenic coating is a product coated with titanium and hafnium nitride by high-frequency magnetron sputtering.

In the present article, the structure, phase composition, distribution of elements on the surface and thickness (Ti-Hf)N-coatings with different hafnium content (Ti:Hf ratio) were investigated. The studies were carried out on model samples in the form of plates of titanium alloy VT6, which were coated with titanium and hafnium nitride by magnetron sputtering. Also, changes in the thickness of the hardness and modulus of elasticity of the coatings were measured by the method of instrumental indentation. The maximum values of hardness (~35 GPa) and modulus of elasticity (~500 GPa) were obtained from coatings of composition (Ti_{0.85}Hf_{0.15})N and (Ti_{0.8}Hf_{0.2})N. The coatings with these compositions have the most uniform Hf thickness distribution.

KEYWORDS: (Ti-Hf)N-COATING, STRUCTURAL PROPERTIES, MECHANICAL PROPERTIES

1. Introduction

The development of new nanostructured coatings with high hardness values (> 40 GPa), elastic modulus and high thermal stability (> 1200 °C), as well as long-term stability, is one of the urgent tasks of modern materials science. Such coatings have a wide range of applications, among which protection of products with different functional purposes (increased crack resistance, wear resistance of the cutting tool, its hardness; improvement of thermal, chemical and radiation resistance of products) [1]. The practical use of superhard nanostructured coatings poses the problem of expanding the range of protective functions, as well as their combination in one coating material.

Research of the physical causes of high physical and mechanical properties of nanostructured materials, including coatings, has been intensively carried out in recent decades. The basis of these studies is the study of the composition and structural features of coatings, which is associated with the existence of dependence for nanomaterials on the "composition-structure-dispersion-property" [2].

A special position is occupied by coatings based on titanium nitride (TiN). A large amount of work is occupied by the study of the properties of superhard nanostructured coatings of a new type based on (Ti-Hf-Si)N and (Ti-Hf)N, on silicon and steel substrates [3-5]. With the help of modern physical methods of analysis and nanoindentation, the elemental composition, phase composition and morphology of these films were studied depending on the parameters of their production. The dependences of their hardness on the grain size, on the phase composition of the films are established.

An important area of application of protective coatings based on (Ti-Hf)N – a bactericidal coating of medical products made of titanium. Hafnium nitride contained in these coatings gives them bactericidal, bacteriostatic properties and increases the microhardness of the surface. Currently, there are works in which coatings with different mass fraction of elements are used: w(Ti) 17-24%, w(Hf) 70-80% and w(N) 3-6%. The use of such a coating for titanium implants that experience long-term contact with tissues of a living organism provides increased hardness and has bacteriostatic properties, preventing the proliferation of pathogens near the implant [6-8].

The nomenclature of implants manufactured by JSC "Medmash" includes more than 20 items. These are screws for osteosynthesis, straight and figured plates, tubular plates, rods for various bones, screws for various purposes, as well as dynamic implant designs. Implants are made of titanium alloy and, as a rule, have a protective coating, which gives the product a high hardness, strength and durability. An implant based on a titanium alloy with

an antibiotic coating represents an product coated with titanium and hafnium nitride by high-frequency magnetron sputtering

This article presents the results of studies of the chemical composition, phase composition, structure and mechanical characteristics (hardness, elastic modulus) of (Ti-Hf)N-coatings with different hafnium content (Ti:Hf ratio). The thickness distribution of the coating chemical composition and mechanical characteristics were evaluated.

2. Samples and methods

The samples were plates of titanium alloy VT6 with thickness of 3.0 mm (chemical composition according to GOST 19807), which were coated with titanium and hafnium nitride by magnetron sputtering. Antibiotic coatings of titanium and hafnium nitrides were produced in "Biomedical technologies" JSC at the installation "Energocomplex" of high-frequency magnetron deposition of coatings. For the manufacture of the cathode for coating the product by magnetron method used titanium-hafnium alloy. To determine the dependence of the coating characteristics on the Hf content, samples of coatings with a thickness of ~3.0 μm of 4 nominal compositions were prepared and studied: (Ti_{0.9}Hf_{0.1})N, (Ti_{0.85}Hf_{0.15})N, (Ti_{0.8}Hf_{0.2})N, and (Ti_{0.7}Hf_{0.3})N.

Surface morphology and chemical composition of coatings (Ti-Hf)N were investigated by scanning electron microscope (SEM) JEM 7600F with adaptors for analysis of characteristic energy-dispersion (EDS) and wave dispersion (WDS) spectra of chemical elements. EDS and WDS spectra readings were taken from the surface of the coatings. In determining the chemical composition the spectra readings were taken from the area of three SEM images (frames) of the surface of each sample, and the data of EDS and WDS were averaged separately. EDS measurements used standards originally laid down in the SEM, and in the case of WDS measurements used external standards: Hf-(La Hf_15kV), V-(Ka V_15kV), Ti-(Ka Ti_15kV), O-(Ka Al2O3_15kV), N-(Ka BN_15kV) and C-(Ka C_15kV).

Also, with the help of EDS the dependence of the chemical composition of the thickness of the coating was analyzed. To study the distribution of the composition in thickness on the samples in the form of plates 10×10×3.0 mm³, cuts were created in thickness with a depth of ~2.9 mm and the sample was broken into these cuts. Electron microscopic measurement, as the thickness of the coating, and the composition distribution throughout the thickness of the coating was carried out on these splits.

X-ray diffraction patterns of the samples were obtained on the EMPYREAN diffractometer (PANalytical), in vertical geometry θ-θ, radiation CuKα1+2. XRD patterns were taken in continuous

mode in the angle range 2θ from 10° to 110° , scanning step 0.0262603° ($\Delta 2\theta$). Exposure time per point was 100 seconds. The processing of XRD patterns, microstructural analysis of crystallite sizes (coherent scattering region) in the isotropic approximation were carried out using the multifunctional software product MADE (Material Analysis Using Diffraction) [9]. The calculations were carried out using the standard strategy of Ritveld refinement of hardware and structural parameters [10].

Raman spectra of the samples were obtained using a laser with a wavelength $\lambda = 532$ nm and were recorded in the backscattering geometry by a Renishaw in Via Raman Microscope equipped with a CCD detector. During the measurement process, a 50-fold lens was used, focusing a laser beam on the surface of the samples as a spot with a diameter of about $1\ \mu\text{m}$.

Measurement of the distribution of microhardness (H) and elastic modulus (E) over the thickness of the coating was carried out using instrumental indentation (GOST R 8.748-2011(ISO 14577-1:2002)) on the nanoindenter "NanoScan-4D" with Berkovich pyramid. On each of the samples there was made an oblique cutoff. The width of the coating in the oblique cutoff was, depending on the sample, $25\text{--}35\ \mu\text{m}$. The maximum load on the indenter was 10 mN, the indenter recess was approximately 120 nm on the coating sections and 250 nm on the substrate sections. The distance between the "injections" (indentation tests) was $2\ \mu\text{m}$.

3. Results and discussion

3.1. Chemical composition and distribution of elements

SEM images of the surface of four samples (Ti-Hf)N coating on titanium alloy VT-6 and the chemical composition of the surface are shown in Fig.1. With increasing Hf content, the coating surface becomes more defective with the formation of extended and more pronounced boundaries of the surface areas. The fine-grained structure of the coatings indicates a sufficiently high deposition rate.

