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RATIONALISATION OF UKRAINIAN INDUSTRIAL ENTERPRISES IN A CONTEXT OF USING TORQUE FLOW PUMPS ON THE BASIS OF VALUATION OF THE LIFE CYCLE OF PUMPING EQUIPMENT

Annotation. *The article is devoted to the justification of economi efficiency of using torque flow pumps for industrial enterprises of Ukraine on the basis of life-cycle assessment of pumping equipment*

Keywords: *torque flow pumps, pumps, pumping equipment, technological process*

Introduction.

During continuous and repeated service, very high requirements are imposed on the pumps designed for various sectors of national economy, including coal mining, metallurgical complex, power industry, pulp and paper industry and food industry relative to efficiency, suction capacity and reliability.

In addition to general industrial equipment, specialized equipment is required when handling considerable volumes of concentrated hydraulic liquids and taking into account the wide range of goods for transportation systems [1].

To this effect, it is necessary to search for new types of pumps. Torque flow pumps refer to such types of pumps. Their design feature enables to apply them for pumping hydraulic liquids with less probability of fluid path clogging. At the same time si nificant hydraulic losses at the pump inlet and, as a result, the appearance of cavitation practically do not change the basic parameters.

The availability of a free chamber before the exposed impeller with radial blades, at the flow of which the cavity pocket is closed after the blade or in a free chamber, reduces the probability of failure of the pump fluid path due to abrasion or cavitation erosion.

Problems of increasing economic, energy and operational process efficiency while reducing overall costs per unit of output are considered in the specialized literature extensively.

However, today such studies often focus on getting short-term economic benefits through the implementation of high advanced technology in the production process as a whole, but not small modernization of its individual components and o which receives much less attention.

It is very important to develop and manufacture the pumps for various industries, including pumping of sanitary sewage and waste waters, transportation of loosened coal and peat to thermal power plants, pulp in the systems of ash and slag handling at thermal power plants, papermaking pulps at pulp and paper plants, as well as various suspensions at sugar refineries and starch and treacle factories. The concept of pumping equipment

development in Ukraine and the suggestions of the cust ide for the reduction of pump sizes number. Therefore the task of pump range extension is based on the development of the standard series of torque flow pumps of modular design. This solution presupposes the interchangeability of pump parts and makes it possible to reduce the name of pump spare parts, as well as ensures efficiency and ease of maintenance. Besides, torque flow pump with impeller located in the cylindrical bore of the rear wall of the casing have a longer service life than common centrifugal pump.

Statement of the problem.

The aim of this study is to justification the feasibility of using torque flow pumps in processes of industrial enterprises of Ukraine by assessing the life cycle cost of pumping equipment.

Results.

Results of researches [2,3,4,5] of torque flow pumps give a reason to believe that they can be used during the development of new pump schemes designed for hand ling abrasive hydraulic liquids with high suction capacity. However, the necessity to solve this problem requires substantiation.

When selecting the pumps, a lot of attention shall be to the definition of total life cycle cost (LCC) as one of the most important indicators of economic efficiency of pumping equipment [6].

Pump life cycle cost includes a complete value of pumping equipment for the entire period of operation, including purchasing, mounting, maintenance, repair and dismounting costs for the pumping unit. The main objective of life cycle analysis consists not in the purchasing of necessary equipment at the lower price, but in the usage of reliable and efficient equipment with minimal costs for maintenance.

The life cycle cost is based on the pump design service life be inning from the date of purchase to complete its disposal and according to the European Association of Pump Manufacturers (Europump) comprises the following costs (1):

$$LCC = Cic + Cin + Ce + Co + Cm + Cs + Cenv + Cd \quad (1)$$

where LCC - life cycle cost;

Cic - investment costs (price of pumping equipment purchasing);

Cin - installation costs (installation and commissioning costs);

Ce - energy costs;

C0 - operation costs (labour payment expenses during the normal operation of pumping equipment);

Cm - maintenance costs (maintenance and repair costs);

C_s - down time costs (loss of production due to equipment downtime);

Cenv - environmental costs (costs for environmental protection measures);

Cd- decommissioning costs (including costs for the decommission and disposal of equipment).

First of all it is necessary to identify and analyze the variable costs of each proposed option the pump which will continue to lie on the unit cost of output. After that it is necessary to determine static and dynamic expenditures, to which special attention shall be paid, as they are crucial for the efficient and continuous operation of the pump. The main analysis objective is to acquire reliable and energy-efficient equipment, which will provide the minimum expenses during its whole service life.

The Figure l shows classical structure of the life cycle costs for a medium-sized pumping unit, which enables to analyze the pump operation in process lines of industrial enterprises.

