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Performance investigation of the dam intake physical hydraulic model using Support Vector Machine with a discrete wavelet transform algorithm

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A B S T R A C T

In the present study hydraulic scaled model was conducted to evaluate an intake structure and checking its safety hydraulic performance. An investigation on the structural and mechanical equipment performance was performed by testing a scaled model to determine discharge capacity and head losses. In addition, the novel method established on Support Vector Machines (SVM) coupled through discrete wavelet transform was designed and adapted to estimate head loss at inlet and outlet section of the horizontal intake structure. Estimation and prediction results of SVM-WAVELET model was compared with genetic programming (GP) and artificial neural networks (ANNs) models. The model test results of SVM WAVELET approach reveal more accuracy in prediction and also attain improved generalization capabilities than GP and ANN. Furthermore, results specified that advanced SVM-WAVELET model can be applied confidently for auxiliary research to formulate predictive model for head loss at inlet and outlet section. Consequently, it was found that using of SVM-WAVELET is principally encouraging as an alternate strategy to predict the head loss as a representative of inner pressure head at intake structure.

1. Introduction

The intake structure (or head regulator) is a hydraulic device constructed at the head of an irrigation or power canal, or a tunnel conduit through which the flow is diverted from the original source such as a reservoir or a river. The main purposes of the intake structure are (a) to admit and control source water from the source, and probably to measure the flow rate (b) to minimize the silting of the canal, i.e. to control the sediment entry into the canal at its intake, and (c) to prevent the clogging of the entrance with floating debris (Novák et al., 2007). The most commonly used intakes are horizontal. Moreover, horizontal intakes followed by a curve to an inclined or upright power tunnel or penstock are used at locations of large difference in elevation between the penstock and intake are large (Wu et al., 2011). The benefit of horizontal intakes contains in the probability to easily place trashracks, gates and stop logs. Based on the initial water head on the intake inlet body (H), horizontal intakes are categorized in two groups: high head intakes ($H \geq 15$ m) and Low head intakes ($H < 15$ m). High head intakes are usually placed in reservoirs or in the body of arch, gravity, earth dams. In this case, the intake structure is placed directly in the reservoir, and water is conveyed through diversion systems to the fore bay where it passes through the intake to the penstock or pressure tunnel. Low head intakes are usually placed in rivers, where the intake is integrated in the body of the dam together with the turbines (Safavi et al., 2009).

According to the statement of Bernoulli's principle for inviscid flow of non-conducting fluid, fluid flow speed rises instantaneously with pressure drop or potential energy reduction. System head losses of the flow over intake block can be determined by applying Bernaulli's equation.

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The accurate design of intake structure is highly complex to transfer the prescribed discharge of flow. A number of theoretical and experimental investigations on the problem have been carried out through past few years (Ghosh and Ahmad, 2006; Righetti and Lanzoni, 2008).

Theoretical investigations are based on several assumptions. The flow field above the intake is considered one dimensional which varies gradually to hold hydrostatic pressure distribution on every single cross section. In practice, however, streamline curvature and, hence, departure from hydrostatic pressure distribution is used to characterize the flow field (Nielsen and Rettedal, 2012; Zhang et al., 2008). Specification of the inlet structure forming has strong impact on the intake hydraulic behaviour (Kumar et al., 2010; Vahid et al., 2011). The diverted discharge of inlet with longitudinal bar is directly related to the local value of the energy of flow; however, discharge at the outlet section with transverse or circular perforations is related to the depth of local flow. In the present study, we concentrate our attention on the intake constructed of longitudinal inlet bars. Another commonly applied assumption is that the dissipation of energy is negligibly small along intake rake, which is considered to be valid for the inlets with longitudinal bars, although the observations from the experiments done by Gómez and Russo (2010) show that dissipation of energy has a tendency to increase with Froude number and opening of split. Brunella et al. (2003) carried out an investigation to measure free surface velocities and concluded that effects of dissipation are negligible apart from the region near the rack end.

Little information has found in the literature on hydraulic modeling of dam intakes. The intake hydraulic model study of Glen Canyon dam was carried out by Vermeyen (1999) to determine increase in the head loss with modification of the intake, provided useful hydraulic information. As part of the design process in favor of irrigation purposes, a hydraulic model was constructed to accumulate hydraulic project data and to ensure satisfactory hydraulic performance. Based on the hydraulic model experiments with a scale of 1:20, an appropriate dimensions for the intake inlets was suggested to retain velocity of the flow within the acceptable value at the trash rack (Safavi et al., 2009).

