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LOCATION OF LEAKS IN THE WATER SUPPLY NETWORK

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Abstract: *The presented algorithm is used to locate the leak of water from the network. The operation of this algorithm is divided into two stages. In the first stage we search the entire water supply network and is selected a pipeline, in which the damage occurs. In a second step it is determined the exact location of the leak. The article presents numerical calculations based on the algorithm developed for the calculation of water supply network. The pipeline, in which the location of the damage has been selected so that finding of the pipeline network was the most difficult. Fault location in the pipeline has been chosen at random. The study shows that in all variants of the measurement nodes and selected locations of damage, the program correctly locates the leak.*

Keywords: Pressure drop, Leak, Water supply network, Pipeline, Node.

1. Introduction

Water supply system is a complex system of piping in which water flows. It can be considered as the electricity network, to which the Kirchhoff law applies (Semkło et al., 2013). Using this analogy, it can be assumed that the current strength in the electricity network corresponds to the mass flow rate (heat flow) in the mains supply (Semkło et al., 2014), and the voltage drop on the section of the power supply - pressure drop (Semkło et al., 2014a) You can therefore save the balance equation for water flow in the nodes of the water supply system and the balance of energy (pressure drop) in the sections of the water supply network (Semkło et al., 2013a).

In this paper will be presented method for detecting leaks of water supply network based on the analysis of the pressure in the selected nodes. This issue is important because the network failure can cause considerable damage not only in its functioning, but in the whole infrastructure of the city.

2. Methodology

The methodology is based on repeated determination of parameters of a damaged water supply system with changing the location of a failure node, symbolizing the network. In this way it is need to solve n (the number of network elements) variants of the water supply system with a damage of known value of leakage (flowing out of the network node by an additional water volume flow) arranged one after the other in each element of the water supply system. Solved equations are increased by one additional mass balance equation. Determining the value of the functional for all variants of the damaged networks, variant of the actual satisfies the minimum of the functional (1).

$$J = \sum_{k=1}^{n_p} \left(p_{kj} - p_{ref\_k}\right)^2 \qquad (1)$$

Denoting by p_{ref_k} pressure measured in the k node measuring network damaged, and the pressure p_{kj} calculated in k node measuring networks damaged with damage located in the j node of this element. As you can see, the method described is based on the search for a minimum of functional (1) has faults that

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cause a variety of complications during solving nonlinear algebraic equations (Semkło et al., 2013b). However, the most serious of them, especially for large networks is a long calculation time.

The algorithm for determining network leakage consists of two steps. In the first step for each line in the network is determined minimum value of the functional (1) based on a bisection method. This process ends for each pipeline when the condition is satisfied:

$$|J_{u2} - J_{u1}| < \varepsilon_r \tag{2}$$

where ε_r is treated as a fraction of the length of the pipeline. The value of this parameter affects the length of the calculation. A low value increases computing time and too much will cause the selection of the pipeline, where the damage occur is incorrect. Distribution of minimum values for functional damage to the network in the next pipeline shows an example of Fig. 1. You can see that the risk of error choice of the pipeline, in which the damage appear, because the distribution of minima of the functional (1) allows for assessment of the risk of error. At high uncertainty can be reduced ε_r value, which increases the computation time or the second step may search for the minimum of the functional in more than one pipeline.

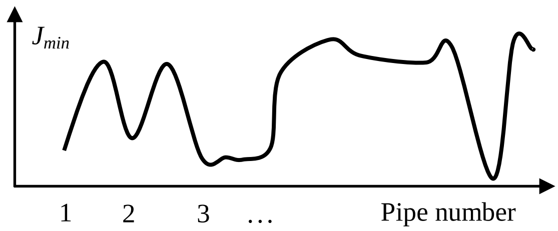

Fig. 1: Dependence of minimum of the functional (1) on the location of damage on the network, example.

In the second step the search for the leak from the network in the selected pipe, the location is searched as in the first step with the difference that the value ε_r is reduced by several orders.

