

Increase of economy of torque flow pump with high specific speed

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Abstract. Torque flow pumps are widely spread types of energy machines, which are used in majority of modern branches of industry for pumping of dirty media. The main task of researchers of torque flow pumps is increase of such pumps effectiveness for higher feed. Hydraulic losses for torque flow pumps are caused by working process of such pumps and are inevitable. Decrease of losses can be obtained by means of optimization of hydraulic flow part geometry.

Modern approach to design of pump outlet introduces new constructive solutions which can increase economy of torque flow pumps.

The aim of this research is increase of economy of torque flow pumps by means of application of spatial outlet and investigation of its geometry on pump characteristics.

Analytical and numerical methods of liquid flow research for hydraulic flow part of torque flow pump were used in this paper. Moreover, influence of hydraulic flow part geometry of different designs of “Turo” type torque flow pumps outlets on pump characteristics was investigated. Numerical research enabled to study process of energy transfer of torque flow pump and evaluate influence of geometrical dimensions of spatial spiral outlet on its characteristics. Besides numerical research confirmed introduced regularity of peripheral velocity distribution in outlet. Velocity moment distribution in outlet was obtained during implementation of numerical research.

Implemented bench tests of torque flow pump prototypes enabled to obtain real characteristics of pump and confirm effectiveness of spatial geometry of outlet application for such pump.

1. Introduction

Torque flow pumps are priority types of pump equipment, which are used in majority of branches of industry for pumping of dirty media.

Opposed to centrifugal pumps, which not always can pump liquids with big solid inclusions, nowadays torque flow pumps are widely used in technological processes of particular production types, such pumps are progressive pumping equipment [1, 2].

Range of optimum values of specific speed for “Turo” type torque flow pumps is well-known and overrun leads to efficiency decrease. Majority of torque flow pumps has maximum energy



effectiveness for the range of specific speed values $n_s=60\text{--}140$. Pump operation out of this range is not economically reasonable. However, nowadays non clogging torque flow pumps operating at high specific speed $n_s>140$ are of great necessity [3, 4].

Experimental material of paper [5] shows that torque flow pump outlet takes part not only in energy transfer process, but simultaneously with impeller forms vortex liquid flow, which is major part in energy transfer process of such pump.

Analysis of earlier researches [6] showed that specific speed and efficiency of torque flow pump are determined by outlet geometry for optimum geometry of impeller. Thereby criterion of achievement of maximum value of efficiency for torque flow pump with high specific speed value turns into optimization of outlet geometry by means of decrease of hydraulic losses.

Taking into account experience of centrifugal pumps designing, expansion of torque flow pump parameters range can be reached by outlet geometry modification. First attempt in this direction was implemented by E. Egger [7] during creation of “Turo” type torque flow pump outlet with internal axial spiral. Side channel in pump body is made in such way that it provides faster medium flow from suction pipe to discharge pipe. However such constructive solution of outlet greatly influences on flow and leads to increase of hydraulic shock losses.

Tests implemented by the author [8] concerning influence of outlet on torque flow pump characteristics showed that its form (annular or spiral) insignificantly influences on pump parameters. However these results differ from experimentally obtained data [9], according to which efficiency of torque flow pump with spiral outlet is 1.5% higher than for pump with annular outlet.

In the paper [4] technical solution was proposed for significant decreasing of metal quantity for torque flow pump and improvement of its characteristics keeping values of other parameters. However the author mentions that considered results can't be stable for “Turo” type torque flow pumps which have different parameters.

For increase of specific speed of torque flow pumps [10] it was proposed to turn into two-stream scheme of liquid flow in pump. Such constructive solution allows moving optimum operation mode of pump to area of higher feed, but significantly complicates its design and consequently pump price.

For creation of torque flow pump with high specific speed authors of the paper [3] decided to modify impeller and outlet design. As a result they proposed “Turo” type torque flow pump outlet elongated in axial direction (“screw-shaped”) [11]. However, implemented tests of pump prototype didn't show desired results, because efficiency was too low.

Probing of flow in free chamber of torque flow pump [12] allowed to obtain flow pattern in pump with real velocity distribution. Liquid flow was unsteady. Flow coming from impeller partially is directed backwards to pump inlet and partially to outlet. And meridian velocity in pump has maximum value near impeller decreasing when approaching to outlet side opposite to impeller (Figure 1 (a)).