Current paper explains designing a Horizontal Intake Structure (HIS) for a rock fill dam with 65 m in height. Outcomes discharge of the HIS was intended to be used for irrigation. A 1:20 scale model was fabricated to guarantee satisfactory hydraulic performance. Vortex formation, discharge dimensions and head losses at HIS were investigated through a laboratory scaled model.

Being one of few asphaltic concrete faced rockfill dam that is still in existence around the world today, Pedu dam at Malaysia has been in service for the last 45 years without failure in enabling double-cropping paddy cultivation per annum. Due to the inevitable natural aging effects presently experienced especially on the outlet works, refurbishment on the dam is required to enhance the operation life span of the dam. Therefore, refurbishment and upgrading work would need to be completed in separate stages with the initial challenge of formulating a permanent upstream solution to enhance the control of water release through the dam. For this purpose, the hydraulic model should be constructed to gather design data for the proposed design of the new intake structure. The hydraulic data obtained from the model study were near-field discharges and head losses in submergence conditions. The present contribution thus intends to investigate the hydraulic behaviour of the intake block structure, and outlet of this structure to confirm the adequacy of hydraulic design performance. For intake structures placed on reservoirs, studies should be conducted in order to determine the fluctuations of the water level. The efficiency of the structure should be checked for normal and extreme levels. These include the determination of Physical Hydraulic Models (PHM) construction for the dam intake structure based on the Froude number. In addition, series of the tests were conducted on the model to ascertain the hydraulic characteristic of the model for the new intake, with specific observation on head loss through the structure. The differential head across the structure is an important component in the design of the new intake structure.

The head loss analysis requirements perfect on-line identification. In this paper, we stimulate a predictive model of head loss at inlet and outlet section by supplementing Support Vector Machine (SVM) a soft computing methodology through a discrete wavelet transform algorithm.

Currently, researchers devote up-to-date computational method to resolve the actual problems besides defining the optimal functions and values in a variety disciplines of science. Support vector machines (SVMs) as a soft computing procedure is considered in a variety disciplines of engineering (Jain et al., 2009; Ornella and Tapia, 2010). The accuracy of prediction of an SVM model greatly depends on appropriate determination of model parameters. Even though structured policies of selection parameters are essential, alignment of parameters of the model required to be made, correspondingly. Previously, several conventional optimization algorithms have applied by different researchers for the selection of model parameters, although they succeed limitedly (Bao et al., 2013; Friedrichs and Igel, 2005; Lorena and De Carvalho, 2008). Among these are grid research algorithm (Hsu et al., 2003), algorithm of gradient decent (Chapelle et al., 2002; Chung et al., 2003), to mention just a few. Computational complication is the main shortcoming of grid research algorithm, which limited applicability to simple problems. The algorithm, conversely, is typically liable to limited minima. In a major percent of the optimization problems, multiple local solution do occur, however, evolutionary algorithms seems to be the superlative method due to providing comprehensive solution for these optimization cases.

Current research developed an analytical model of head loss at inlet and outlet section by means of Support Vector Machines (SVM) using the isolated algorithm of wavelet transform (SVM-WAVELET) method. The time series data was decomposed into its different components with wavelet analysis, and the separated components were used to enter or the SVR model. Outcomes demonstrate that proposed model can predict satisfactory head loss at inlet and outlet section. SVM-WAVELET outcomes were also evaluate with genetic programing (GP) and artificial neural networks (ANNs) findings.

2. Hydraulic modelling and experimental setup

2.1. Hydrological parameters

Annual reservoir high and low level data from 1974 to 2011 for the Pedu dam is summarized in Table 1.

Based on these data and geometric characteristics of the dam (Fig. 1), Head Pressure, H_p, was obtained as 59.13 m. Moreover, considering the main characteristics of the dam, the design, draw-off for the dam that consists of 2 intake blocks is 141.600 m^3/s. Therefore, the discharge per intake block, Q_p = 70.8 m^3/s and flow discharge per inlet side = 35.4 m^3/s.

Table 1
Highest and lowest level in feet and meter MSL for the Pedu dam.

Annual level (1974–2011)	Level (m)	Storage × 10^6 m^3
Highest	98.6	1150.8
Lowest	75.6	121