

HYDRAULIC CALCULATIONS OF A TELESCOPIC WATER INTAKE

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Abstract

Telescopic water intake structures allow for the selective intake of water from the top layers of a reservoir. A telescopic water intake has a high degree of mobility, and a wide field of application; at the same time, it is very simple and convenient to operate. Despite these advantages, an exact calculation method for a telescopic water intake is lacking (Lipin, 2020; Lipin, 2022). Therefore, the purpose of this research is to develop an exact calculation method for a telescopic water intake. In order to perform this task, all the structural elements of a telescopic water intake were analyzed separately by means of existing hydraulic principles. The impact of the critical submergence depth of the water intake funnel on the operability of a telescopic water intake was studied, and an equation for the critical submergence depth calculation was proposed. The optimal range of the flow rate coefficient ($\mu = 0.30 - 0.45$) was proposed for calculating the funnel flow rate, and the correlation between the flow rate and funnel inlet diameter was defined. The optimal curvature radius of the elbow was proposed. In order to verify the above mentioned parameters and correlations, analytical and numerical calculations of specific examples were performed. The results of the numerical modelling demonstrated that the critical submergence depth and shape of the water intake funnel, as defined by the analytical calculations, ensured its effective operation free of cavitation and vortices. The analytically calculated dimensions of the telescopic column, following the numerical modelling results, provided normal hydraulic conditions without active cavitation. According to the numerical modelling, the proposed curvature radius of the elbow was sufficient to avoid significant cavitation and vortex formation in the elbow structure. This research can provide guidance for the design of telescopic water intake structures.

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Key words

- Water,
- Structure,
- Calculation,
- Funnel,
- Elbow,
- Fluent,
- Finite element method.

1 INTRODUCTION

The main purpose of the telescopic water intake is intake of water from top layers of the water source. Top layers of water are free of sediments and have higher temperature because of

direct heat of sun rays, evaporation and etc. Telescopic water intake works in automatic regime according to the depth changes in the water source. It means, the head above the crest of the funnel is constant and does not change with depth fluctuations.

Traditionally, specialists involved in the design of surface water intakes have faced the problem of vortex formation. Therefore, in order to understand the physical processes occurring in a vertical telescopic water intake funnel, we consider it appropriate to review the processes of vortex formation.

Most scientists who have studied the formation of vortices noted the importance of the Froude number of the water intake for the intensity of the formation of vortex processes. However, in addition to the Froude number, the dimensions of the structure, especially the pressure pipeline, the depth of the water intake, the volumetric circulation of the suitable flow and the ratio of the head on the crest of the funnel to its diameter (H/D) are also important (Jain et al, 1978). Although the above parameters are important for all types of water intakes, they are especially important for submerged water intakes, where an insufficient depth of penetration can lead to the formation of vortex processes and where flow rate losses can be significant compared to other types of water intakes.

The term „critical submergence depth“ (H_c) was introduced in 1978 by Jain (Jain et al, 1978) as the minimum depth at which strong and unwanted eddies do not form. If the submergence depth is less than H_c , a vortex will form, but this is not always true in the opposite case, since insignificant vortices can form with an increasing depth.

Studies have established the relationship between the submergence depth and vortex formation to provide guidance for the design of surface water intakes. They mainly considered vortex flows that entrain air, since these processes are the main cause of the destruction of hydraulic structures. In 1987, Hecker (Hecker, 1987) proved that the air is most of all en-

trained by the 5 and 6 types of vortex flow (Fig. 1).

One of the earliest recommendations for the design of pumping stations was done by (Prosser, 1977). It was said that the flow should be uniform across the entire width of the channel at a speed of no more than 1 m/s; the supports should be streamlined to avoid flow separation; stagnant areas of the flow should be filled; and debris traps should work as flow straighteners. He also stated that the factors below are the result of poor design and should be avoided: abrupt changes in flow direction, steep slopes, and non-streamlined supports. If all the conditions proposed by Prosser are met, then the minimum submergence depth of the water intake is determined by the equation:

$$H = 1.5 D, \quad (1)$$

where D is the diameter of the inlet part of the funnel (m); H is the funnel crest head (m).

(Reddy and Pickford, 1972) were the first who used the relative head to study the probability of the formation of vortex processes. They determined that the main free surface eddies occur when the relative head is less than:

$$H/D = 1 + Fr, \quad (2)$$

where Fr – the Froude number.

Yildirim and Kochabas (1995) conducted a study of the critical depth in the water intake during the formation of a vortex with an air barrel. To form a flow zone, theoretically, a funnel was combined with a uniform channel flow. In this study,

