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UDK 622.276.6

Environment-Friendly Enhanced Oil Recovery Based on Oscillation Generator with Modernized Microturbine

K.A. Bashmur, E.A. Petrovsky, T.N. Kolenchukova, V.V. Bogachev

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Key words and phrases: screw rotor; microturbine; hydrodynamic device; oscillation generator; enhanced oil recovery; vibrowave impact; downhole equipment.

Abstract. The aim of the paper is to study the dynamic parameters of a rotary oscillation generator based on the modernized screw-type microturbine rotor. The hypothesis of the study is to study the possibility of effective influence of the generator on the oil reservoir. The objectives of the study are reduced to conducting hydrodynamic simulation in the SolidWorks Flow Simulation software module to analyze the mutual influence of the microturbine rotor and flow parameters. It is shown that the developed device is capable of generating low-frequency high-amplitude vibrations, ensuring efficient autonomous operation of the microturbine rotor.

The technology of low frequency vibratory oil production has great potential to improve the injection and production of complex reservoirs due to its advantages of low cost, high efficiency, no formation damage and environmental pollution [1]. In this case, a liquid of a certain frequency (from 0.01 to 15 Hz) is supplied to the oil reservoir, and with a periodic change in the pulse pressure, the injected liquid will propagate deep into the reservoir in a fluctuating manner. After a period of multiple pressurization, the rock matrix and fluid within it will pulsate, causing periodic expansion and contraction of rock pores, thereby improving reservoir permeability [2].

To implement the technology of low-frequency vibration processing, a helical rotor of the generator microturbine (Fig. 1) [3] was developed, containing a shaft made either together with the working helical surface, for example, using casting or 3D printing, or it can be fixed on it with a detachable or inseparable connection. The helical surface can be made single or multiple. On the helical surface, steps are located perpendicular to the medium flow, partially overlapping the free flow section.

An increase in the productivity of oil wells is due to the fact that, against the background of the flow along the helical surface of the rotor, separation vortices appear, which is described in detail in [4]. These detached vortices periodically generate pressure pulsations. Under the influence of elastic pressure fluctuations on the formation, contaminants are displaced from the cracks and pores of the rock. With periodic use of the device, the productivity of the formation is

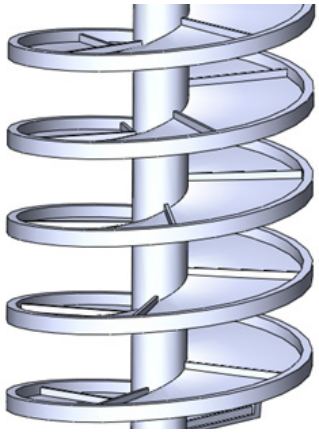

Fig. 1. Helical rotor of the microturbine

Table 1. Simulation data

Parameter	Value
Shaft length [m]	1
Shaft diameter [m]	0.044
Rotor diameter [m]	0.140
Number of steps	20
Number of turns	50
Inlet flow velocity [m/s]	5
Pressure [MPa]	5

increased due to the unhindered movement of hydrocarbons through the channels.

To estimate the parameters of the helical rotor of a microturbine as part of a hydrodynamic oscillation generator, hydrodynamic modeling was carried out in the SolidWorks Flow Simulation software. The initial data for modeling the flow through a helical rotor are presented in Table 1.

To estimate the amplitude and frequency of pressure fluctuations, a graph of the pressure distribution along the length of the microturbine screw was obtained (Fig. 2).

Based on the graph (Fig. 2), it can be seen that pressure fluctuations are uneven in different areas. The pressure fluctuation frequency is within 5 Hz. The flow velocity is 3.81 m/s with a flow time through the device of 2.36 s.

The pressure amplitude of the oscillator after the rotor during the deceleration of the main flow can be estimated in accordance with the theory of N.E. Zhukovsky according to the formula:

$$\Delta p = \rho(v_1 - v_0)c, \quad (1)$$

where Δp is the pressure change, Pa; ρ is the density of the liquid, kg/m^3; v_1 и v_0 are the average velocities in the device before and after channel section overlap, m/s; c is the velocity of shock wave propagation (assuming the walls are absolutely rigid, the velocity of propagation of the shock wave is equal to the speed of sound in the liquid).

Having constants for water ρ = 1,000 kg/m^3; c = 1,400 m/s; v_0 = 0 (complete deceleration of the flow) and v_1 = 3.81 m/s, we obtain by formula (1) pressure increase:

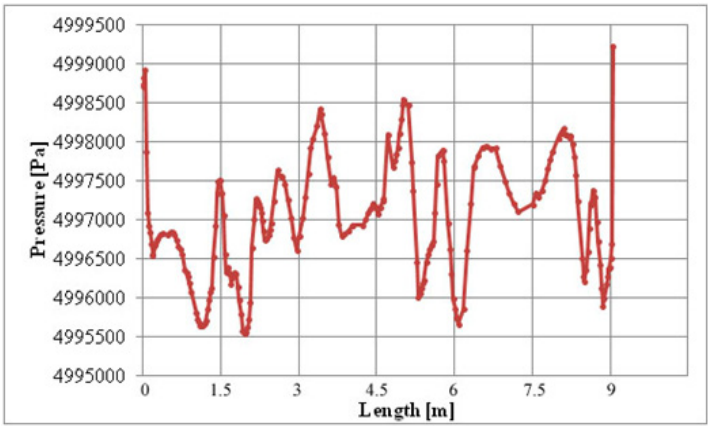

Fig. 2. Pressure distribution along the length of the microturbine rotor

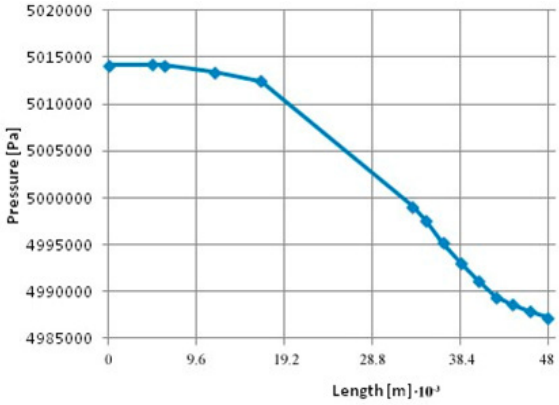

Fig. 3. Pressure distribution along the length of one stage

$$\Delta p = 1000 \times (3.81 - 0) \times 1400 = 5.334\ MPa.$$

According to the authors of the study [5], the generator should excite high-amplitude pressure fluctuations from 3 MPa at the bottom of the well.

Consequently, when the flow passes through the developed generator, pressure fluctuations occur with a frequency and amplitude that are effective for influencing the bottomhole formation zone. At the same time, there are no elastic elements and a large number of moving parts in the device, which positively affects its reliability.

To test the hypothesis about the possibilities of autonomous operation of the microturbine, we will find its torque. The torque generated by the action of the flow on the steps can be determined by the formula:

$$M = P \times k \times A \times l = P \times k \times a \times b \times \frac{R + r}{2}, \quad (2)$$

where P is the pressure acting on one stage, Pa; k is the number of steps; A is the area of the step edge (rectangle area), m^2; l is the lever arm, m; a is the step length, m; b is the step height,

m; *R* is the radius of the rotor, m; *r* is the shaft radius, m.

The dependence of the pressure distribution along the length of the stage was obtained in the SolidWorks Flow Simulation program (Fig. 3).

By finding the average value of the function, the average pressure on the step edge was obtained – 5014.117 kPa.

Let us find the torque of the microturbine rotor by substituting the obtained pressure value on the stage face and the data of Table 1 into the formula (2):

$$M = 5014117 \times 20 \times 0.048 \times 0.012 \times (0.07 + 0.022) / 2 \approx 2.66\ kN \times m.$$

This value of the torque is sufficient to ensure the efficient operation of the microturbine rotor; it significantly exceeds the starting torque of known types of rolling bearings. The hypothesis about the possibility of efficient autonomous operation of a microturbine is proved.

Thus, the amplitude and frequency of a generator with a helical rotor of a microturbine, which are effective for influencing the bottomhole formation zone, have been evaluated. The quantitative characteristic of the torque is determined and the possibility of effective autonomous operation of the oscillation generator is proved.

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Экологически чистое повышение нефтеотдачи пластов на основе генератора колебаний с модернизированной микротурбиной

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Ключевые слова и фразы: виброволновое воздействие; винтовой ротор; генератор

колебаний; гидродинамическое устройство; микротурбина; повышение нефтеотдачи; скважинное оборудование.

