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REVIEW

Improvement of water distribution networks analysis by topological similarity

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Abstract In this research paper a methodology based on topological similarity is used to obtain starting point of iteration for solving reservoir and pipe network problems. As of now initial starting point for iteration is based on pure guess work which may be supported by experience. Topological similarity concept comes from the Principle of Quasi Work (PQW). In PQW the solution of any one problem of a class is used to solve other complex problems of the same class. This paves way for arriving at a unique concept of reference system the solution of which is used to obtain the starting point for starting the iteration process in reservoir and pipe network problems.

Contents

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Nomenclature

Bold letters	matrices	H_i	head of reservoir/ node; (i = A, B, C).
D_i	diameter of the pipe 'i'; i = 1, 2, 3,...	L_i	length of pipe line 'i'.
EL	Elevation Level	m, n	subscripts which represent different topological similar systems
f_i	Darcy–Weisbach coefficient for pipe 'i'.	Q_i	discharge of pipe 'i'
g	acceleration due to gravity	$\{Q\}_n$	discharge of pipes in a TSS_n
$\{h\}_n$	head loss of pipe in a TSS_n; n = 1, 2, 3, ...	r_i	resistance parameter for the pipe 'i'.
$\{H\}_m$	Head of reservoir in a TSS_m; m = 1, 2, 3, ...		
h_i	head loss of pipe		

1. Introduction

Development of residential or industrial areas or discovery of new sources of supply leads to changes in the pattern of large scale pipe networks. This requires development of new robust analysis tools. Various methods for analysis of pipe networks available in the literature are Hardy-Cross method [1–4,18,19], Newton–Raphson [4,5] and linearization method [6,7], Ayad et al. [8] and Ates [9]. All the available methods solve a set of non-linear simultaneous equations iteratively beginning with an initial trial solution based on guess work. Guessing the initial solution for iterations is not easy especially for a beginner.

In this paper, for the first time concept of topological similarity as exclusively used in [10–15] to solve truss, beam and column problems with advantage is carried over into the domain of fluid mechanics (viz. reservoir and pipe networks). Pandita et al. [10] derived theorems, based on Principle of Quasi Work, useful for discrete structural models forming the lower end of finite elements. Topological similarity was advantageously used by Pandita et al. in [11] for obtaining redundant reactions of beam. A quick and simplified method for obtaining nodal deflections of an indeterminate truss using topological similarity is presented by Pandita [12]. An easy methodology for obtaining deflections of structures without resorting to internal forces/moments was given by Pandita and MarufWani [13]. Topological similarity was advantageously used by Pandita [14] to determine Euler critical load. Pandita [15] has derived the PQW and arrived at the definition of topologically similar systems. Topological similarity concept (through modified Bett's theorem) has also been successfully used to calculate the deflection of beam on an elastic foundation with advantage by Borak and Marcian [16]. As it has been successfully used in structural domain, here in this paper an attempt has been made to apply the same principle in the domain of fluid mechanics. Concept topological similarity was first demonstrated by Kheer [17] in the realm of fluid mechanics.

As PQW connects two topological similar systems the solution of one system can be used to arrive at the solution of all other system of the same class with ease. Hence, existence of a system whose solution can be used to solve all other topological similar problems exists. Here, such a system is designated as 'Reference system'. In this paper an attempt has been made to define such a reference system. Solution of this reference system is used for obtaining initial starting point for carrying out iteration in the cases of other reservoir and pipe network problems.

It is usually difficult to assess the initial trial values for head or for discharges. For example, in the case of three reservoir problem (Fig. 1), initial guess for the junction head 'H_J' is usually made by taking average of highest and lowest heads of the reservoirs. If this guideline is applied to this problem then average of maximum and minimum comes out to be 170 m. This is equal to the head of second reservoir and the flow in pipe '2' is equal to zero. With this value of initial guess it will be difficult to arrive at the solution of the problem as it will take much more number of iterations. Hence, the problem is to resolve weather the guess should be less than 170 m or greater than 170 m in order to arrive at the final solution in minimum number of iterations. By present method, initial trial value of head for starting iterations comes out to be 168 m which is on the correct side (i.e. on the side of actual head of 148.8 m).

By present approach, guess work is completely eliminated and initial trial head/discharges in pipe network problems. This initial trial using topological similarity comes out to be quite closer to the actual solution and hence the numbers of iterations to arrive at the final solution are also considerably reduced.

2. Relations connecting two topologically similar networks

In this section general relation is derived for connecting two topological similar systems. These relations are used to calculate initial trial point in case of reservoirs and pipe network systems.

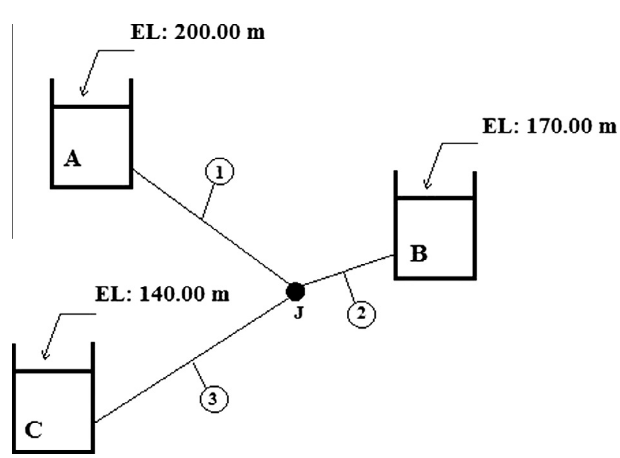

Figure 1 Three reservoir problem.