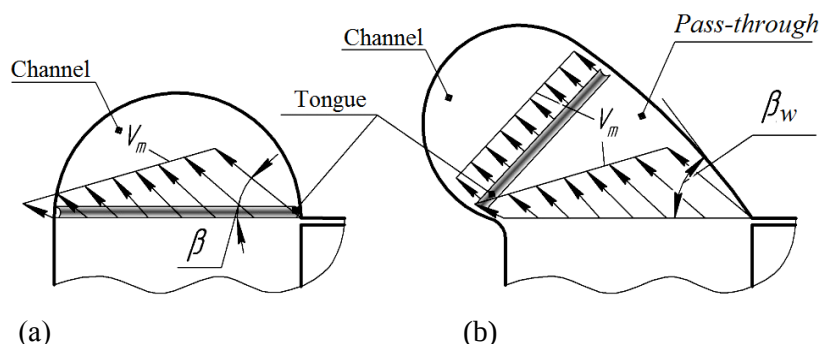


Figure 1. Meridian velocity distribution in free chamber of torque flow pump: (a) annular outlet; (b) spatial spiral outlet.

Obtained meridian velocity distribution leads to increase of hydraulic shock losses because of unconformity of inflow angle and angle of outlet wall setting, especially for torque flow pump with

high specific speed value. For decrease of these losses it was proposed to configure outlet wall in such way that it provided free liquid flow. Thereby geometry of outlet should be designed for provision of steady distribution of velocity at outlet entrance.

As a result new design of torque flow pump body [13] with spatial spiral outlet was obtained (Figure 1 (b)). For exclusion forming of stagnant vortex area at outlet, angle of wall, conjugated with pump body β_w , must be close to angle of meridian velocity of flow β . In such case steady distribution of velocity at outlet entrance provides minimum losses and absence of detached flow in its channel.

2. Influence of outlet form on liquid flow forming in hydraulic flow part of torque flow pump

Complex process of energy transfer and turbulent character of liquid flow do not allow identifying optimum design of torque flow pump outlet by means of experiment. However modern numerical methods of research allow to determine influence of outlet design on liquid flow structure forming in free chamber of torque flow pump [14], and indicate optimum design of outlet for pumps with high specific speed $n_s > 140$.

Existing methods of hydraulic flow part design calculation for “Turo” type torque flow pumps were approved for range of specific speed values $n_s = 60\text{--}140$ [15], therefore investigated designs of pumps were determined for range of n_s with maximum effectiveness – $n_s = 100$.

Pump designs with different types of outlets were chosen for research, these types of outlets were used earlier or proposed for the first time: with annular No.A, spiral No.B, double-volute spiral No.C, spatial No.D, chamber-free No.E and with reverse spatial spiral No.F (Figure 2)

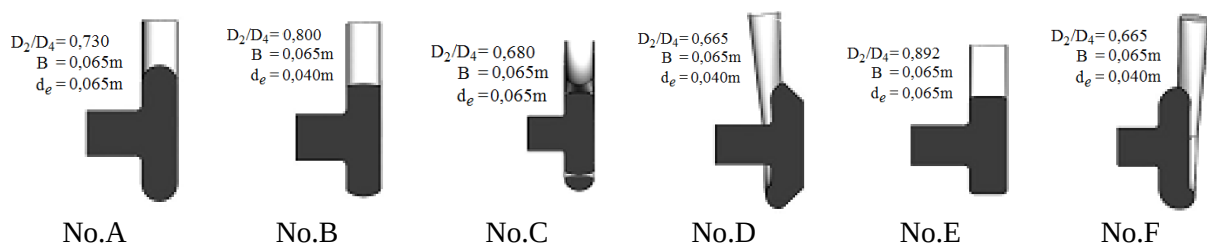


Figure 2. Configuration of investigated outlets of torque flow pump.

Application of spatial spiral outlet (No.D) for torque flow pump allowed increasing pump efficiency in operative mode of feed, where its maximum value is 56% (Figure 3). Satisfactory results showed pump with spiral outlet (No.B), its efficiency value for rated mode is 52 %. Concerning pumps with double-volute spiral, chamber-free and reverse spatial outlets (No.C, E and F), efficiency is in the level of 46%, which indicates their ineffectiveness.