Аннотация. Целью работы является исследование динамических параметров генератора колебаний вращательного действия на основе модернизированного ротора микротурбины винтового типа. Гипотеза исследования состоит в изучении возможности эффективного влияния генератора на нефтяной пласт. Задачи исследования сводятся к проведению гидродинамического моделирования в программном модуле SolidWorks Flow Simulation для анализа взаимовлияния ротора микротурбины и параметров потока среды. Показано, что разработанное устройство способно генерировать низкочастотные высокоамплитудные вибрации с обеспечением эффективной автономной работы ротора микротурбины.

UDK 629.7.064.3

Development of a Model of Descriptive Languages for Recognizing the State of the Working Fluid of Aircraft Hydraulic Systems

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Key words and phrases: image; recognition; hydraulic system; aircraft; working fluid.

Abstract. The purpose of this work is to consider the features of the development of a model of descriptive languages for recognizing the state of the working fluid of hydraulic systems of aircraft. The research tasks are the study of the possibilities of using a progressive image recognition approach based on artificial intelligence to assess the state of the working fluid of hydraulic systems of aircraft. In the course of the research, special attention is paid to the theoretical aspects of the concept of pattern recognition. To describe the image of the working fluid of hydraulic systems of aircraft, it is proposed to use a two-weighted neural network. As the results of the study showed, the proposed model will expand the functionality for solving a complex problem related to determining the state of the working fluid of hydraulic systems of aircraft, image recognition methods are of particular importance today.

In aviation, hydraulic systems are the circulatory systems of the aircraft and are crucial to ensure smooth flight and the functioning of the aircraft as a whole. Hydraulics finds its application on airplanes of all sizes, since it ensures the operation of most equipment, such as landing gear, brakes, flaps, thrust reversals, and also controls all important and critical components of flight [1]. The hydraulic system performs the function of moving and actuating the main components of the aircraft that require energy costs.

Taking into account the role and importance of hydraulic systems in aviation, it is of particular importance to ensure their reliability during operation, which determines the need for regular technical assessment [2].

At the same time, it should be noted that with the development of automation, aircraft equipment tends to increase in size, complexity, intellectualization and high parameterization. This makes the structure and operating condition of modem equipment increasingly complex and difficult to assess. This is especially true for the assessment of their technical serviceability according to the state of the working fluid. In addition to controlling the temperature of the

working fluid as an integral diagnostic parameter of the hydraulic system, evaluation methods based on the analysis of the color, contamination of the fluid, allowing to determine its qualitative and quantitative composition, are currently being developed.

A variety of numerical methods are currently used to model the structure of the working fluid flow in various industrial devices. However, their application is limited by complex geometry, numerical stability and the high cost of calculations [3]. At the same time, the use of artificial intelligence methods to study large data sets with a combination of computational fluid dynamics capabilities makes it possible to use new approaches to diagnostics, including, in particular, pattern recognition, which today is one of the most promising tools for assessing the technical condition of the working fluid.

Pattern recognition is a data analysis method that uses machine learning algorithms to automatically recognize patterns in data [4]. This data can be anything from text and images to sounds or other specific qualities. Image recognition systems allow you to quickly and accurately identify known patterns. But they can also recognize and classify unfamiliar objects, identify shapes and objects from different angles, and identify patterns and objects, even if they are partially hidden [5].

In the process of pattern recognition, disparate data is processed and converted into a form suitable for machine use. Pattern recognition includes the classification and clustering of images.

In classification, the corresponding class label is assigned to a template based on an abstraction that is generated using a set of training templates or domain knowledge. Classification is used in teaching with a teacher.

Clustering generates data partitioning, which helps to make decisions, perform specific decision-making actions that are of interest to the researcher. Clustering is used in unsupervised learning.

The formal basis of recognition is the database of descriptions of images of standards (the alphabet of classes), presented as a set of sets [6].

To study the states of the structure of working fluids, it defines a subfamily $\mathcal{R}'$ of $\mathcal{R}$, including its indicators that form the basis for evaluating the real structure of the working fluid. Then the real environment from the formal perspective, there are three $\langle U, \mathcal{R}, \mathcal{R}'\rangle$ where $\langle U, \mathcal{R}\rangle$ is environment and $\mathcal{R}'$ is a subfamily in the real structure of $\mathcal{R}$. The elements of the subfamily $\mathcal{R}'$ are called the input properties of the environment. The finite family of the working fluid structure $\mathcal{R}' = \{P_1, P_2, \ldots, P_n\}$ is complete if

$$p_{i_1} \cap p_{i_2} \cap \ldots \cap p_{i_n} \neq \emptyset.$$

This family of the structure of the working fluid sets the boundaries of the distinguishability of the elements of the field of reasoning. Any object in U can be completely specified by specifying its belonging to the set of elements of each property $\mathcal{R}'$ then we can enter the following definitions. We are always given a real environment $\langle U, \mathcal{R}, \mathcal{R}'\rangle$. A generalized object in it can be represented by a string of the form $(P_{i_1}, p_{i_1}; P_{i_2}, p_{i_2}, \ldots, P_{i_n}, p_{i_n})$, where n is such a finite integer that $P_{i_k} \in \mathcal{R}'$, $p_{i_k} \in P_{i_k}$ and for any k.

To solve the problem of image synthesis of the working fluid, the theory of image synthesis within the framework of precise formalism is used in the work. The problem is considered from formal positions.

The sets of all generators $\mathcal{A}$ consists of non-overlapping classes of generators $\mathcal{A}^\alpha$, $\mathcal{A}^\alpha \subset \mathcal{A}$, where α is the general index, the index of the class of generators, $\mathcal{A} = \cup_\alpha A^\alpha$, A^α are disjoint classes.

Table 1. Performance standards of the working fluid [7]

№	Parameter	Standard	Restriction
1	Kinematic viscosity at 40 °C, mm^2s^{-1}	ASTM D445	± 20 % 8.44–22.66
2	Density per 25 °C, kg m^{-3}	ASTM D4052	99–1005
3	Acid number, mg KOH g^{-1}	ASTM D974	1.5 max
4	Water content, %	ASTM D6304	0.2 max
5	Purity code		9 max
6	Electrical conductivity cm^{-1}		0.5 min
7	Elemental composition		
8	Number of particles per 100 cm^3 sample with particle size, μm		

The interpretation of this partition is that generators that are qualitatively similar will belong to the same class.

Forming within a given area of reasoning are samples of the working fluid having reference and analyzed values. They have certain input properties.

Thus, the generators of the working fluid are characterized by a set of numbers – the results of a certain set of measurements that characterize it with the help of signs, the number of which is relatively small for estimating its frequency, which allows us to apply a discriminant approach to constructing its image.

Based on the task of describing the image of the hydraulic fluid of the aircraft and the concepts introduced above, the area of reasoning about its condition is determined by the analysis of samples of the working fluid, the standard of which is shown in Table 1.

For convenience, we denote the elements of the domain 1, 2, 3, …, 8, as shown in Table 1. Formally, the domain has eight input properties, the names of which are the functions described in Table 1. This area has the property that each individu2al element belongs to a separate and unique state of the object. Therefore, each subset of the domain is an image, a state.

The image of the working fluid standard is formally described on the basis of predicates, which consist of statements of the form $P(x) = p$, where P is a property, p is its value, and x is a variable. This predicate is true for all elements, i.e. any element from the working fluid standard satisfies the statement $G(x)$, where $G(x)$ is

$$(P_{i_1} = p_{i_1}) \wedge (P_{i_2} = p_{i_2}) \wedge \ldots \wedge (P_{i_n} = p_{i_n}).$$

This statement is considered as a formal description of the working fluid:

$$(P_{i_1}, p_{i_1}; P_{i_2}, p_{i_2}; \ldots; P_{i_n}, p_{i_n}).$$

The implementation of pattern recognition consists in “superimposing complex geometry in a high-dimensional space”. This makes it possible to study the properties of a liquid in the feature space and as a result get a reasonable overlap so that you can “find out” its current state.

According to dimension theory [8], to divide an n-dimensional space into two parts, the interface must be an n-1-dimensional hyperplane or hypersurface. A neuron in an artificial neural network acts as an n-1-dimensional hyperplane or hypersurface in an n-dimensional space, it can represent various complex closed hypersurfaces.

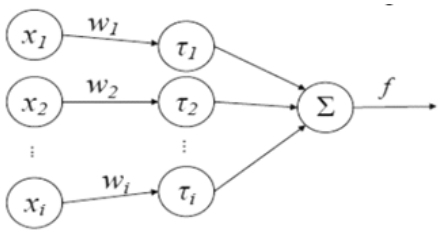

Fig. 1. Structure of a two-weighted neuron

Thus, artificial neural networks are a very suitable tool for describing and implementing image recognition of the working fluid in the hydraulic system of the aircraft. Existing neural networks are based on single-weight neurons, which in practice can build simple, regular geometric shapes. The BP network is a hyperplane, and the RBF network is a hypersphere [9], but none of them satisfies the requirements of "complex geometry in high-dimensional space".

