UOT 678.5; 628.1
DOİ: https://doi.org/10.30546/09085.2024.106.108

STUDY OF OPTIMAL PARAMETERS OF SMALL HYDROELECTRIC PLANTS USING POLYETHYLENE PIPES

JALALADDIN VALIYEV

Baku Engineering University, Baku /Azerbaijan

cavaliyev@beu.edu.az

ARTICLE INFO

Article history:
Received: 2024-10-14
Received in revised form: 2024-10-22
Accepted: 2024-11-04
Available online

Keywords:
Polyethylene,
pipe,
speed,
flow rate,
pressure,
losses,
hydraulic shock,
permissible parameters.

ABSTRACT

The issues of determining the optimal value of its consumption when using pressurized polyethylene pipes (PE 100) and determining the allowable value of static pressure for PE 100 (1.0 MPa) were considered in the article. For this purpose, during the use of PE 100 (1.0 MPa) brand polyethylene pipes with an outer diameter of 800 mm, the value of the appropriate consumption (Q) for determining their main parameters and the maximum value of the hydraulic pressure (Pmax) generated inside the pipe, which ensures the reliable operation of the pipes, were determined in accordance with the norms.

The investigation of the considered issue was considered in the examples of "Gusar-1" small HPP on the Gusar tributary channel and "Balakan-1" small HPP on the Balakan river.

If we take into account that the main parameters that determine the power of the hydroelectric station are consumption (Q) and pressure (Hg), then the power of the hydro unit:

$$N = 9{,}81 \cdot Q \cdot H_g \cdot \eta \qquad (1)$$

where: η - is the useful work coefficient of the hydro unit.

Pressurized polyethylene pipes (PE) - should ensure the minimization of pressure losses when supplying water to hydroturbines and maintaining the internal hydraulic pressure created in PE pipes during the entire period of operation of small HPPs.

Therefore, when using PE 100 (1.0 MPa) brand polyethylene pipes with an outer diameter of 800 mm, the value of consumption (Q) corresponding to the minimal pressure loss that can be released for the application of their main parameters and the maximum value of the available hydraulic pressure available inside the pipe that ensures reliable and safe operation of the pipes (Pmax) should be determined according to the norms [2, 3, 4, 6, 9].

1. Determining the optimal cost of PE pipes consumption

The total pressure loss during the movement of water in pressurized pipes consists of hydraulic losses along the length of the pipe and local hydraulic losses. Local losses occur when water passes through nets, drawers, bends, places where the diameter of the pipe changes, and do not exceed 10-15% of the hydraulic losses along the length of the pipes.

Hydraulic losses along the length of the pipes are proportional to their length (L), water consumption or average velocity, internal diameter of the pipe, roughness of the walls and in which hydraulic mode they work. The Darcy-Weisbach formula that connects all these features is defined by the following expression:

$$h_e = \lambda \frac{L \cdot \upsilon^2}{d \cdot 2g} \quad (2)$$

where λ - is the coefficient of hydraulic resistance of the pipe material.

When the speed of water is υ>1,2 m/sec., the value of coefficient λ of PE pipes depends on the inner diameter of the walls and the Re number, and it works in the "hydraulic smooth pipes" zone, which does not depend on the roughness. The coefficient of hydraulic resistance for polyethylene pipes with an inner diameter of 700 mm is determined from the tables in the survey book and is λ= 0.0095 [2,6,7,8].

For the work of pipes, the form of replacing speed with consumption in formula (2) is more convenient ($Q=\upsilon \cdot \omega=\upsilon \cdot \pi \cdot d^2/4$). Since the pressure loss (h_e) is proportional to the length (L) of the pipe, it is possible to calculate the pressure loss for different pipe lengths by defining the loss per unit length by the dimensionless quantity $i_e = \frac{he}{L}$, i.e. $h_e=i_e \cdot L$. The formula (2) for the unit pressure loss for a pipe with an inner diameter of 700 mm can be reduced to:

$$i_e = \frac{h_e}{L} = 0.0095 \frac{16 \cdot Q^2}{\pi^2 \cdot d^5 \cdot 2g} = 0.0047 Q^2 \quad (3)$$