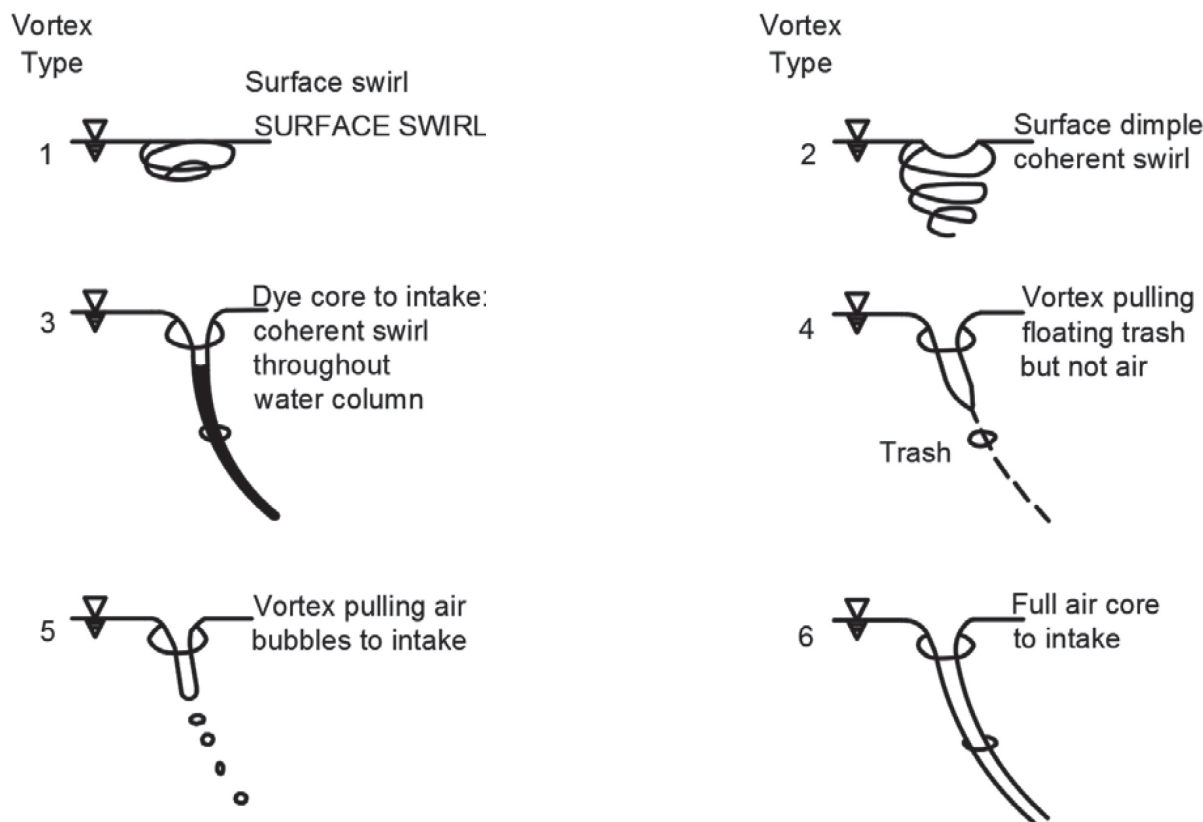


Fig. 1 Classification of types of vortex funnels (Hecker, 1987)

the funnel flow was equated to the uniform flow to ensure continuity of the system. In experiments, the critical depth was equated to the funnel diameter (Yildirim and Kocabas, 1995).

$$\frac{H_c}{D} = \frac{1}{2\sqrt{2}} \left(C_d \frac{V}{U_\infty} \right)^{1/2}, \quad (3)$$

where C_d is the vertical clearance of the point C to the canal bottom (m); V is the average intake velocity (m/s); U_∞ is the cross-sectional average velocity of the incoming flow (m/s).

Gordon 1970 identified four main criteria that determine the filling properties of a vortex in an intake: the geometry of the approach flow to the intake, the velocity in the flow region, the critical depth, and the size of the intake (Gordon, 1970). Twenty nine water intake structures were studied, and a formula for industrial use was obtained. Taking into account the hydraulic features of the flow, two equations were developed; for the symmetrical case, the equations have the following form:

$$\frac{H_c}{D} = 1.7Fr, \quad (4)$$

Experimentally, Vadoud derived an equation for determining the critical submergence depth of a simple vertical intake (Vadoud et al, 2013):

$$H_c = 3Fr^{0.248}, \quad (5)$$

This expression is valid for Froude numbers in the range of 0.68 – 2.86.

MATERIALS AND METHODS

Analytical method for calculating a telescopic water intake

The hydraulic calculation of a vertical telescopic water intake consists of the following elements: funnels; a telescopic column; float; elbow; outflow tract; stilling well (Gasarov and Lipin 2021) (Fig. 2). A stilling well is required for dissipation of the flow energy downstream when transporting in an open way, i.e., using the channel. The calculation of the outflow tract and stilling well is not considered in this work.

The calculation of the water intake is carried out in the following sequence: firstly, we calculate the funnel. The water intake funnel is one of the main structural elements of a vertical telescopic water intake. The efficiency, durability, and profitability of the entire intake structure depend on the correct design of the funnel.

In a funnel-shaped water intake with a decrease in the cross-section, the flow velocities increase, and the pressure along the central axis of the water intake decreases. In this case, if the pressure along the central axis of the water intake does not fall below atmospheric, then vortices are not formed. Thus, the phenomenon of vortex processes is formed from the interaction of the water intake's shape, the depth of the water intake, and the properties of the liquid, such as viscosity and the surface tension.

