HYDRAULIC MODEL BASED METHOD FOR LEAKS LOCATION IN URBAN WATER DISTRIBUTION NETWORK

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Abstract
The paper describes the use one of the methods for locating leaks based on an accurate model of the network. The paper presents the results of this approach for the active experiment which was carried out on the water supply. The experiment consisted of releasing water with the varying intensity of the fire hydrants located on the test area. Based on the readings of flow meters located in the district, the aim was to identify pre-defined areas in which the simulated leaks occurred. The results are summarized in conclusions.

Keywords: urban water distribution network, epanet model, similarity measure, hydraulic model.

Introduction

Water supply systems supplying water to our homes, workplaces and other institutions are very complex systems of interconnected pipes, valves and all other hydraulic fittings. Their purpose is to ensure continuous access not only to water but also to provide the water to the correct pressure. Due to their complex nature and the distribution below the surface, appear to uncontrolled leaks are a major problem for operating these networks. The cause of these leaks is the most common condition of the pipeline, which as a result of the natural process of usage leads to a weakening of the structure of the pipe, the other to such differences in temperature for different times of the year. External leaks are usually easy to spot, and if they occur in residential areas relevant services are usually quickly informed about the event. In the case of leakage, the external symptoms do not appear or appear only after a long time of occurrence. It is difficult to determine the intensity and location of which leads to a financial loss of water supply companies. Therefore, to reduce these losses have been studies conducted jointly by teams from the Silesian University of Technology and PWiK Rybnik in the project for the construction of the diagnostic system for the detection and location of leaks in water distribution networks [2,3,4]. As part of these activities has developed a number of methods for the detection and location of leaks.

Hydraulic model based method for leaks location

The developed methodology was based on the many stages of the construction and applications developed network models [2, 3]. The role of the basic model meets here the exact model of the network environment EPANET2 developed in [5]. This model has been prepared on the basis of GIS data used at PWiK Rybnik, which allowed the recording of the network structure and on the basis of accounting data partitions (water consumption by users). Accounting data also served to prepare the averaged profile of water consumption zones concerned. The resulting model was then calibrated based on data obtained from pre-positioned flowmeters. Model then was used to carry out simulations of the network for different states (simulated leaks of varying degrees of intensity and a different location). During the study assumes that the location of leaks will be conducted with an accuracy of the areas identified in the study area. Number of areas and their size and shape depend on the complexity of the network. Areas identified based on the knowledge of experts, taking into account the interest of some distinction PWiK of them due to the various aspects of usage. A limitation was the number of flowmeters installed on the network because of the investment costs. Depending on the number and distribution we have varied quality of leaks location in various areas. As part of the study was also carried out to optimize flowmeters distribution in predefined locations on the network. Optimization was performed with the use of evolutionary algorithms. Was considered a limited number of locations that can be installed flowmeters because of the possibility of their physical location and because of the legal nature of the network location.

One of the methods used for leaks location was hydraulic model based method [1]. This method is based on the flow data obtained from the model for the localized virtual leaks in particular areas of the zone. For each leakage flow values are obtained on the model nodes where flowmeters are physically located on the network. Size-generated leakage is determined on the basis of the model by comparing the flow values of the inputs to the state without leakage (simulated using the model) with the value measured on the real flowmeter input. Comparing the value flow from the model with the values of the actual flowmeters using simple Euclidean distance measure designating (1) between the values, obtained similarity value (2) of the actual situation to situation simulated for the leak location. The higher the similarity obtained for the area in which the simulated leak then was greater certainty that in this area it really occurs.

$$\Delta p_j = \frac{1}{n}\sqrt{\sum_{i=1}^{n}\left[\left(Pr_{ij} - Pm_{ij}\right)^2\right]} \quad (1)$$

$$\prod p_j = \frac{1}{1+\Delta p_j} \quad (2)$$

where:

Δp - the average distance of the data model and the actual data.