A two-weighted neural network has two weights, one of which is equivalent to the directional weights of the BP network and one equivalent to the main weights of the RBF network. Considering this, according to the author, a neural network with double weighting can be used to obtain complex geometric shapes, response characteristics and anisotropic properties of the highest order, hereditary properties to meet the requirements of recognition of images of the working fluid.

Weighted neurons in this case can be expressed as follows:

$$Y = f[\delta(W_1, W_2, \ldots, W_n, X) - \theta],$$

where X is the input vector; W is the weight of the n-th vector; δ is the neuron function; f is the transfer function; θ is the threshold of the neuron. When n = 2, the above formula is a dually weighted inequality, denoted as:

$$Y = f[\delta(W_1, W_2, X) - \theta].$$

When two points W_1 and W_2 in space have a certain unique intermediate layer, it can be expressed this way:

$$Y = f\left[\sum_{i=0}^{n}\left(\frac{w_i\left(x_i - \tau_i\right)}{\left|w_i\left(x_i - \tau_i\right)\right|}\right)^s \left|w_i\left(x_i - \tau_i\right)\right|^p - \theta\right],$$

where w_i is the directional weight from the i-th input of the neural network, which determines the direction of scaling of the neural network; τ_i is the main weight from the i-th input of the neural network, which determines the central location of the neural network; x_i is the eigenvalue of the i-th input; p is the metric parameter; n is the spatial dimension; p and n together define multiple hypersurface constructions of a neural network; i is the parameter of the method for determining the one-sided positive and negative sign, and the one-sided sign is always positive when s = 0, and the one-sided sign remains the same as wi when s = 1.

A diagram of the structure of a two-weighted neuron is shown in Fig. 1.

Thanks to this approach, each layer of the description of the working fluid is performed

independently, and the results are transmitted to the next layer. Each subsequent layer focuses on describing one specific set of features, assuming that all the necessary information has already been found by the higher layers of the neural network.

After describing the image of the working fluid in the hydraulic system of the aircraft, it is necessary to choose a recognition method, it seems appropriate to use structural recognition methods to solve the problem.

To solve a complex problem related to determining the state of the working fluid of hydraulic systems of aircraft, image recognition methods are of particular importance today. Compared to traditional manual diagnostic and control approaches, pattern recognition is capable of constructing closed, complex geometries to cover all types of fluid samples, on the basis of which conclusions can be drawn about the technical condition of hydraulic systems.

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Разработка модели описательных языков распознавания состояния рабочей жидкости гидравлических систем летательных аппаратов

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Ключевые слова и фразы: гидравлическая система; образ; рабочая жидкость; рас-

познавание; самолет.

Аннотация. Цель данной статьи – рассмотреть особенности разработки модели описательных языков распознавания состояния рабочей жидкости гидравлических систем летательных аппаратов. Задачи: исследование возможностей использования прогрессивного подхода распознавания образов на базе искусственного интеллекта для оценки состояния рабочей жидкости гидравлических систем летательных аппаратов. В процессе исследования особое внимание уделено теоретическим аспектам концепции распознавания образов. Для описания образа рабочей жидкости гидросистем самолетов предложено использовать двухвзвешенную нейронную сеть.

Как показали результаты исследования, предлагаемая модель расширит функциональные возможности для решения сложной задачи, связанной с определением состояния рабочей жидкости гидравлических систем летательных аппаратов, методы распознавания изображений сегодня имеют особое значение.

UDK 338.4

Influence of Design Factors on the Optimum Size of the Extension of the Bored Piles

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Key words and phrases: high-tech production complex; plastic recycling; polyester fiber production; PET fiber; resource-saving and environmental production systems; flex.

Abstract. The article presents a project to create resource-saving and environmentally friendly production systems based on the production of PET fibers from recycled plastic. Despite the presence of a wide range of domestic economic and social problems that came to the fore in early 2022, there are still environmental challenges and problems that the country faces, including pollution of water bodies, air, household waste, etc. These problems are of strategic nature, however, they require an immediate operational solution, since the negative consequences may turn out to be uncontrollable and large-scale. On the basis of the study, it is proposed to create a high-tech complex for the production of polyester fiber.

The amount of waste, primarily plastics, is growing at an extremely fast pace, and it is obvious that there are no clear prerequisites for this trend to reverse or even slow down due to the rapid growth of the world's population and a decrease in the general level of well-being. Under such conditions, an entrepreneurial idea becomes extremely attractive, which would allow to take advantage of this trend, benefiting nature and society. All this fits into the currently popular concept of ESG (Environment, Social, Governance), which in a broad sense implies the sustainable development of the company.

In Russia, this approach is less popular than abroad, but the dynamics of recent years shows a positive trend, as well as a general awareness of problems and methods to change the situation for the better. The issues of environmental responsibility of business were actively discussed at SPIEF-2022, which inevitably leads to the involvement of more Russian companies in this trend. Thus, at least a third of Russian banks have already implemented performance assessment within the framework of ESG in their lending process.

Speaking about the light industry in the environmental aspect, as well as taking into account the most recent trends, one can see that they have certain intersections that can be used with a reasonable entrepreneurial approach. In particular, the use of recycled plastic and other waste for chemical fibers production with improved consumer properties. Nowadays, it is rare to find textile products that are made of 100 % natural fibers, since such a product is not economically

viable and is not competitive in physical and many other parameters. This has brought the industry into the current situation where synthetic fibers are becoming the main raw material. It is at this stage that large industrial concerns come to understanding that current technologies allow the use of recycled waste for the production of light industry products, thereby reducing the cost of production and mitigating the environmental footprint.

Not only bottles, but also other kinds of plastic waste can take part in the clothes manufacturing. The most famous example is polyester, nylon, organza, taffeta, which can be obtained from PET. Polyester fibers are used both in pure form and as part of fabrics, which allows to significantly change the properties of the product, making it, for example, more durable or elastic. The primary stage is the sorting of the original waste by color, after which it is cleaned, sterilized and crushed, resulting in crumbs, which are then melted and pulled into long threads, dyeing them in the desired color.

Among the most famous wardrobe items that are made using plastic are tights, many fleece jackets, eco-fur coats, sportswear, raincoats and raincoats, etc. It is noteworthy that often these products have a wider range of characteristics, including aesthetic ones, which makes them absolutely competitive. “Recycled PET fibers are used in a wide variety of ways. Geotextile fabric may be made entirely from recycled PET, subject to consistent quality and guaranteed supply. Another way to use the fibers is to make upholstery for cars and carpets for residential and office spaces. Recycled PET is also used to make smaller diameter fibers. They produce artificial wool used for knitted shirts, sweaters and scarves” [1].

It is noteworthy that one T-shirt, on average, takes 20–30 plastic bottles, and about 100 bottles for a suit made of dense fabric. At the same time, it is important to note that clothes that are 100 % synthetic fabrics can harm a person, so the industry, at the moment, resorts to various combinations of natural and artificial fabrics, as well as various types of weaving, which reduces the negative aspects, however makes it difficult to recycle them.

An interesting fact is that back in the 1990s, Paco Raban, a famous French designer, predicted that mankind would wear clothes made from waste. He turned out to be right, since already at the beginning of the 21st century, the world’s leading fashion houses began to demonstrate models made from recycled polymers, thereby setting new global trends, and in 2008, mass market brands joined this trend and began releasing accessories from these materials. Now among the well-known brands that have these product lines, you can see Nike, Asics, Max Mara, Levi’s, H&M. “People have always looked at the discarded bottle as garbage, but we are able to fix this and prove that the reuse of PET bottles is nothing more than another great idea of mankind” [2].

According to the latest data from the Ministry of Natural Resources of the Russian Federation, more than 80 plants operate in Russia, aimed at the processing and disposal of plastic waste. There are plans to build and launch another 200 factories by 2024, as the environmental problem is gaining more weight in society. However, a significant problem is the shortage of raw materials for these enterprises, which occurs as a result of waste sorting, the level of development of which is still at a low level in the country. “One of the most pressing modern problems of environmental protection is the prevention of waste accumulation. Polymeric materials make up an increasing share of household and industrial waste entering landfills. Due to their high resistance to environmental influences, these materials are preserved in natural conditions for a long time (for example, PET – for 80 years). The solution to the problem, which makes it possible to reduce the negative impact on nature, can be the development and application of technologies for the processing of polymer waste” [3].

