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Estimating the aeration performance of venture-conduit by artificial bee colony programming

Venturi kanalının havalandırma performansının yapay arı kolonisi programlama ile tahmin edilmesi

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Estimating The Aeration Performance of Venturi-Conduit by Artificial Bee Colony Programming

Highlights

- ❖ *Aeration performance of venturi-conduit was modeled by Artificial Bee Colony Programming.*
- ❖ *Functions that can model aeration performance are defined for 2 different contraction ratios, 0.75 and 0.90.*
- ❖ *Defined functions can predict the ventilation performance of conduits with venture-conduit without the need to build an experimental setup. Using these functions, the outputs (aeration performance) of different input values (Reynold, beta and length) can be calculated without the need for a training step.*
- ❖ *The average RMSE value of the developed functions was measured as 1.64 for the contraction ratio 0.75, and 2.66 for 0.9.*

Graphical Abstract

Functions that can model air intake rates were produced with ABCP in the dataset, which includes air inlet rate measurements in conduits with venturi with 2 different contraction rates (0.75 and 0.90) obtained by experimental measurements.

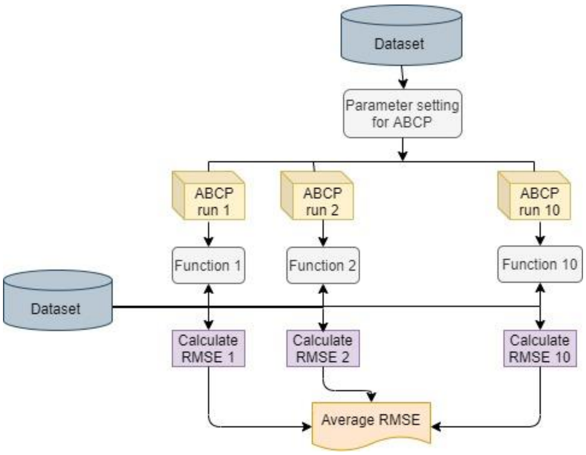

Figure. Flow chart of the proposed method

Aim

Within the scope of the study, it is aimed to define a function that can model the air intake rate in venturi-conduits at different contraction ratios.

Design & Methodology

Within the scope of the study, the data obtained from the experimental results using venturi mounted conduits were modeled with artificial bee colony programming, which is a symbolic regression method. Implementation of the algorithm and experimental studies were done in Matlab environment.

Originality

Symbolic regression trees containing functions were created using ABCP.

Findings

The ABCP algorithm was run 10 times to ensure statistical validity therefore 10 functions that can model the data is obtained. R and RMSE values for conduits with venturi with a contraction ratio of 0.75 were obtained as 0.99 and 1.64, respectively. For conduits with venturi with a contraction ratio of 0.9, the R and RMSE values were found to be 0.99 and 2.66, respectively.

Conclusion

Functions generated by ABCP can be used to model aeration performance of venturi-conduit.

Declaration of Ethical Standards

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Estimating The Aeration Performance Of Venturi-Conduit By Artificial Bee Colony Programming

Araştırma Makalesi / Research Article

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ABSTRACT

Oxygen concentration dissolved in water is an important parameter used to measure the quality of water. Increasing the concentration of oxygen by transferring oxygen from the atmosphere is named as aeration. Aeration can be performed with many hydraulic structures. Two of the structures that have become widespread in the field of hydraulics are gated conduit and venturi. Venturi has throat part and air hole located into throat part. A difference of pressure, which provides aeration occurs between the venturi inlet and the throat part. A pressure difference occurs between up and down flows of the door in a partially opened gated conduit. Air entrains into flow from an air vent that were drilled downstream of the gate. A venturi was placed on air hole of a circular conduit that as called venturi-conduit, a new aeration system. The basic steps of the Artificial Bee Colony Programming (ABCP) developed for the solution of the symbolic regression problem come from the Artificial Bee Colony (ABC). In this study, ABCP is proposed to obtain functions that can model the ventilation performance of conduits with venture-conduit. The results of the method trained with experimentally measured data on 2 ventures with different contraction ratios were compared with artificial neural networks and genetic programming. ABCP outperformed genetic programming and neural networks on test data with an R2 value of 0.99 in both datasets. The RMSE values of 1.64 and 2.66, respectively, in the 2 data sets indicate that ABCP is capable of generating the appropriate function for the problem.