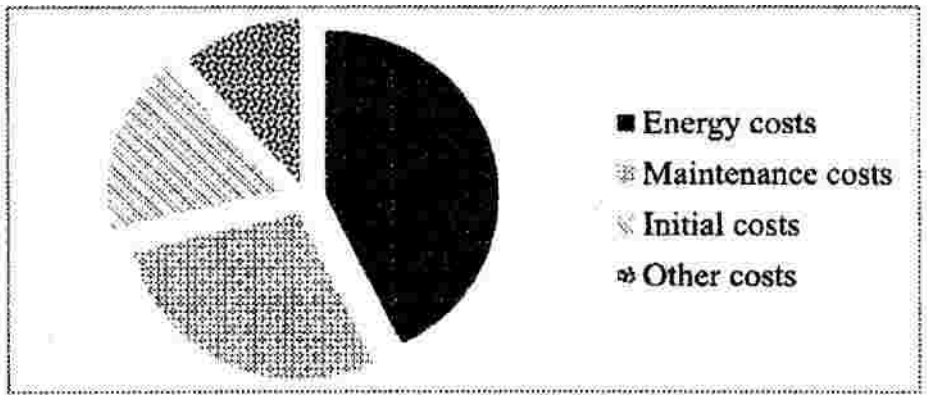

Figure 1 - Classical model Life Cycle Costs for a Medium-Sized Industrial Pump

Usually only such factor as equipment initial cost (sometimes installation costs also shall be taken into account) is used for the feasibility study or payback period evaluation. However it is ignored that this price comprises only a part of the total amount of expenditures borne by the customer beginning from the date of pumping equipment hase to the moment of its disposal, and this costs include electric power consumption costs, expenses for maintenance and r, etc.

The reduction of life cycle cost determines major development trends at the pump market with specific directions of its updating.

The first direction is the reduction of energy consumption:

- upgrading of the pumps and pumping systems efficiency;
- manufacture of pumps designed directly for the customer;
- application of more efficient motors;

- extensive use of devices for optimizing the pump operation, for example, by means of changing the rotational speed of the motor shaft.

The second direction is the reduction of costs for maintenance and repair (service maintenance, running repairs and staff expenses):

- minimization of the human factor impact on the equipment operation;
- extensive use of devices for control and adjustment of the pumps during the operation along with the systems of early diagnostics and malfunctions prevention;
- minimization of maintenance and resource costs for equipment operation throughout the life cycle;
- minimization of time and staff qualification during the pumps repair (usage of a modular design, which presupposes the interchangeability of pump parts, a small range of spare parts, repair profitability and serviceability).

The volume of electric power and materials, which are used for the pumping unit, depends on the pump series, unit type and operation method. It should be noted that the above factors are absolutely interdependent. Besides, they shall be accurately selected to ensure during its operation the lowest power consumption, operation costs, etc. The initial purchase price of the pump is a small part of the life cycle cost of widely used pumps.

When operating the pumps designed for handling pure liquids or liquids of low-level contamination during the life cycle cost analysis, all attention shall be focused on the first direction of costs reduction. However, under complicated conditions when pumping hydraulic liquids and viscous or gas-saturated liquids, the costs for maintenance, spare parts, unscheduled downtime, recovery of the fluid path as a result of wear and tear, loss of efficiency and elimination of the seal failures of the pump will make up an essential part of the life cycle cost, prevailing over investment and current operating costs.

Thus, the pumps of different constructions are used in the technological hydraulic transport systems of hydraulic mines, coal-preparation plants and sections in the coal industry, including hydraulic transport of flotation tailings and stowing materials. The second direction of life cycle cost analysis shall be applied namely for these pumps, which are complicated in operation, but at the same time the possibility of energy consumption reduction shall not be excluded. The service life and reliability of the pumps operation in such conditions are the most important technical and economic factors.

The majority of pumping units operate with centrifugal pumps, the principle of which is in the force interaction of impeller blades with the liquid flowing in the intervane channels. In this case, the destruction of the fluid path is inevitable, and, consequently, the decrease of the pump performance and the increase of energy consumption can be observed. Thus, during operation the pumping equipment, which is more efficient at the time of purchase, can be found inefficient and less reliable than its prototype.

When analyzing LCC of a new pump or its upgraded design, the consumers should consider various alternatives to evaluate the pumping equipment and the associated opportunity costs (lost profits). The cost of electricity for the tire service life and the rep air costs will prevail in the LCC for the most part of enterprises. Therefore, it is very important to determine accurately the current cost of electricity, the expected annual price growth during the expected useful life, the expected cost of spare parts and salaries of service personnel. Other components,

such as losses due to idle time, costs for environmental protection measures, equipment dismantling and disposal, usually are evaluated based on the experience available at the Company. Depending on the technological procedure, losses due to equipment idle time can exceed costs for electricity and repair. As a result, is necessary to assess losses due to downtime accurately.