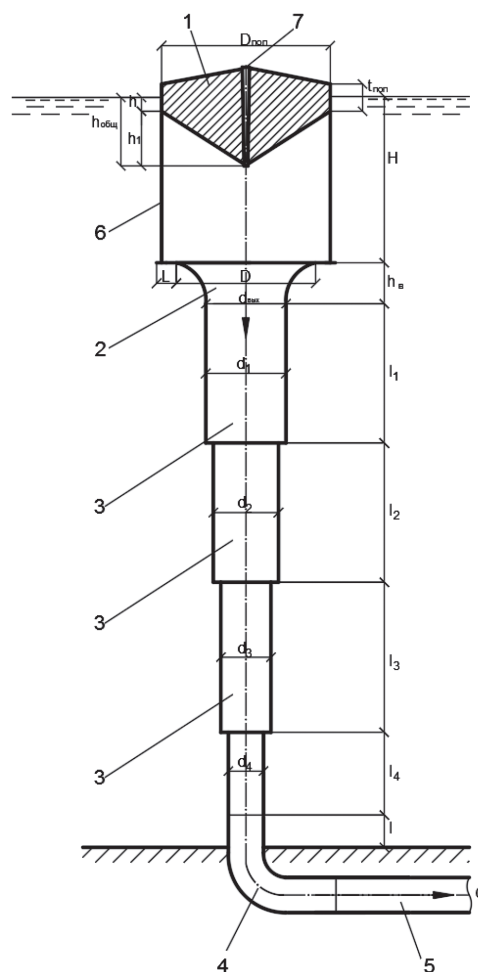


Fig. 2 Scheme for calculating the telescopic water intake: 1-float, 2- inlet funnel, 3- telescopically connected pipes (tapering downwards), 4- elbow, 5- discharge pipe, 6- connecting elements, 7- conical air supply tube

Numerous research works were analyzed in order to determine critical submergence depths and vortex formations in a funnel. As a result of these studies, different formulas for calculating the critical submergence depth were developed (Prosser, 1977; Reddy and Pickford 1972; Yildirim and Kocabas 1995; Wu et al., 2006; Vadoud et al, 2013). In our research we use Prosser's equation (1) in order to study hydraulic processes inside a funnel (Prosser, 1977).

The main parameters for the design of a telescopic water intake funnel are the inlet diameter of the funnel (D) and the funnel crest head (H). By means of these parameters and the μ flow rate coefficient, the funnel flow rate can be defined by the equation (Shterenlikht, 2004; Uginchus and Chugaeva, 1971):

$$Q = \mu \cdot \frac{\pi \cdot D^2}{4} \cdot \sqrt{2 \cdot g \cdot H}, \quad (6)$$

where Q is the flow rate of water taken by the water intake (m^3/sec); μ -flow rate coefficient, dimensionless; H funnel crest head above, m; $g=9.81$ (m/s^2) is the acceleration of gravity.

For purposes of the calculations, the funnel should be realized as a flooded nozzle having a conical or conoidal shape. In textbooks on hydraulics for a submerged conical nozzle, the flow rate coefficient should be taken as $\mu=0.85-0.87$ at an angle at the top of the funnel cone $\Theta=30-50^\circ$, for a conoidal

nozzle at large Reynolds numbers $\mu = 0.97-0.98$ (Shterenlikht, 2004). In practice, conoidal nozzles do not occur due to their complicated shape and difficulty of manufacturing; in most cases, they are replaced by a close-shaped nozzles assembled from several truncated cones.

It should be noted that a tower spillway with a flooded funnel has a similar operating principle as a telescopic water intake. Only a handful of works have been devoted to the study of spillways, most notably, those by Mois (Mois, 1959; Mois, 1970). Mois noted a dependence between the flow rate coefficient and relative head (Mois, 1970), i.e., as the flow rate coefficient increases, the ratio between the inlet and outlet diameters of the funnel decreases.

In practice, there is no calculation of a funnel flow rate with a float located at the top. We carried out analytical calculations and verified the results by means of numerical modelling in order to investigate the hydraulic processes occurring in the funnel of the telescopic water intake. According to Mois, the ratio of the inlet and outlet diameters of the funnel decreases as the coefficient of the flow rate increases. Based on the results of the analytical calculations and the numerical modelling of a large number of models with different values of the flow rate coefficient, it was concluded that the particles of water entering the funnel acquire a very large horizontal component of the velocity with an increase in the value of the flow rate coefficient. This results in the separation of the flow from the funnel walls and the formation of significant cavitation processes, that interfere with the normal operation of the structure. It was found that the use of a flow rate coefficient in the range $\mu = 0.30 - 0.45$ together with height of the funnel equal to the inlet diameter $h_{fun} = D$ and submergence depth of the funnel crest equal to 1.5 inlet diameter of the funnel $H = 1.5D$ can ensure normal hydraulic conditions without vortex formation and avoid the formation of significant cavitation, hence, protecting the funnel from erosion. In this research for the analytical calculation of the funnel flow rate, we accept the flow rate coefficient $\mu = 0.36$. Thus, considering equation (1) and the constants in equation (6) we get:

$$D = 0.85 Q^{\frac{2}{5}}, \quad (7)$$

It should be noted that the water flow rate Q taken from the source is set according to the water consumption. In order to connect the funnel inlet with the float behind the funnel crest, an initial section with a length of $L = (0.4 - 0.5) D$ is arranged. In this case, taking into account the length of the initial section, the diameter of the funnel is determined by the equation:

$$D_{fun} = D + 2L, \quad (8)$$

In order to determine the diameter of the outlet part of a funnel, the height of the outlet part is assumed to be equivalent to the diameter of the inlet part, for the research purpose, i.e., $h_{fun} = D$, and the diameter of the outlet part of the funnel is thus determined by the equation:

$$d_{out} = \sqrt{\frac{4Q}{\varphi \pi \sqrt{2g(H+h_{fun})}}}, \quad (9)$$

where d_{out} is the diameter of the outlet part of the funnel (m);

φ is the velocity coefficient (dimensionless, in our case $\varphi = 0.96$); H is the funnel crest head above (m); and h_{fun} is the head from the funnel outlet level to the funnel crest (m).