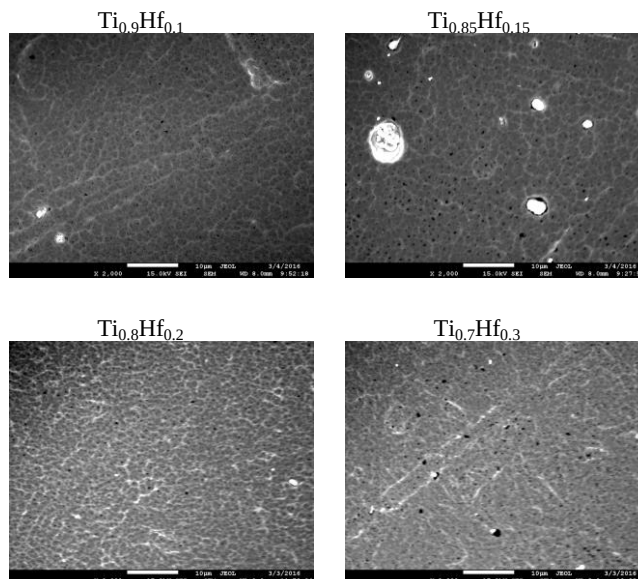


Figure 1. SEM images of the coating surface (Ti, Hf) N on the alloy of titanium BT-6.

Table 1 shows the chemical composition of coatings, determined by the methods of EDS (regular) and WDS (italics).

As follows from the data Table 1, elemental analysis of the coating surface (Ti-Hf)N indicates the chemical composition according to the specified percentage of Hf in the coating. The analysis showed the presence of other elements, among which there are traces of O($\sim 0.5\%$), Al($\sim 0.2\%$), Si($\sim 0.2\%$), V($\sim 0.3\%$) and Rb($\sim 0.5\%$) in all samples. The presence of these elements in the chemical composition is determined, respectively, by the residual gases of the working atmosphere (oxygen), the composition of the target and the impurities of the substrate.

Table 1. EDS (regular font) and WDS (italics) analysis of all elements is performed (normalized). All results in atomic%.

Coating	Chemical composition, at.%											
	C	N	O	Na	Al	Si	Ti	V	Mn	Rb	Hf	Ti:Hf
Ti _{0.9} Hf _{0.1}	0.01	51.31	0.34		0.05		41.66	0.08		1.20	5.68	7.33
		58.45					36.86	0.33			4.02	9.17
Ti _{0.85} Hf _{0.15}	0.75	48.39	1.38	0.05	0.19	0.14	40.46	0.28	0.05	0.52	8.55	4.73
		57.55	0.44	0.02			34.92	0.29	0.04	0.01	5.89	5.93
Ti _{0.8} Hf _{0.2}	0.63	49.47	0.49	0.07	0.17	0.20	38.03	0.20	0.05	1.24	10.57	3.60
		57.42		0.02			33.55	0.30	0.01	0.43	7.15	4.69
Ti _{0.7} Hf _{0.3}	1.47	45.42	0.58		0.48	0.86	36.99	0.39			15.86	2.33
		56.23					30.73	0.24			10.70	2.87

3.2. SEM images and chemical analysis for coating thickness

The distribution of the basic elements (Ti, Hf, N) was determined both over the entire area of the SEM image (mapping) and along lines and in points lying at different distances from the coating surface. In Fig.2 the SEM images of the coating sections of samples (Ti-Hf)N, and titanium and nitrogen distribution maps over the area of the images are presented.

In Fig.3 the SEM images with EDS lines and points (a), hafnium distribution maps by area of images (b), spectral patterns along line 1 for Ti_{0.7}Hf_{0.3} and at point 5 for Ti_{0.9}Hf_{0.1} (c) and distribution of the basic elements (N, Ti, Hf) in the thickness of these coatings are presented.

The same data, with the exception of the spectral patterns, for coatings Ti_{0.8}Hf_{0.2} and Ti_{0.85}Hf_{0.15} are shown in Fig. 4.

Chemical composition measurements were carried out on two SEM images at different cross-section locations and these data were practically identical.

It can be concluded that in all coatings the concentrations of the basic elements are uniformly distributed over the thickness of the coating, except for the point lying near the surface. At this point, the concentration of Hf and, to a greater extent, N, is reduced.

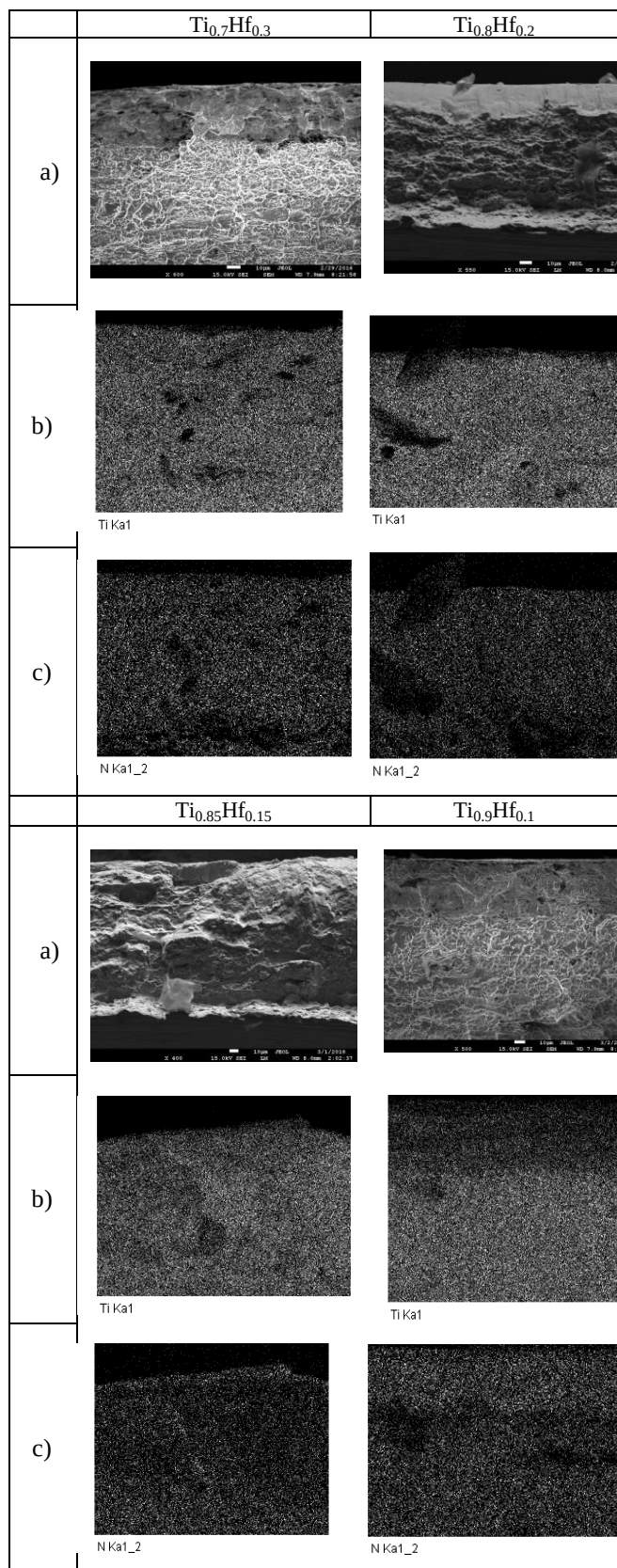


Figure 2. SEM images of sample splits (Ti-Hf)N (a), titanium (b) and nitrogen (c) distribution maps over the area of the images.