Keywords: Aeration, air injection, artificial bee colony programming, venturi-conduit.

Venturi Kanalının Havalandırma Performansının Yapay Arı Kolonisi Programlaması ile Tahmin Edilmesi

ÖZ

Su kalitesinin en önemli göstergelerinden biri sudaki çözünmüş oksijen konsantrasyonudur. Azalan oksijen konsantrasyonunun değerini artırmak için atmosferden transfer edilen oksijene havalandırma denir. Havalandırma için birçok hidrolik yapı kullanılır. Kapılı borular ve venturi, son yıllarda popüler hale gelen hidrolik yapılardır. Venturi boğaz kısmına ve boğaz kısmına yerleştirilmiş hava deliğine sahiptir. Venturi girişi ile boğaz kısmı arasında havalandırmayı sağlayan bir basınç farkı oluşur. Geçitli bir kanalda, kapı kısmen açıldığında, kapının yukarı ve aşağı akışları arasında basınç farkı oluşur. Hava, kapının akış aşağısında açılan bir havalandırma deliğinden akışa girer. Yeni bir havalandırma sistemi olan venturi-conduit olarak adlandırılan dairesel bir kanalın hava deliğine bir venturi yerleştirildi. Temel yapısı Yapay Arı Kolonisi algoritmasına dayanan Yapay Arı Kolonisi Programlama (ABCP) algoritması, sembolik regresyon problemi için önerilen bir otomatik programlama yöntemidir. Bu çalışmada, venturili kondüitlerin havalandırma performansını modelleyebilecek fonksiyonlar elde etmek için ABCP önerilmiştir. Daralma oranı farklı boyutlarda olan 2 venturili konduit üzerinde deneysel ölçülmüş veri ile eğitilen yöntemin sonuçları yapay sinir ağları ve genetik programlama ile karşılaştırılmıştır. ABCP, her 2 veri kümesinde de, 0,99 R2 değeri ile test verisinde genetik programlama ve yapay sinir ağlarından daha iyi performans göstermiştir. 2 veri kümesinde sırasıyla 1,64 ve 2,66 RMSE değerleri ABCP'nin problem için uygun fonksiyonu üretme yeteneğine sahip olduğunu göstermektedir.

Anahtar Kelimeler: Havalandırma, hava enjeksiyonu, yapay arı kolonisi programlama, venturi-conduit.

1. INTRODUCTION

Parameters that determine the water quality are temperature, pH value, electrical conductivity, suspended solids, turbidity and etc. [1]. Dissolved oxygen concentration is another important parameter that indicates the water quality. Oxygen concentration value is increased by transferring oxygen from air to water. The process of introducing oxygen into the water from the atmosphere is called aeration. The aim of aeration is to remove these gases from water or to transfer gases to water [2].

Aeration with hydraulic structures is more economical than ventilation with different methods. In other methods, the electrical energy to be used to pump water and compressed air increases the operating cost.

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Hydraulic structures such as ventures, sluices, water jets and conduits are actively used in the aeration of water.

Many investigators studied aeration of water by hydraulic structures. Kalinske and Robertson were studied the air entrainment of closed conduits. [3]. A theoretical solution to the problem of air that can occur in a rectangular duct where the flow is free is proposed at [4]. Sharma classified different two-phase regimes in closed conduits [5]. Harshbarger et al. compared data obtained from a 1:20 scale gated structure model with field measurements [6]. In their study where they analyzed the air-water flow of the bottom outlets in the conduits, Speerli and Hager presented results showing the maximum air concentration and the development of these concentrations in terms of stream wise through the tunnel [7].

Unsal et al. investigated the aeration performance of free-surface conduits [8].They emphasised that the free surface conduits were very effective for oxygen transfer in waters. Also they were suggested an equation for aeration efficiency in free surface conduits with high correlation value.