The diameter of the first telescopically connected pipe is accepted to be equal to the diameter of the outlet part of the funnel, i.e., $d_1 = d_{out}$.

The diameter of the second pipe (d_2) is determined by the equation:

$$d_2 = d_1 - 2(\delta + a), \quad (10)$$

where d_1 is the inner diameter of the first pipe (m); δ is the thickness of the wall of the second pipe, (mm); a is the gap between the walls of the pipes or the thickness of the support ring (mm).

The diameter of the subsequent pipes is determined by equation (10) according to the diameter of the previous pipe and the thickness of the wall, for example, the diameter of the third pipe is determined as follows: $d_3 = d_2 - 2(\delta + a)$.

The elbow is an important structural element of the telescopic water intake; the efficiency of the entire intake structure is dependent on its reliability. Under the action of centripetal acceleration arising when the flow turns in the plane of formation of its velocity structure, centrifugal forces arise, increasing the pressure on the convex surface and decreasing the pressure on the concave surface. As a result, the pressure can drop so much, on the convex surface of the elbow, that intense cavitation processes of destruction may occur.

The diameter of the elbow and the outlet pipeline is taken to be equal to the diameter of the last pipe, i.e., $d_{elbow} = d_{last} = d_{out,pipe}$. The last pipe connected to the elbow is considered to be fixed.

To prevent cavitation processes and vortex formation in the elbow a large number of numerical models with different curvature radiuses were previously studied. According to the recommendations available in the literature, the curvature radius should be assigned in the range $R_0 = 2 - 5d_{elbow}$. To study and prevent cavitation, we propose the curvature radius:

$$R_0 = 2.5d_{elbow}, \quad (11)$$

By means of computer modelling, we can study the hydraulic processes occurring in the elbow.

Calculation of the float

The calculation of the float consists in determining its buoyancy, i.e. its operability, taking into account the load imposed on it, and thereby determining the depth of the immersion, height and diameter of the float.

According to Archimedes' law, to ensure the buoyancy of the float, the lifting force P_f is equal to the force G , which tends to immerse it in water:

$$P_f = G, \quad (12)$$

The lifting force (N) is determined by the formula:

$$P_f = \gamma \omega h = \gamma W, \quad (13)$$

where $\gamma = \rho g$ is the volumetric weight of the water (kg/m^3); ω is the cross-sectional area of the float, limited by the wetting

contour (m^2); h is the immersion depth of the float (m); W is the volume of water displaced by the float or the volumetric displacement (m^3); and ρ is the density of the water (kg/m^3).

The force tending to immerse the float in water (G) includes the weight of the float itself, the funnel, telescopically connected pipes (hanging pipes) and other elements of the device. The weight of each element is determined by the following formula:

$$G_i = g \Sigma \rho_i W_i = g \Sigma \rho_i S_i \delta_i ; (i = 1, 2, \dots, n), \quad (14)$$

where ρ is the density of the material from which the element is made (kg/m^3); W_i is the volume of material, m^3 ; S_i is the element's surface area (m^2); δ_i is thickness of the wall's material (m).

Considering (13) and (14), equation (12) has the form:

$$\gamma W = \Sigma G_i, \quad (15)$$

Through equation (15), the buoyancy or operability of the float is established, and its dimensions are also determined.

Displacement is determined by the shape of the float. In this specific case:

$$W = \frac{1}{3} h_1 \omega + h \omega, \quad (16)$$

where h_1 is the height of the conical part of the float, which is completely submerged in water (m); the cross-sectional area of the cylindrical part of the float (m^2); D_{float} is the float diameter (m); and h is the immersion depth of the cylindrical part of the float (m).

The displacement of the float can be calculated by equation (15) if the load acting on it is known. Considering the known value of displacement W and diameter of the float D_{float} , the immersion depth of the float's cylindrical part is determined by equation (16).

Draft i.e., the total immersion depth of the float (measured by the sum of the immersion depths of each conical h_1 and each cylindrical h in Figure 2), is calculated as follows:

$$h_{total} = h_1 + h, \quad (17)$$

It should be noted that the calculation of the float is carried out by the approximation method since the dimensions and the weight of the float are not known. Therefore, in the first approximation, the height (t_{float}) of the cylindrical part of the float is accepted, and then its weight is calculated. In case, the accepted height of the float turns out to be less or significantly higher than the calculated one during calculations, then its value should be increased or decreased and the calculations should be performed again.

The calculation of the float can be done in different ways, for instance, using the depth of the immersion to calculate its diameter. Using this method to solve the problem is more difficult.

$$\gamma \left(\frac{1}{3} h_1 + h \right) \frac{\pi D_{float}^2}{4} = \Sigma G_i, \quad (18)$$

where all symbols are the same.

Let us look at a specific example.

Example. Calculate the telescopic water intake using the following initial data. The flow rate of water into the reservoir is $Q = 7 \text{ (m}^3/\text{s)}$; the depth of the reservoir is 23.5 (m); the dead level is 6 (m); the float is cylindrical and has a conical base; the cone height is $h_1 = 0.4 \text{ (m)}$.