$\prod p$ - the value of the similarity between the model and actual flows.

P_r - the value of the actual flowmeter.

P_m - the value of the virtual flowmeter.

i - an index that describes the number of flowmeters.

j - index describing the number of areas.

n – number of flowmeters are located.

This method assumed that the leak is simulated at one node of the area. Thus, the number of emitters is equal to the number of control areas. If the areas are well isolated (there are well distinguishable even for small leaks) is this assumption is correct, because all the places in the area are equally representative and in the same way revealed the appearance of leaks anywhere in the area flowmeters installed. This method is characterized by a very fast operation. This approach allows the location of individual leaks on the water supply network.

Example of the application

The example concerns the location real leaks on the network, which was obtained by the experiment active on the network (water drop the hydrant by varying the flow rate for the duration of the 10 min flow rate). The experiment was conducted in the district Popielów - Rybnik PWiK operations area, one of the zones where the run is to implement the developed system. This zone is characterized by buildings from houses. Table 1 shows the location of the leaks introduced, their size and duration of the experiment. In every place generated by a variety of leak flow rates. Figure 1 shows the location of the leaks entering the network. Figure 2 shows the breakdown zone areas (26 areas).

Table 1 The parameters of the experiment

Leak time	Leak size [m3/h]	Node number in model
09:15	1.932	4196
09:30	3.198	4196
09:45	4.752	4196
10:15	2.094	6966
10:30	3.486	6966
10:45	4.878	6966
11:00	1.872	7356
11:15	3.132	7356
11:30	3.624	7356
11:45	4.902	7356
12:30	2.052	7672
12:45	3.258	7672
13:15	2.088	693
13:30	3.372	693
13:45	5.1	693