Such a pattern was noted in [7], where, even with the thickness (Ti-Hf)N of the coating in 1-1.5 μm , the subsurface layer was depleted by Hf and N. It is most likely that this phenomenon is due to the formation of a thin film of aluminum carbide in the near-surface layer [10], or other metal present in the layer.

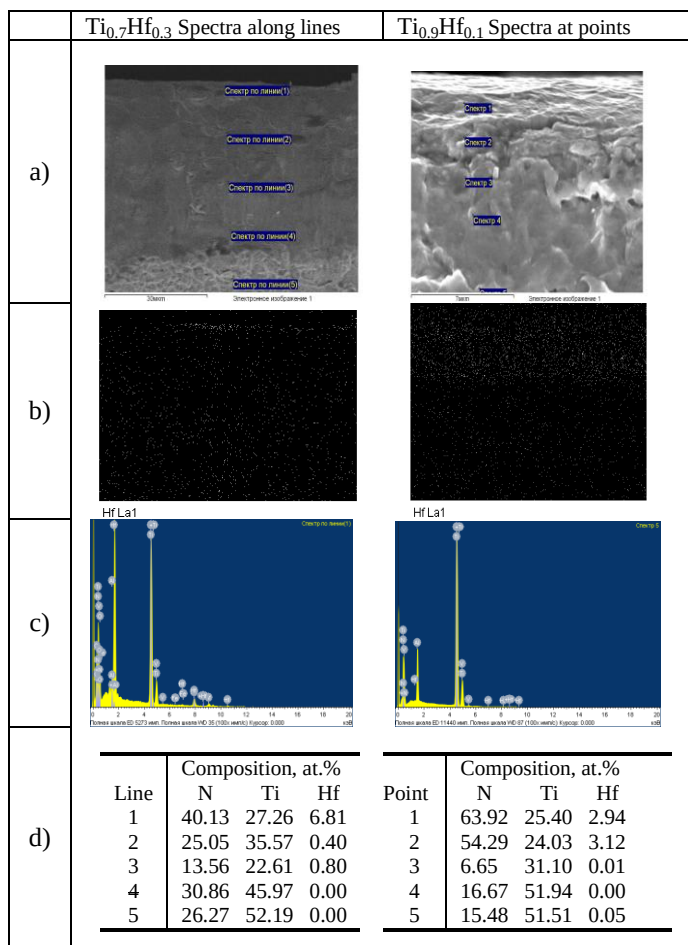


Figure 3. SEM images with EDS lines and points (a), hafnium distribution maps by area of images (b), spectral patterns along line 1 for $Ti_{0.7}Hf_{0.3}$ and at point 5 for $Ti_{0.9}Hf_{0.1}$ (c) and distribution of the basic elements (N, Ti, Hf) in the thickness of coatings (d).

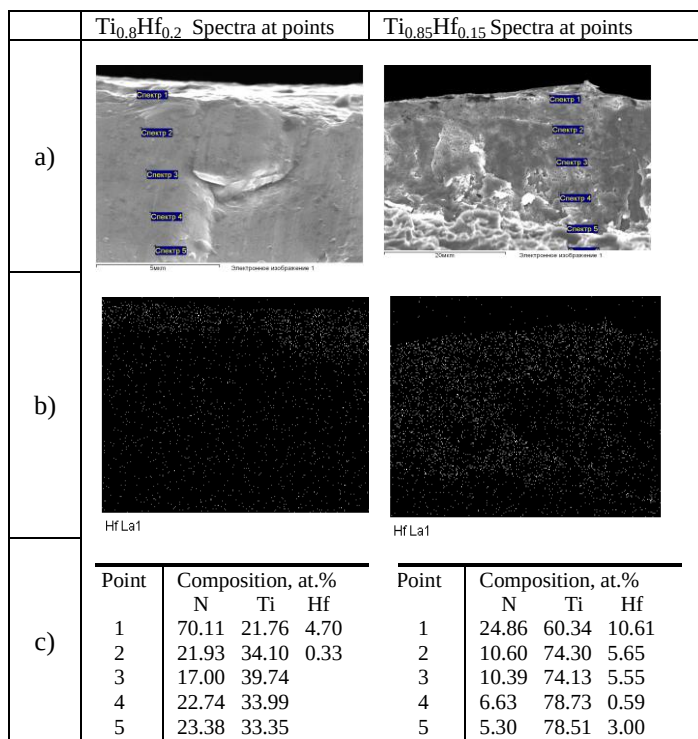


Figure 4. SEM images with EDS points (a), map of hafnium distribution by area of images (b) and distribution of the main elements (N, Ti, Hf) for the thickness of coatings along points for $Ti_{0.8}Hf_{0.2}$ and $Ti_{0.85}Hf_{0.15}$ coatings (c).

3.3. Structural studies

X-ray diffraction studies of the phase composition of the coatings showed the presence of only one phase: titanium nitride with HCC lattice of NaCl, B1Fm3m type [10]. On all XRD patterns shown in Fig.3 there are diffraction peaks (111), (200), (220) and (222). The intensity of the peaks indicates that it is a single-phase polycrystalline titanium nitride. Table 1 shows the dependence of the lattice parameters in the (Ti,Hf)N coatings on the concentration of hafnium.

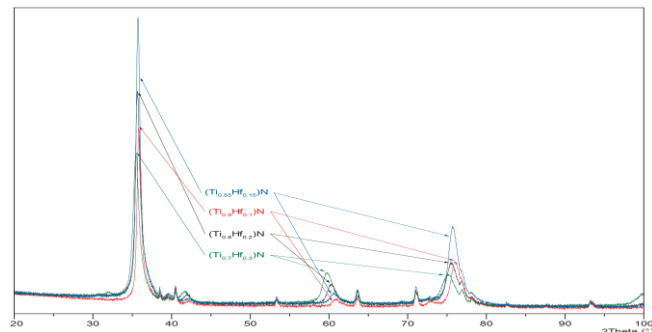


Figure 3. XRD patterns of four samples (Ti-Hf)N coatings

As it is known [10], TiN (structural type NaCl) crystallizes in the space group Fm3m with the parameters of the unit cell: $a=0,422-0,426$ nm. The estimation of crystal sizes by coherent scattering region showed that coatings with a high content of Hf have smaller grain size.

There is a monotonic increase in the crystal lattice parameter of titanium-hafnium nitride with an increase in the Hf content. This can be explained as follows. Titanium nitride coatings are not ideally stoichiometric due to the wide area of homogeneity of the TiN. Therefore, its properties are highly dependent on the amount of nitrogen in the nitride. The decrease in the nitrogen concentration, which is established according to the SEM, leads to the formation of a defective structure due to the lack of nitrogen atoms in the metal lattice. In addition, an increase in the lattice parameter may indicate a high level of internal stresses.

3.4. Raman spectroscopy

In Fig. 4 the Raman spectra obtained at a wavelength of exciting radiation of 532 nm are presented.