The most successful model for integrating a waste processing system with a view to their

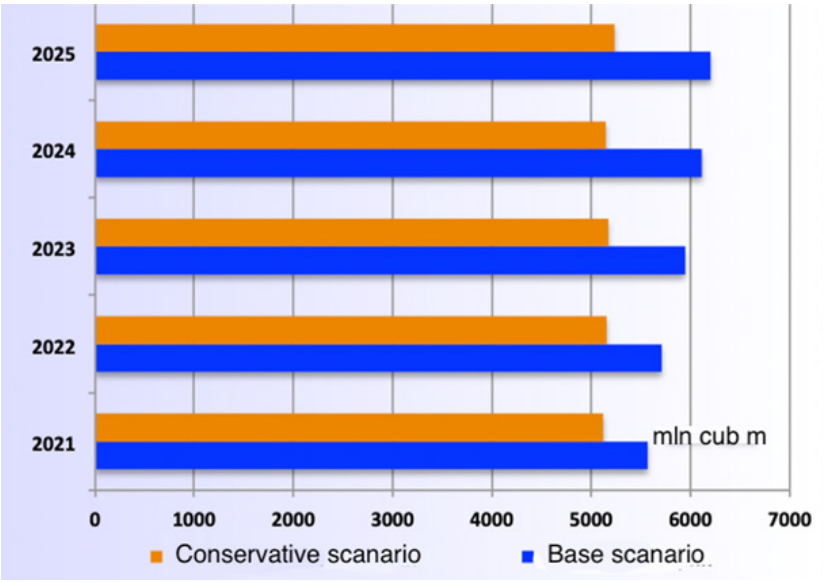

Fig. 1. Forecast of non-woven materials consumption in physical terms in the Russian Federation mln. m. [MA ROIF Expert]

subsequent use as raw materials in light industry is the “green” cluster, which is a modified version of the classic cluster, which includes an enterprise that is able to process and supply such raw materials in the required quantities. “The problem of recycling waste polymer materials is becoming relevant not only from the point of environmental protection, it is also related to the fact that in conditions of raw materials scarcity, plastic waste becomes a powerful raw material and energy resource” [4].

As part of this study, it is proposed to conduct an analysis for an investment project, the purpose of which is to create a complex for the polyester fiber production. This project can open up a new promising direction for the company, since these products can be used as an import substitution for foreign artificial fabrics, and the production itself can become an integral part of the green cluster, which will make it possible to obtain raw materials at extremely competitive prices from recycled waste.

The growth dynamics of the textile and construction industries, agriculture, and road construction in the Russian Federation forms a steady trend towards an increase in the consumption of polyester fibers in the context of the main product groups (fiber, geotextiles, nonwovens) in the short term (Fig. 1).

It is important to note that the market for the consumption of synthetic fibers is a moderately growing market in the Russian Federation – according to experts, it will grow at an average rate of 8–10 % in the next few years. At the same time, the share of polyester fiber is expected to grow faster than the rest of the market. PET fibers in the future remain practically the only driver of growth in textile production in the Russian Federation, providing fiber manufacturers with constant stable demand from textile enterprises and not experiencing seasonal/annual fluctuations.

It is proposed to install a modern automated production line from Zhangjiagang Guangyin Industry (China), known in the market as one of the most high-tech, producing equipment for the chemical, textile and light industries.

The technological line consists of machines and units, including advanced innovative

Table 1. Forecast of financial results (fiber), thousand rubles

Metrics	2022	2023	2024	2025	2026
Revenue	672.000	672.000	672.000	672.000	672.000
COGS	620.823	620.840	620.840	620.840	620.840
Gross margin	48.439	48.481	48.539	48.598	48.656
EBITDA, margin	7.2 %	7.2 %	7.2 %	7.2 %	7.2 %
EBIT	45.971	45.881	45.939	45.998	46.056
EBIT, margin	6.8 %	6.8 %	6.8 %	6.8 %	6.8 %
Net Profit	36.476	36.244	36.291	36.338	36.384
Net Profit, margin	5.4 %	5.4 %	5.4 %	5.4 %	5.4 %

Table 2. Forecast of financial results (flex + fiber), thousand rubles

Metrics	2022	2023	2024	2025	2026
Revenue	672.000	672.000	672.000	672.000	672.000
COGS	549.294	477.719	477.719	477.719	477.719
EBITDA	119.576	191.480	191.583	191.685	191.787
EBITDA, margin	17.8 %	28.5 %	28.5 %	28.5 %	28.5 %
EBIT	116.042	186.830	186.932	187.034	184.137
EBIT, margin	17.3 %	27.8 %	27.8 %	27.8 %	27.8 %
Net Profit	91.221	146.379	146.461	146.542	146.624
Net Profit, margin	13.6 %	21.8 %	21.8 %	21.8 %	21.8 %

equipment, has a high level of automation and is controlled by high-quality computer systems from leading European countries. The set of equipment includes a line for the production of polyester fiber and a line for extruding polyester thread.

In order to achieve the maximum economic effect and taking into account the available area of the site, it is advised to place on it additional capacities for the production of polyester fiber, a workshop for the production of flax from sorted plastic bottles, as well as place additional storage facilities.

The maximum financial and economic effect is achieved by reducing the cost of polyester fiber production. This result can be achieved by replacing expensive equipment purchased on the PET flex market with raw materials of our own production. Let us turn to the forecast of the company's financial results, considering the production of only polyester fibers (Table 1).

Based on the analysis above, the forecast can be concluded that the production implies a below-average net profit margin of 5.4 % of finished products. However, if we include the flex production, it shows a significantly higher margin (Table 2).

With the organization of own flex production from sorted plastic bottles, an increase in gross profit by 3–4 times is expected. Thus, in the case of the production of only polyester fiber, the gross profit will be 8 %, while the production of flex will increase this figure to 30 %, which is

significantly higher than the industry average.

The production complex has a number of strategic advantages that distinguish it in the market for the production of polyester fiber from recycled PET among similar industries, which increase its investment attractiveness, namely.

• Demand and quality of products. These products will be guaranteed to be in demand due to their low cost and high quality, which can be ensured due to the presence of our own raw materials, technological equipment and highly qualified personnel.

• Advanced innovative solutions. The production line has the latest engineering systems, a high level of automation and is controlled by advanced European computer systems. In addition, the production line, the units and components of the complex have undergone a serious renovation.

• Reserve for production expansion. The prospects of this industrial direction within the country determine the possibility of a multiple expansion of production and sales markets.

The implementation of the presented investment project will increase efficiency and reduce costs for light industry industrial enterprises. “It is precisely the qualities that are inherent in PET that are involved in the fiber manufacturing process. Usually, fiber formation is made from a base that consists predominantly of recycled PET, i.e. the mechanical performance of recycled PET fully meets the criteria for making fiber based on PET. Recycled fiber is used in textile production and in the manufacture of carpet coverings. Most often, PET fibers are used for artificial insulation in winter clothing or for the manufacture of plush forms in the clothing. Recycled PET fiber has a large number of advantages over other synthetic fibers” [5].

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Создание ресурсосберегающих и экологических производственных систем на основе производства ПЭТ-волокон из переработанного пластика

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Ключевые слова и фразы: высокотехнологичный производственный комплекс; пере-

работка пластика; производство полиэфирного волокна; ПЭТ-волокно; ресурсосберегающие и экологические производственные системы; флекс.

Аннотация. В статье представлен проект создания ресурсосберегающих и экологических производственных систем на основе производства ПЭТ-волокон из переработанного пластика. Несмотря на наличие широкого спектра внутренних экономических и социальных проблем, которые вышли на передний план в начале 2022 г., остались экологические вызовы и проблемы, с которыми сталкивается страна, среди которых загрязнения водоемов, воздуха, бытовые отходы и др. Данные проблемы носят стратегический характер, однако требуют немедленного оперативного решения, так как негативные последствия могут оказаться неконтролируемыми и масштабными. На основе проведенного исследования предлагается создание высокотехнологичного производственного комплекса по производству полиэфирного волокна.

UDK 52.08

Elimination of Adhesive Wear of the CMM Probe from the Aluminum Oxide Shroud

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Key words and phrases: probe; measurements; control; quality; coordinate measuring machine; adhesive wear; deviation from par.

Abstract. The manufacturing of high-quality aircraft, mechanical engineering and radio electronics products is based on accuracy, which is set by the design documentation. A large share of control operations in advanced production accounts for the measurement of angular and linear dimensions. Coordinate measuring machines are particularly widespread in quality control in modern industry. The relevance of the chosen topic is due to the high level of quality control of the parts produced by the enterprise in order to improve the quality of the final unit (node).