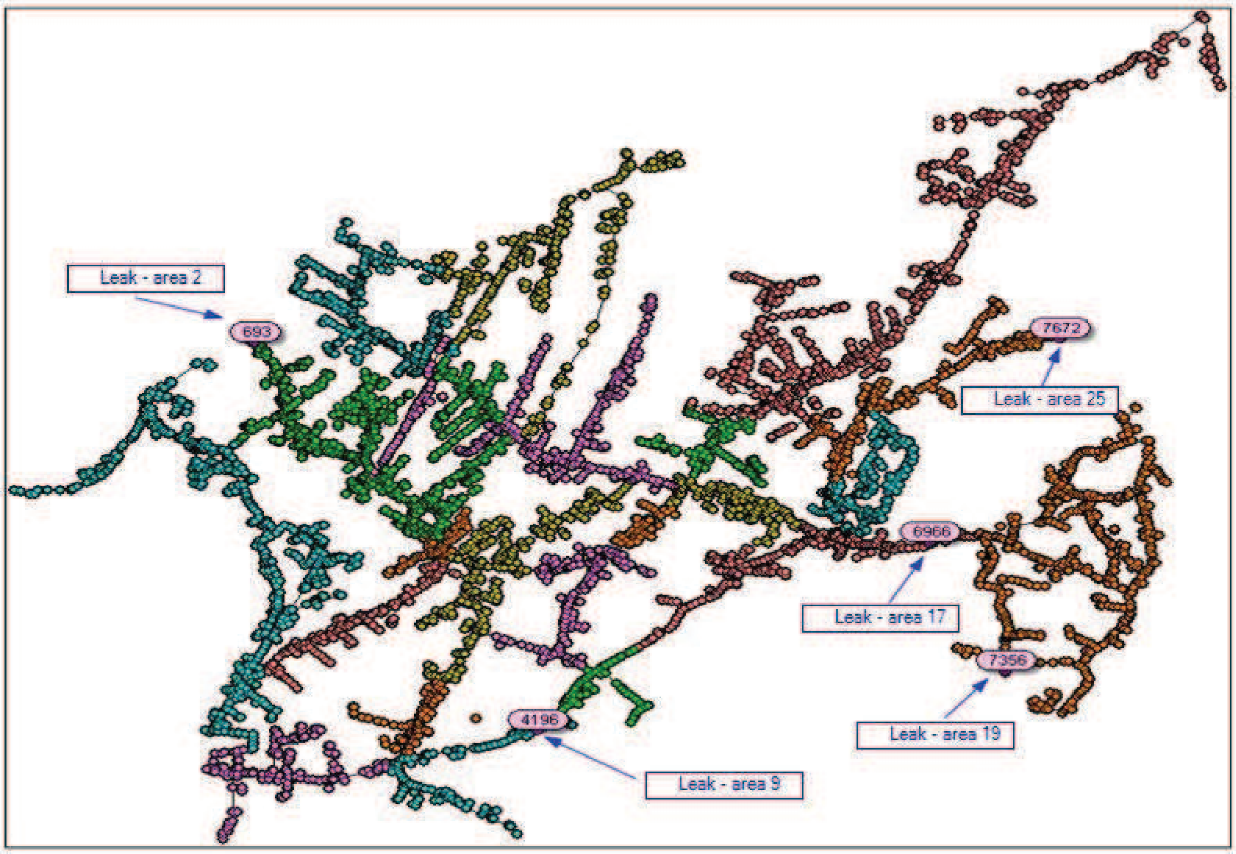

Fig. 1 Location of leaks

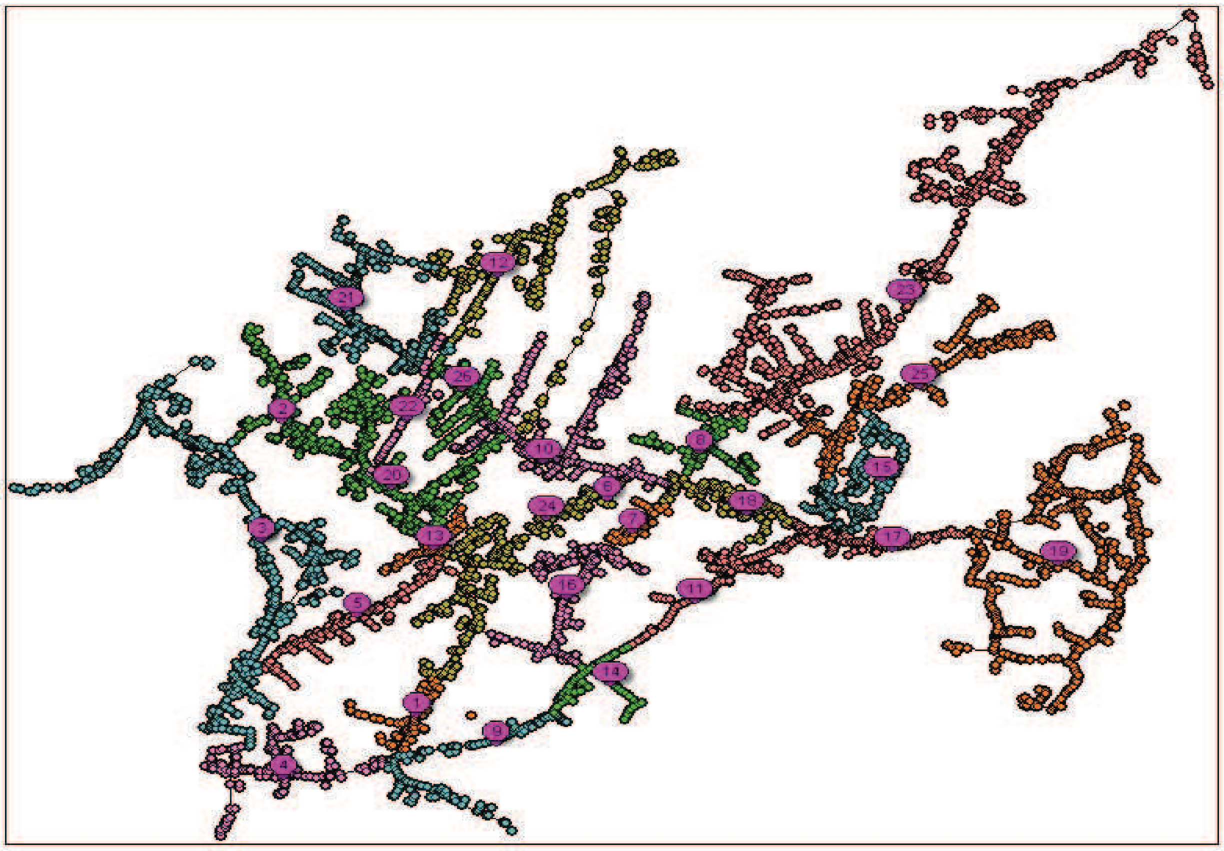

Fig. 2 The division zone areas

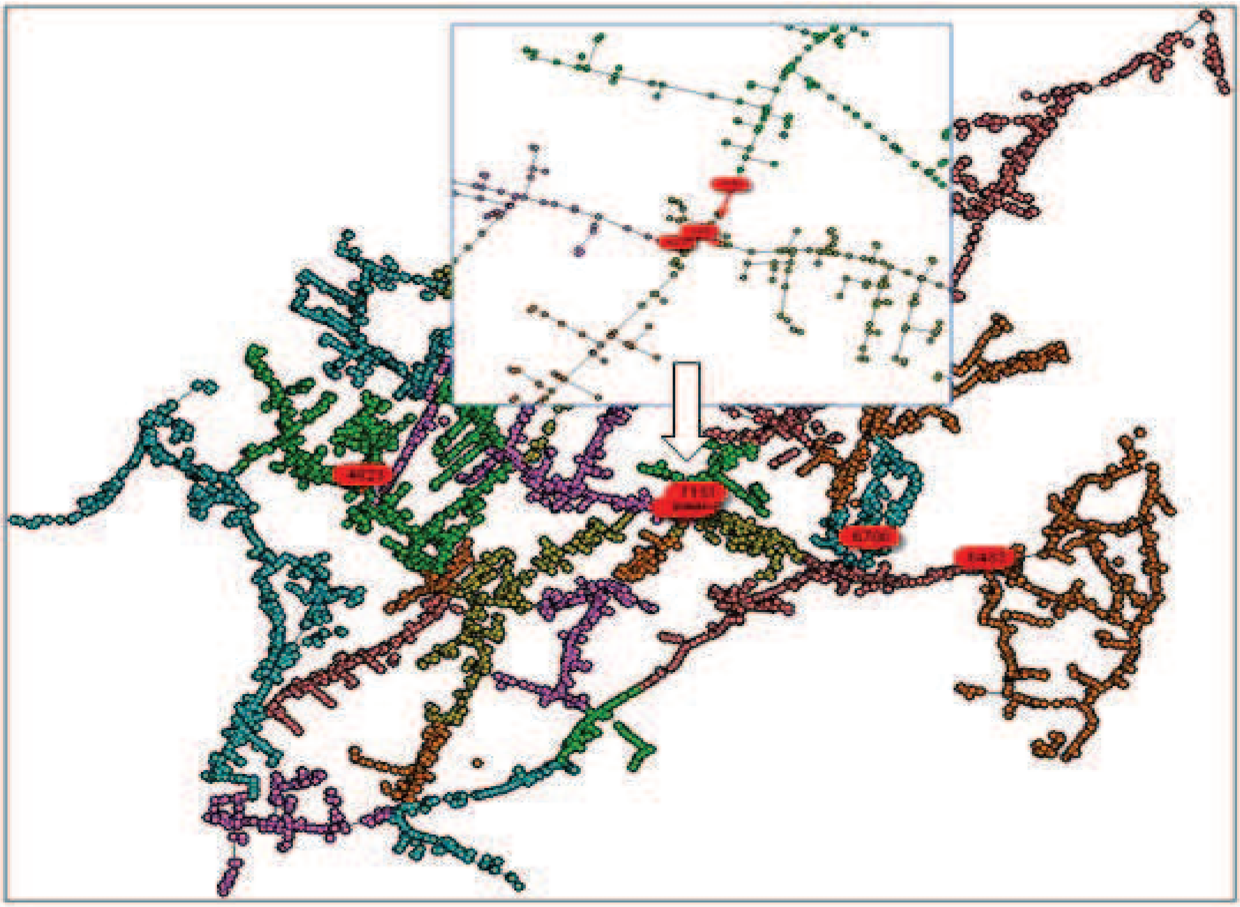

Fig. 3 Distribution flowmeters

Figure 3 shows the state of flowmeters distribution on the real network. As of the experiment was installed six flowmeters planned 11th As you can see it is especially poorly metered zone down.

Here are the results for each leaks location using the following method. The collated results include only selected results with the highest similarity.

Table 2. LEAK - AREA 9

09:15:00		09:30:00		09:45:00	
leak = 1.932		leak = 3.198		leak = 4.752	
Area	Similarity	Area	Similarity	Area	Similarity
2	0,8	9	0,87	3	0,83
3	0,78	5	0,85	4	0,81
4	0,76	1	0,82	2	0,81
5	0,75	4	0,82	5	0,78
9	0,74	24	0,81	9	0,74
14	0,73	16	0,81	1	0,65

Table 3. LEAK - AREA 17

10:15:00		10:30:00		10:45:00	
leak = 2.094		leak = 3.486		leak = 4.878	
Area	Similarity	Area	Similarity	Area	Similarity
11	0,85	14	0,84	17	0,88