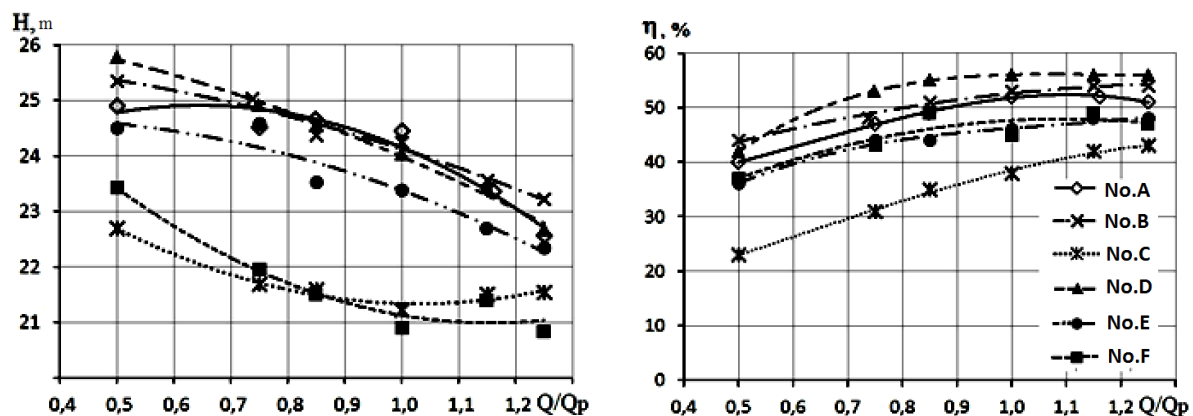


Figure 3. Characteristics of torque flow pump with different types of outlets.

Level of efficiency for investigated outlets is caused by level of hydraulic losses. The lowest value of hydraulic losses was obtained for pump with spatial spiral outlet No.D (Figure 4). It should be mentioned that curve of losses for pump with outlet No.D is almost linear. There is no optimum value on the curve of hydraulic losses for investigated range of pump feed values.

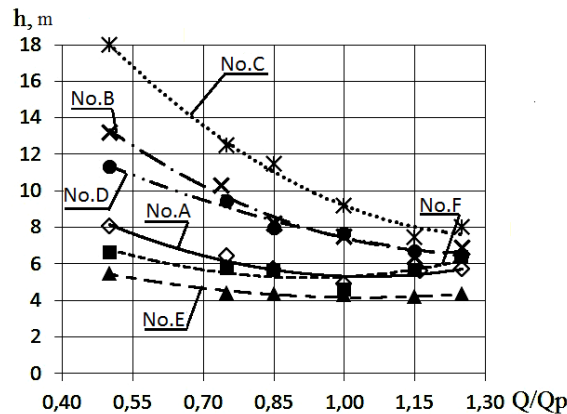


Figure 4. Hydraulic losses h for torque flow pumps with different types of outlets.

Analysis of velocity moment distribution patterns (Figure 5) showed, that for design of torque flow pump with spatial spiral outlet No.D more steady velocity moment distribution is observed, it is presented in concentric circles and very close to the law $V_u \cdot r = \text{const}$. Presence of local areas of velocity moment increase and its unsteady distribution is typical for other designs of outlets.

