ADDITIVE MANUFACTURING OF SPARE PARTS FOR SPECIAL VEHICLES IN THE OIL AND GAS INDUSTRY

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ABSTRACT

At oil and gas production facilities and other industries, special transport and technological machines of foreign production are often used. One of the tasks of the technical department of organizations is to provide cars with spare parts and consumables. Many spare parts may not be manufactured in a particular country. In this regard, a rather long supply chain of spare parts with a large number of intermediate links is being formed. This increases the delivery time and the already high cost of spare parts. The article proposes a solution to the problems of long terms and cost of supplying spare parts by introducing additive manufacturing technologies for spare parts in organizations that manage the fleet of vehicles.

Keywords: additive technologies, spare parts, special vehicles, stocks, vacuum molding, import substitution, fleet management.

INTRODUCTION

Oil and gas production enterprises operate a large number of special vehicles and special equipment for various purposes. They are involved in the processes of drilling wells, oil and gas production, preparation of production, transportation of resources, repair of oil and gas equipment. More than 90% of all technological operations are carried out using machinery, as a result of which transport and technological services are an important process for ensuring the continuity of the main production.

An analysis of the fleet of vehicles of a large oil producing company made it possible to determine the structure of the fleet and the ratio of domestic and foreign vehicles (Figure-1).

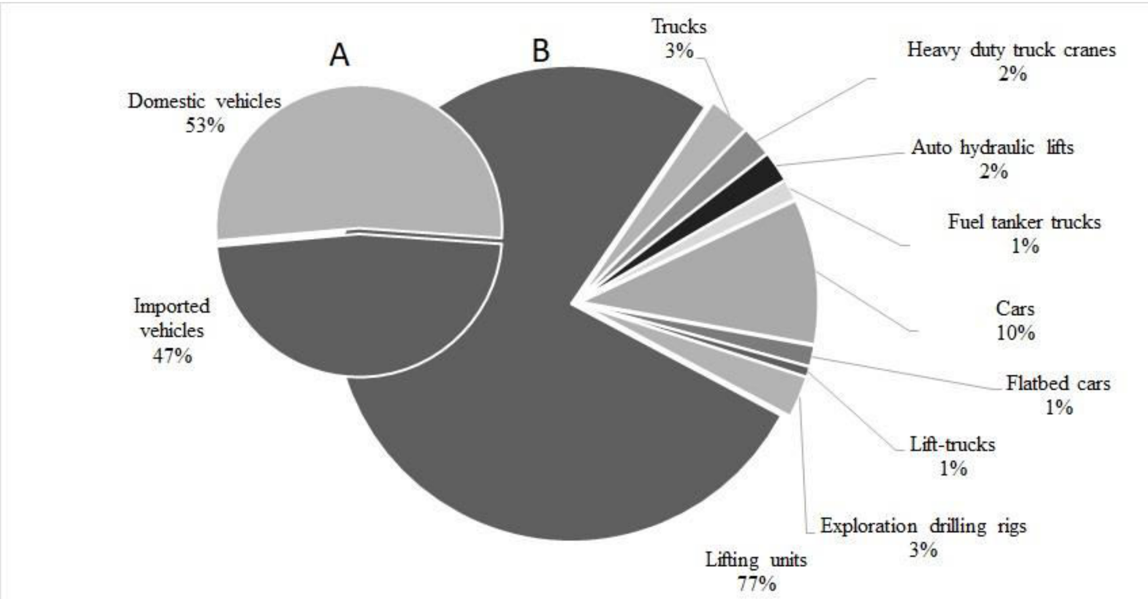

Figure-1. The structure of the fleet of vehicles: A - manufacturer, B - type of foreign-made motor vehicles.

Of the total number of foreign-made vehicles, accounting for 47% of all vehicles in the division, 77% are occupied by lifting units, the main brand of which is Cardwell KB210 (more than 75% of all lifting units). The company also uses lifting units of the HAIHUA and NATIONAL Oil WELL brands.

Many parts for these vehicles may not be produced locally and are shipped directly from the factory. In this case, the supply chain can reach 5-6 links: manufacturer, supplier, carrier, distributor in the customer's country, local supplier, customer [1, 2]. Each of the links increases the final cost of the part [3, 4]. In this regard, an effective way to reduce the cost of the process of providing a car fleet with spare parts can be the manufacture of spare parts with a high share of demand by the organization using additive technologies [5].