Baylar, Ozkan and Unsal investigated the impact of air inlet hole diameter on the performance of air injection in their laboratory experiments on venturi tubes. The findings showed that the diameter of the air inlet hole in venturi tubes is significant for injection of air [9].

Yagci, Unsal and Ercan have used for aeration a new aeration system is called venturi-conduit [10]. A venturi was placed on air hole of a circular conduit. Two air holes were drilled on the throat portion of venturi. To investigate the aeration performance of venturi-conduit for three cases of venturii a series of experiments were conducted. The results obtained from the experimental methods were procured by using regression analysis method. Analysis results were examined and successful results were obtained.

Yucel, Unsal and Yağcı experimentally investigated that the air hole diameter was play an important role in aeration [11]. Furthermore, genetic expression programming technique, which is a successful artificial intelligence technique, was used to model the air injection rate with a regression equation.

In this study, the aeration performance of a venturi-conduit system was modelled by Artificial Bee Colony Programming. ABC Algorithm simulates e food source search strategy of a honey bee swarm [12]. Due to its fast and strong convergence ability, besides many optimization problems in computer science such as feature selection, intrusion detection, clustering, missing value imputation, it is also applied to optimize many engineering problems [13-16]. Disributed generation allocation problem, composite design optimization problem, photovoltaic parameter estimation problem, flow shop scheduling problem, estimation of the fundamental period of vibration are just some of the application areas. ABCP is an ABC based method for symbolic regression and applied benchmark function optimization problem [17-22].

Conduit

When a high-pressure door of a conduit is partially opened, a high-velocity flow is created downstream of that gate, causing subatmospheric pressure. (Fig. 1). This pressure, which can be as low as the vapor pressure of water, could theoretically cause structural damage. This is due to cavitation. Air can be supplied by connecting the conduit to the atmosphere with a vent. This process, which is done to keep the pressure level at the bottom of the gate at a safe level, also avoids severe subatmospheric pressure. The amount of air required depends on the carrying capacity as well as the entrainment of the flow. The decline of pressure due to the atmosphere behind the gate can be expressed as a function of the gate opening. [23].

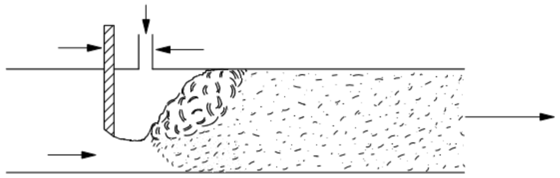

Fig. 1. Two-phase current at downstream of conduit with pressure gate [23]

Venturi

Venturi aeration is one of the aeration method is popular. In order to enhance the velocity of the fluid flow in the pipe, a narrowing is made in a throat area with a smaller cross-sectional area than the pipe section at the inlet. (Fig. 2). In the contraction zone, there is a decrease in pressure in parallel with the increase in fluid velocity. Thanks to this pressure drop, air is injected through the intake holes and dynamically directed into the flow. As the jet stream spreads to the venturi tube outlet, the velocity drops and is converted to pressure energy (but at a lower level than the venturi tube inlet pressure).

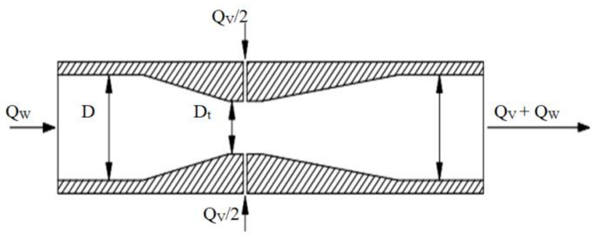

Fig. 2. Air suction produced venturi tube [9]

2. MATERIAL and METHOD

In this study, to generate functions, Artificial Bee Colony Programming which is a symbolic regression method is used. To measure its performance, obtained results are compared with Artificial Neural Network and Genetic Programming.