Solution. By using formula (7), we determine the diameter of the funnel inlet by taking the flow rate coefficient, which is 0.36

$$D = 0.85 \cdot 7^{\frac{2}{5}} = 1.85 \text{ m.}$$

By means of equation (1) we determine the head at the funnel crest:

$$H = 1.5 \cdot 1.85 = 2.78 \text{ m.}$$

Accepting the length of the initial part of the funnel $L = (0.4-0.5) \cdot 1.85 = 0.925 \text{ (m)}$ according to equation (8), we can determine the full diameter of the inlet funnel:

$$D_{fun} = 1.85 + 2 \cdot 0.925 = 3.7 \text{ m.}$$

The height of the funnel is taken to be equal to the diameter of the inlet part of the funnel $h_{fun} = D = 1.85 \text{ m}$. and, using formula (9), we can calculate the diameter of the outlet part with a velocity coefficient $\varphi = 0.96$

$$d_{out} = \sqrt{\frac{4 \cdot 7}{0.96 \cdot 3.14 \sqrt{2 \cdot 9.81 \cdot (2.78 + 1.85)}}} = 0.99 \text{ m.}$$

Considering the depth and water dead volume level in the reservoir, we accept 4 steel pipes each 5 (m) long and with a thickness of the wall $\delta = 10 \text{ mm}$.

The diameter of the first pipe is taken to be equal to the diameter of the funnel outlet part $d_1 = 990 \text{ mm}$. The diameter of the second pipe is found by the formula (10) with a gap between the walls $a = 5 \text{ mm}$ and a pipe wall thickness $\delta = 10 \text{ mm}$.

$$d_2 = 990 - 2(10 + 5) = 960 \text{ mm.}$$

By means of equation (10), we find the diameter of the third $d_3 = 930 \text{ mm}$ and the fourth $d_4 = 900 \text{ mm}$.

We accept $d_{elbow} = d_4 = d_{out, pipe}$ and, by means of equation (11), we find the elbow bending radius:

$$R_0 = 900 \cdot 2.5 = 2250 \text{ mm}$$

The float and the inlet funnel are made of steel sheets 10 mm thick. The diameter of the float is taken to be equal to the full diameter of the funnel inlet part $D_{float} = D_{fun} = 3.7 \text{ m}$.

Based on the total surface area $\omega_{total} = 28.75 \text{ m}^2$ of the float, sheet wall thickness $\delta = 0.01 \text{ m}$ and steel density $\rho = 7850 \text{ kg}/\text{m}^3$, we calculate the weight of the float using formula (14):

$$G_{float} = 9.81 \cdot 7850 \cdot 28.75 \cdot 0.01 = 22.14 \text{ kN}$$

In the same way, we find the weight of the inlet funnel $G_{fun} = 6.54 \text{ kN}$. By the diameter and wall thickness of the pipes, we find the weight of the pipes $G_{pipe} = 34.85 \text{ kN}$. Total float load:

$$\Sigma G_i = G_{float} + G_{fun} + G_{pipe} = 22.14 + 6.54 + 34.85 = 63.53 \text{ kN}$$

Using equation (13), we find the displacement of the float by considering the volumetric weight of the water $\gamma = 10 \text{ kN/M}^3$

$$W = \frac{63.53}{10} = 6.353 \text{ m}^3$$

By means of formula (16), we can determine the immersion depth of the cylindrical part of the float $D_{float} = 3.7 \text{ m}$. and $h_1 = 0.4 \text{ m}$.

$$h = \frac{4 \cdot 6.353}{3.14 \cdot 3.7^2} - \frac{1}{3} \cdot 0.4 = 0.458 \text{ m}$$

According to equation (17), we find the draft, i.e., the total immersion of the float:

$$h_{total} = 0.4 + 0.458 = 0.858 \text{ m}$$

By means of equation (18), we check the buoyancy of the float:

$$10 \left(\frac{1}{3} \cdot 0.4 + 0.458 \right) \frac{3.14 \cdot 3.7^2}{4} = 63.58 \text{ kg}$$

$$63.58 \geq 63.53.$$

Since equation (14) complies with the accepted and determined values, the calculation of the float stops.

Numerical calculations of the telescopic water intake

The hydrodynamic modeling of the telescopic water intake was done using two solvers of the ANSYS package. ANSYS FLUENT and ANSYS CFX both use the Navier-Stokes equations as the governing equations (Rutvika, 2016; Ansys Inc, 2013). The main difference between these two solvers is the way, in which they integrate the fluid flow equations and their solving strategies. In addition, ANSYS CFX uses the finite elements approach to discretize the domain, while ANSYS FLUENT uses finite volumes. ANSYS CFX uses a single method to solve the governing equations of motion (a coupled algebraic multigrid). ANSYS FLUENT offers three options to solve the governing equations, i.e., the density approach, the segregated approach,

and the coupled pressure-based method. Both solvers allow for the solving of complex hydrodynamic tasks. The purpose of using two solvers was to study the cavitation and vortex formation in various parts of the telescopic water intake by means of different solving strategies and different mesh sizes and topologies.

A 3D model was created on a 1:1 scale, all the dimensions for the modelling were taken from the above example. The Air confuser was modelled as a conical pipe passing through the float from top to bottom with a top diameter of 150 (mm) and a bottom diameter of 100 (mm). The same boundary conditions were assigned for both solvers: a water inlet was applied by means of a velocity inlet- 0.262 (m/s) to the cylindrical shape surface between the float and funnel crest; the air inlet was applied by means of opening to the top surface of the confuser with atmospheric pressure; outlet was applied by means of the outlet with atmospheric pressure at the end of the outflow tract; all the walls were assigned as solid walls.