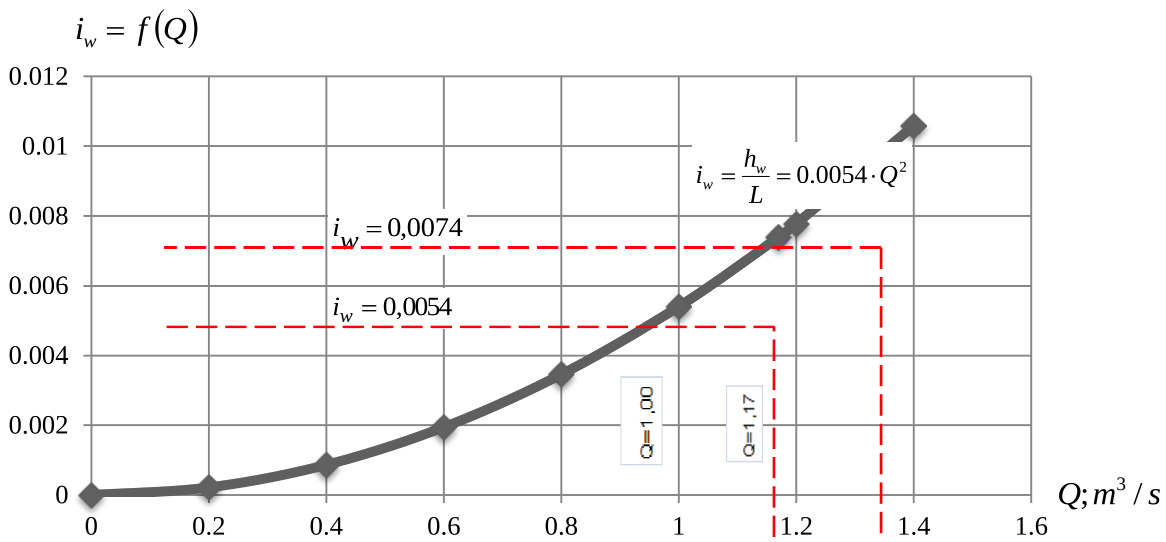
If we take into account the local losses, which cannot exceed 15% of the longitudinal losses, then

full hydraulic losses for 1 p. m. of PE 100 brand pipe can be determined as:

$$i_w=0,0054 \cdot Q^2 \quad (4)$$

In order to simplify the calculations, a graph of the dependence of the unit losses on the consumption was established for the PE 100 pipe with an outer diameter of 800 mm (Fig. 1).

Fig. 1 Graph of pressure unit losses i_w=f (Q)



2. Allowable value of static pressure for PE 100 (1.0 MPa). Determination

They take the internal design pressure equal to the greatest pressure that can occur in the pipe during operation. In pressurized pipes, a phenomenon of hydraulic shock occurs, which can increase the internal pressure several times. With the help of various constructive measures (extinguisher, waste water discharge, etc.), it is not possible to eliminate it completely, it can only be significantly reduced. It is recommended to limit the maximum relative pressure increase Z=◎H/Ho during hydraulic shock at the end of the polyethylene pipe to the following values [4]:

$H_o \leq 40$ m when	Z=0,7÷0,5
H_o=40÷100 m when	Z=0,5÷0,3
$H_o \geq 100$ m when	Z=0,3÷0,25

Taking this into account, the internal pressure of the pipe

$$P = H_o \cdot (1+Z) \tag{5}$$

will be.

For pressurized PEB whose internal limit pressure is equal to the P^0_{limit}, it can be used if the following condition is met [1, 2, 3, 4, 5]:

$$P \leq k_y \cdot k_d \cdot \gamma_n \cdot P^0_{limit} \tag{6}$$

where: P^o_{limit} – limit pressure of PE 100 (1.0 MPa) brand pipe Pohaddi=1.0 MPa = 10 atm. = 100 m; ky is a coefficient that takes into account the working conditions of PEB, ky =0.96; Kd is a coefficient that takes into account the decrease in the strength properties of PEB during the operation process due to the change in water temperature; kd = 0.80 (for t = 30^0 C); γ_n – reliability coefficient taking into account the class of devices, γ_n =0.98 (class III); ky; kd The values of γ_n coefficients [1, 2, 3, 4, 5, 6] are generally accepted.

If we substitute these values in the formula, we get:

$$P \leq 0{,}96 \cdot 0{,}80 \cdot 0{,}98 \cdot 100 = 76{,}0 \text{ m} \quad (7)$$

$$\text{or } H_o(1+Z) \leq 76{,}0 \text{ m}$$

When using PEBs of PE 100 (1.0 MPa) brand, the maximum value of static pressure (Ho) will be as follows:

H_o^{max} = 53,0...54,0 m

Let's show the results of the calculations with examples:

1. "Gusar-1" small HPP on the Gusar tributary channel (Fig.2)

The main parameters given are:

H_o=40,53 m; Q=1,17m^3/s; L=577 m

Determining the possibility of using PE 100 (1.0 MPa) branded pipes with an outer diameter of 800 mm as pressure pipes.