Additive technologies or Additive manufacturing are technologies that involve the manufacture of products according to a digital model by adding material layer by layer. The main stages of additive manufacturing are the development of a three-dimensional model of a part, its manufacture by 3D printing, post-processing, mold making, polyurethane vacuum casting and obtaining the finished product [6]. Despite a few downsides [7] such methods have a number of advantages over traditional manufacturing methods, such as rapid prototyping and production of the part, production flexibility, and lower tooling costs for scaling up production by liquid polymer casting [8]. Additive technologies are currently applied in various fields, for example, for the manufacture of automotive components [9, 10] or in the aerospace sector [11, 12]. Automotive engineering is a vast field for the application of additive technologies [13]. Many transport organizations have workshops for the manufacture of rubber products. They can be converted to use the proposed technologies [14]. This can facilitate the adoption of additive manufacturing (AM) in an organization [15]. This will allow organizations to reduce dependence on foreign suppliers, as well as significantly reduce the cost of the part without compromising its quality [16, 17].

Thus, the aim of the study is to increase the efficiency of the transport and technological service for oil and gas production through the introduction of additive manufacturing of spare parts for imported cars and, on this basis, to reduce the supply chains of spare parts and dependence on manufacturers.

MATERIAL AND METHODS

The work used ABC / XYZ methods for analyzing consumption and forecasting the demand for rubber and plastic spare parts, methods for statistical analysis of data on the consumption of spare parts and determining the distribution of time between failures of vehicle parts. In the course of the study, the method of vacuum casting with liquid two-component cold-hardening polyurethanes was tested. This method was used to produce coolant pump spline coupler adapters that were subjected to torsional torque testing. The method of economic calculation of production for the maintenance and repair of lifting units in the organization served as the basis for the formation of recommendations for the transport departments of oil and gas producing organizations.

THEORY AND CALCULATION

In an automobile enterprise, additive manufacturing technologies can be used primarily for the production of rubber and plastic spare parts. To determine the share of these spare parts from those that limit the reliability of lifting units, an assessment of their consumption was carried out using the ABC XYZ analysis [18].

Rubber and plastic spare parts for lifting units, which can be produced by additive manufacturing, account for 16.78% of the total share of demand (Table-1).

Table-1. ABC, XYZ distribution of rubber and plastic spare parts.

No	Name	Share in consumption, %	Costs per year, rub.	Total weight per year, kg.	Groups
1	Gasket	12.6	1 601 662.3	485.5	AZ
2	Seal	3.5	1 963 669.5	133.5	AZ
3	Membrane	0.4	1 032 379.5	24.7	BZ
4	Hydraulic accumulator cylinder	0.3	2 901 419.8	31.1	BZ
5	Splined pump coupling	0.05	24 506.4	0.7	CZ
6	Fuel filter bowl	0.04	63 254.1	5.5	CZ
-	Sum	16.8	7 586 891.6	681.0	-

An analysis of the characteristics of demand using the XYZ distribution method showed that the considered list of spare parts for production is included in group Z, which is defined as a group with the lowest accuracy in forecasting consumption. The consumption of spare parts for 10 years for each item is characterized by uneven demand. The AZ group (positions 1.2) is characterized by low predictability and high consumption volumes, and the BZ group (positions 3.4) is characterized by medium consumption volumes. The attempt to guarantee the availability of all items in these groups by over-insurance of spare parts funds results in a significant increase in the average stock of funds. The CZ group (positions 5,6) is characterized by low predictability and unstable demand, the number of spare parts from this group must be constantly monitored, since illiquid and hard-to-sell stocks arise from it, due to which the company incurs losses [19].

Further, the mean time between failures (MTBF) for these parts was determined [20]. The time between failures of these spare parts has an exponential distribution, which is typical for sudden failures of many non-recoverable elements, which include plastic and rubber products (Figure-2).

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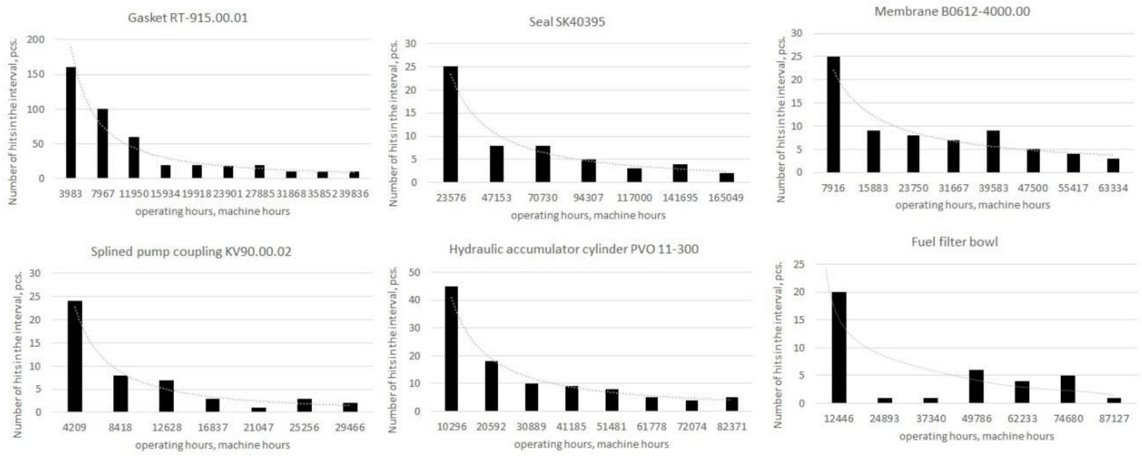

