

Optimization of hydraulic systems of industrial productions of microbiological means for protection of plants

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The purpose. To develop approaches to optimization of hydraulic systems of industrial productions of microbiological means for protection of plants in order to increase their power efficiency. **Methods.** Analytical and synthetic. **Results.** Functional link between hydraulic losses and power inputs on transportation of technological liquids is specified. Available approaches to optimization of hydraulic systems on the basis of analysis of methods of decrease of hydraulic resistance are considered. New approach to optimization of hydraulic systems of bioproductions on the basis of ordering the structure of flow is offered. **Conclusions.** The expediency of optimization of hydraulic systems of bioproductions on the basis of decrease of water resistance is positioned. New approach to such optimization is developed. It increases power efficiency of liquids' transportation processes.

Key words: *optimization, bioproduction, power efficiency, hydraulic system, decrease of water resistance.*

Hydraulic and aerodynamic systems are the integral part of various microbial fermentation manufacturing plants in pharmacy, food, biotechnology industry. Biofactories of microbial pesticides production for plant protection are not exception. Engineering facilities of such factories are including different hydraulic, aeration-agitation and pneumatic systems.

Complication of the systems, as a rule, takes place in tandem with increasing of manufacturing volume. However energy usage for liquids and gases transmission in microbial pesticides production is not as high as for sterilization or fermentation processes. Furthermore, in comparison with the equipment complexity for fluid medium preparation, sterilization and microorganism cultivation, the liquids transmission problem is not so significant or technically challenge [1]. In our opinion the design of biofactories hydraulic systems is downplayed by reason of such an attitude.

Standard approach to the design of microbial manufacturing plants' hydraulic systems is based on the concept of met needs in process requirements and saving in materials. But it is not enough for designing of energy efficiency hydraulic systems by now. Already-existing systems projected on this base are functioning with high consumption of electric energy.

Reason identification of energy consumption increasing of biological manufacturing plants hydraulic systems and development of their optimization methods are relevant research tasks for today.

The purpose. The development of the approach to microbial fermentation manufacturing plants hydraulic systems' optimization with the purpose of energy efficiency improvement.

Methods. Analytical research method and information synthesis were applied. Hydraulic systems' design concept of biomanufacturing plants was analyzed. Standard techniques of hydraulic calculations were investigated. The functional connection between pressure drop and electric energy consumption in fluid pumping process in the microbial pesticides production was examined. The existing methods of head losses (energy losses) reduction in hydraulic resistances were analyzed. New approach to the hydraulic systems optimization of biofactories, producing microbial pesticides for plant protection was generated.

Results. On the base of the analysis was discovered that design concept and organization of hydraulic systems in biopesticides production factories was not differ greatly from ones applying in pharmacology, chemical or food industry [1-5]. However due to the engineering complexity the primary focus was on technology basic processes, so detailed description of secondary system designing was neglected in literature sources. The principles of biofactories hydraulic systems design and calculation, for example, of

ten are printed in shorthand form and contain references to the calculation methodology from other literary sources.

The analysis of standard techniques, used for calculations of microbial fermentation manufacturing plants hydraulic systems [2, 3], indicated that the base of designing decision making was “optimum velocity”. It is recognized that maintaining “optimum” value of velocity leads to selection of economically feasible diameter of pipes, fittings and valves. The main thrust of the economic feasibility was economizing on materials. In order to get such economizing, pipe diameters and fittings were reduced by applying of “optimum velocity” increase.

Downside of such approach is increasing of the system’s hydraulic resistance. It is worth to remark that hydraulic resistance for engineering system is proportional to velocity squared. Consequently, “optimum velocity” high value fixing leads to artificial increasing of head losses. That is why pumps head must be increased the same as pumps power. Thereby energy consumption of pumping is often set too high.

There is derivation of functional dependency between head loss and electric energy consumption for transmission of liquids on the base of hydraulic calculation standard techniques [6]. Energy consumption of pumping is calculated as a product of pump power and elapsed time [2, 4, 5]:

$$E = N \cdot \tau, \quad (1)$$

E – electric energy consumption of transmission of liquids, kWh;

N – pump power (pump input), kW;

τ – elapsed time, h.

