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OPTIMIZATION OF DREDGE AND VARIABLE DISPLACEMENT PUMPS

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Nonproductive expenditures of electric energy occur at pumping stations with variable operating regimes owing to the fact that with a decrease of water consumption the head increases, whereas the network resistance, conversely, decreases, as a consequence of which the head exceeds the required values by 10-40% for the greater part of the day [1, 2, 3]. This leads not only to an overconsumption of energy but also worsens the operating conditions of the network with the shut-off regulating equipment being overloaded by the excess head in regimes with a reduced water delivery of the pumping stations, which in turn leads to a decrease of the operating life of the system and to an increase in the consumption of metal for its construction and maintenance.

At present the problem of reducing this type of nonproductive energy expenditure is being solved either by changing the number of operating pumps according to the time of day (stepped control) or by a gradual change of their "head--delivery" characteristic by changing the rotative speed of the shaft of each pump and its impeller by means of an additional unit connecting the motor shaft with the pump shaft.

Neither of these methods eliminates nonproductive energy expenditures. Nonproductive expenditures can be eliminated only in the case of creating such designs of centrifugal pumps for which the "head--delivery" characteristic can be varied gradually (in a number of cases without a strict relation between the delivery and head) and in a wide range not only without reducing the efficiency but also at a constant relative speed of the impeller, which will make it possible to use the most simple and reliable types of electrical drive operating without a decrease of efficiency when the operating regimes of the pumps are changed.

Only in the presence of such pumps is it possible to operate a system with varying regimes of delivery of the fluid (water, oil, etc.) without nonproductive energy expenditures – due to a synchronous relation of the varying characteristics of the simultaneously operating pumps and network. In this case the centrifugal pumps should provide the delivery needed by the consumer and should develop a head which is needed for overcoming the resistances in the network and for delivering the fluid to a height.

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In the case of stepped control the head developed by the pumps during the greater part of the day exceeds that required, and at the time of changing the number of operating pumps, moreover, the unsteadiness of the flow regime in the pipelines intensifies.

In the case of a gradual variation of the rotative speed of the pump impeller by means of hydraulic or electromagnetic clutches coupling the pump shaft with the electric motor shaft the nonproductive energy expenditures are reduced substantially, especially in the pump, but not due to an increase of its efficiency but due to providing a more complete correspondence with respect to hours of the day between the required head in the system and that being developed by the pump. Since in this case there occur additional losses of power in the converting clutches, being machines equivalent in power to the pumps and operating in succession with them, the resultant machine efficiency of the entire system with clutches (product of the efficiencies of the electric motor, clutch, and pump) will always be substantially less than that without clutches. Moreover, the greater the range of variation of the rotative speed of the pump impeller, which one must strive for, the lower the efficiency of the clutches, which is inversely proportional to the rate of adjusting the rotative speed of the pump shaft, and, consequently, the lower will be the efficiency of the entire system. The indicated governors, including also electrical frequency converters whose cost, as a rule, is considerably higher than the cost of pumps, will substantially increase also the capital expenditures on equipment of the pumping stations.

The optimal solution is regulation of the head and delivery by changing the dimensions of the main operating elements of the pump by gradual variation of the outlet diameter of the impeller, or gradual variation of the width of the passages in the impeller and discharge pipe, or simultaneously by changing in certain combinations both the outlet diameter of the impeller and width of the impeller passages and discharge pipe. In this case a synchronous relation will be provided between the pumps and the system of water lines regardless of the hydraulic characteristics of the network. If in this case the efficiency of the pump is preserved and it does not drop in regulating regimes, then the saving in electric energy can amount to 10-20%.

There are a number of suggestions aimed at improving the energy indices of the reversible units of pumped-storage stations and solving the problem of increasing the head of the machine precisely by increasing the diameter of the impeller of the machine during its operation in a pump regime [4]. In this case the outlet diameter of the impeller is increased either by introducing additional vanes continuing the main vanes into the impeller passage through a slot in the upper rim having a larger diameter than the lower rim, or by 180° swept-back vane tips. In these designs the size of the impeller diameter is changed only in a nonoperating state of the machine and not gradually but stepwise with the change in the length of the vanes, which makes these designs unacceptable for pumps; for reversible machines the shortcoming of these designs is determined by the absence of a synchronous relation be-

Fig. 1. Centrifugal pump with an adjustable head.