https://doi.org/10.26160/2474-5901-2023-34-76-81

INCREASING THE RELIABILITY OF FOOD PUMPS

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Keywords: food pumps, wear, failure, seals, wearing, reliability.
Abstract. The article discusses the ways to improve the reliability of food pumps, contact and non-contact pumps, as well as early signs of their failure. Two most possible types of wear mechanism are considered while evaluating the reliability, which occurs at the points of surface contact of the working bodies with the pumped medium and associated parts. A friction pair cage - single-screw pump is considered as an example.

ПОВЫШЕНИЕ НАДЕЖНОСТИ ПИЩЕВЫХ НАСОСОВ

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Ключевые слова: пищевые насосы, износ, отказ, уплотнения, изнашивание, надежность.
Аннотация. В статье рассматриваются пути повышения надежности насосов для пищевых продуктов, контактные и бесконтактные насосы, а также ранние признаки их отказа. При оценке надежности рассматриваются два наиболее возможных вида механизма износа, контактирующих поверхностей рабочих органов с перекачиваемой средой и сопряженных деталей. В качестве примера рассмотрена пара трения обойма – винт одновинтового насоса.

In the modern world, there are a huge number of different types and scales of production. In addition to those that are usually associated with the word “industry” (engineering, energy, and metallurgy), there are also smaller-scale industries that also have processes and apparatus, equipment and control systems. The food industry is characterized by special requirements for the operation of equipment, because this literally concerns each of us, since the reliability of this equipment also ensures the safety of products.

In the process of production, increasing importance is given to improving the technology of transportation of raw materials and finished products. Pressure transportation is carried out by pumps, which must have a design of a flow part and working bodies, providing the necessary parameters for transporting the product (supply and pressure) and not destroying the structure of some products such as kefir, yogurt, sour cream, and such easily destructible inclusions as berries, pieces fruits, etc.

The main aim of our research regarding the pump reliability is to find ways to obtain the greatest reliability of the results and, on their basis, to develop recommendations necessary for pump design and selection.

The accumulated experience shows that the study of the mechanism of forming failure patterns of pumps and pumping, in particular, non-Newtonian liquids with solid inclusions, makes it possible to approach an acceptable probability of estimating the duration of their serviceability in given parametric indicators.

While evaluating the reliability, two most possible types of wear mechanism are considered, which occurs at the points of surface contacts of the working bodies with the pumped medium and associated parts. First, microdestruction of the surface of the part and the particle itself occurs when a solid particle of the pumped product hits the solid surfaces of the flow path. Thus, smaller particles appear in this way, which instantly turn on the movement, fill the smaller pores of the parts and increase the effect of destruction. In this case, solid particles come into dry shock contact with the surfaces of the flow path. It destroys the surface film. A zone is formed that is unprotected from chemical attack. This contributes to the violation of the integrity of the surface. There is a more intensive mechanochemical process of reducing the strength of the material.

The second type of wear, which can occur simultaneously with the first one, consists in the fact that at certain points, especially in places where the liquid film breaks, the surface layers are intensely heated and soften the less hard material in the boundary layers. Often this leads to adhesion of solids from the pumped product. Then the softened particle, together with the solid inclusion, is torn off by the flow and carried away. This, based on the results of observations, is noted by a number of authors [1-3]. The described picture is shown especially fully here.

As an example, we can consider a friction pair of a holder – a screw of a single-screw pump. The wear rate of working mating surfaces can be quantified as follows. If we assume that the elementary section of the cage, a cone inclined to the axis of rotation of the rotor, then the wear rate can be described by the following equation [4]

$$v_{wear}=f\cdot k\cdot e\cdot (p\cdot v)n,$$

f – complex coefficient of friction, taking into account the lubricity of the pumped medium and the content of solids in it, f = 0,05 ÷ 1,0;

k – constant characterizing distribution of irregularities in height, which is associated with the topography of the friction surface;

e – a value that characterizes the mechanical and chemical properties of the material of the part and the change in their parameters under the influence of temperature;

p – pressure on the contact surface;

v – relative sliding speed of friction pairs;

n – indicator that depends on the phase of wear. If no wear occurs during running-in, then n = 1. With normal wear n = 1.2 ÷ 1.8 and with catastrophic wear n = 1.8 ÷ 2.4.

The rate of wear is largely influenced by the mode of operation of the pump. Here three modes can be distinguished: calculated, gentle and forced. Figure 1 shows how the wear rate v_{wear} changes when the pump is operating in different modes.

The graph is based on the results of processing materials from tests of a disk pump on a mixture of water and sand in different ratios: from 1 to 15% sand by volume, published in [5] and processed according to the method of Professor A.S. Pronikova. It is taken into consideration that the forced mode can cause phenomena that are not typical for the design mode and qualitatively change the pattern of failures.

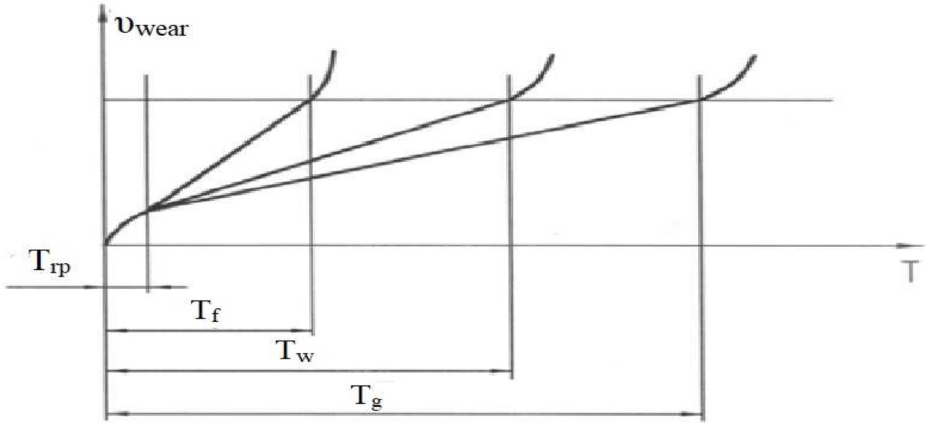

Fig. 1. Wear rate v_{wear} during pump operation in various modes: T_{rp} – run-in period, T_w – duration of the estimated workable period, T_q – duration of the workable period in a gentle mode of operation, T_f – the duration of the workable period in the forced mode

