CALIBRATION OF WATER DISTRIBUTION SYSTEMS: EVOLUTIONARY APPROACHES WHILE ACCOUNTING FOR FLUID TRANSIENTS

BONG SEOG JUNG

PhD Candidate, Dept. of Civil Engineering, Univ. of Toronto,
35 St. George St., Toronto, ON, M5S 1A4, Canada
(Tel: +1-416-978-5972, e-mail: jung@ecf.utoronto.ca)

A number of mathematical models are used nowadays to describe behaviour of the real-life water distribution system (WDS). To be used meaningfully, any WDS mathematical model must be calibrated first. Calibration is the process by which a certain number of WDS model parameters are adjusted until the model mimics the behavior of the real WDS as closely as possible. When designing an expansion or modification to a water distribution network, accurate estimates of pipe parameters like friction factors and demands must be known to accurately represent the network. Therefore, the calibration of system parameters in the WDS is important and the confidence of the model is strongly dependent upon the confidence associated with the estimate of system parameters.

A related and challenging issue for WDS is the leakage problem. It has been reported that a typical range for lost water (UFW) in Europe is 9-30%, while 43% for Malaysia or 56% Bangladesh. This is very costly for the loss of water and treatment chemicals, unnecessary capacity expansion, the increased energy expenditure required to feed the leaks. Water quality concerns such as transient intrusion have added another dimension to the stimulus for leak related research.

The calibration of system parameters and leakage detection are, at least theoretically, possible using inverse methods where the results of measurements are known but parameters of physical system are unknown. With the rapid development of both fast computers and powerful efficient numerical models, a mathematical model can be applied to assist in achieving an optimal set of system parameters in the inverse methods. However, WDS model complexities that arise from, for example, nonlinearity, discontinuity, and discreteness, limit the application of traditional gradient-based search methods such as Netwon-Raphson or Levenberg-Marquardt methods. Such limitations have been overcome recently by directly coupling the WDS models with Evolutionary Computational Algorithms (ECAs). ECAs are a set of probabilistic optimization algorithms based on an analogy between natural biological systems and engineered systems. There are several types of ECAs in use today such as Genetic Algorithms, Evolutionary Programming, Particle Swarm Optimization and Ant Colony Optimization. These optimizations aim at mimicing natural computational systems and thus at developing more robust and efficient algorithms for solving complex real-world optimization problems. The specific problems dealt with by such computational systems are usually highly nonlinear and often contain inaccurate and noisy data.

This paper explores a comprehensive numerical study for leak detection and system calibration using an inverse problem method accounting for fluid transients. ECAs, specifically Genetic Algorithms and Particle Swarm Optimization are applied as optimization tools to solve an inverse problem in which system parameters (such as lumped leak coefficients and friction factors) are determined from measured or numerical transient pressure head data. This paper also examines systematically the difficulties and limitations of ITC when applied to real water distribution system. Due to the uncertain system parameters such as pipe diameter, wave speed and water demand, a systematic calibration approach to explicitly include these additional uncertainties during the ITC process are investigated. However, even these approaches can often be expected to converge poorly when the full scale of the field problem is reflected in the search space.