We determine the total hydraulic losses of the pressure:

According to the value of consumption Q from Fig. 1, we determine the unit losses of pressure for PEB.

i_w=0,0074

$h_w = i_w \cdot L = 0{,}0074 \cdot 577 = 4{,}26$ m

We define the existing raid: $H_g = H_o - h_w = 36{,}27$ m

For the turbine, Hg=36.44 m is assumed, which corresponds to the pressure available when using PE 100 (1.0 MPa) polyethylene pipe.

We determine the value of the hydraulic pressure (Pmax) that can be released in the pipe by the formula (6).

For pressure Ho=40.53 m, z=0.4 is taken.

P_{max} =40,53(1+0,4)=56,75 m

P_{max}<76,0 m because the conditions are followed.

PE 100 (1,0 MPa) branded polyethylene pipe can be used.

Fig.2 "Gusar-1" small HPP on the Gusar tributary channel

2. "Balaken-1" small hydropower station on the Balaken river (Fig.3)

The main parameters given are:

H_o=63,4 m; Q=1,0 m^3/s; L=1960 m

Let's determine the total hydraulic losses:

First, we determine the unit losses of pressure corresponding to consumption Q=1.0 m^3/s from Fig.1

i_w=0,0054 later $h_w=i_w \cdot L=0,0054 \cdot 1960=10,58$ m we define.

We define the existing raid: $H_g=H_o-h_w=63,4-10,58=52,8$ m

In the design, the design head for the turbine is assumed to be 60.0 m. When using PE 100 pipe, the losses make up more than 17% of the static pressure.

We determine the allowable value of the hydraulic pressure in the pipe (Pmax) by the formula (6).H_o=63,4 m when, z=0,5 is accepted

P_{max} =63,4 (1+0,5)=95,1 m

P_{max}>76,0 m

Acceptance of PE 100 (1.0 MPa) brand pipes due to violation of pipe strength condition is not considered appropriate, therefore, a pressed steel pipe with a diameter of 1500 mm was adopted in the project.

Fig.3 "Balaken-1" small hydropower station on the Balaken river

CONCLUSION

1. Pressurized polyethylene pipes must ensure the minimization of pressure losses when supplying water to hydroturbines and maintaining the internal hydraulic pressure generated in PE pipes during the entire operation of small HPP.
2. In order to simplify the calculations in order to determine the optimal value of pipe consumption, a dependence graph of unit losses on consumption was established for a PE 100 pipe with an outer diameter of 800 mm.
3. As a result of our investigations, when using PE 100 (1.0 MPa) branded pipes with an outer diameter of 800 mm, it was determined that the maximum value of the static pressure is H_o^{max} = 53.0...54.0 m.
4. The investigation of the considered issue was considered in the examples of "Gusar-1" small HPP on the Gusar tributary channel and "Balakan-1" small HPP on the Balakan river. It was determined that PE 100 (1.0 MPa) brand polyethylene pipe can be used in "Gusar-1" small HPP. In "Balakén-1" small HPP, due to the violation of the strength condition of the pipe, it is not considered appropriate to accept PE 100 (1.0 MPa) pipes, therefore, a pressed steel pipe with a diameter of 1500 mm was adopted in the pro

REFERENCES

1. Abdilov S.Ə., Mahmudov T.M. Su enerjisindən istifadə Dərslik., Bakı, "Təhsil" NPM, 2007, 304 s. (in Azerbaijani)
2. Əliyev İ.Z., Musayev S.A., Əliyev N.İ., Ağacanov R.Q. Plastik kütlələrin sintezi və emalı. Dərs vəsaiti. Bakı,"Xəzər" Universitetinin nəşriyyatı,2016, 316 s. (in Azerbaijani)
3. ГОСТ 18599-83. Трубы напорные из полиэтилена. Технические условия. ОКП 2248 М., 1985.(in Russian)
4. Инструкция по проектированию технологических трубопроводов из пластмассовых труб. СН 550-82. От.22.04.1982 г. №102. М., Госстрой СССР, 1982. .(in Russian)
5. Сомов М.А. Водопроводные системы и сооружения. М., Стройиздат, 1988, 399 с.(in Russian)
6. Шевелев Ф.А. Таблицы для гидравлического расчёта стальных, чугунных, асбестцементных и пластмассовых труб. М., Стройиздат, 1973, 113 с. .(in Russian)
7. Gabriel, L.H., Bennett, O.N., and Schneier, B., Polyetylene Pipe Specifications, NCHRP Project 20-7, Task 68, Transportation Research Board, Washington D.C., Oceober 1995.
8. Kampbell, N.E., Kozman, D.P. and Goddard, J.B., Changes in Hydraulic Capacity of Corrugated HDPE Pipe With Time, Proceedings of the Third Conference on Structural Perfomance of Pipes, Ed., Mitchell, Sargand and White, Ohio University, 1988.
9. ISO 178:2010 Plastics-Determination of flexural propertties.