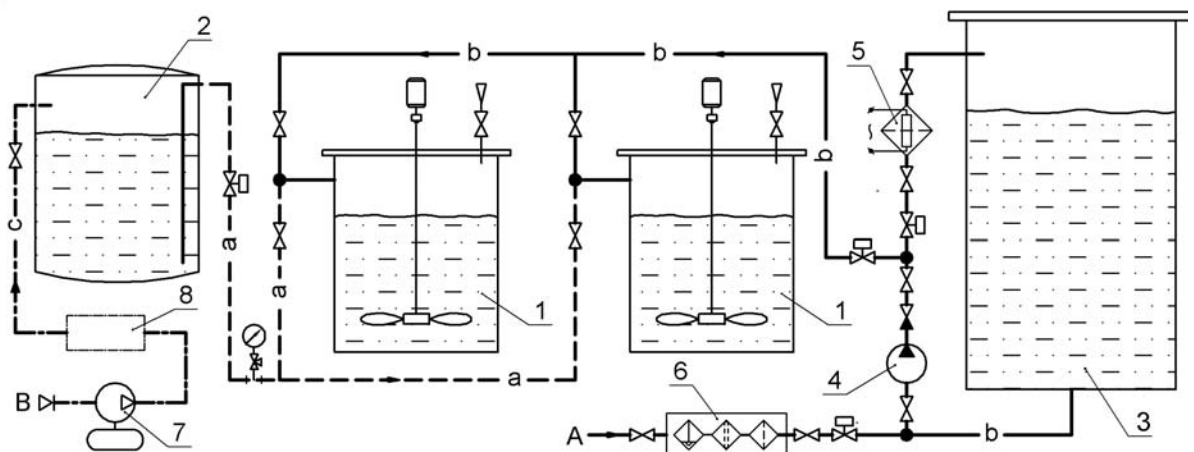
Pump input N defined by pump hydraulic power (pump output). It is calculated as a product of capacity and total head at the pump operating point.

$$N = 3,6 \cdot H \cdot Q \cdot \rho \cdot g / \eta, \quad (2)$$

H, Q, η – pump parameters: total head, mH₂O, capacity, m³/h, and efficiency at the pump operating point;

ρ, g – liquid density, kg/m³, and gravitational acceleration, m/sec².

Hydraulic systems foundation of transmission of liquids at biofactories of microbial pesticides production is not run continuously as a rule. The batch fermentation method is often used for microbial pesticides production [1, 5], so hydraulic systems’ usage in particular has periodic nature. Typically pumps are turned on for fixed time. The transmission of liquid from one apparatus to the other is taking place at the same interval (fig. 1) [5].



- 1 – thin-wall fermenter; 2 – steam sterilizer; 3 – tank for treated and sterilized water;
 4 – pump; 5 – flowing water sterilizer; 6 – water filtration system; 7 – air compressor;
 8 – air filtration system; a – concentrated fluid medium; b – water; c – compressed air;
 A – waterline inlet; B – air inlet

Fig. 1. The scheme of hydraulic systems used in small-scale production of

Pump capacity can be submitted for periodic process in a form of liquid volume transmitted at the time interval of pump work.

$$Q = V / \tau, \quad (3)$$

де Q – pump capacity, m³/sec;
 V – liquid volume, m³;
– pumping time interval, sec.

Pump head H can be defined on base of head losses h_w calculation [6]. As is well known head losses are caused by hydraulic resistance to flow. In engineering calculations pump head exceeds value of head losses by not more than 5-10 %, so $H \approx h_w$.

Let's rewrite equations (1), taking the above, into account:

$$E = 3,6 \cdot h_w \cdot V \cdot \rho \cdot g / \eta, \quad (4)$$

The equation (4) shows the fact that electric energy consumption of transmission of liquid, concentrated fluid medium or water for example (fig. 1), E is determined by head losses in hydraulic resistances h_w . Therefore artificial increasing of head losses h_w , described above, is inevitably resulted in electric energy consumption increasing E – parameter inversely related to energy efficiency. In summary it can be said that biofactories systems' energy efficiency improvement (or energy consumption decreasing) can be obtained by hydraulic resistance reduction.

It should be noted that the great part of head losses in hydraulic systems of biofactories are accounted for local resistances (pipe fittings, valves etc.). Local losses are attended by formation of stagnation zones and eddy. These hydrodynamic phenomena are the most undesirable for systems of transmission of fluid medium (fig. 1). Liquid substrates usually are suspensions by nature. So flow velocity drop in local hydraulic resistances leads to setting-out of substrates' insoluble components that can stay inside stagnation zones. Such precipitates availability complicates pipeline system's cleaning and sterilization processing significantly. Therefore hydraulic system's resistance reduction by means of fittings and valves (local losses) modernization leads to additory simplification of cleaning processing and cut the likelihood of fluid medium microbial contamination.

