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CALCULATION OF RING-TYPE WATER NETWORKS USING COMPUTER SOFTWARE

PRORAČUN PRSTENASTIH VODOVODNIH MREŽA PRIMENOM RAČUNARSKOG SOFTVERA

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ABSTRACT

There are two types of water supply networks, branched and looped (ring-type). Looped water supply network consists of a number of closed loops (rings) surrounding the consumers while supplying them with water through sections. This type of water supply networks has an advantage over branched type because they do not require stopping of water in the entire network in a case of exclusion of certain parts of the network. When all input parameters are known, it is necessary to calculate the diameters of all sections and meet the required pressure drop in each of them. In this paper a computer program for reducing the calculation time and to increase the accuracy of the calculation with no additional cost has been made. The program does not require previous experience and advanced a computer knowledge to operate it. Accuracy of mathematical model and computer programme is proved by comparing the our results with the results of engineering literature at the same network calculated from other author.

Key words: *computer software, ring wter supply network.*

REZIME

Postoje dva tipa vodovodnih mreža, razgranata (magistralna) i prstenasta (kružnog, zatvorenog tipa). Prstenasti tip se sastoji od više zatvorenih prstena okolnih potrošača koji se snabdevaju vodom kroz sekcije. Ovaj tip vodovodnih mreža ima prednost u odnosu na razgranatog tipa, jer oni ne zahtevaju zaustavljanje vode u celoj mreži u slučaju isključenja pojedinih delova mreže. Kada su poznati svi ulazni parametri, neophodno je izračunati prečnik svih sekcija i odrediti pad potrebnog pritiska u svakoj od njih. U ovom radu autori si izradili računarski program za proračun prstenastih vodovodnih mreža. Program ne zahteva prethodno iskustvo i napredno znanje računara kako bi se mogao koristiti. Tačnost matematičkog modela i računarskog programa dokazana je poređenjem dobijenih rezultata sa rezultatima iz inženjerske literature, koji se odnese na isti tip vodovodne mreže.

Ključne reči: *softver, prstenasta vodovodna mreža.*

INTRODUCTION

Distribution networks are an essential part of all water supply systems. There are two types of water supply networks, branched and looped.

Branched supply is used for water supply of smaller number of consumers away from each other in which is allowed short-term disruptions in supply, caused by any reason (*Mitrevska et al., 2016*). Generally, urban and industrial water distribution supply has looped configurations and receives water from single or multi-input points (*Sharma and Swamee, 2013*). This type of water supply networks has an advantage over branched type because they do not require stopping of water in the entire network in a case of exclusion of certain parts of the network. When calculation for looped type of water supply network is performed, two laws of hydraulics have to be satisfied (*Popovski et al., 2016*).

a) The sum of volume flows in every node must to be zero, that is the amount of water entering and leaving the node must be equal and

b) At constant flow, the pressure difference between two cross-sections in the network is used to overcome the resistance and geodetic height between the cross-sections. The optimization of looped water distribution systems is a complex problem, as the pipe flows are unknown variables. Mathematically, it is a non-linear, constrained, and multi-modal problem included in the class of complex combinatorial problems known as NP-hard (*Reca et al., 2008*). In this paper a new computer program called LWSN (Loped Water Supply Network) has been developed with the aim reducing the calculation time and to increase the accuracy of the calculation.

Nomenclature

d (m)	diameter of the section
H (m)	geodetic height of node in
l (m)	length of section
p (Pa)	pressure in network
q (m^3/s)	volume flow of water in section
w (m/s)	velocity of water in section
Δp (Pa)	energy loss due to friction

MATHEMATICAL MODEL

In order to explain the mathematical model, which used as a base for development of computer programme, an example shown in Fig. 1 is used.

Every branch is labeled with number and the corresponding volume flow (ex. 1-14 means branch 1, 14 l/s). Network is comprised of 4 loops also labeled with numbers in the middle. To run the computer programme properly, it has to be previously "filled" with input data (with known network data). Volume flow (inlet and outlet) and length of section represent input data for every node. Total allowed pressure drop in the system is $\Sigma\Delta$p = 5000 Pa, (*Šašić, M., 1982*).

This value of pressure drop is enough to allow the complete calculation of the network to be with satisfying accuracy, but the computer programme itself allows the total pressure drop in some cases to reach values smaller than 100 Pa.

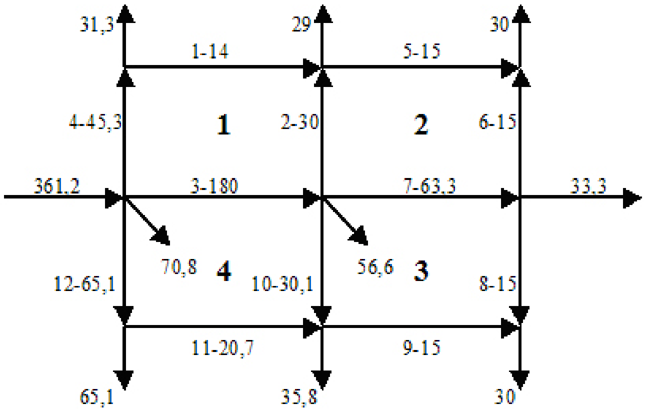

Fig. 1.Looped - type water network

The total number of loops are j = 4, while the Number of sections are i = 12. In calculation the values of the friction coefficient of the pipe is $\lambda = 0.018$ and density of water is $\rho = 1000$ kg/m^3.