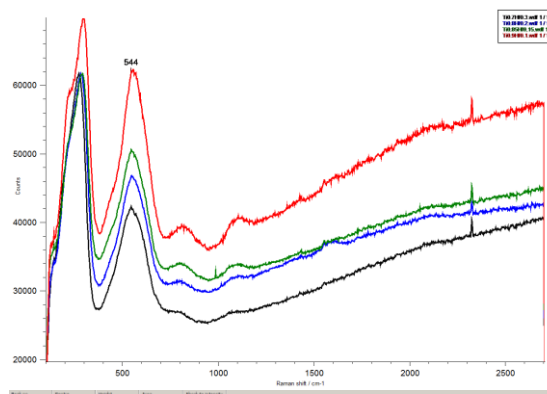


Figure 4. Raman spectra of four samples (Ti-Hf)N coatings

Pure TiN has a structure of NaCl type, and in the Raman spectrum the bands associated with the density of states of acoustic modes (225 cm^{-1} (TA) and 310 cm^{-1} (LA)) and optical mode in the region of 540 cm^{-1} are manifested. In the Raman spectra of the studied samples there are bands in the region of 220 cm^{-1} (shoulder), 272 cm^{-1} , 540 cm^{-1} , 805 cm^{-1} and 1083 cm^{-1} . The bands in the area of 220 cm^{-1} , 272 cm^{-1} and 540 cm^{-1} belong to phase (Ti-Hf)N with NaCl type structure (similar to pure TiN).

The presence of bands in the region of more than 700 cm^{-1} may be associated with the appearance of chains of polyhedra $[\text{TiN}_x]$. Polyhedra $[\text{TiN}_5]$ correspond to the band with a maximum in the region of 700 cm^{-1} , and $[\text{TiN}_4]$ - in the region of 840 cm^{-1} .

The introduction of Hf into the structure leads to the displacement of bands towards large wave numbers. Thus, the band in the region of 272 cm^{-1} in the sample $(\text{Ti}_{0.7}\text{Hf}_{0.3})\text{N}$ shifts to 295 cm^{-1} in the sample $(\text{Ti}_{0.9}\text{Hf}_{0.1})\text{N}$. The shift towards large wave numbers may be related to the stresses arising in the titanium nitride-hafnium coating.

4. Mechanical properties

In Fig.5 a photo of the measurement area of one of the samples is shown.



Figure 5. A photograph of the area in which the indentation was made.

Data of the dependence of the hardness on the profile coordinates are shown in Fig.6. The Fig.7 shows the change in the hardness of the coating thickness. The hardness drops towards the substrate at a distance of less than 1 μm to the substrate boundary (due to the effect of the substrate properties).

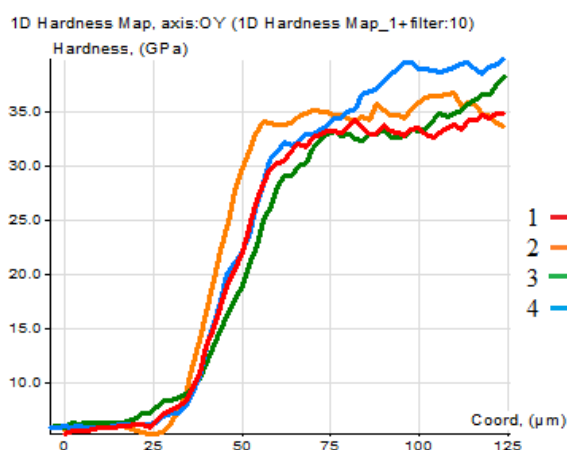


Figure 6. Dependence of the hardness of the samples on the coordinate Y. The origin was on the substrate, the point (0; 125) was on the coating. Figures in the legend to the graph indicate the numbers of the samples (1- $(\text{Ti}_{0.7}\text{Hf}_{0.3})\text{N}$, 2- $(\text{Ti}_{0.85}\text{Hf}_{0.15})\text{N}$, 3- $(\text{Ti}_{0.9}\text{Hf}_{0.1})\text{N}$, 4- $(\text{Ti}_{0.8}\text{Hf}_{0.2})\text{N}$).

The average results of measurements of hardness (H_S and H_C) and elastic modulus (E_S and E_C) for the regions of the substrate (S) and coating (C) are given in the Table. 2.

Sample	H_s , GPa	H_C , GPa	E_s , GPa	E_C , GPa
1	5.9 ± 0.8	33.4 ± 4.1	199 ± 29	431 ± 58
2	5.5 ± 0.8	34.9 ± 3.4	166 ± 22	504 ± 80
3	5.7 ± 0.6	32.7 ± 3.6	173 ± 30	397 ± 49
4	6.0 ± 0.4	36.7 ± 3.5	181 ± 23	447 ± 75

Table 2. Results of measurement of hardness and elastic modulus.

The values of hardness and elastic modulus of the coating, within the error, are the same, do not depend on the content of Hf in the coating at the studied relations Ti:Hf and correspond to the hardness values known from the literature data.

5. Conclusion

The results of the study of the dependence of the composition, structure and mechanical characteristics (hardness, elastic modulus) on the content of Hf coatings (Ti-Hf)N on a substrate made of titanium VT6 were presented. The distribution of the chemical composition in the thickness of the coatings was studied. For the first time the hardness distribution over the thickness of coatings with different ratio Ti:Hf was studied. The heterogeneity of the hardness distribution over the thickness of the coating with the inhomogeneity of the distribution of Ti and Hf in the coating was established. The maximum values of hardness (~35 GPa) and elastic modulus (~500 GPa) were obtained from coatings of composition (Ti_{0.85}Hf_{0.15})N and (Ti_{0.8}Hf_{0.2})N. (in weight ratio (Ti40.7Hf26.8) and (Ti38.3Hf35.7)). The coatings of these compositions were characterized by the most uniform distribution of Ti and Hf in thickness.

6. Acknowledgments

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APPLICATION OF THE EXPLOSIVE ELECTRON-BEAM VACUUM EVAPORATION METHOD FOR MANUFACTURING OF WC + W₂C GRANULAR POWDERS

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Abstract: The specifications for manufacturing of relit (WC + W₂C) granular powder by the method of explosive evaporation of condensation in vacuum using electron-beam technologies are presented. It is established that when depositing material on cooled surfaces, it is possible to refine the precipitation products by metallic and non-metallic impurities, depending on the elasticity of their vapors.

Key words: ELECTRON-BEAM TECHNOLOGIES, EXPLOSIVE EVAPORATION-CONDENSATION, RELIT, GRANULAR POWDER.

1. Introduction

In the late 60's and early 70-ies of the last century in Paton Institute of Electric Welding of NASU (Ukraine) has been developed a method for obtaining thick (more than 5 microns) films of metallic and nonmetallic materials by high-speed electron-beam evaporation and subsequent condensation in a vacuum. In industrially developed countries, including Ukraine, this method served as a basis for the creation of industrial technologies for the deposition of protective coatings of a wide range of applications. At present, this method is widely used in modern technology for coating various products, obtaining massive compositions in the form of sheet billets separated from the substrate, used to make electrical contacts and electrodes [1, 2].

It is noted that when composites and materials are formed by evaporation of alloys consisting of components with different vapor pressures, the degree of their fractionation by composition decreases with increasing temperature. This regularity of the process is based on the explosive method of evaporation of alloys, proposed by Harris and Siegel in the middle of the 20th century [3]. The method consists in that particles of finely divided material (an alloy of the required composition or mixture of components) are uniformly supplied to the evaporator, heated to the temperature of intensive evaporation of the most difficult component of the alloy. Due to ultra fast heating of the alloy, its explosive evaporation takes place, which is characterized by an almost complete matching of the composition of the supplied material with the vapor composition above the evaporator and the condensed product. Depending on the substrate temperature, the condensate can be obtained as a coating or as a dispersed product.