In the automotive and mechanical engineering, as well as in many other areas, coordinate measuring machines with a large range of measurements of the quality of products are required.

Coordinate measuring machines (**CMM**) are used when it is necessary to carry out high-precision measurements. The more complex or numerous the measurements are, the more profitable it is to use the CMM.

Usually CMMs are used for quality control and inspection. That is, they are used to verify that the part meets the requirements and specifications of the customer. They can also be used to reverse engineer existing parts by making precise measurements of their characteristics.

A CMM is a measurement tool designed to perform coordinate measurements. That is why coordinate measuring machines are widely used at the leading enterprises of the machine-building industry. This equipment allows you to optimize the control process, the possibility of full automation both at the stage of implementing the coordinate measurement method and at the stage of processing the results of these measurements. This equipment allows you to optimize the control process, the possibility of full automation both at the stage of implementing the coordinate measurement method and at the stage of processing the results of these measurements.

Simply put, a coordinate measuring machine is a device that is used to quantify the physical geometric attributes of a physical object.

This procedure uses a sensor mounted on the third movable axis of the CMM machine, which is used to measure the characteristics of the part in question.

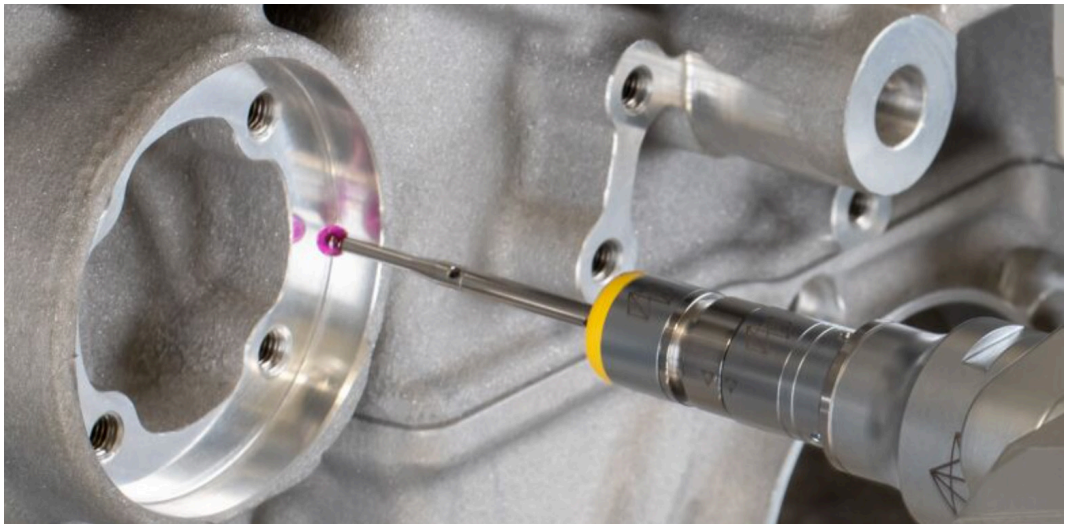

Fig. 1. Configuration of the measuring probe

The CMM is additionally used to test and validate the site or collection to ensure that it agrees on the proposed plan. A typical CMM can be programmed to perform measurement tasks multiple times. You don't have to reprogram the machine after each measurement. This explains why they are ideal for large-scale measurement tasks when you have to measure several objects at once. The machines also eliminate the need to use different types of measuring machines in a single project.

Absolutely any means and methods of control are doomed to have errors. Coordinate measuring machines are no exception. The constant difference in the results during repeated control operations is caused by the presence of a systematic error.

Errors may occur in the following situations:

- the correct measurement procedure is not followed;
- there is a constant discrepancy between the required measurement parameters (temperature, humidity, room pressure, vibration);
- an incorrectly functioning measuring device (aging of mechanisms, development, inappropriate maintenance of the CMM).

As an example, the situation of wear of the place of contact with the part on the tip of the measuring probe or the occurrence of aluminum oxide captivity can be cited.

Coordinate measuring machines are provided with optical or contact sensors, which can be selected by the machine operator independently, depending on the task of measuring and quality control of the products. All together, it provides an optimal combination of tools for solving various kinds of tasks.

During the use of the CMM, not only the time for measuring parts has been reduced, the quality of control has improved, etc., but also the need for the manufacture of individual items for universal measuring devices has decreased. The machine is quite easy to operate. It employs people not only with higher technical education, but also with appropriate additional training and secondary specialized education.

The probe (Fig. 1) is the part of the measuring system that comes into contact with the part, causing the sensor to trigger. The generated signal allows you to obtain measurement data. The type and size of the probe used is determined by the part element to be measured. However, in any case, the most important characteristics of the probe are its rigidity and the degree of

Fig. 2. Probe (tip) made of synthetic ruby

Fig. 3. Tip (ball) made of silicon nitride

Fig. 4. Tip (ball) made of zirconium dioxide

sphericity of its tip.

Electronic probes can be of several types.

– A switchable type probe (touch probe). When touching the surface of the part, it emits an electrical signal. A spherical tip is installed on the probe. Most often, the tip is made of artificial ruby (however, for aluminum parts, a tip made of silicon nitrite is used, since aluminum is wrapped on the ruby tip, which leads to a measurement error. This is especially evident when working in scanning mode). When a touch signal is received, the position of the head is read by the displacement sensor.

– A scanning probe. This probe is a separate measuring system. Inside this probe there are three axes of movement and three optical rulers. When working in scanning mode, the deflection of the probe is measured.

– Contactless systems (for example, laser systems).

As a rule, trigger and analog sensors use several materials from which the probe (tip) is made.

Synthetic ruby (Fig. 2) refers to materials that are used for a wide range of measurement tasks. Synthetic ruby optimally combines high hardness and low cost. Despite the vastness of a number of measuring tasks, there are two cases in which it is necessary to use probes of other materials. The first case can be attributed to scanning on aluminum during heavy operation. Due to the attraction of materials, a phenomenon known as adhesive wear may occur, in which an increase in aluminum passing from the measured surface occurs on the tip. The second case is a cast iron scan. The contact between cast iron and ruby leads to abrasive wear of the probe tip.

Silicon nitride (Fig. 3). This is a very hard and wear-resistant ceramic material, from which high precision spheres can be obtained during processing. The surface of the ball can be further polished. Silicon nitride does not attract aluminum particles, therefore, unlike ruby, this material is not subject to adhesive wear. However, silicon nitride has significant abrasive wear when scanning on steel surfaces, so its scope of application is mainly limited to aluminum.

Zirconium dioxide (Fig. 4) is an exceptionally durable ceramic material, which is not inferior to ruby in hardness and wear. Due to its surface properties, this material is ideal for performing scanning in harsh conditions on cast iron parts.

Synthetic ruby is a material with the highest hardness, exceptionally smooth surface, high

Fig. 5. A probe without sticking

Fig. 6. A probe with sticking

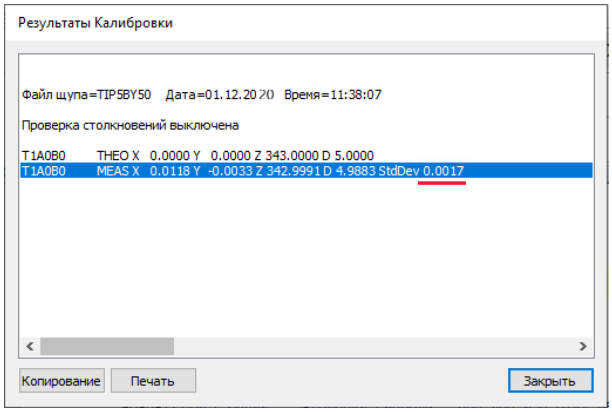

Fig. 7. Calibration of the probe before etching

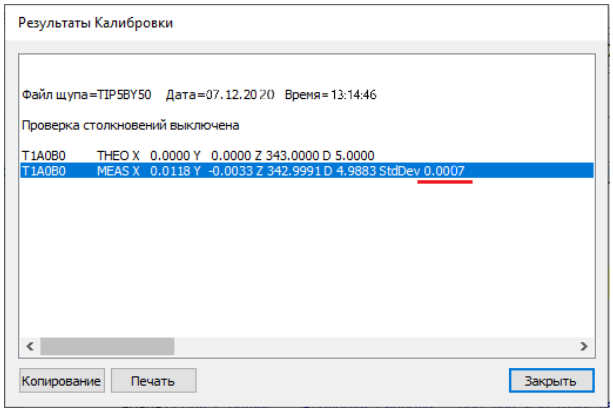

Fig. 8. Calibration of the probe after etching

compressive strength and high resistance to mechanical corrosion.