Artificial Bee Colony

Artificial Bee Colony, a heuristic algorithm, is population-based. The solution-seeking strategy was developed by modeling the foraging behavior of honey bees. The algorithm proposed by Karaboga to solve multidimensional and multi-model optimization problems [12]. There are 3 kindss of bees in the population; employed and onlooker bees with a scout bee. The sources that bees go to search for food are possible solutions of the problem. The quality of the solution found is directly proportional to the amount of nectar contained in the source and expresses the objective function.. The duty of the bees is to improve their sources. Each source is represented by a vector. The number of parameters that the problem needs to be optimized is equal to the dimension of the vector. For each source there is a trial value which set as 0 when the algorithm is initialized. ABC is an iterative algorithm and each iteration consists of four stages:

I. Initialization: The initial positions of the resources in the search space are randomly determined. using Eq. (1):

$$x_{ij} = x_j^{min} + rand(0,1)(x_j^{max} - x_j^{min}) \quad (1)$$

where, i=1,2,..,SN and j=1,2,..D. SN is the number of sources and D is the number of parameters to optimize. Rand(0,1) is a uniformly distributed number. It takes a random value between 0 and 1. x_j^{max} and x_j^{min} are the minimum and maximum limit values of j. parameter respectively.

II. Employed Bee Phase: Each employed bee is tasked with healing a source. They searches for a new solution in the near the current source using Eq. (2) and evaluates the quality of it. If the quality of this new source is better than the current source, employed bee takes this source into memory and the trial value of new source is set as 0. The information of old source is forgotten. Otherwise trial value of current source is incremented by one.

$$v_{ij} = x_{ij} + \varphi_{ij}(x_{ij} - x_{kj}) \quad (2)$$

For each source x_i, a neighbour source v_i is obtained by changing the randomly chosen parameter j between 1 and D. φ_{ij} is a uniformly distributed random number between -1 and 1.

III. Onlooker Bee Phase: Employed bees share their search experiences with the onlooker bees. Onlooker bees selects a source in proportion to the amount of nectar (fitness value) in the source. For each source, a probability value is calculated according to Roulette Wheel Method at Eq. (3). If this probability value is greater than a random value between 0 and 1, onlooker bee produces a neighbour source using Eq. (2) and applies a greedy selection between these two sources.

$$p_i = \frac{fitness_i}{\sum_{i=1}^{SN} fitness_i} \quad (3)$$

where p_i is the probability value for i^{th} source and $fitness_i$ is the fitness value of i^{th} source.

IV. Scout Bee Phase: If the trial value of a source reaches a predetermined "limit" threshold value, this source is considered as local optimum. Scout bee produces a new random source using Eq. (1).

Artificial Bee Colony Programming

Artificial Bee Programming is an extended version of ABC algorithm to solve symbolic regression problem [22]. The purpose of ABCP is to find the best combination of variables, symbols and coefficients to create a function that satisfy a set of fitness cases. ABCP uses same terminology as ABC. In ABCP, sources are represented by trees instead of vectors. Each source shows a possible model as in ABC. In the tree, internal nodes represent operations (+,-,*,/) or functions(sin, cos, exp, log) and leaf nodes represent terminals. Fig. 3 shows tree representation of Eq. (4). In this notation x and y are independent variables and f(x,y) is dependent variable.

$$f(x, y) = ((\log(y) + (x * y)) - \tan(x)) \quad (4)$$

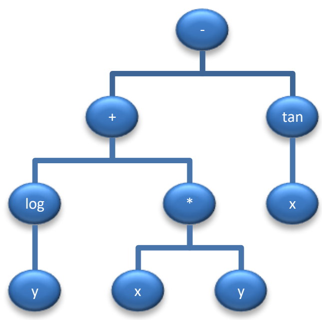

Fig. 3. Tree represenation of Eq. (4)

In ABCP, the new source generation strategy in ABC cannot be directly applied because the equations created by the algorithm are of different lengths and represented by a tree structure. Candidate solutions are generated using one point crossover operator between two randomly selected nodes. At Fig. 4, (a) is current source (x_i) and (b) is randomly selected source (x_k) from the population. A subtree is chosen randomly from each of the two sources and replaced (c). Whether the node to be randomly chosen is terminal or function/operator is determined by a probability. The function/operator is chosen with probability p and the terminal with

