Archive of SID

University of Tabriz

Journal of Civil and Environmental Engineering
Volume 48 (2018), Issue 2 (Summer), 71-80

EXTENDED ABSTRACTS

Estimation of Dynamic Pressure in Two-Phase Air-Water Flow Using ANN and ANFIS

Faezeh Moghadas [a], Abdorreza Kabiri-Samani[a,*], Maryam Zekri [b]

[a] *Department of Civil Engineering, Isfahan University of Technology, Isfahan, Iran*
[b] *Department of Electrical and Computer Engineering, Isfahan University of Technology, Isfahan, Iran*

Received: 26 January 2017; **Accepted:** 26 August 2017

Keywords:
Air-water flow, ANN and ANFIS models, APSO algorithm, dynamic pressure, two phase flow.

1. Introduction

Two phase gas-liquid flows occur in a wide variety of situations, *i.e.*, in water supply systems, petroleum industry, pressurized tunnels and pipelines, culverts and water conduits (Mishima and Hibiki, 1996, Kabiri-Samani and Borghei, 2010). Air entrainment into a pipeline is a result of vortices at water intakes. Due to the severity of two-phase air-water flow at hydraulic systems, estimation of the dynamic pressure and pressure fluctuations in such systems is of great importance in practice (Yan et al., 2014). Most of the former studies have focused on two-phase gas-liquid flow in micro-channels and small pipelines, however, there is a lack of fundamental studies on pipelines with larger dimensions as used in hydraulic systems. Recently, some computational intelligence approaches such as ANN and ANFIS are very effectively used to predict complex problems with several parameters involved (Jang et al., 1997, Sebakhi, 2010, Fan and Yan, 2014). The present study focuses on estimation of dynamic pressure in two-phase air-water flow using ANN and ANFIS combined with PSO algorithm and subtractive clustering technique.

2. Methodology

Experiments were conducted in a horizontal/inclined air-water flow pipeline at the hydraulic laboratory of Sharif University of Technology, Iran. The setup included a 10 m long transparent pipe with an inner diameter of 90 mm. The governing dimensionless equation relating the dynamic pressure inside the pipe as a function of independent parameters is

$$\frac{h_d}{h} = f(Fr, E_0, Sh, K_f, \alpha, \bar{C}, wfs) \quad (1)$$

where h_d/h is the dimensionless dynamic pressure, Fr, E0, Sh, We, Kf, and $\bar{C}$ are Froude number, Eotvos number, Strouhal number ,Weber number, friction factor ($K_f = f_{tp}L/D$, L is a characteristic length) and averaged air concentration ($\bar{C} = \beta/(1+\beta)$, $\beta = Q_a/Q_w$) respectively. From the 302 selected data points, 70% were chosen as the training data, 20% as the checking data and the remaining 10% as the testing data to evaluate the models' performances. For better optimization of the models, the data were normalized to be in the range of [0, 1] as follows

$$x_n = (x - x_{\min})/(x_{\max} - x_{\min}) \quad (2)$$

* Corresponding Author
E-mail addresses: f.moghadas@cv.iut.ac.ir (Faezeh Moghadas), *akabiri@cc.iut.ac.ir* (Abdorreza Kabiri-Samani), mzekri@cc.iut.ac.ir (Maryam Zekri).

www.SID.ir

Archive of SID

where x, x_n, x_{min} and x_{max} are the real data, normalized data, minimum and maximum values of data in each datasets. After surveying the dataset by applying the input and output variables, the developed ANN, ANN–PSO, ANFIS, ANFIS-PSO, ANFIS-SUBC, and ANFIS-PSO-SUBC models were applied to estimate the dynamic pressure in two-phase air-water flow.

3. Results and discussion

Fig. 1 compares the results of ANN and ANN-PSO for the training and testing data, whereas, Fig. 2 and Fig. 3 compare the results of ANFIS and ANFIS-PSO as well as ANFIS-SUBC and ANFIS-PSO-SUBC, respectively.
Table 1 compares the results of ANN, ANN-PSO, ANFIS, ANFIS-PSO, ANFIS-SUBC and ANFIS-PSO-SUBC, models, applying NRMSE error values and R^2 for the training and checking datasets. These error functions were considered as the objective functions to tune the clustering and fuzzy antecedent and consequent parameters. According to the results, the ANFIS and the ANFIS-PSO have better recognition rate than the ANN and ANN-PSO models. Furthermore, the ANFIS models with fuzzy sub-clusters have been effectively improved the results. From Table 1, it can be concluded that the ANFIS-PSO-SUBC is apparently the best model among the developed models (NRMSE=0.19 and R^2=0.96) for the testing data. Figure 1 compares the results of the best predictor model (ANFIS-PSO-SUBC) with those of Kabiri-samani et al. (2007). According to this figure, ANFIS-PSO-SUBC is superior than the empirical relation given in (Kabiri-Samani et al., 2007).