Pumping of hydraulic fluids by centrifugal pumps is accompanied by an increase in hydraulic losses in the impeller. Besides, the pump input in the wide range of *flows* increases and the pump suction capacity impairs, as well as pump capacity, head and total efficiency decreases.

When pumping hydraulic fluids, the replacement of centrifugal pumps by torque flow pumps takes the priority. And a flat change of the head/capacity curve of torque flow pumps allows controlling the pump capacity at a constant head value.

Torque flow pumps have a simple and convenient service design, high reliability and service life when working with hydraulic fluids, that their economic efficiency for hydraulic transportation of different solids and products. This is possible due to the availability of the free chamber before the impeller that reduces t bability of the pump clogging. And the passage of only part of the liquid through the impeller reduces wear of its elements.

Unlike standard centrifugal pumps, in torque flow pumps only the portion of hydraulic fluid is directed to the intervane channels and a seco portion passes through the free chamber without interaction with impeller blades. The specific design feature of torque flow pumps is the placement of semi-open impeller in the cylindrical bore in the rear wall of the casing, whereby a free chamber is formed between the end face and front of the causing. Only 15 to 20% of the pumped liquid goes through the impeller, therefore the impeller receives the increased by 1.5 to 2 times working lifetime in comparison with the centrifugal pump impeller. The design of hydraulic passages ensures a complete balance of the radial forces acting on the shaft through the impeller and that is why the shaft works almost without vibration.

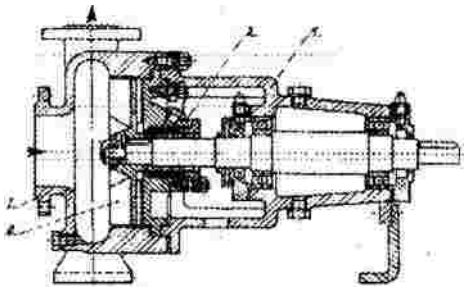

Figure 2 - Torque Flow Pump Design

This protects both the components of the hydraulic fluid from the effects of the impeller and the impeller from the effects of the hydraulic fluid. The construction of

the torque flow pumps with specific hydraulic passages is the most effective among the variety of the pumps designed for handling hydraulic fluids.

For example, torque flow pumps are effectively used for pumping liquids with solids, fibrous and viscous masses, as well as for hydraulic transportation of fluids with great number of abrasive inclusions [7]. The availability of a free chamber in torque flow pumps allows pumping of hydraulic fluids with inclusions of different sizes depending on the pump size.

Pumps, operating at the Companies engaged in the coal, metallurgy, cement, mining and chemical industries, as well as energy industries, handle hydraulic fluids with abrasive ability, determined by the properties of the solid component. The total amount of mineral impurities in the slime is relatively high and amounts to 10 to 40% [8].

While handling hydraulic fluids and suspensions with volume concentration of solids up to 70% [9], torque flow pump is not clogged and is not stopped. Liquids containing abrasive particles are pumped with minimal wear of the hydraulic passages. You can find below the impellers of centrifugal pumps and torque flow pumps (in the center) after pumping abrasive hydraulic fluids [10] in the lime department of sugar refineries.

Torque flow pumps ensure high reliability of operation when pumping liquid-gas mixtures containing up to 50% of air (gas). Bubbles in liquid do not block the inlet to the impeller and due to the availability of a free chamber and wide passages in the impeller it is possible to prevent cavitation.

In comparison with the pumps of another series, the lifecycle cost of torque flow pumps can be assessed by the following advantages:

1. Capital expenditure. As regards the expenses for purchase, the pumps shall be compared only according to the purchasing cost. During the pump life-cycle this cost becomes insignificant in comparison with other expenses that occur when using the pumps for hydraulic transportation of liquids, complicated for pumping.

2. Spare parts for the pump. Indispensable precondition for the efficient pump operation is the necessity for the pump spare parts. The cost of maintenance spare parts is not more than 2% of the total value of torque flow pumps, supplied to the Company. Therein lies an additional difference from the majority of other pumps, for which, there is a need to store spare parts for repair.

3. Service life. The specific construction of torque flow pumps ensures balancing of radial forces acting on the shaft through the impeller. Reaction forces, occurring in the shaft bearings, are insignificant and the shaft works almost without vibration. Tear and wear of impeller surfaces practically do not affect the required dynamic load rating of the bearings. All this ensures long-term service life of the pump components.