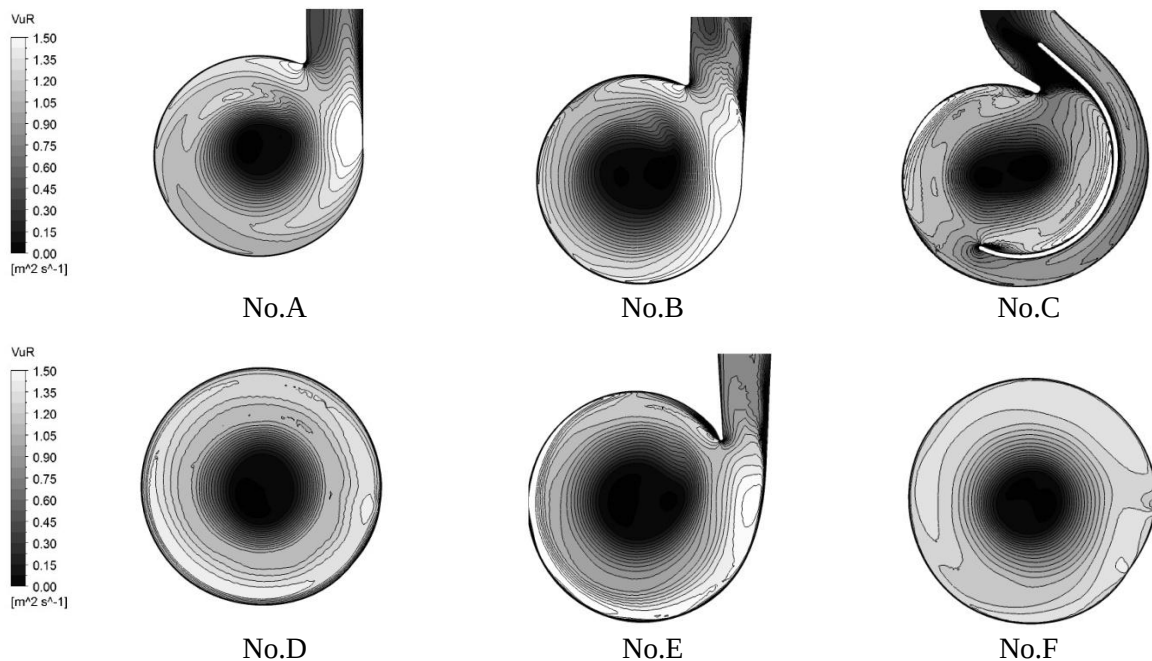


Figure 5. Isoprofiles of velocity moment distribution in middle section of free chamber of torque flow pump with different outlets.

Given results of numerical research showed that torque flow pumps with spatial outlet No.D have more steady flow structure and pressure distribution in free chamber and consequently advanced energy indexes.

3. Research of spatial outlet geometry influence on characteristics of torque flow pump with high specific speed ($n_s > 140$)

As is known [15], outlet geometry greatly influences on torque flow pump parameters. Modelling of liquid flow in torque flow pump with spatial spiral outlet was implemented for research of this issue.

Influence of outlet design section area on torque flow pump parameters was investigated, this area changed for constant width of free chamber B (Figure 6a). Increase of relative design section area ε

from 0.23 to 0.57 ($\varepsilon = \frac{S_e}{S_2} = \frac{1}{D_2} \cdot \left(\frac{4F_c}{\pi} \right)^{1/2}$, where F_c - area of outlet design section) leads to decrease of pump efficiency from 55 to 42%, in this case head of pump decreases by 18%, but specific speed of torque flow pump increases from 100 to 180. Obtained results confirm conclusions of papers [5, 16] about the fact that value of exit section area of outlet significantly influences on torque flow pump parameters.

When relative width of free chamber of pump changes in the range $\bar{B}_0 = B / B_2 = 0.29 - 0.4$ (D_2 – impeller diameter) pump head increases by 5 % (Figure 6 (b)).

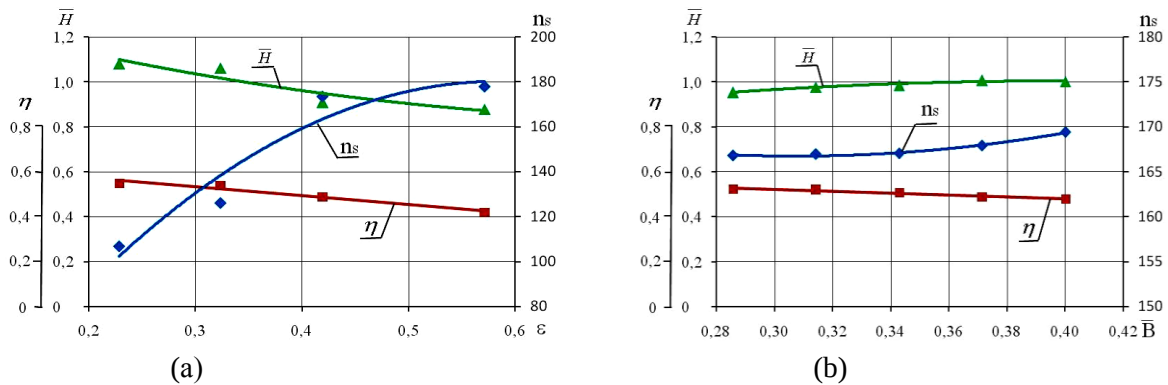


Figure 6. Relation of optimum parameters of torque flow pump: (a) depending on relative area of exit section with ε ; (b) depending on relative width of free chamber $\bar{B}$ ($\bar{H} = \frac{7200}{\pi^2} \frac{gH}{n^2 D_2^2}$).