Simple engineering logic, confirmed by practice, prompts us to assign parameters, select materials for parts and determine their places in the structure so that the pump operates in a mode shifted to a gentle one. For example, a shift to a gentle mode is ensured by the design of the shaft seal assembly with flushing or a hydraulic seal, as it makes it possible to exclude the operation of sealing rings in the dry friction mode. Separation of the seal assembly from the hot liquid and the use of a cooling barrier reduce the load from the thermal field.

Numerous publications make it possible to identify the factors that most strongly affect the wear rate of the surfaces of the flow path. These factors include the following: the speed of the impeller, its shape, the wear resistance of the material from which it is made, the properties of the pumped medium, the volume content of solids, their size, the shape of the outlet, pressure as well as operating mode.

Food pumps can be divided into contact and non-contact pumps. The first are rotary pumps, in which the moment on the driven working body is transmitted directly to the master. These pumps include the following: gear, one - and three-screw. Non-contact pumps are bladed, disk, twin-screw, rotary, in which synchronizing gears are built.

Operating experience and failure analysis with an acceptable approximation allows the pump elements to be ranked according to decreasing failure rates as follows:

– elastic impeller type rotor;
– casing of a single-screw pump;
– omental stuffing;
– swivel joints in a single-screw pump;
– sliding bearing;
– mechanical seal bellows;

– mechanical seals.

In food production, liquids are used in a wide range of viscosities: from Newtonian to pseudoplastic and dilatant ones. The more viscous the product, the higher the pressure in the same path and the greater the power consumption (Figure 2).

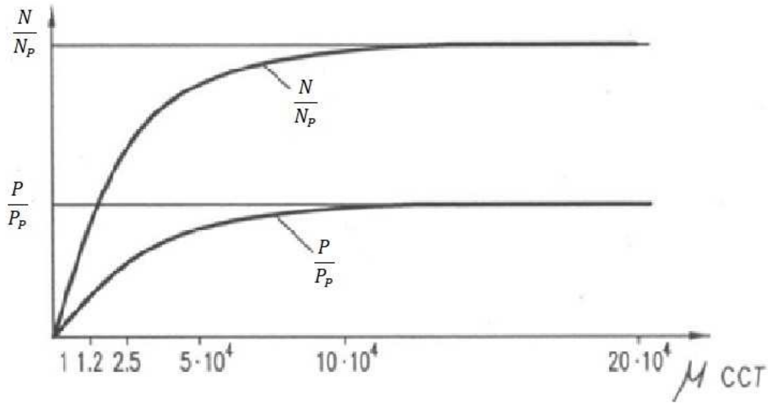

Fig. 2. Dependence of pressure and power on the viscosity of the product

Pumps are estimated on water. Its engines in terms of power are often selected without taking into account the influence of viscosity. This is justified by the fact that calculations for a specific medium sharply narrow the comparison base and scope, and as a result, a large uncertainty is created when selecting a pump. But when assigning to specific conditions, it is necessary to take into consideration and calculate the pumps, taking into account both the viscosity and the density of the pumped medium, because it is already an area of reliability, so the danger of going into forced operation can affect the technical condition of the pump.

The technical condition can be judged by the boundary values of the output parameters, which determine its suitability and performance. For example, these values include a drop in pressure, an increase in temperature, or an increase in current or power consumption. But at the same time, a change in viscosity can occur during the working process and it is determined by the technological regulations of production. All this must be taken into account when selecting a pump and assessing its condition [5].

But there are some clear and unambiguous early signs of failure. This is the acceleration of seal wear and the appearance of leakage. It also includes overheating of bearings, the appearance of products of destruction of the material of the flow path in the pumped medium as well as changes in vibroacoustic characteristics.

Early recognition of signs of failure is of great importance for the economics of production. This avoids the replacement of the entire pump and reduces the amount of repairs. The losses associated with the replacement of the pump are the sum of the cost of the replacement pump, the residual value of the replaced pump, the cost of repair and restoration work, and the loss of the volume of unreleased products that remained in all sections of the tract and they cannot be used.

Pumps are machines that are characterized by a wide range of operating modes and operating conditions. Therefore, the definition of reliability cannot be limited to testing on a test bench. This is only the first source of information. The second source is predictive calculations of a possible change in the output parameters of the pump during operation. We can use the methods of physical and statistical modeling of wear processes, for example, the ones used in machine tool building. To do this, along with statistical data on the results of testing and operation, information is needed on the patterns of aging processes of materials, on the conditions for using pumps and the level of their maintenance and condition monitoring.

The third source should be the focus of both developers and users. This is the response of the system where the pump is installed and the influence of its operating conditions. The systems and operating conditions are very diverse. Thus, the wider the range of data, the more clearly it is possible to establish the permissible and rational scope of pumps of specific types and sizes. In addition, the database of data on the serviceability and reliability of pumps, replenished in this way, makes it possible to analyze designs, which serves as the source material for improving and creating pumps of a higher level. Hence, wider research is needed to systematize the early signs of failures [6].

A purposeful search for reserves to improve the reliability of pumps is of paramount importance. This is the direct and most economical way to reduce operating costs.

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Received 16.02.2023