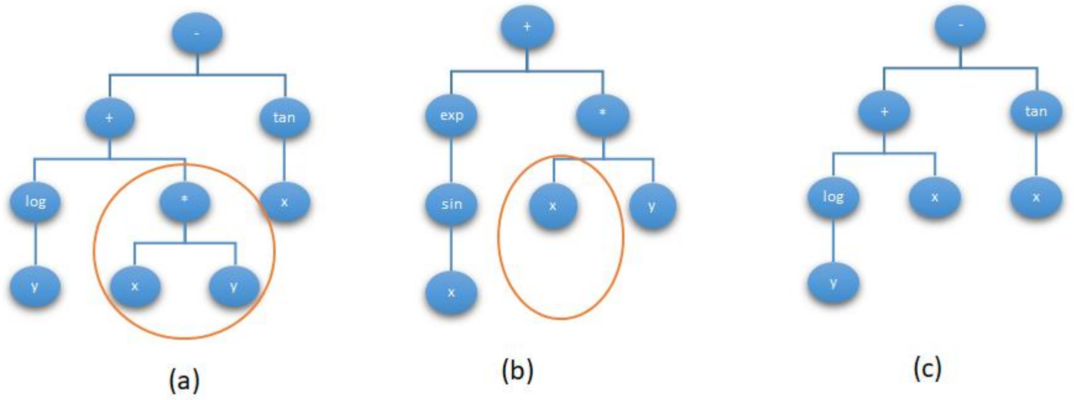

Fig. 4. Information sharing mechanism of ABCP

probability (1-p). The fitness value is calculated for candidate solution and a greedy selection process is applied between x_i and x_k.

Gene Expression Programming (GEP)

GEP was developed by [24]. In Gene Expression Programming the main principles of genetic algorithms and genetic programming are used. The methodology of gene expression programming uses character linear chromosomes composed of genes structurally organized in a head and a tail. The problems are encoded in linear chromosomes of fixed-length as a computer program. A gene is consist of two parts. These are head and tail. The head of a gene includes main variables used to code the any mathematical expression such as some functions, variables and constants. In the head of the gene trigonometric and arithmetic functions takes part such as (+, -, *, /, , sin, cos, tan). The tail includes exclusively variables and constants which may be required for additional terminal symbols, in case the variables in the head are incompetent to encode a function. In the gene tail there are constants and independent variables of the problem, like [24-26]. By using GEP, a mathematical function is defined as a chromosome with multi genes and developed using the data presented to it [24].

Artificial Neural Networks (ANN)

ANNs are designed and copied according to biological nervous system to have capability to learn like a human. Architecture of conventional ANNs consist of layers, neurons and weighted connections between neurons and layers. In a typical ANN, there are three layers called as input, hidden and output layers. Number of hidden layer is chosen as one in most of applications. But it can be two or more. The weighted connections between neurons in the layers can be adjustable during the learning level according to training algorithms. This level is also known as training of neural networks. After that desired outputs for target variables are generated by input parameters. ANNs have been used in the solving of several engineering such as estimation, control, modeling and etc. [27-29].

3. EXPERIMENTAL SETUP

In this study, the aeration performance of venturi system placed on circular conduits was investigated. The experiment set is called Venturi-Conduit which is composed of a combination of conduit and venturi. The ventures with different contraction ratios were placed on the conduit and the changes in the aeration performance depending on β, different conduit lengths and different flow rates were investigated. β is the ratio of the water cross-sectional flow area to the conduit cross-sectional area. Conduit contraction rates are β=20%, β=35% and β=50%.Güneş enerjili hava kolektöründe faydalı enerji, kollektörden geçen akışkanın giriş ve çıkış sıcaklığına bağlı olarak,

Fig. 5. Venturi-conduit

In the experiment, two different ventures were used Dt/D = 0.75 and Dt / D = 0.90 contraction rates. These ventures are placed in a circular conduit with a diameter of 27.7 mm. The lengths (L) of conduit are 75, 100 and 125 cm. In both ventures, two air holes were opened to provide air injection to the throat area. The diameter of the air holes is 5 mm.