The ANSYS CFX input was the following: a program-controlled linear CFD fluent mesh was assigned with a max. element size 90 (mm) growth rate 1.2, an additional inflation of 12 layers with a first layer thickness of 5.656 (mm) and a growth rate of 1.3 was applied to the walls of the water intake structure. Total mesh elements 962189. k- ϵ model were chosen for calculations.

The ANSYS FLUENT input was the following: the CFD fluent mesh was assigned with a max. element size 40 mm. growth rate 1.2, an additional inflation of 5 layers with a smooth transition, and a growth rate of 1.01 was applied to the walls of the water intake structure. The total mesh elements were 4968387. A realizable k- ϵ model, with enhanced wall treatment, was chosen for the calculations. Calculations were done in pressure based model in steady mode.

RESULTS

The ANSYS FLUENT and ANSYS CFX solvers provided very close results.

Comparing the water velocity diagram of the two models, no vortex formation was observed at the funnel crest. No signif-

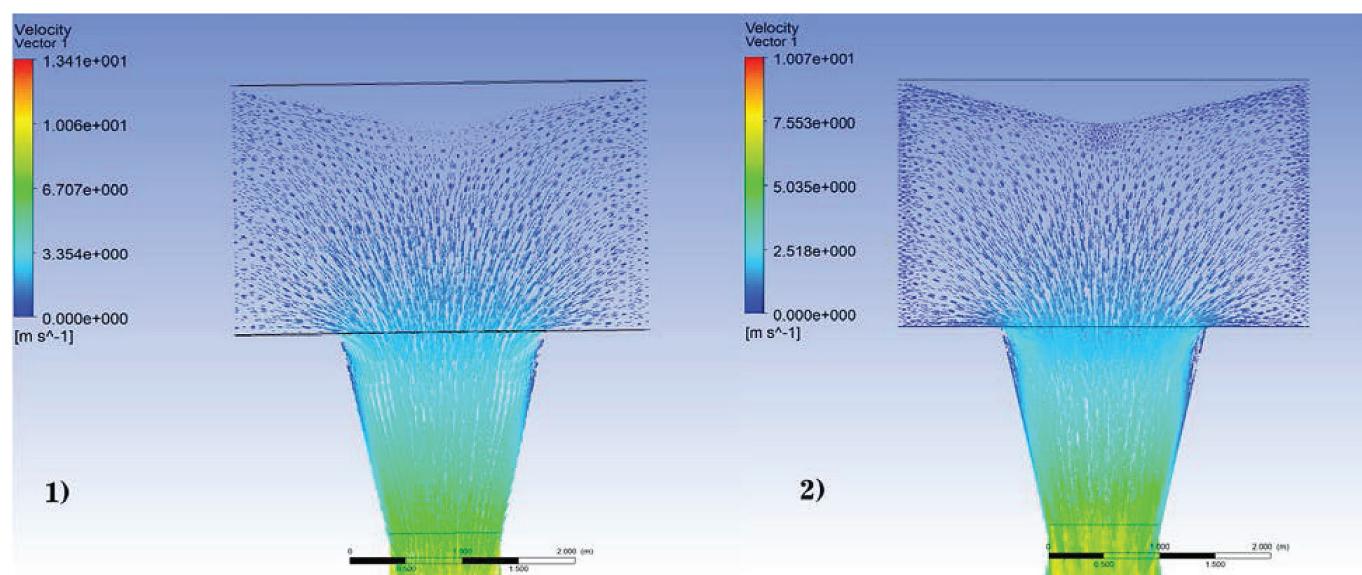


Fig. 3 Diagram of the distribution of the velocities in the longitudinal section of the funnel: 1- Ansys CFX results; 2- Ansys Fluent results

