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# Mathematical Model and Computer Program for Calculating Energy Losses of Friction at Ring-Type Water Networks

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**Abstract:** A computer program has been made to reduce the calculation time and to increase the accuracy of the calculation with no additional cost. The program does not require previous experience and advanced computer knowledge to operate it. There are two types of water supply networks, branched and ring-type. Ring type consists of a series of closed rings surrounding the consumers and supply 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.

**Key words:** ring water supply networks

## 1. Mathematical Model for Computer Program

According to hydraulic connections, there are two types of water supply networks, branched and looped (ring-type). Looped water supply network, Fig. 1, consists of a number of closed loops (rings) surrounding the consumers while supplying them with water through sections. This ring of network has advantage over branched type because there is no need to interrupt the supply to all network if and intervention is required only on one part of it. When calculation for looped type of water supply network is performed, two laws of hydraulics have to be satisfied.

(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.

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).

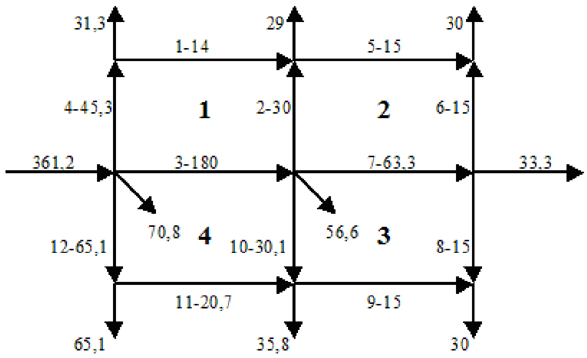


**Fig. 1 Ring-type water network [1].**

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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, [1]. 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.

Number of loops: j = 4

Number of sections: i = 12

Friction coefficient of the pipe: $\lambda = 0.018$

Density of water: $\rho = 1000$ 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 necessary 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: Pipe diameter,

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

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,

$$S_i = \rho \cdot 0{,}01454 \cdot L_i \cdot D_i^{-5{,}33} \text{ Pa·s}^2/\text{m}^6 \tag{2}$$

Energy losses due to friction (pressure drop),

$$\Delta p_i = S_i \cdot q_i^2 \text{ Pa} \tag{3}$$

Correction of the flow in the loop,

$$\Delta q_j = -\frac{\sum \Delta p_i}{2 \cdot \sum S_i \cdot q_i} \text{ m}^3/\text{s} \tag{4}$$

**Table 1 Review of calculate water flow in each iteration [1].**

| Section | *l* m | *Q* l/s | *q* – 1 l/s | *q* - 2 l/s | *q* - 3 l/s | *d* mm | *p* Pa |
|---|---|---|---|---|---|---|---|
| 1 | 880.000 | 14.000 | 9.410 | 9.241 | 9.233 | 100.0 | 234975 |
| 2 | 735.000 | 30.000 | 32.242 | 32.362 | 32.362 | 151.0 | 267734 |
| 3 | 880.000 | 180.000 | 185.000 | 185.469 | 185.445 | 313.9 | 212451 |
| 4 | 735.000 | 45.300 | 36.760 | 36.593 | 36.602 | 160.3 | 249003 |
| 5 | 880.000 | 15.000 | 14.280 | 14.281 | 14.241 | 100.0 | 559026 |
| 6 | 735.000 | 15.000 | 16.305 | 16.304 | 16.365 | 100.0 | 616599 |
| 7 | 880.000 | 63.300 | 64.744 | 63.719 | 63.708 | 211.1 | 208051 |
| 8 | 735.000 | 15.000 | 15.908 | 16.739 | 16.739 | 100.0 | 645149 |
| 9 | 880.000 | 15.000 | 14.485 | 15.035 | 15.035 | 100.0 | 623128 |
| 10 | 735.000 | 30.100 | 30.722 | 29.906 | 29.909 | 151.0 | 228694 |
| 11 | 880.000 | 20.700 | 18.623 | 18.291 | 18.275 | 125.0 | 280049 |
| 12 | 735.000 | 65.100 | 62.434 | 62.163 | 62.147 | 211.1 | 165357 |

## 2. Numerical Example and Comparison of Results

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 according to [1]. Comparison is presented on Table 2.

**Table 2 Comparison of results.**

| Section | Starting flow l/s | Calculated flow l/s | Calculated flow l/s according to [1] | *l* m | *D* mm | *d* mm according to [1] |
|---|---|---|---|---|---|---|
| 1 | 14.000 | 9.233 | 9.470 | 880 | 100.0 | 150 |
| 2 | 30.000 | 32.362 | 32.500 | 735 | 151.0 | 200 |
| 3 | 180.000 | 185.445 | 190.480 | 880 | 313.9 | 400 |
| 4 | 45.300 | 36.602 | 40.770 | 735 | 160.3 | 200 |
| 5 | 15.000 | 14.241 | 12.970 | 880 | 100.0 | 150 |
| 6 | 15.000 | 16.365 | 17.030 | 735 | 100.0 | 150 |
| 7 | 63.300 | 63.708 | 67.580 | 880 | 211.1 | 300 |
| 8 | 15.000 | 16.739 | 17.250 | 735 | 100.0 | 150 |
| 9 | 15.000 | 15.035 | 12.750 | 880 | 100.0 | 150 |
| 10 | 30.100 | 29.909 | 33.800 | 735 | 151.0 | 200 |
| 11 | 20.700 | 18.275 | 14.750 | 880 | 125.0 | 150 |
| 12 | 65.100 | 62.147 | 59.150 | 735 | 211.1 | 250 |

## Nomenklature

$d$ diameter of the section,

$H$ geodetic height of node in the network,

$l$ length of section,

$p$ pressure in network,

$q$ volume flow of water in section,

$w$ velocity of water in section,

$\Delta p$ energy loss due to friction.

## References

[1] Šašić M., "Transport fluida u cevima", Mašinski fakultet, Beograd, Serbija, 1982.

[2] Stojanovski V. and Popovski K., Transportni sistemi i transport vo cevki, Zbirka na rešeni i ispitni zadači, I del, Tehnički fakultet, Bitola, Makedonija, 2004.

[3] Dymond J. H. and Nieto de Castro C. A., *Transport Properties of Fluids: Their Correlation, Prediction and Estimation*, Cambridge University Press, UK, 1996.

[4] Swamee P. K. and Sharma K. A., *Design of Water Supply Pipe Networks*, Wiley-interscience, 2008.