18	0,83	11	0,8	11	0,86
17	0,83	17	0,78	18	0,78

14	0,8	18	0,77	14	0,75

Table 4. LEAK - AREA 19

11:00:00		11:15:00		11:30:00		11:45:00	
leak = 1.872		leak = 3.132		leak = 3.624		leak = 4.902	
Area	Similarity	Area	Similarity	Area	Similarity	Area	Similarity
19	0,84	19	0,8	19	0,84	19	0,86
18	0,76	11	0,68	17	0,62	17	0,55
11	0,76	17	0,68	18	0,62	11	0,55
17	0,76	18	0,67	11	0,62	14	0,54

Table 5. LEAK - AREA 25

12:30:00		12:45:00	
leak = 2.052		leak = 3.258	
Area	Similarity	Area	Similarity
15	0,79	25	0,77
14	0,78	15	0,76
25	0,78	23	0,7
1	0,74	14	0,66

Table 6. LEAK - AREA 2

13:15:00		13:30:00		13:45:00	
leak = 2.088		leak = 3.372		leak = 5.1	
Area	Similarity	Area	Similarity	Area	Similarity
2	0,65	2	0,68	2	0,71
3	0,62	3	0,64	3	0,65
4	0,6	4	0,61	4	0,59
5	0,58	5	0,58	5	0,57

Summary

From the above results it can be concluded that the accuracy of the above leaks location is relatively high. Furthermore, it shows areas are usually close to each other. Despite the incomplete number of flowmeters planned to run on the zone even in case of leakage in area 9 (Table 2) located at a narrow circle of search to a few neighboring areas. In this case, it was known that the value of leakage from a simulation which was performed certainly had a positive effect on the results of the location. It can be seen that the leakage of larger intensities are more localized as clearly manifested in the network and stronger flows affect the value obtained from measuring devices. However, the established threshold of detectability the size of 5m3 / h is maintained. The advantage of the proposed method is the possibility of direct application is independent of the number of currently available flowmeters. There is the necessity to build a new model, only we have to deal with the deterioration of location accuracy. The quality of the results is also affected by location or network numerical model was valid and properly calibrated.

References

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