Despite the existing disadvantages in the form of adhesive and abrasive wear, it is synthetic ruby that is the industry standard and the optimal material for manufacturing the ball of probes used by the CMM for most of a number of measuring tasks.

Since synthetic ruby is 99 % aluminum oxide, when the ruby tip interacts with the aluminum surface, an oxide shroud forms on it (Fig. 5; 6).

With a large sticking of aluminum, the tip loses its spherical shape, which contributes to a low level of quality control of the parts produced by the enterprise and a decrease in the quality of the final unit (node) [2].

The purpose of the proposed technical solution is cleaning of the ruby probe of the KIM from the aluminum oxide shroud in a chemical solution.

Since all aluminum parts in production undergo the process of etching with a chemical solution to achieve this goal, it was decided to apply the process of chemical etching on the ruby tip. For this purpose, a solution of NaOH 40–60 g/l was used, at the operating temperature of the etching bath 50–70 °C. Etching time is 2–2.5 min [3].

In our case, the probe (tip) Ø5 mm was etched. The calibration process of the probes was carried out using a ceramic sphere Ø25 mm. All experimental control measurements were carried out on the same certified coordinate measuring machine of the portal type and took place in the measuring laboratory. During the recalibration, identical temperature and humidity indicators were maintained.

Before the chemical etching process, the tip with an adhesive layer of aluminum was calibrated. The result with the measurement error using this tip is shown in Fig. 7.

After the etching process, the probe was recalibrated. The result with the measurement error using the tip after the etching process is shown in Fig. 8.

The difference in errors before and after etching the ruby tip turned out to be significant, about 0.001 mm.

Thus, the proposed technical solution has the following advantages:

- high accuracy of measurement of aluminum parts is maintained;
- the cost of purchasing new probes is reduced;
- high quality of the final unit (node).

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Устранение адгезионного износа щупа КИМ от окисной пелены алюминия

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Ключевые слова и фразы: адгезионный износ; измерения; качество; контроль; координатно-измерительная машина; отклонение от номинала; щуп.

Аннотация. В основе изготовления качественных изделий авиастроения, машиностроения и радиоэлектроники лежит точность, которая задается конструкторской документацией. Большая доля контрольных операций в усовершенствованном производстве приходится на измерение угловых и линейных размеров. Особо широкое распространение при контроле качества в современном производстве получили координатно-измерительные машины. Актуальность выбранной темы обусловлена высоким уровнем контроля качества выпускаемых предприятием деталей с целью повышения качества конечного агрегата(узла).

UDK 658.56

Knowledge Management in the Quality Management System: University Case

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Key words and phrases: information resources; knowledge; knowledge management; knowledge management tools; learning; university.

Abstract. Nowadays the main resource of any organisation ensuring its development is people, their knowledge, professional qualities and competences. Knowledge management is an indispensable process leading to the organization's competitiveness growth. The article describes the knowledge management process implementation in accordance with the quality management system (**QMS**) ISO 9001 international standards requirements on a university example, which carries out scientific, educational and innovative activities. The hypothesis of the study is based on the assumption that an effective knowledge management system at the university will allow the university to obtain certain advantages in increasing competitiveness in various fields of activity. The methods used are system analysis, synthesis, analogy, generalization, classification. The knowledge management functioning requirements and principles are considered. It is shown that the knowledge management importance in accordance with the QMS is played by the work information support.

In the ongoing changing world, when science and education act as drivers in the development of the country, the issue of training highly qualified personnel as a result of effective educational activities and the creation of advanced technologies in the framework of scientific research is important and timely. One of the directions for solving the problems facing universities is the development of a knowledge management system and the organization of the knowledge management process in accordance with international standards. In this regard, in order to create organizational conditions for the systemic formation and development of knowledge management, the issue of developing knowledge management standards within the framework of the quality management system (**QMS**) at the university becomes relevant [1; 2].

The analysis of publications in this scientific field has shown that Russian and foreign researchers works a significant number are devoted to the knowledge study as production a factor and its significant impact on qualification, training, organization and innovation [3; 4].

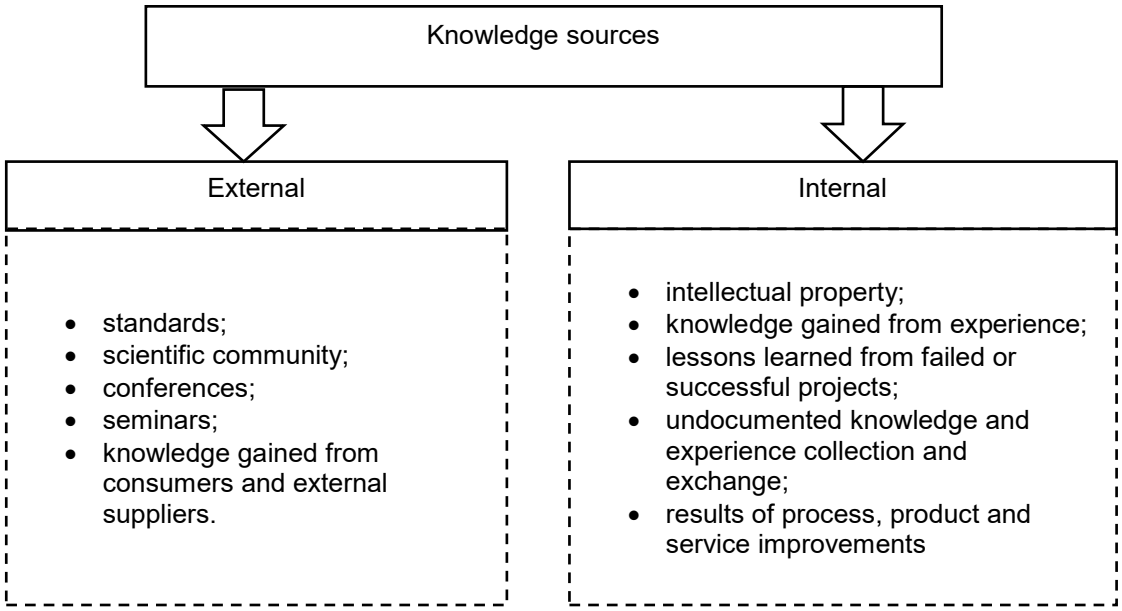

Fig. 1. Knowledge base sources at SPbPU

However, issues of formation and development of the knowledge management system are not sufficiently covered. In this connection, this study topic is relevant.

Using the example of Peter the Great St. Petersburg State Polytechnic University (**SPbPU**), the standard in formation and development of knowledge management was developed and implemented. This standard was developed taking into account the requirements of GOST R ISO 9001-2015 [5] and defines the procedure for the comprehensive use of knowledge and ensuring the effective functioning of the QMS at the university.

The creation and continuous development of knowledge management is necessary to ensure the functioning of the SPbPU QMS processes, to achieve compliance and high quality of products and services.

The maintenance and development of the knowledge management is based on the following requirements and recommendations:

– international organizations in the field of quality assurance and safety;
– Russian norms and standards;
– SPbPU projects;
– the best international and Russian experience and practices in the field of maintaining and developing knowledge management.

The principles of functioning of knowledge management at SPbPU are: creation of new knowledge; search for knowledge; systematization of knowledge; access to knowledge; use of knowledge.

At SPbPU, the knowledge base is formed from external and internal sources (Fig. 1).

Information support is important for knowledge management in accordance with the QMS. The SPbPU has its own website where the information is constantly updated and modern electronic library systems integrated into the electronic information and education system (**EIOS**). The EIOS includes such educational resources and information systems as:

– information and educational project “Open Polytech”, which is a single electronic space in which resources related to educational and research activities are combined;

– employee's personal account, which includes information about the employee, his qualifications, publication activity, implementation of scientific contracts, intellectual property objects, etc.;

– an information and library complex comprising the SPbPU Fundamental Library, the Centre for Information and Library Systems and the Digital Reprography Centre, which in addition to electronic access includes scientific and educational literature departments and library reading rooms that are accessible to the SPbPU employees during working hours in accordance with the schedule;

– the university administrative, scientific and educational divisions Websites;

– the online anti-plagiarism service with access for students and staff.

Information and documents necessary for the SPbPU departments work organisation and for the SPbPU employees' official use are located in the corporate electronic document management system Directum. This system accumulates both local normative acts regulating the university activities as a whole and documents necessary for the employees to perform their immediate functions (orders for business trips, conferences, etc.).