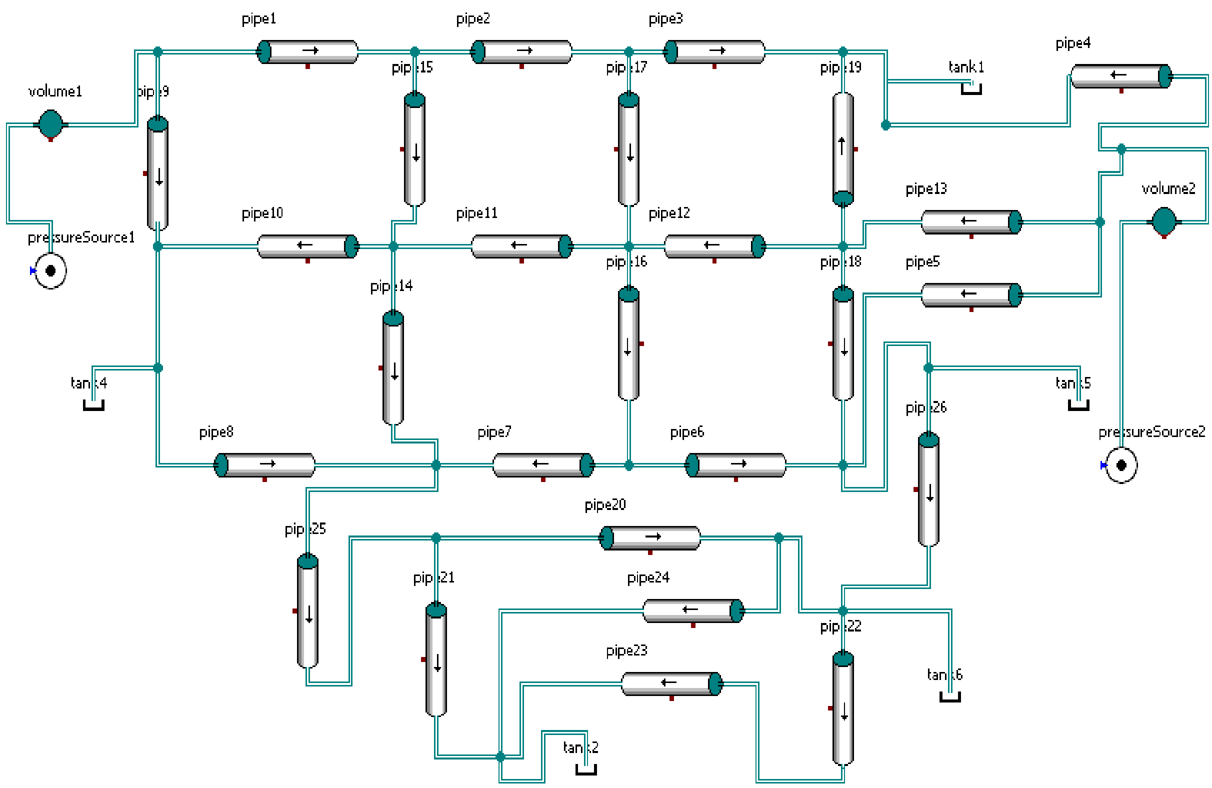

Fig. 2: Sample water supply network with 26 pipes and 18 nodes.

3. Calculation

In order to determine the location of a leak, the algorithm recalculates the network on the basis of the measurement node. Measurement nodes are used only in the first step. The number of measuring nodes varies from 1 to 6. It should be remembered that for more complex examples of the network 1 measurement node may not be sufficient and may adversely indicate the location of the leak.

For simple, less complex networks from a single measurement node is sufficient to properly identify the location of pipeline damage. The value of the functional (1) (determined in step 1) marked in green is several orders less than in other pipelines.

For networks with complex structure (Fig. 2) and a large number of data correlation minimum of the functional (1) the location of the damage in the next pipe network is shown in Figs. 3 and 4. Properly found the pipe in which there is physical damage is identified in these drawings, circled in green. Wrong identification is red. There is a possibility of a situation for which the value of the functional (1) is similar to the value of this functional for the pipeline, in which the actual damage occur. In this case, the location of leaks may be incorrectly interpreted.

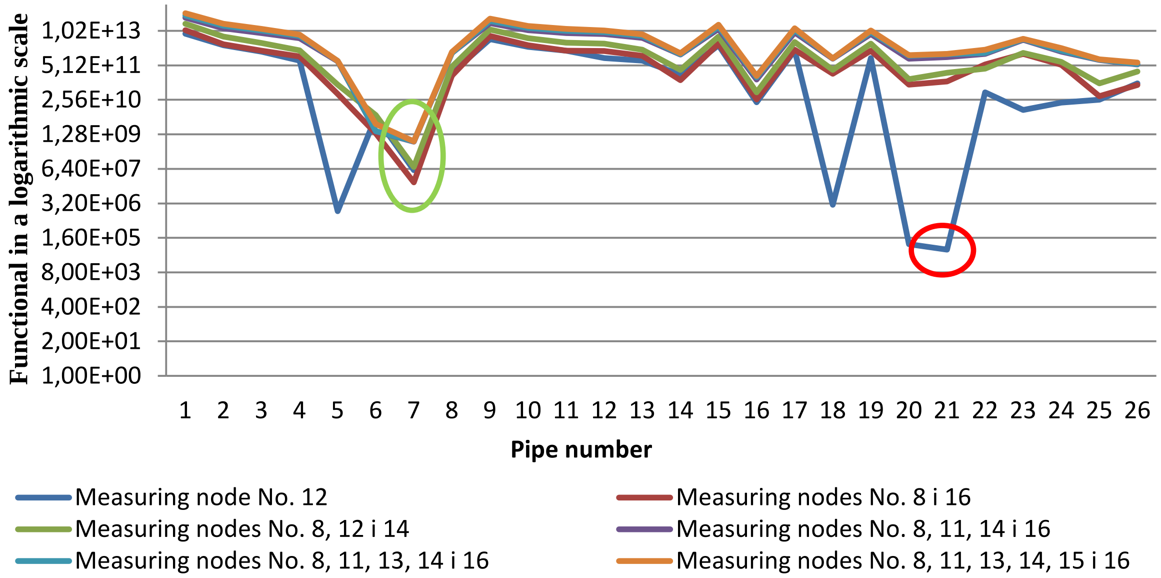

Fig. 3: The minimum of the functional dependence (1) of the leak location in the next pipes of the network; leak in pipe 7.