This technology is quite complicated in execution, since it requires a precise adjustment of the power supplied to heat the evaporator to create conditions for congruent evaporation of the alloy components. The evaporation temperature should be selected in such a way as to minimize the release of solid particles observed during overheating and at the same time to ensure the stability of evaporation by eliminating the accumulation of a volatile component in the evaporator when the temperature decreases. Apparently, in each case, there is an optimal relationship between the temperature of the evaporator, the mass, the shape of the particles and the speed of their supply, but there is still very little relevant data in the literature [4].

2. Materials and experimental procedure

The Frantsevich Institute for Problems of Materials Science of the National Academy of Sciences Ukraine in cooperation with Research Association "ELTEHMASH" (Vinnitsa, Ukraine) conducted scientific research to assess the possibility of applying

this method to obtain a granulated relit – eutectoid mixture of tungsten carbides WC+W₂C.

As it is known, relit has a unique complex of physical and mechanical properties: high strength, hardness, moduli of normal elasticity, satisfactory plasticity. The relit contains (by weight): 95,8-96,4 % tungsten and 3,6-4,0 % of bound carbon. The content of free carbon does not exceed 0,05 %, iron – 0,15% [5].

Blanks with a diameter of 45 mm and a length of 50-60 mm prepared from a mixture of tungsten powders of industrial production and carbon were manufactured as starting materials for explosive evaporation, taking into account the production of a mixture of WC + W₂C carbides in the final product. Paraffin wax from 3 to 8% by volume was added to the initial mixture of tungsten and carbon powders, and then dried at a temperature of 50-60 °C. The cooled mixture was wiped through a sieve with a cell size of 0,5 mm. The resulting granules were filled into a matrix and double-sided pressing was carried out at a pressure of 400-500 GPa. The blanks were then placed in a muffle filled with ceramic chips and subjected to annealing at a temperature of 1050 °C in a hydrogen medium to remove paraffin, residual oxides and other harmful impurities. The final sintering of the blanks was carried out in vacuum at a level of at least 10⁻² Pa at 1450 °C for 1 hour. Explosive evaporation of sintered blanks was carried out in an industrial electron beam installation of the new generation L-4 [6].

The gas-discharge electron guns used in the design of the installation allow for precise control and maintenance of the specified power during the evaporation process. The layout of the main units for the realization of the process of explosive evaporation in the working chamber of the plant is shown in Fig. 1. A single charge into the copper mold 3, for evaporation of the raw materials 5, was 1.9 to 3 kg. To collect the evaporation products from above, a steel uncooled sarcophagus 8 was installed in the form of a cylinder on the crystallizer with evaporating material, which was covered with a water-cooled lid with an opening for passage of the electron beam. The choice as a heater for evaporation of the gun 4 was determined by the need to maximize the angle between the trajectory of the electron beam and the main direction of the material movement to prevent contamination of the cathode by the evaporated material. The power of the electron guns for evaporation was 100 kV each at an accelerating voltage of 30 kV. During the experiments, the vacuum in the working chamber is maintained at a level of 5·10⁻²...10⁻¹ Pa. The evaporation process was monitored through a viewing window 7 located in a sarcophagus 8. The electron beam current was varied from 0.8 to 1 A. The evaporation time was no more than 25 min.

The control of the rate of evaporation, due to the input power to the crystallizer 3 with the evaporated material 5, and control of rate of crystallization of the vapor flow on the cooled and uncooled walls of the sarcophagus 8 ensured fractionation by the dispersion and shape of the particles of the precipitated product.

condensate base is 20...25 GPa, the microhardness of the inclusions is higher and can reach 40 GPa.

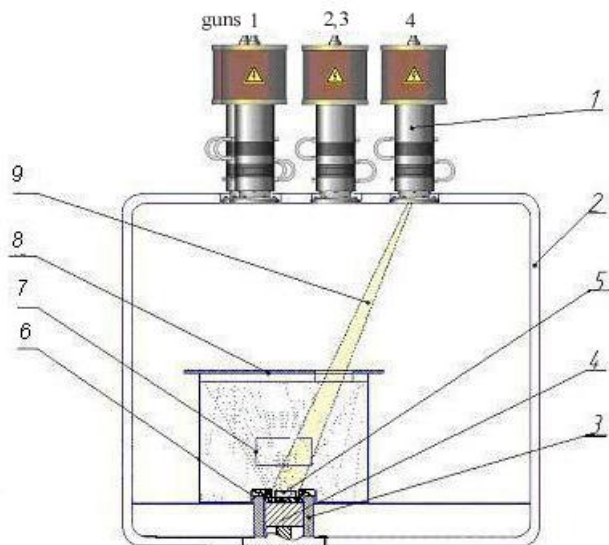


Fig.1. Schematic location of the main units in the working chamber of the L-4 installation for obtaining by the explosive evaporation-condensation method of the granulated relit: 1 - electron beam guns; 2 - process chamber; 3 - crystallizer; 4 - device for supplying the starting material to the evaporation zone; 5 - evaporated material; 6 - water-cooled crucible; 7 - viewing window for observation; 8 - sarcophagus with water-cooled lid and hole for electron beam passage; 9 - trajectory of the electron beam path

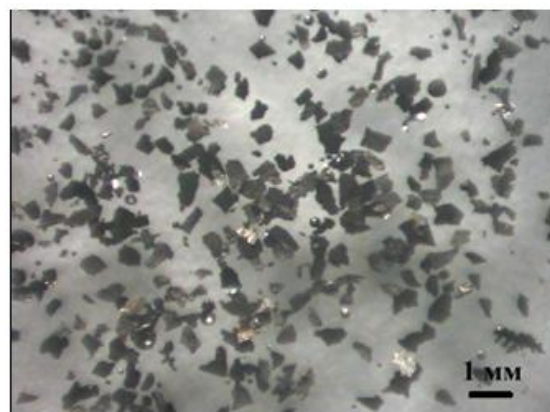
3. The results and discussion

During experiments on explosive evaporation, it was established that the appearance and composition of precipitation products on the cooled and non-cooled surfaces of the sarcophagus is characterized by morphology. When deposited on uncooled walls of the sarcophagus, a film product is formed, which is a porous layering of islet coatings 100 μm thick or thicker, which, due to increased brittleness, easily breaks down to form flocculate particles (Fig. 2, a). At the same time, the condensate obtained by depositing the material on the cooled surfaces of the sarcophagus is predominantly granules with a shape close to a spherical and smooth surface (Fig. 2, b).