For calculation of the network parameters, relative direction of water movement in the loops have to be adopted. In this case, we adopt clockwise direction to be 'positive'. With above shown input data it is neccessary to calculate cross-sections of all section and to match the allowed pressure drop in each of them.

The calculation goes under the following order. The pipe diameter is,

$$D_i = 0{,}025 \cdot (\rho \cdot q_i)^{0,48} \quad (1)$$

Calculated diameter is standardized onto the first greater standard size. Recommended values for velocity of water in pipes are, w = 0.75-2 m/s.

Hydraulic resistances were calculated according to equation (2)

$$S_i = \rho \cdot 0{,}01454 \cdot L_i \cdot D_i^{-5,33} \quad (2)$$

while the energy losses due to friction (pressure drop), were calculated from equation (3)

$$\Delta p_i = S_i \cdot q_i^2 \quad (3)$$

Correction of the flow in the loop was calculated according to equation (4),

$$\Delta q_j = -\frac{\sum \Delta p_i}{2 \cdot \sum S_i \cdot q_i} \quad (4)$$

RESULTS AND DISCUSSION

Calculation is performed through iterations while the number of iterations is determined by the value of pressure drop, i.e. number of iterations must be sufficient to result in pressure drop equal or smaller than recommended value. Number of iteration depends on the accuracy determined in the computer programme. In this case, the accuracy is set to 0.11 l/s which means that the difference between calculated flow in the section from the previous iteration and currently calculated flow in the same section should not be greater than 0.1 l/s. Accuracy of mathematical model and computer programme is proved by comparing with the same network calculated (*Šašić, M., 1982*). In Tab. 1 the values of input parameters ate given, while in Tab. 2 the calculated values water flow in each iteration, pipe diameter and the pressure drop are given.

Table 1. Review of input parameters

Section	*l* m	*q* l/s
1	880.0	14.00
2	735.0	30.00
3	880.0	180.00
4	735.0	45.30
5	880.0	15.00
6	735.0	15.00
7	880.0	63.30
8	735.0	15.00
9	880.0	15.00
10	735.0	30.10
11	880.0	20.70
12	735.0	65.10

Table 2. Review of calculated water flow in each iteration, the pipe diameter and the pressure drop

Section	*q* – 1 l/s	*q* - 2 l/s	*q* - 3 l/s	*d* mm	Δ*p* Pa
1	9.410	9.241	9.233	100.0	234975
2	32.24	32.36	32.36	151.0	267734
3	185.0	185.5	185.4	313.9	212451
4	36.76	36.59	36.60	160.3	249003
5	14.28	14.28	14.24	100.0	559026
6	16.31	16.30	16.37	100.0	616599
7	64.74	63.72	63.71	211.1	208051
8	15.91	16.74	16.74	100.0	645149
9	14.49	15.04	15.04	100.0	623128
10	30.72	29.91	29.91	151.0	228694
11	18.62	18.29	18.28	125.0	280049
12	62.43	62.16	62.15	211.1	165357

In Tab. 3 and Tab. 4 the comparison results are presented.

Table 3. Comparison of results of the flow of the water calculated by the computer program and the example taken from Šašić, 1982

Section	Starting flow l/s	Calculated flow l/s	Calculated flow l/s *Šašić, 1982*
1	14.00	9.233	9.470
2	30.00	32.36	32.50
3	180.0	185.4	190.5
4	45.30	36.60	40.77
5	15.00	14.24	12.97
6	15.00	16.37	17.03
7	63.30	63.71	67.58
8	15.00	16.74	17.25
9	15.00	15.04	12.75
10	30.10	29.91	33.80
11	20.70	18.28	14.75
12	65.10	62.15	59.15

Table 4. Comparison of results from calculated diameter of the pipe calculated by the computer program and the example taken from Šašić,1982

Section	*l* m	*d* mm	*d* mm *Šašić,1982*
1	880	100.0	150
2	735	151.0	200
3	880	313.9	400
4	735	160.3	200
5	880	100.0	150
6	735	100.0	150
7	880	211.1	300
8	735	100.0	150
9	880	100.0	150
10	735	151.0	200
11	880	125.0	150
12	735	211.1	250

CONCLUSION

The new computer program called LWSN (Loped Water Supply Network) was developed for calculation looped water supply network. The calculation of the network is made in iterations, while the number of iterations depends on the accuracy in the program. In our case the accuracy is 0.1 l/s, which means that the difference between the calculated flow in the section of the previous iteration, and the current calculated flow in the same section should not exceed 0.1 l/s. The accuracy of the mathematical model and the computer program is proved by comparing the same network calculated by (*Šašić, 1982*).

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