4. Maintenance and wear. The specific shape of the hydraulic passage sharply reduces wear of the hydraulic passage elements when pumping hydraulic liquids and it is less disposed towards clogging. The construction of torque flow pumps is easy maintainable.

In slurry pumps, the parts directly contacting hydraulic fluids are subjected to hydro-abrasive wear. These parts include impeller, pump inle nd outlet, casing wear ring, as

well as pump shaft seal. The absence of the front seal in torque flow pumps eliminates the reason of its wear, and the fundamental difference of flow pumps from the centrifugal pumps favors less wear of the impeller when pumping abras ve hydraulic fluids.

5. Reliability and operation continuity. The advantage of torque flow pumps is the duration of continuous operation and pump reliability. This is the most important in terms of the pump operation, when any of its simple idles may cause stoppage in production. In such cases, the financial losses in case of the pump breakage can be large compared to the pump cost and operating charges. When pumping hydraulic fluids, torque flow pumps surpass centrifugal pumps in terms of reliability.

6. During service, torque flow pumps do not require a lot of time for their repair. Besides, the effect of the human factor is minimized during the maintenance of motor pump units with torque flow pumps,

7. The comparative study of total expenditures (Figure 3) for different pump types when pumping liquids with a high concentration of abrasive particles, suspensions, containing great amount of solids, as well as fibrous inclusions points out the benefits and expediency of torque flow pumps operation.

The diagram shows probable operating charges for the first year of the pump service,

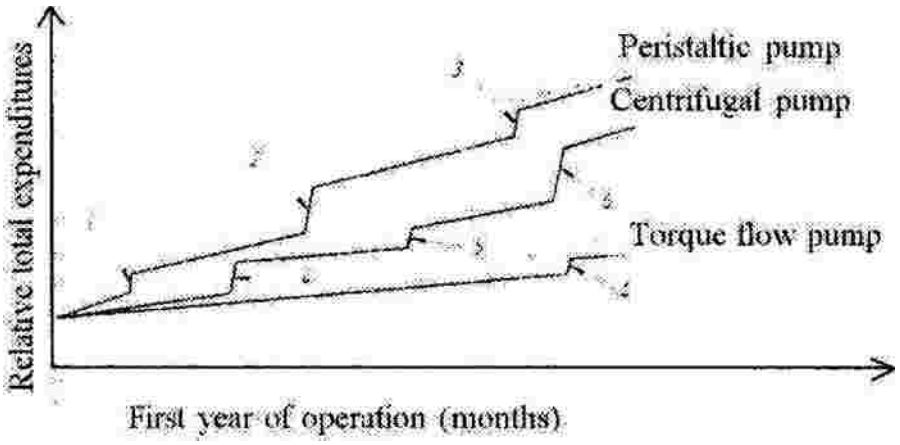

Figure 3 - Diagram of Total Expenditures When Operating the Pumps Of Different Types

which include the following:

1) pump clogging, that causes pump stoppage and requires further repairs;
2) the stator and rotor replacement;
3) wear and replacement of the shaft seal;
4) seal wear due to radial forces;
5) clogging of the pump with its subsequent halt and repair;
6) impeller replacement.

Conclusions.

Analysis of the life cycle components of the pumping equipment and main trends in development of the pump market with specific tendencies of its improvement allow to determine the advantages in the usage of torque flow pumps. Torque flow pumps are more profitable in comparison with centrifugal pumps when pumping liquids with high concentration of solids, as well as hydraulic fluids w a high content of abrasive solids, liquids with high viscosity and high content of air or gas.

Torque flow pumps have been used instead of centrifugal pumps ? H-270 for pumping anthracitic slurry at the Production Company «Torczantratsit» [11]. The replacement of dredging centrifugal pumps by torque flow pumps in the ash handling system at LenGRES-8 power plant made it possible to reduce the number of repairs approximately by 2 times. It was found out, that the service life of the torque flow pumps was 2 to 3 times higher than of the dredging centrifugal pumps. The application of torque flow dredging pumps made it possible to reduce the metal costs for the parts replacement approximately by 3 times in comparison with centrifugal pumps [12]. Taking into consideration better economic performances, the torque flow pumps have the advantage for a package arrangement of ball cleaning system o steam turbine condensers at the thermal power plants [13]. When pumping mud suspensions and lime milk, the torque flow pumps have more advantages than centrifugal pumps [14].

At the industrial enterprises the advantage of torque flow pumps application is achieved by the reduction of operating costs. Easy-to-install and serviceable motor pump units with torque flow pumps make it possible to minimize the cost of operating expenses during the life cycle, which is important for the Customer in the current economic realities of the industrial market.

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