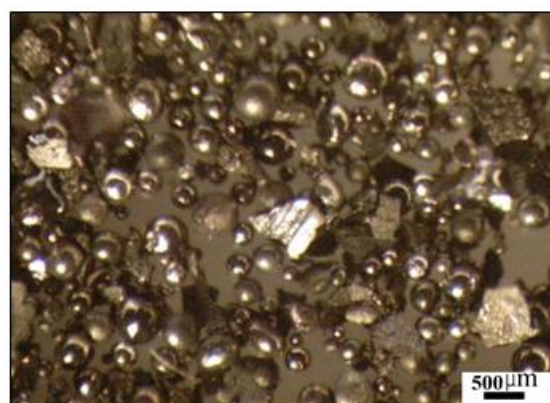
In a granular condensation product, fractions with particle sizes of 3000/500 μm are more than 80% by weight, fractions of 500/350 and 350/100 μm do not exceed 3,8 and 13,5 % by weight, respectively, and fractions of 100/71 μm occupy less than 1% by weight. Morphometric analysis of particles carried out by computer processing with an automatic image analyzer "AMIS" [6] showed that more than 80% of the number of particles are characterized by a spheroidal factor of 0.98...1 (calculation by the Saltykov form coefficient formula [7]). The histogram of the particle size distribution has a shape close to the normal distribution with an average statistical value of a diameter of 600 μm diameter (Fig. 3).

X-ray diffraction analysis of samples carried out on a DRON-3M diffractometer in K_{Cu} radiation with the application of powdered silicon as a reference to the surface showed the correspondence of the phases obtained during the condensation to the original composition of the mixture of WC and W_2C (Fig. 4).

The surface of the film sediment is relief with signs of phase separation, the microhardness in this case does not exceed 10 GPa, which is probably related to its porosity (Fig. 5, a, b). In contrast, the granules are characterized by a high density, a polycrystalline microstructure with inclusions of secondary phases, apparently carbides and intermetallics uniformly distributed in the bulk of the particle material (Fig. 5, c). The microhardness of the granular



a



b

Fig. 2. General view of the condensate obtained during explosive evaporation of the vacuum in vacuum upon deposition on the uncooled (a) and cooled surfaces of the sarcophagus (b)

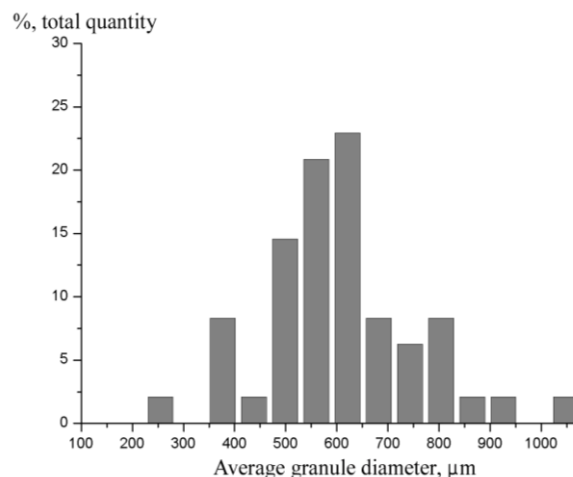


Fig.3. Histogram for the distribution of the average linear dimensions of granules obtained during explosive evaporation-condensation of a relit on the cooled walls of a sarcophagus

It should be noted that the composition of the granular product is close to the composition relit, while in the film sediment some shifts in the chemical composition from the initial are observed due to the increase in the amount of iron, nickel, and copper. Titanium and other metal impurities, as well as oxygen and carbon, which is explained by the difference in the elasticity of the vapor of these elements and tungsten. Thus, by varying the

parameters of electron-beam heating, it is possible to create conditions for evaporation of the material in which, with the maintenance of the basic composition, oxygen and some metallic impurities are removed from the precipitated product.

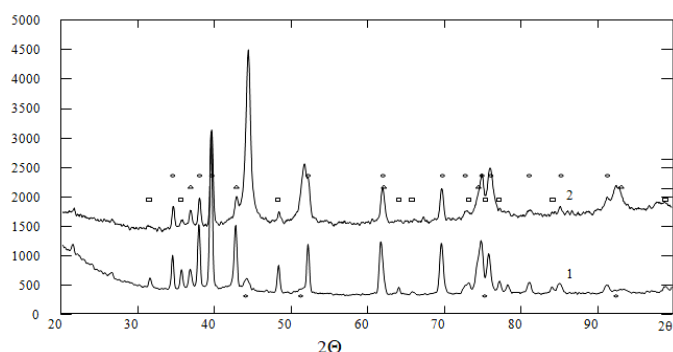
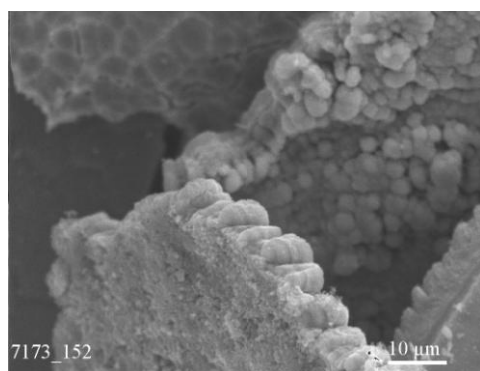
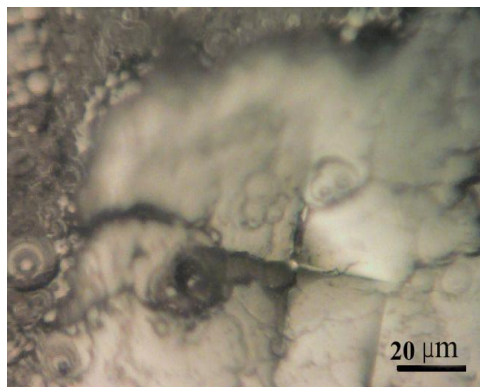


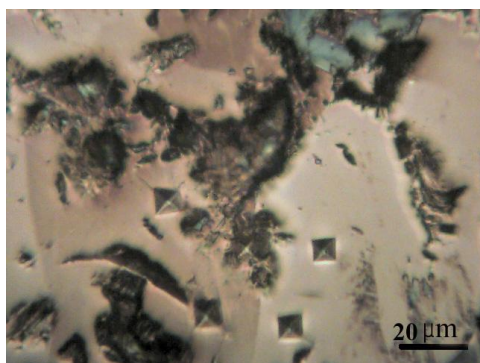
Fig. 4. X-ray picture of the initial relit product (1) and deposition product on the cooled walls of the sarcophagus by explosive evaporation (2): Δ - WC; $\circ$ - W_2C



a



b



c

Fig. 5. Microstructure of relit deposition products on uncooled (a, b) and cooled walls of the sarcophagus (c) at different magnifications

Conclusions

The method of explosive evaporation-condensation in vacuum was used to obtain a relit - W_2C -WC mixture in granular form. The shape of granules are close to spherical, the average particle size is 600 μm , the microhardness is on average 30 MPa. In the conditions of precipitation on the cooled surfaces, the content of the main components in the sediment corresponds to their quantity in the initial product, but in this case the material is refined by metallic and non-metallic impurities, depending on the elasticity of their vapors.

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THE COMPATIBILITY FACTOR IN MATERIAL SCIENCE OF MIXED ENGINEERING NANOBLEND

ФАКТОР СОВМЕСТИМОСТИ В МАТЕРИАЛОВЕДЕНИИ СМЕСЕВЫХ МАШИНОСТРОИТЕЛЬНЫХ НАНОКОМПОЗИТОВ

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Abstract: Features of the structure of blends obtained by thermomechanical blending of thermoplastic components with different molecular structure are considered. The possibility of formation of structures with different levels of ordering (from heterophase structure with a pronounced boundary between the components to the macrogomogeneous structure with high compatibility of matrix and modifying components) is shown. Under injection of nanosize particles with different chemical composition into the blends, a synergistic effect of simultaneously increasing the parameters of tensile stress-strain and tribotechnical characteristics of items and its resistance to thermal oxidation is achieved. Nanosize particles in the active state perform the function of a physical compatibilizer, forming a cross-linked structure with physical bonds in the volume of the composite. The engineering nanoblends with increased performance parameters have been developed.