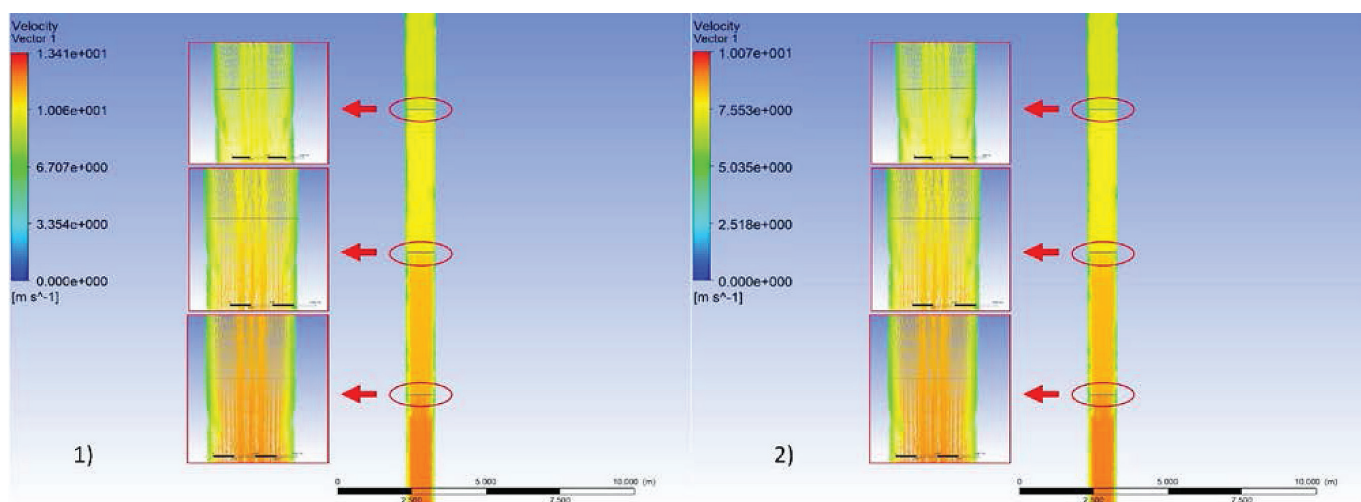


Fig. 4 Diagram of the distribution of the water velocities in the longitudinal section of the telescopic column: 1- Ansys CFX results; 2- Ansys Fluent results

icant cavitation was observed on the funnel walls. The shape of the funnel, which was obtained by analytical calculations, using the flow rate coefficient $= 0.36$, and $h_{fun}=D$ dimension ratio, enabled avoiding formation of vortex at the immersion depth calculated according to formula (1). The shape of the funnel enabled avoiding active cavitation on the walls of the funnel. Hence, a long service life and normal operation of the funnel are ensured.

structural solutions. At the same time, calculation of the curvature radius by means of equation (7) permits keeping dimensions of the elbow compact.

A velocity distribution diagram was obtained for all the main cross-sections of the water intake tract (Fig. 6).

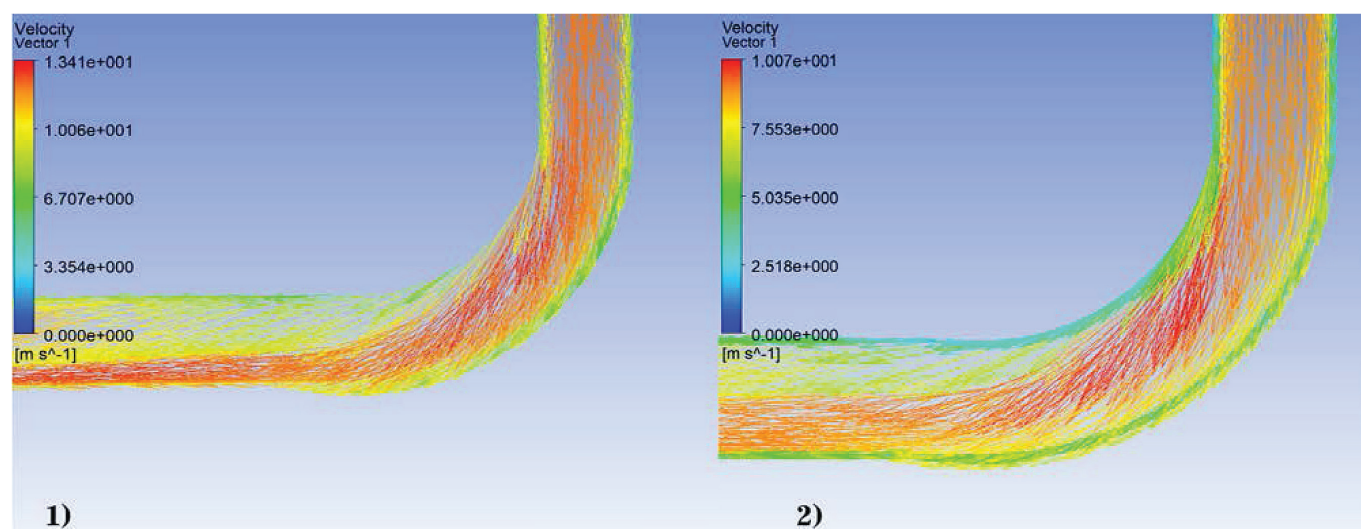


Fig. 5 Diagram of the distribution of the water velocities in the longitudinal section of the elbow: 1- Ansys CFX results; 2- Ansys Fluent results

When comparing the results of the two models, a weak turbulence of the flow without active cavitation was observed in a telescopic column in places where the cross-sections of the pipe change (Fig. 4.). Consequently, equation (6) was used for calculation of the telescopic column diameters to avoid formation of a destructive cavitation.

We observed the flow separation at the elbow. In spite of the higher velocities near the convex surface than those near the concave surface, active cavitation processes and vortex formation were not observed in the elbow (Fig. 5). The curvature radius determined by formula (7) avoids the formation of active cavitation without the implementation of additional

DISCUSSION

Since the telescopic intake takes water from the surface, the main purpose of this work was to calculate the optimal immersion depth and the shape of the inlet funnel to avoid vortex processes and cavitation in the funnel, as well as to prevent cavitation in other parts of the structure. In a previous research (Gasanov and Lipin 2021), a calculation of the telescopic water intake was presented without taking into account the critical depth of immersion and the formation of cavitation. These processes have a serious impact on the operation of the telescopic water intake and cannot be ignored.