For the design of title pages and presentation materials, the SPbPU Corporate Identity Guide has been developed, access to which is provided on the university website. The manual contains instructions for employees on the correct use of the rules responsible for the visual component of corporate identity.

Information support of work on the QMS is carried out in order to timely provide the management of the organization and interested services with the necessary and sufficient information for the preparation, justification and adoption of rational decisions on quality assurance at all levels of management and stages of development, production and operation; as well as the timely supply of information to the university staff on the results of quality work in order to make everyone active participants in the process of improving the quality of scientific and technical products and educational services.

For the functioning of the information support system for quality work, each unit that processes the information received conducts:

– collection at all stages of development, production and operation of products and services of the necessary quality records;

– collection of information necessary for the preparation of various reports, monitoring the progress of work in the organization, etc.;

– creation of information arrays from the above data;

– definition of performers, their job responsibilities, as well as those responsible for the timely collection, analysis, distribution of information.

SPbPU conducts systematic work to improve the qualifications and competence of employees. To maintain the professional qualifications of employees at the required level, both the accumulated experience of SPbPU and the experience of third-party organizations are used.

The main resoruces supporting the training of SPbPU employees include:

– means for organizing joint work (access to the Internet, group work, means for communications and organization of meetings);

– opportunities for obtaining fundamental knowledge (fundamental library of the university);

– seminars on the study of normative and technical documentation of the work performed and the transfer of experience, organized by the head of the work.

The university monitors the degree of development and effectiveness of knowledge management in the units included in the QMS, and on the basis of this assessment, the necessary recommendations for appropriate actions have been developed.

Thus, using the example of SPbPU, it is shown that the presence in the organization of a knowledge management system in accordance with the QMS, management decision-making is more efficient due to the availability of information support that allows you to rely not only on your own experience and knowledge, but also receive information from outside. The knowledge management system makes it possible to most effectively use various types of information combined in a single information space, which in turn has a positive effect on the company's competitiveness.

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Управление знаниями в системе менеджмента качества на примере университета

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Ключевые слова и фразы: знания; информационные ресурсы; обучение; средства управления знаниями; университет; управление знаниями.

Аннотация. В настоящее время основным ресурсом любой организации, обеспечивающим ее развитие, является человек, его знания, профессиональные качества, компетентность. Управление знаниями является неотъемлемым процессом, приводящим к росту конкурентоспособности организации. Целью статьи является исследование процесса управления знаниями в соответствии с требованиями международных стандартов системы менеджмента качества (**СМК**) ИСО 9001. Гипотеза исследования строится на предположении, что эффективная система управления знаниями в университете позволит получить вузу определенные преимущества в повышении конкурентоспособности в различных областях деятельности. Применяемые методы: системный анализ, синтез, аналогия, обобщение, классификация. Рассмотрены требования, принципы функционирования менеджмента знаний. Показано, что важную роль при управлении знаниями в соответствии с СМК играет информационное обеспечение выполнения работ.

UDK 721.021

Creating Documents in Autodesk Revit Automatically with Dynamo

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Key words and phrases: Dynamo; Revit; node; script; schedules; documentation; create schedules automatically; placement schedules on a sheet automatically.

Abstract. The purpose of the study is the development and implementation of algorithms for the preparation of documentation for the project. The research hypothesis is based on the assumption that automating the process of forming schedules and placing them on sheets will save the designer's time resource. The research methods are analysis, synthesis, and modeling. As a result of the study, the scripts "Automatic creation of schedules with addition filters" and "Automatic placement of schedules on sheets" were developed.

Introduction

Documentation is a mandatory step in the design of an information model of a building or structure. The sheets contain not only drawings illustrating the views of the project, but also explanatory information in a convenient tabular form. For example, schedules can contain information on the volumes of wall materials used, areas and volumes of rooms, data on equipment for ventilation and air conditioning systems.

In a situation where a multi-storey facility contains a huge number of elements, rooms and engineering systems, this procedure takes a lot of time. Each action takes a many click of the mouse, and if you also need to give the sheet a unique name, then the process takes longer. In this regard, you should think about automating such a process.

Description of the algorithms of the developed scripts for automating the documentation process

The authors of the article developed two scripts. The first one allows you to automate the creation of the same type of schedules, and the second one enables to place them on sheets. The Dynamo visual programming environment was used as the development environment [1].

To create schedules on sheets, the following sequence is most often followed:

– creating the necessary schedules;
– creating a sheet of a given format with a specific frame and title;

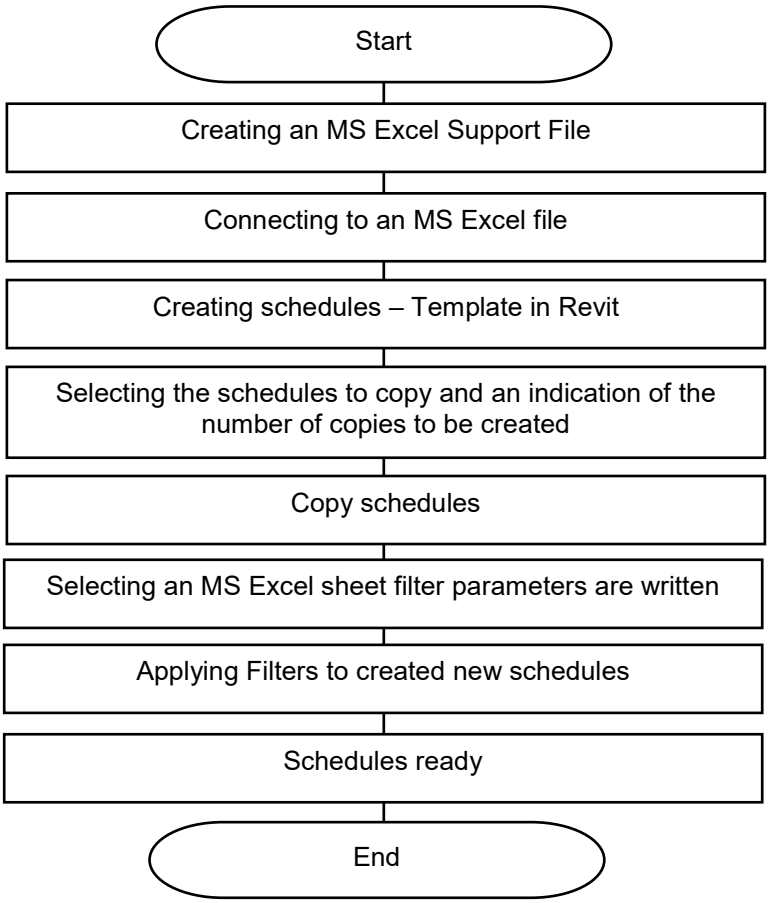


Fig. 1. Script algorithm for automatic generation of schedules

– selecting schedules;

– placing schedules on a sheet in one of the following ways: drag it from the Program Project Manager window or insert a view on a sheet by selecting the desired schedules from the list.

Fig. 1 shows the script algorithm for generating schedules, additionally using an external MS Excel file, which contains the names for new schedules and a list of parameters for filters that filter out only the necessary information.

In our case, the same type of schedules is tabular data on the composition and characteristics of the engineering systems of the building.

For example, if the standard schedules represents one engineering system, and seven systems are developed in the project, then the number of copies should be set to seven.

In the standard Dynamo nodes, there is no ability to copy elements, so this step was implemented by writing code in Python.

In the Autodesk Revit program, the frame, title block and additional columns are a separate independent family. Many design organizations use their own standards, element families, annotations, and this also applies to sheet templates. Therefore, to implement such a task, it is difficult to develop a universal script suitable for everyone, but in the future it can be adapted.

Fig. 2 shows the algorithm of the script “Automatic placement of schedules on sheets”.

The MS Excel auxiliary file in this script is used to store external data: numbers and names of new sheets (Fig. 3).