In practice the hydraulic systems optimization based on hydraulic resistance reduction is realized seldom. Generally such optimization is caused by specific process requirements (devices capacity increasing, noise generation exclusion under transfer by pumping) rather than necessity of pump energy consumption decreasing. That is why there are no specific optimization techniques, oriented to complex hydraulic system resistance reduction. Instead of this there are many methods of hydraulic resistance reduction that were worked out for specific devices placed in specific systems. Generalization of this practical experience on the one hand and specific techniques adaptation to biofactories hydraulic systems on the other should provide the creation of new approach to design of the effective hydraulic systems.

The methods' analysis of head losses reduction in hydraulic resistances [6-10] allows combining them within the confines of several problem solving approaches:

- energy approach;
- structural approach.

The first one describes processes inside hydraulic resistances through the prism of energy redistribution between transit flow and vortices [6]. It is based on Navier-Stokes mathematical model of flow. Lack of attention to flow pattern inside hydraulic resistance is the main detriment of energy approach. In fact there are energy parameters such as inlet and outlet velocities and pressures quite enough for the flow description (black box concept). Standard methods based on the energy approach anticipate relative roughness of the resistance' walls decreasing, surfactants usage for friction reduction, channelizing devices applying, substitution of one flow into several parallel flows, etc. [6]. Among non-standard methods should be noted ones based on turbulent effects features usage and on directional waves creation in fluid flow [7, 8].

The second approach based on flow pattern analyzes. Flow structure characterizes mass exchange inside hydraulic resistance [11]. Structural approach is found on flow pattern optical visualization [12, 13]. Comparison complexity of flow pattern with its energy parameters is the main difficulty of the approach. Thereby inlet and outlet pressures and velocities are determined in standard way. Structural approach based methods provide flow passage correction in order to avoid flow separation. Several of them use adjusting of flow passage to the form of free fluid flow or eddy zones substitution by solid elements [9, 10].

Both described approaches were developed with the aim of individual elements optimizing but not the whole system. Due to this the new approach for optimization of hydraulic systems of microbial fermentation manufacturing plants should be developed. Latest researches, that were carried out in Engineering and Technological Institute "Biotechnica" NAAS, can be taken as a basis of such approach. These researches were aimed at finding the conditions of creating and maintaining separation-free flow in hydraulic systems of biofactories.

According to new approach hydraulic system elements should be considered as factor of influence into flow structure. There is currently considered that valves and fittings flow passage configuration act on fluid flow as structure forming factor and the action is out-of-control. The elements of flow pattern such as slipstreams, vortices that moving apart from the main stream and in different manner (rotate for example) arise in this case. Preservation of one type of movement for the whole volume of liquid, using flow swirling along the passage axis, should allow configuring uniform stream. In such manner adverse conditions for separation flows forming that are the main cause of head loss in system will be created.

The optimization method of hydraulic system of microbial pesticides production biofactories based on new approach provides creation and maintaining of necessary flow pattern by using of special devices inserting into different places in system. Such devices have flow-through structure and have no electric drive that makes optimization process easy. The result of such system improvement is considerably reduction of electric energy consumption of pumping (under 15...50 % as per calculation). Energy efficiency of transmission of liquids increases as well.

Conclusions

Hydraulic and aerodynamic systems constructing is downplayed in the microbial fermentation manufacturing plants designing process. This leads to construction of low energy efficiency systems. The analysis indicates that energy consumption of transmission of liquids and gases has significant magnitude in consequence of high head losses in hydraulic resistances. Therefore hydraulic systems optimization based on head losses reduction is one of energy efficiency improvement ways applicable for biofactories of microbial pesticides production for plant protection.

The new approach to the hydraulic system optimization based on flow structure streamlining that allows reduction of energy consumption of pumping is suggested. In contrast to other approaches it is offered not to overcome natural turbulent phenomena connected with energy losses but to avoid of their inception, creating and maintaining definite flow pattern in system. The optimization method of biofactories hydraulic systems' developed on the base of this approach allows essentially energy efficiency improvement of transmission of liquids.

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