Application of Gamma Test and Neuro-Fuzzy Models in Uncertainty Analysis for Prediction of Pipeline Scouring Depth

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Abstract

The process involved in the local scour below pipelines is so complex as to make it difficult to establish a general empirical model to provide accurate estimation for scour. This paper describes the use of an adaptive neuro-fuzzy inference system (ANFIS) and a Gamma Test (GT) to estimate the submerged pipeline scour depth. The data sets of laboratory measurements were collected from published literature and used to train the network or evolve the program. The developed networks were validated by using the observations that were not involved in training. The performance of ANFIS was found to be more effective when compared with the results of regression equations and GT Network modelling in predicting the scour depth of pipelines.

Keywords

Pipelines, Local Scour, Gamma Test, ANFIS

1. Introduction
Scour is a major cause for the failure of underwater pipeline. Interactions between the pipeline and its erodible bed under strong current and/or wave conditions may cause scouring around the pipelines. This process involves the complexities of both the three-dimensional flow pattern and the sediment movement. Scouring underneath the pipeline may expose a section of the pipe, causing it to become unsupported in the stream. If the free span of the pipe is long enough, the pipe may experience resonant flow-induced oscillations, leading to settlement and subsequently structural failure. Accurate estimate of the scour depth is important in the design of submarine pipelines [1]. The estimation of the scour characteristics of underwater pipelines continues to be a concern for hydraulic engineers.

A number of empirical formulas have been developed in the past to estimate equilibrium scour depth below pipeline, including [1]-[6]. A summary of these equations is shown in Table 1.

Predictive approaches such as artificial neural networks (ANNs) and adaptive neuro-fuzzy inference systems (ANFIS) have been recently shown to yield effective estimates of scour around hydraulic structures. ANNs have been reported to provide reasonably good solutions for hydraulic engineering problems, in cases of highly non-linear and complex relationship among the input-output pairs in corresponding data.

The objective of this study is to develop a predictive model for scour depth, and in particular 1) to develop an ANFIS model with the aid of Gamma Test, 2) to evaluate the uncertainty inherent by using ANFIS and Gamma Test models for scour depth estimation in clear-water condition and (3) to compare the results obtained the ANFIS model with the empirical methods.

2. Local Scour below Underwater Pipelines
The variables influencing the equilibrium scour depth $d_s$ below a pipeline in a steady flow over a bed of uniform, spherical and cohesion less sediment as shown in Figure 1 are: flow condition, sediment characteristics, and pipe geometry. The scour depth can be represented by the following general functional relationship:

$$ d_s = f(\rho, \rho_s, \nu, V, Y, g, d_0, S_o, D) $$

where $\rho$ = fluid density, $\rho_s$ = sediment density, $\nu$ = fluid kinematic viscosity, $V$ = Average velocity, $Y$ =

<table>
<thead>
<tr>
<th>Author</th>
<th>Equation</th>
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<tbody>
<tr>
<td>Chao and Hennessy (1972)</td>
<td>$H - R = \frac{d_s}{2} \left[ \frac{H}{R} \right]^{\frac{2}{3}} \left( \frac{H}{R} \right)^{-1}$ for $H \geq R$.</td>
</tr>
<tr>
<td>Kjeldsen et al. (1973)</td>
<td>$d_s = 0.972 \left( \frac{V}{\sqrt{g}} \right)^{1.66}$ D$^{0.5}$</td>
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<tr>
<td>Ibrahim and Nalluri (1986)</td>
<td>$d_s = 4.706 \left( \frac{V}{\sqrt{g}} \right)^{1.06} + 0.06$ clear water</td>
</tr>
<tr>
<td>Dutch research group</td>
<td>$d_s = 0.084 \left( \frac{V}{\sqrt{g}} \right)^{1.36} + 1.33$ live bed</td>
</tr>
<tr>
<td>Moncada-M. and Aguirre-Pe(1999)</td>
<td>$d_s = 0.929 \left( \frac{V}{\sqrt{g}} \right)^{1.55} D^{0.5} d_0^{0.04}$</td>
</tr>
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Table 1. Empirical formulae for estimate pipeline scour depth.