Efficiency of torque flow pump will decrease by 4.5% with increase of free chamber width, and specific speed will increase by 2% in this case. Obtained results indicate no effectiveness of specific speed growth by means of free chamber width increase for torque flow pumps. Optimum value of relative width of free chamber is in the range 0.3 – 0.35 for torque flow pump with spatial spiral outlet.

Modification of angle of wall inclination β_{cm} of outlet at the exit of impeller in the range of 30-50 degrees leads to growth of pump head by 11% (Figure 7 (a)). Maximum value of efficiency was obtained for angle of wall inclination equal to 45 degrees.

Modification of suction pipe diameter influences in head and efficiency of pump. And for increase of relative value of inlet diameter $\bar{D}_0 = D_0 / D_2$ from 0.4 to 0.62 head decreases by 2%, and pump efficiency – by 2.5% (Figure 7 (b)).

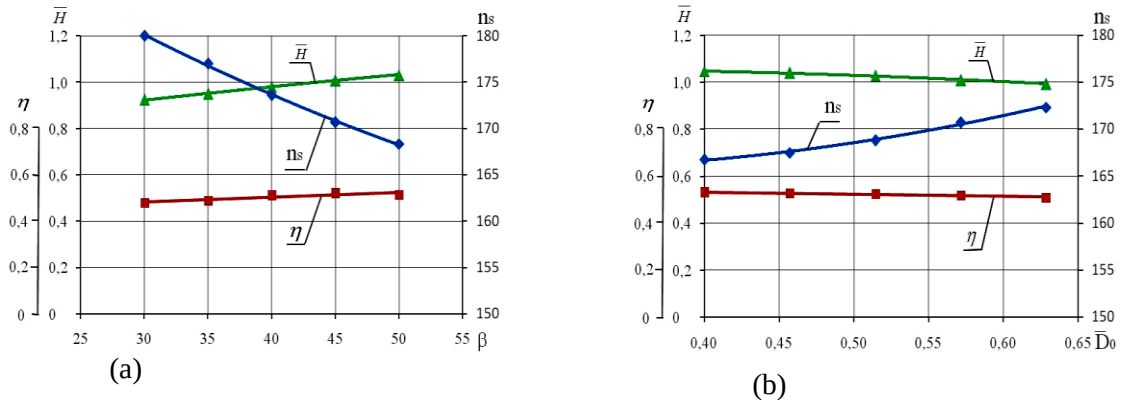


Figure 7. Relation of optimum parameters of torque flow pump:
 (a) depending on inclination angle free chamber wall β_{cm} ;
 (b) depending on suction pipe diameter D_0 .

Taking into account obtained results series of torque flow pumps with spatial spiral outlet was designed and investigated for the range of specific speed $n_s=60-200$. Significant increase of efficiency for this pump was obtained comparing to pump with annular outlet (Figure 8). Recommended range of application for torque flow pumps with spatial spiral outlet is $n_s = 60 - 180$, for this case pump efficiency equals 48–55 %.

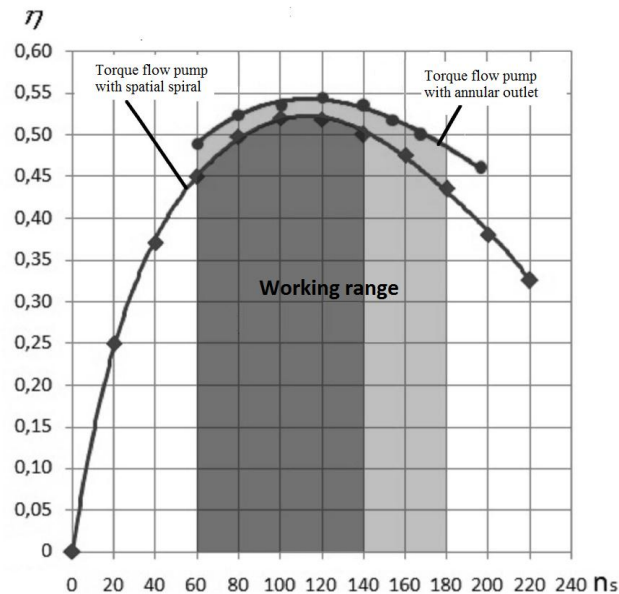


Figure 8. Dependence between torque flow pump efficiency and specific speed.

