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EXTENDED ABSTRACT

Modeling and Predicting the Rate of Scour Depth below Pipelines in Waves Using Gaussian Process Regression (GPR) and Support Vector Machine (SVM) Methods

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1. Introduction

Pipeline network is one of the major agents of the economic growth and development of a country, which is used to transport fluid fuels, wastewaters, and any other fluids. When these pipelines meet seas and oceans, pipes are laid on the solid bed and it causes changes in the flow pattern around the pipes. In result of these changes, the shear stress of the bed under pipelines and turbulence of current will be increased, and scour will occur under pipelines and the scour hole will form and develop. These holes cause damage and failure to the pipe due to the pipe weight and oscillating loads. Therefore, it is very important to study the scour depth and effective variables to reduce scour and prevent damage. Researchers have conducted experimental and numerical studies on scour phenomenon, considering various types of flows and conditions, and have provided different relations over the years.

In this research, the effect of various factors on this phenomenon in waves is investigated using Gaussian process regression (GPR) and support vector machine (SVM). To this end, several laboratory data were used and after defining several non-dimensional parameters the performance of these methods was evaluated. The result of this research demonstrated that these methods are better than experimental relations and have promising outcomes. This study has shown that an SVM model with KC, Re and e/D variables in wave-induced current has the best results. It is worth mentioning that the KC variable has the most significant effect on the scour below pipelines.

2. Support vector machine and Gaussian process regression

In addition to the importance of gathering reliable information, it is essential to use accurate methods to estimate scour depth. Therefore, in this study, two powerful methods of Gaussian process regression and support vector machine, which are among the soft computational, are used to calculate the scour depth and study this phenomenon. How the SVM algorithms work is similar to most intelligent methods, by training and testing. The system is first trained by a portion of the data, then the problem solution for the test data is evaluated. SVM is able to move the problem to a more dimensional space, which is done by kernel methods. According to the circumstances and the problem different types of kernels can be chosen. In this study, we used the RBF kernel which gave the best result among others. The Gaussian process can be considered as an infinite-

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dimensional distribution of multivariate Gaussian. The regression process actually provides a possible non-parametric modeling method that is used to solve various engineering problems.

The data of experiments in a rectangular flume and in a wave-induced current, from various research conducted by Sumer, Fredsoe (2002); Cheng, et al. (2020); Sumer, Fredsoe (1990); Zang, et al. (2019); Kazeminezhad, et al. (2010); Dogan, Arisoy (2014); Mousavi, et al. (2009); Sumer, et al (2001), are used in this study.

3. Modeling and predicting the scour depth

According to the parameters measured in the experiments, non-dimensional parameters are defined and a combination of these criteria is introduced to estimate the scour depth, which can be expressed in the following relation.

$$\frac{S}{D} = f(KC, \theta, Re, \frac{e}{D}) \tag{1}$$

Where S is the equilibrium depth of scour, D is the pipe diameter, KC is Keulegan-Carpenter number, θ is the Shields parameter, Re is the Reynolds number; and e is the initial distance between pipe and bed.

Numerous models were processed by SVM and GPR methods and R, NSE, and RMSE coefficients were used to evaluate these models. The best results were obtained from a model with the following parameters:

$$WF6 = f(KC, \theta, Re, \frac{e}{D}) \tag{2}$$

Afterward, the obtained results were compared with the results of 2 functions presented by the previous researchers, and it is shown that better and more accurate results can be achieved utilizing methods introduced in this study. By selecting the WF6 model as a model that provided the best results, sensitivity analysis has been used to investigate the effect of different parameters in predicting the rate of scour depth under pipelines and to select the most effective parameter.

4. Conclusions

In this research, using experimental data in wave-induced currents, it is demonstrated that the model with input parameters of $KC, \theta, Re, \frac{e}{D}$ with the values of RMSE=0.047, R=0.959 and NSE=0.903 is selected as the superior model and leads to more accurate results in estimating the scour depth below the pipelines than other models.

By performing sensitivity analysis on the superior model, it was observed that KC parameter play an essential role in estimating the scour depth under pipelines in waves, and it can independently provide acceptable results for the study and prediction of that phenomenon. According to the comparison of the results obtained from these models, it can be concluded that the effect of e/D on scour depth is more than the Reynolds number.

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