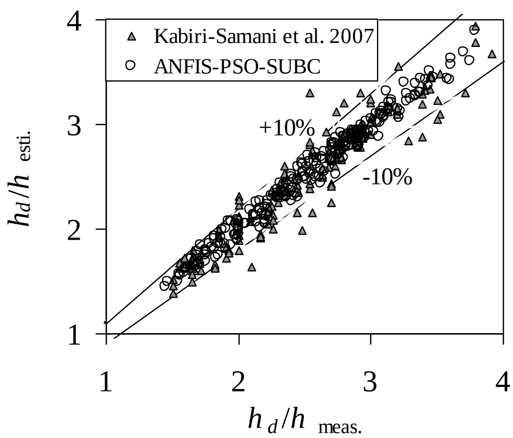

Fig. 1. Results of ANFIS-PSO-SUBC compared to those of Kabiri-Samani et al. (2007)

Table 1. A comparison among the results of predictor models

Model	Train		Test	
	NRMSE	R^2	NRMSE	R^2
ANN	0.25	0.93	0.35	0.88
ANN-PSO	0.25	0.91	0.3	0.91
ANFIS	0.22	0.95	0.23	0.94
ANFIS-PSO	0.186	0.97	0.19	0.96
ANFIS-SUBC	0.228	0.95	0.23	0.92
ANFIS-PSO-SUBC	0.18	0.96	0.19	0.96

4. Conclusions

In the present study, ANN and ANFIS models have been developed to determine the dynamic pressure in two-phase air-water flow. The present models were also combined with PSO algorithm. The antecedent parameters of ANFIS were optimized, using PSO, whereas the consequent parameters were optimized, using least-square error algorithm. ANFIS includes complex processes with different parameters involved, thereby produces several rules. To overcome this complication, fuzzy clustering preprocessing was employed to decrease the number of fuzzy rules and to increase the efficiency of ANFIS. To these models with subtractive clusters, a PSO algorithm was applied to optimize the clustering parameters and to control the fuzzy- if- then rules in subtractive clustering. Another PSO algorithm was also employed to tune the fuzzy rule parameters associated with fuzzy if-then rules. The SUBCLUST fuzzy clustering technique was applied for estimating the variation of dynamic pressure in two-phase air-water flows. Performances of the models were evaluated using

www.SID.ir

Archive of SID

RMSE, NRMSE, and R^2. Results show that the ANFIS model is more accurate than the empirical correlations presented in the literature. Furthermore, by combining the ANFIS model with PSO algorithm and the subtractive fuzzy clustering technique, the results were improved significantly.

5. References

Mishima K, Hibiki T, "Some characteristics of air-water two-phase flow in small diameter vertical tubes", International Journal of Multiphase Flow, 1996, 22(4), 703-712.

Kabiri-Samani AR, Borghei SM, "Pressure loss in a horizontal two-phase slug flow", Journal of Fluids Engineering, 2010, 132(7), 1-8.

Yan C, Yan C, Sun L, Wang Y, Zhang X, "Slug behavior and pressure drop of adiabatic slug flow in a narrow rectangular duct under inclined conditions", Annals of Nuclear Energy, 2014, 64, 21-31.

Sebakhi E, "Flow regimes identification and liquid holdup prediction in horizontal multiphase flow based on neuro-fuzzy inference systems", Mathematics and Computers in Simulation, 2010, 80(9), 1854-1866.

Fan S, Yan T, "Two-phase air-water slug flow measurement in horizontal pipe using conductance probes and neural networks", IEEE Transaction on Instrumentation and Measurement, 2014, 63(2), 456-466.

Jang JSR, Sun CT, Mizutani E, "Neuro-Fuzzy modeling and soft computing", Prentice Hall, Englewood Cliffs, 1997.

Kabiri-Samani AR, Borghei SM, Saidi MH, "Fluctuation of air-water two-phase flow in horizontal and inclined water pipelines", Journal of Fluids Engineering., ASME, 2007, 129(1), 1-14.

www.SID.ir