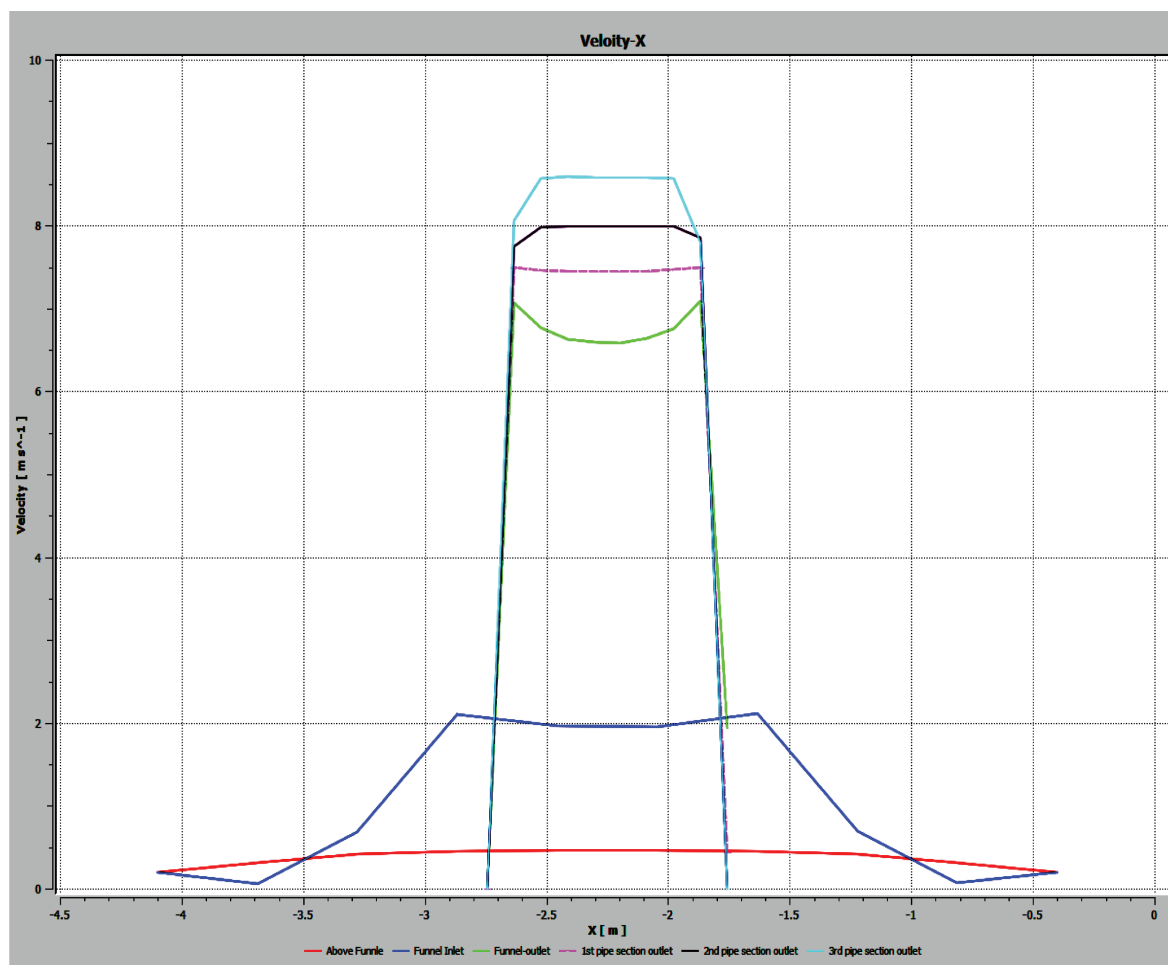


Fig. 6 Velocity distribution diagram for all the main cross-sections of the water intake track

Vortex with a gas core significantly reduces the throughput of the intake funnel and negatively impact the buoyancy of the float. To prevent vortex formation, it was necessary to determine the optimal immersion depth and the funnel shape. This shape of the inlet funnel avoids cavitation on its walls.

The results of the analytical calculations of the telescopic water intake are compared with the results of numerical models. The results of numerical models confirm the correctness of the analytical method of calculation. The results of this research helped to form a method for hydraulic calculation of the telescopic water intake.

CONCLUSION

In this work, calculations of a vertical telescopic water intake were studied. The following main conclusions were obtained:

1. A hydraulic calculation method of the telescopic water intake was developed. All the structural elements of the telescopic water intake were analyzed separately by means of existing hydraulic principles. A specific example for its implementation was given and verified by numerical calculations.
2. The equation for the calculation of the critical submergence depth of the funnel crest was proposed. The re-

sults of the manual calculations were verified by numerical modelling. At the critical submergence depth $H=1.5 D$, no vortex formation was observed at the funnel crest.

3. The optimal range of the flow rate coefficient $\mu=0.30-0.45$ for the funnel throughput calculation is directly affecting the shape and submergence of the funnel. The shape of the funnel achieved, with proposed flow rate coefficient range and dimension ratio of the funnel $h_{fun}=D$, helps to achieve critical submergence depth $H=1.5 D$, without vortex formation. In addition, this shape protects the funnel walls from significant cavitation and erosion. The results of the numerical modelling illustrated the lack vortex and the lack of active cavitation on the funnel walls.
4. Based on the results of the numerical calculations it can be concluded, that the equation proposed for calculation of telescopic pipe diameters allows avoiding active cavitation in the telescopic column, hence protecting it from erosion.
5. An optimal elbow curvature radius $R_0=2.5d_{elbow}$ was proposed. The results of the numerical calculations of the model created with the above-mentioned radius showed a lack of significant cavitation and a lack of vortex. Hence, the proposed curvature radius protects the elbow from erosion without the installation of additional elements such as a vortex chamber, etc.

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