Figure-2. Distribution of time between failures of plastic and rubber spare parts of lifting units.

The mean time between failures of individual elements varies from 7089 machine hours for the KV90.00.02 spline pump coupling to 42000 machine hours for the RT-915.00.01 gasket [21, 22].

The technological process of casting with liquid two-component cold-hardening polyurethanes, optimized using vacuum casting, consists of ten main technological operations: 1 - printing a master model; 2 - formwork printing; 3 - fixing the model in the formwork; 4 - mixing cast silicone using a mixer and a degasser; 5 - pouring silicone; 6 - mold extraction; 7 - determination of the volume or weight of the manufactured part; 8 - mixing cast polyurethane; 9 - pouring polyurethane into the mold; 10 - receipt of the finished part.

These operations are shown in Figure-3.

Figure-3. Technology for manufacturing samples by 3D printing and polymer injection.

As a result of experimental studies, it was revealed that the physical indicators of the products obtained by this method are not inferior to factory analogues. The tests were carried out with polymer-cast adapters for the KV90.00.02 pump spline coupling installed in the coolant pump drive system of the lifting units. The coupling serves to dampen the pump drive system, cutting off shock loads that occur during start-up. The coupling connects the electric motor and the pump drive system through adapters, which were tested to

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simulate the twisting moments that occur in the pump drive system. The essence of the test is to rigidly fix one part of the adapter to a fixed surface, while a torque wrench is attached to the other part, which measures the moment of resistance to twisting. Figure 4 shows an experimental setup consisting of a platform, movable and fixed adapter elements, a torque wrench, and a deviation scale in degrees.

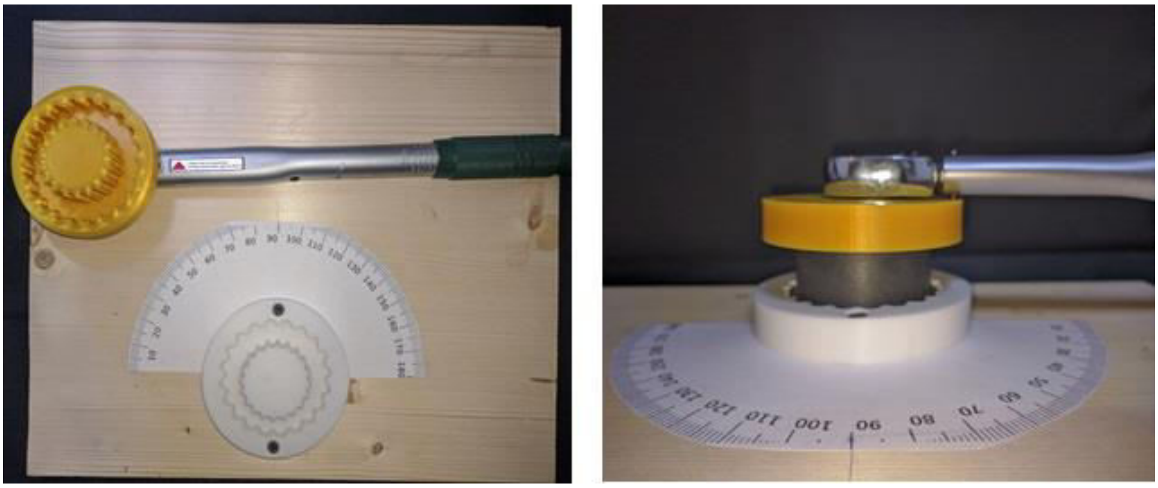

Figure-4. Scheme for testing a sample obtained by 3D printing and polymer casting.