KEYWORDS: NANOBLEND, COMPATIBILITY, NANOSIZE PARTICLES, SYNERGISTIC EFFECT, PHYSICAL COMPATIBILIZER

1. Introduction

In the brand assortment of engineering materials a blends based on thermoplastic components with different chemical composition, structure, molecular weight are occupied a special place. Managing the compatibility parameters of the components of blends by using special technologies for producing composites or functional ingredients that regulate the intensity of interfacial interaction processes (compatibilizers) can be form a structure with set-up parameters of the organization that ensures the achievement of the required performance characteristics of the products under given conditions of their application [1-3].

At the same time, the structure of the blend in the depending on operational requirements for the products varies according to the homogeneity parameters – from the macrogomogeneous with the pronounced phases of the matrix and modifying components [3] to the macrohomogeneous one, in which, as a result of complete thermodynamic compatibility, the modifying component in the matrix is dissolved [1, 2]. Both fundamentally different types of structure of blends have their own peculiarities in the implementation of the specified parameters of performance characteristics, have found wide application in engineering practice and are not antagonists. Therefore, further development of scientific ideas on the mechanisms and kinetics of the formation of the structure of blends with a given level of ordering is have considerable interest for materials science and technology of polymeric functional materials. At the same time, both main types of blends with different levels of thermodynamic compatibility of components are characterized by the commonness of the basic features, the most important of which is the structure of the boundary layers of composites, which largely determines the parameters of the product performance characteristics. In the structure of the optimal level of ordering, the boundary layer between the components must possess the necessary parameters of stress-strain characteristics that can be realized only when controlling the intermolecular interaction processes using different approaches. In this aspect, studies of the influence of nanosize particles on interphase interaction processes are of particular interest, since their special energy state suggests the possibility of forming the structure of boundary layers with increased parameters of characteristics [4, 5].

The purpose of this paper is to evaluate the role of nanosize particles of various types in the formation of the structure of blends with different levels of thermodynamic compatibility.

2. Research methods

For the research we used polymer materials widely applied in engineering for the production of functional products of various design versions – polyamide 6 (PA 6) and polyethylene terephthalate (PET) produced at JSC Grodno Azot and JSC Mogilev Khimvolokno. To modify the matrix components were used aliphatic polyamides PA 11, PA 12 in the industrial supply state, fine-grained particles of carbon-containing components (colloidal graphite preparation KGP C-1, carbon nanotubes CNT, products of explosive synthesis – charge) and layer silicates – mica (phlogopite) and talc. The components were blended using a twin-screw extruder (Compex), a material cylinder of an injection molding machine with a screw extruder (Demag, Battenfeld), and a fluidized bed coating plant. The parameters of stress-strain, tribological and adhesive characteristics of composites were evaluated by using standard techniques on solid samples and coatings.

3. Results and discussions

Analysis of the physical and mechanical characteristics of blends obtained by thermomechanical blending of thermoplastic components PA6 + PET shows its nonmonotonic dependence on chemical composition (Fig. 1). In the range of small concentrations of the modifier (up to 0.5-1.0 wt. %) the effect of increasing the tensile strength, bending and wear resistance is observed. Earlier, similar effects were noted for thermoplast-thermoplast composites [3]. The effect of increasing the strength and tribological characteristics is probably due to the formation of modifying phase reinforcing aggregates (PET and PA, respectively) in the matrix and the processes of copolymerization mechanochemical reactions during the composite formation. This reactions lead to the formation of a copolymer product with increased resistance to external influences. Analysis of the morphology of the cleavage of samples cooled in liquid nitrogen confirms the presence of modifying phase aggregates with dimensions of 0.5-10 μm, depending on the ratio of composites in the mixture. PET and PA particles are close to spherical, and PA and PET particles are more various in shape and size (Fig. 2). At the ratio of components is close to 50:50 wt. % the phase inversion is observed, that to lead to a significant decrease of all parameters of physical and mechanical characteristics.

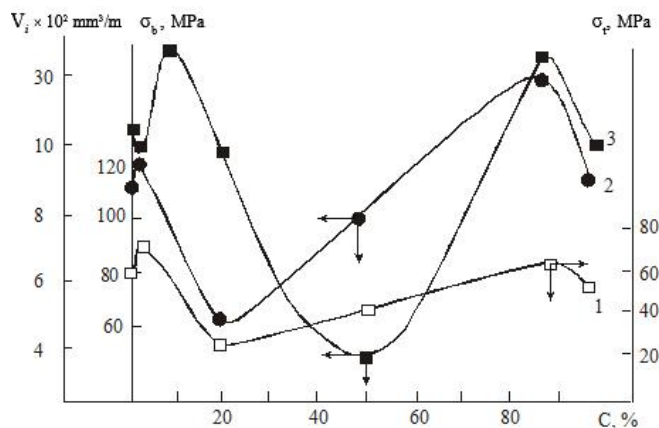


Fig. 1 Dependence of the tension (1), bending (2) stress and abrasion factor (3) on the content of PA 6 in PET

Thus, the traditional technology of thermomechanical blending provides the production of composite materials based on PA 6 and PET with high service characteristics. Such materials can be successfully used as binary matrices for engineering materials of various functional purposes include tribotechnical. The advantage of combined PA/PET matrices is a higher resistance to moisture and operating factors compared to polyamides, which causes an increase in the operational range of their use.

When introducing layered silicates into the composite PA 6 / PET mixture, it is possible to control the compatibility parameters of the components due to the influence of the factor of their increased energy activity [4].

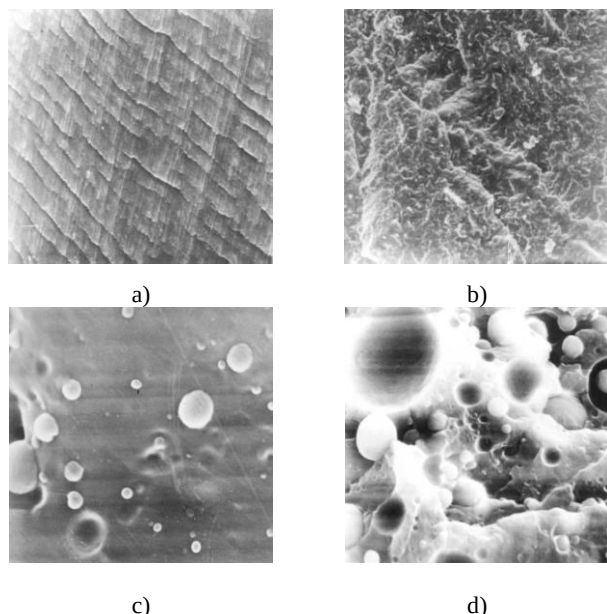


Fig. 2 A typical view of cleavage in liquid nitrogen of PA 6 (a), PET (b) and composite materials PA 6 + 10 wt. % PET (c) and PA 6 + 50 wt. % PET (d)

Modification of matrix polymers and blends (PA 6/PET) by layered silicates significantly increased their wear resistance and significantly reduced the coefficient of friction during operation without the supply of external lubrication (Fig. 3). It is obvious that during the blend formation is taking place the thermal degradation of silicate microparticles with the formation of nanosize plate aggregates [4], into the interlayer space of which the macromolecules of the matrix and modifying components penetrate.