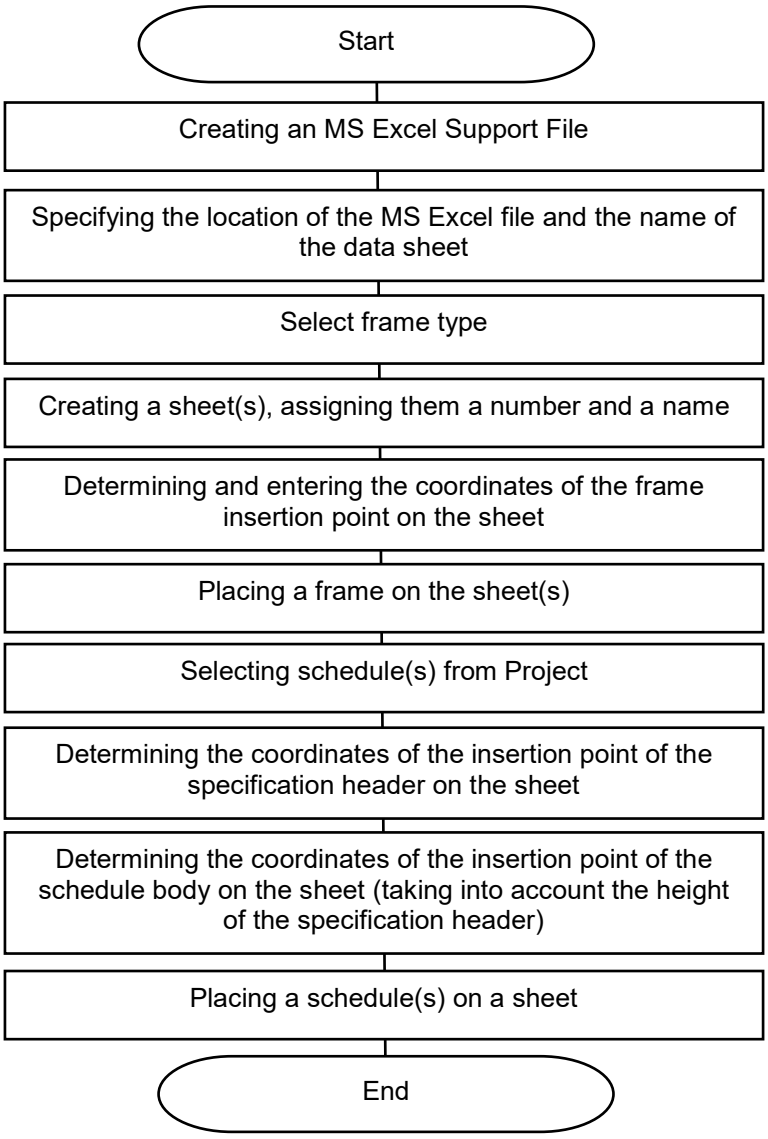
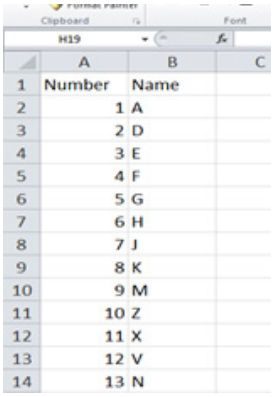


Fig. 2. Script algorithm for placing schedules on sheets



	A	B	C
1	Number	Name	
2	1	A	
3	2	D	
4	3	E	
5	4	F	
6	5	G	
7	6	H	
8	7	J	
9	8	K	
10	9	M	
11	10	Z	
12	11	X	
13	12	V	
14	13	N	

Fig. 3. Data for the script in a MS Excel sheet

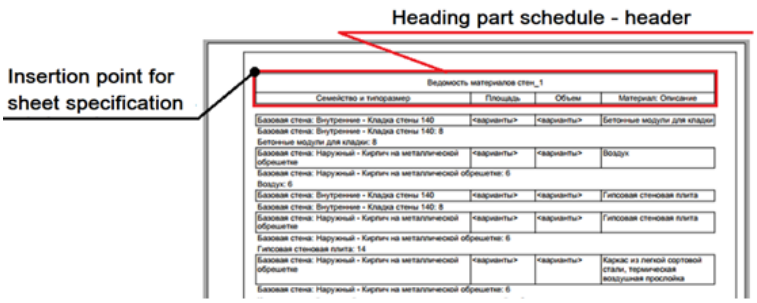


Fig. 4. Schedule elements

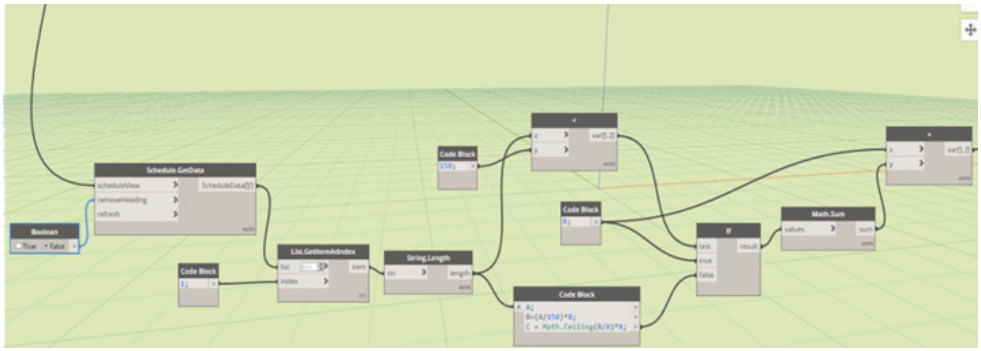


Fig. 5. A fragment of the algorithm for calculating the insertion point of the second schedule

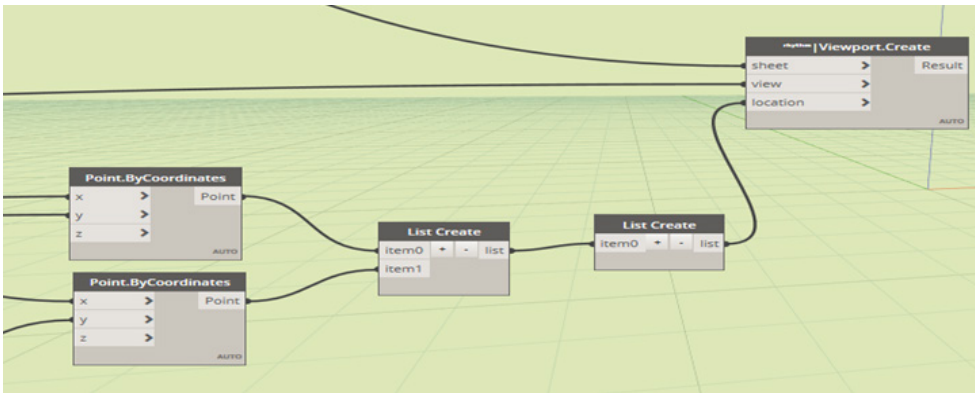


Fig. 6. Placement step on the sheet

Any schedule is a table with a common element of the same type, which is called a header – a heading part (Fig. 4). The insertion point on the sheet will be the upper left point, the coordinates of which must be determined by the engineer by performing a test operation of inserting the header. This feature is due to the fact that there is no unique sheet format and schedules size.

If several schedules were selected for placement, then the second will be placed under the first, and the insertion point will be determined by calculating the height of the first schedule (Fig. 5).

Placement of the schedule on the sheet is performed using the node Viewport.Create (Fig. 6).

As a result of the script execution, sheets are created with a frame, title block, header and content part of the schedule placed on them.

Tips for working with scripts

For the scripts to work correctly, it is necessary to prepare MS Excel files with unique numbers, sheet and schedules names and filter parameters. The specialist in the process of executing the script must himself clearly determine the coordinates of the points of insertion of elements on the sheet, since incorrect values may not lead to the result that would satisfy the task.

For development, the Dynamo environment version 2.0.1 was used, additional packages

"Clockwork for Dynamo 2.x 2.3.0" and "Bimorphnodes 3.0.3" [3; 4].

Conclusion

The originality of the developed scripts lies in the fact that they can be used by any specialist who is faced with the task of designing standard sheets in Autodesk Revit. In this case, only a preparatory step in the project is required, and the remaining parameters are external and are predetermined by the engineer. The tasks that served as the basis for the implementation of the algorithms were selected based on the real experience of the design organization.

One can combine the functionality of these scripts into one, but there are certain nuances: different companies apply their own requirements.

The savings in time are obvious. For example, if a project has seven ventilation systems, and for each system the designer must create twelve specifications, then the total will be eighty-four. You can imagine how much time it takes to create these specs and with a script it can be done in just 10 minutes.

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Автоматическое создание документов в Autodesk Revit с помощью Dynamo

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Ключевые слова и фразы: Dynamo; Revit; автоматизация размещения спецификаций на листе; автоматизация создания спецификаций; документация; нод; скрипт; спецификация.

Аннотация. Целью исследования является разработка и реализация алгоритмов для оформления документации к проекту. Гипотеза исследования: автоматизирование процесса формирования спецификаций и размещения их на листе приведет к экономии временного ресурса проектировщика. Методы исследования: анализ, синтез, моделирование. В результате исследования были разработаны скрипты «Автоматическое создание спецификаций с добавлением фильтров» и «Автоматическое размещение спецификаций на листах».

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