For testing, six samples are made with different hardness polyurethane Polidel 30, Polidel 60 and Polidel 90. The hardness of the product from 30 to 90 on the Shore A scale can be achieved by mixing types of polyurethane in calculated proportions. The measured values during the test are entered in the table, after which they are interpreted as fractions of the elasticity deviation from the reference sample. The sample with the smallest deviation value is considered closest to the reference sample. The experimental technique can be used to determine the type of starting material for the additive manufacturing of parts in the conditions of a motor transport organization.

RESULTS AND DISCUSSIONS

The economic calculations carried out made it possible to determine the feasibility of introducing additive manufacturing technology into one of the production units of an oil and gas producing company (Figure-5).

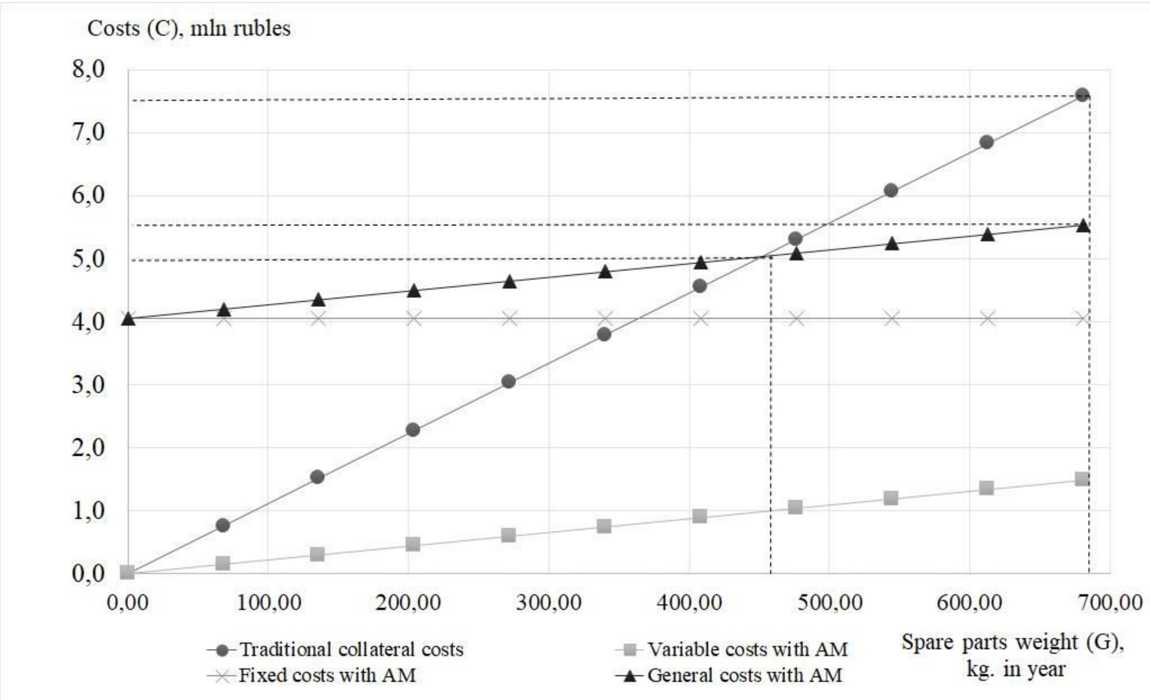

Figure-5. Determination of the break-even point for the introduction of additive manufacturing technology for spare parts for the motor transport division.

The average annual cost of providing the organization with 681 kg of spare parts from the above list is 7.6 million rubles. When using the additive manufacturing site of the same volume of these parts, the average annual costs will decrease by 2 million rubles and amount to 5.6 million rubles. In this case, the point of critical production of spare parts corresponds to 453 kg. A further increase in the volume of additive manufacturing will bring an economic effect in the form of a reduction in the cost of the system for providing vehicles with spare parts relative to the traditional method. The feasibility of introducing an additive manufacturing site equipped with an FDM printer, a vacuum injection molding machine, a 3D scanner, a heating cabinet, a degasser, a personal computer and places for preparing and storing materials is the higher, the larger the fleet of lifting units the organization has. The plot pays off with a fleet of 60 units or more.

CONCLUSIONS

Thus, as a result of the theoretical and experimental studies, the following tasks were solved:

- a list of spare parts for production using additive technologies has been defined,
- the method of 3D printing and injection molding was tested, the physical characteristics of the manufactured part were determined,
- practical recommendations were developed for a motor transport enterprise on the introduction of additive manufacturing.

It should be noted that additive manufacturing has a number of advantages in the management of an organization. It will make it possible to manufacture spare parts independently, to ensure the import substitution of expensive products. It will also significantly reduce the existing supply chains and reduce the cost of providing equipment with spare parts by up to 30% without losing the quality of using the fleet of vehicles.

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