The energy state of the plate aggregates determines the formation of a cross-linked structure with physical bonds that contribute to the increase of the operational characteristics parameters.

The carried out researches have allowed to develop blends PA 6 + 10 wt. % PET and PET + 10 wt. % PA 6. Under introduced into the matrices 5-20 wt. % dispersed particles of mica the

synergistic effect of increasing the parameters of tribological and adhesion characteristics while maintaining high values of the parameters of stress-strain characteristics, estimated by the criterion $\sigma_t \geq 62-65$ MPa is achieved.

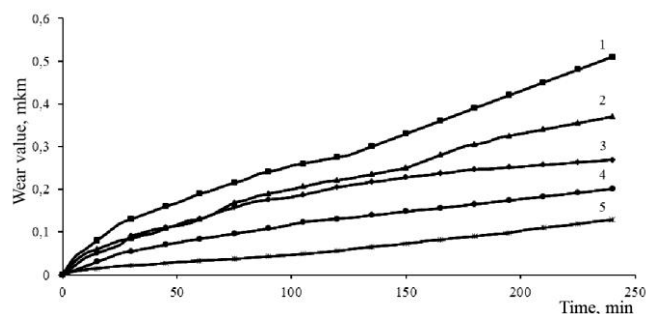


Fig. 3 Dependence of the wear value of blends based on PA 6 on the time for the "finger-disk" test at $p = 2.8$ MPa, $V = 1.1$ m/s: 1 – PA 6; 2 – PA 6 + PTFE (90:10); 3 – PA 6 + talc (90:10); 4 – PA 6-L-FG30; 5 – PA 6 + mica (90:10)

To control the compatibility parameters of components in composites based on aliphatic polyamides, carbon-containing particles of various production technologies – KGP C-1, CNT, charge, were used.

The data in Tables 1 and 2 show the effectiveness of the action of highly dispersed particles in blends based on aliphatic polyamides. A probable mechanism of modifying effect of carbon-containing modifiers is the formation of physical adsorption bonds in the transition layer of the composite according to the ideas presented in [4].

Table 1: Parameters of stress-strain characteristics of blends based on the aliphatic polyamides (bending tests).

Chemical composition of blend, wt. %	Characteristics value		
	E, MPa	σ_b , MPa	ϵ_b , %
PA6,6(84,5%) + PA6(10%) + PA12(5%) + KGP C1(0,5%)	2984,7	114,7	6,7
PA6,6(84,5%) + PA6(10%) + PA12(5%) + CNT(0,5%)	2797,8	109,7	6,1
PA6,6(84,5%) + PA6(10%) + PA12(5%) + шихта(0,5%)	2850,5	115,1	6,8

Table 2: Parameters of stress-strain characteristics of blends based on the aliphatic polyamides (tensile tests).

Chemical composition of blend, wt. %	Characteristics value	
	σ_t , MPa	ϵ_t , %
ПА6,6(84,5%) + ПА6(10%) + ПА12(5%) + КГП C1(0,5%)	78,84	3,9
ПА6,6(84,5%) + ПА6(10%) + ПА12(5%) + УНТ(0,5%)	54,19	2,1
ПА6,6(84,5%) + ПА6(10%) + ПА12(5%) + charge(0,5%)	77,78	3,8

Under injection of nanodispersed carbon-containing particles into the composite, which are mainly located in the interspherulite regions, the effect of increasing the resistance to thermal-oxidative destruction increases due to the formation of additional physical bonds of the adsorption type (Fig. 4).

In our opinion, the significant contribution of carbon-containing particles to the resistance to thermal oxidative aging of composites based on aliphatic polyamides is due to the energy state of nanoscale particles, which facilitates the formation of intermolecular physical bonds with the active centers of the macromolecule and a decrease in their activity in the processes of affinity for oxygen.

Thus, nanosize carbon-containing particles serve as a physical compatibilizer, contributing to the formation of a more perfect composite structure at different levels of organization.

A similar effect of the structuring effect of nanosize particles such as natural minerals (clays, zeolites) and diamond processing products is established in the works of Prof. A.A. Okhlopko and co-workers [6] for the modification of polytetrafluoroethylene.

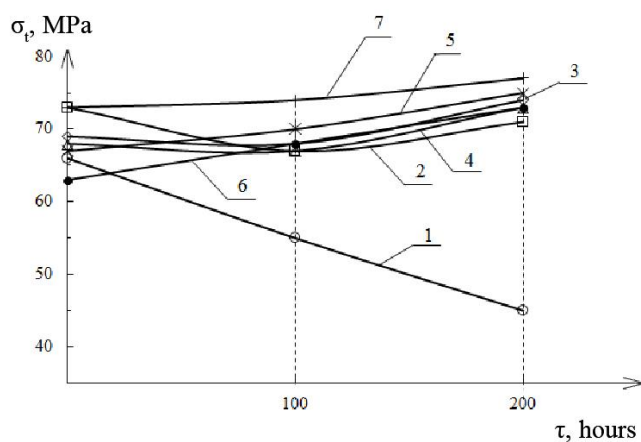


Fig. 4 Dependence of the tensile strength parameter on the time of thermal oxidation at 423 K (150 °C) for composites:

- 1 – PA 6.6-L;
- 2 – PA6.6 (94 %) + PA6 (5 %) + PA12 (1 %);
- 3 – PA6.6 (90 %) + PA6 (5 %) + PA12 (5 %);
- 4 – PA6.6 (85 %) + PA6 (10 %) + PA12 (5 %);
- 5 – PA6.6 (84.5 %) + PA6 (10 %) + PA12 (5 %) + KGP C-1 (0.5 %);
- 6 – PA6.6 (84.5 %) + PA6 (10 %) + PA12 (5 %) + CNT (0.5 %);
- 7 – PA6.6 (84.5 %) + PA6 (10 %) + PA12 (5 %) + charge (0.5 %)

Thus, the modification of blends based on aliphatic polyamides by nanoscale particles of different chemical composition, structure and production technology makes it possible to realize the synergistic effect of increasing the parameters of stress-strain, adhesion, tribotechnical characteristics and resistance to the action of thermal-oxidative operating media. The mechanism for the realization of the synergistic effect is due to the interaction of active centers of nanoscale particles with the centers of polymeric macromolecules with the formation of adsorption type bonds [3-5]. The formation of such bonds changes the intensity of intermolecular interaction in composites based on mono- and blend matrices, which is manifested in the transformation of the structure of the composite at the intermolecular, supramolecular and interphase levels. Due to multi-level structural modification, resistance to the influence of operational factors, including to the processes of tribotechnical interaction in metal-polymer systems and elevated temperatures in the air environment, increases.

4. Conclusions

The established regularities in the formation of the structure of blends based on thermoplastic polymers made it possible to develop composite materials for the manufacture of items of various metal-polymer systems – coatings for friction joints of cardan shafts and turning chucks, elements of shutoff and control valves used in low pressure pipelines [7].

The established regularities can be realized with the use of industrial technological equipment – mixers, extruders, injection molding machines. That allows using the obtained data in practical material science.

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