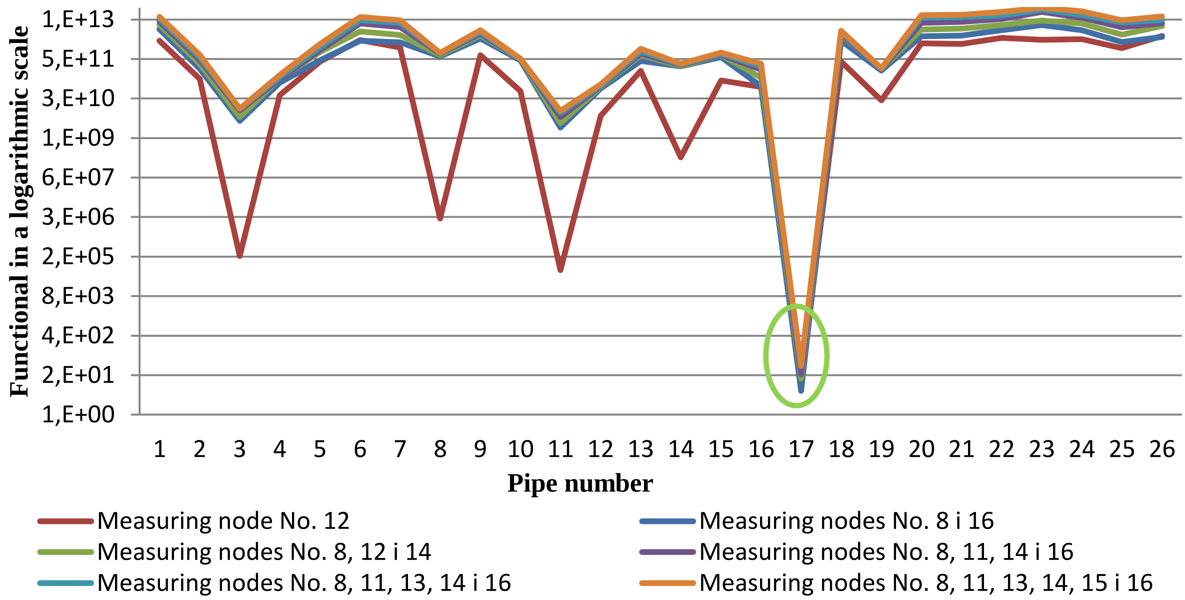

Fig. 4: The minimum of the functional dependence (1) of the leak location in the next pipes of the network; leak in pipe 17.

Fig. 2 shows an example where the damage is generated in the two pipelines numbers 7 and 17. In these pipes damage location was chosen random. Identification of this place was settled by comparing in the functional (1) the reference pressure in measuring nodes with the pressure values calculated during the search algorithm leaks network. Figs. 3 and 4 is shown to correctly identify the faulty pipeline for variants of calculations of the measurement nodes from 2 up to 6. For one node measuring algorithm identified the wrong place damage.

In Fig. 3 we can observe the occurrence of misidentification leak caused by the use of only one measurement node. This place is marked with a red circle. Green circle defines the leak correctly determined both shown in Figs. 3 and 4.

Tab. 1:Values of the functional established for leaks in pipes; the location of the leak is calculated from the starting node.

Number of damaged pipe	Number of measuring nodes					
	1	2	3	4	5	6
7	**196.983 (21)**	**22.86**	**22.84**	**22.86**	**22.86**	**22.86**
17	320.03	**320.04**	**320.04**	**320.04**	**320.04**	**320.04**

Tab. 1 presents a summary leaks locations. It can be seen that the leakage predicting on the pipe 17 is almost identical for any number of measurement nodes. There are no derogation. In the case of a leak on a pipe 7 there is a false reading. In case of using from 2 to 6 measurement nodes there was successful leak detection. If you use only one measuring node the result will be incorrect.

4. Conclusions

The algorithm for finding leaks in the water supply system comprised of two stages: in the first step there is identification number of the pipes in the network in which the demage occur and the second one step the exact location of the leak. On the basis of this algorithm has been developed own program used to locate leaks in water supply network. On the basis of the testing program examples, they were made numerical simulations location of the leak. The results of calculations indicate a faultless location of the leak in all variants calculations.

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