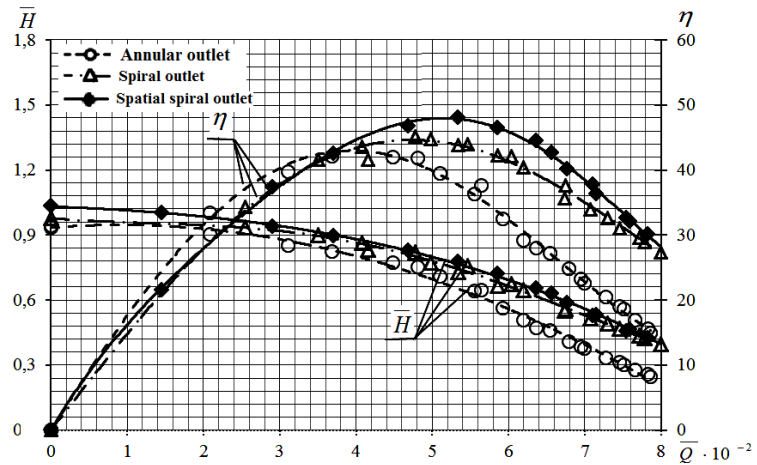
4. Results confirmation at experimental bench

For verification of operation effectiveness of torque flow pump with spatial spiral outlet and confirmation results of numerical calculation tests of pump prototypes with outlets No. A, No. B and No. D were implemented at the experimental bench (Figure 9 (a)). All pumps had specific speed equal to $n_s = 168$.

Tests showed that efficiency of pump with annular outlet equals $\eta = 43.5\%$. Optimum operation mode of pump with such outlet didn't correspond to its rated value (Figure 9 (b)).



(a)



(b)

Figure 9. Experimental researches of torque flow pump: (a) experimental bench; (b) characteristics of torque flow pump with different types of outlets ($\bar{Q} = \frac{240}{\pi^2} \frac{Q}{nD_2^3}$).

Concerning torque flow pump with spiral outlet, its efficiency for optimum operation mode $Q=120 \text{ m}^3/\text{h}$ equals $\eta=45\%$. No correspondence of optimum modes of these pumps is caused by the fact that outlet geometry modification leads to flow structure modification and consequently to increase of hydraulic losses and decrease of pump efficiency.

For tests of torque flow pump with spatial spiral outlet, value of efficiency increased by 48% which is much higher than efficiency of pump with annular outlet. Growth of efficiency comparing with pump with spiral outlet is 3% and comparing with pump with annular outlet – 4.5%. Optimum mode of this pump corresponds to rated value area for specific speed $n_s = 168$.

5. Conclusion

Implemented set of researches showed that application field of torque flow pumps with high specific speed values can be expanded by means of modification of outlet geometry.

Calculations of geometrical parameters of pattern hydraulic flow parts were implemented and tests were implemented for $n_s = 100 - 180$.

Conclusion concerning significant influence of free chamber width on pump characteristics among all dimensions of hydraulic flow part was experimentally confirmed for invariable diameter of torque flow pump impeller.

Radial and annular irregularity of flow in spatial spiral outlet was eliminated, which allows to create advanced outlet with improved hydraulic indexes, for example efficiency of “Turo” type torque flow pump with high specific speed ($n_s=168$) can be increased by 3-4% by applying this outlet.

It was proved by physical experiment that torque flow pump with spatial spiral outlet is more energy efficient because its efficiency is 3% higher than efficiency of pump with spiral outlet and 4.5% higher than pump with annular outlet.

Hydraulic flow part of outlet, which can be used for creation of more economical “Turo” type torque flow pumps, was obtained as a result of researches [13].

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