In the experiment, an air hole of 10 mm diameter was opened at the downstream of the conduit gate. The ventures with a contraction ratio of 0.75 and 0.90 with an inlet diameter of 10 mm were placed on this air hole. In order to determine the air entrainment performance of the venturi conduit, measurements were made by placing 75, 100, and 125 cm length conduit pieces respectively for the main hole with 5 mm air hole diameter. Six different flow rates were used in experiments, respectively 0.9; 1.8; 2.7; 3.6; 4.5 and 5.4 m^3/h. Aeration performance was investigated primarily only main air hole, then main hole and one air hole and finally main hole and two air holes.

Different flow rates were used in the experiments and different water velocities were determined depending on these flow rates. The Reynolds number was calculated by using the water velocities where the contraction occurred. The equation used to calculate the Reynolds number is given in Eq.(5).

$$Re = \frac{V_w 4R}{V} \tag{5}$$

where Re is Reynold number, V_w is water velocity (m/s), R is hydraulic head (m) and V is Kinematic viscosity of the fluid (m^2/s).

The experimental setup includes storage tank, flow control valve, electromagnetic flowmeter, sluice gate, venturi, conduit, water pump and anemometer (Fig. 6).

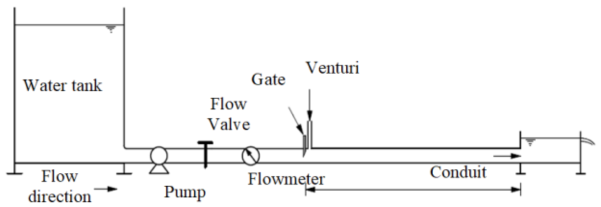

Fig. 6. The experimental setup.

At the beginning of each set of experiments, water was supplied to the water tank to ensure that the tank was filled with full volume of tap water. The flow rate of the water pumped from the water tank was adjusted by means of a control valve and passed through a venturi conduit. The venturi-conduit, the average speed of the incoming air was taken by anemometer with a thirty second measurement. This average speed was multiplied by the hole area to calculate the flow rate of the incoming air. In the experiments, β=%20, β=%35 and β=%50 of were used for all conduit lengths (Fig. 7).

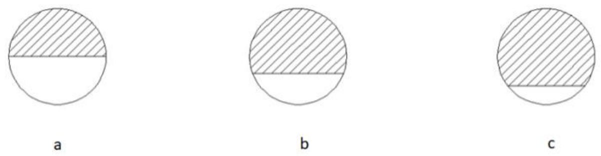

Fig. 7. a-β=%50, b-β=%35, c-β=%20

The dataset consists of 162 observations for the venturi contraction ratio of 0.75 and 0.90. For both venturi, observations were made separately, with only main air hole, main hole with one air hole and main hole with two air holes. There are 54 observations in each of these 3 groups. The data contains 3 inputs (reynold (Re), beta (β), length (L)) and 1 output. To avoid overfitting problem, datasets divided 70% training and 30% test randomly. The performances of methods are measured with R^2 value using test sets.

The data used in this study were taken from [10]. ABCP algorithm was coded with the Matlab 2019b, taking into account the flow diagram presented in the study [22] in which it was presented. The parameters of ABCP are given in Table 1. As mentioned Section 2, in a regression tree, nodes represent operations and terminals represent variables. At the proposed method, arithmetic operators and functions used as operations. The former set consists of operations with 2 operands; addition, subtraction, multiplication and division operators. The later one consists of functions with one operand; sine, cosine, tangent, logarithm and exponential functions.

At previous work [30], estimating aeration performance problem considered as a simple regression problem and ANN was applied. In the related study, ANN was implemented with Matlab ANN toolbox. Levenberg-Marquardt Back Propagation algorithm was used in the training phase.

For comparison, data also modelled with the demo version of genetic algorithm based GEP software [31]. GEP is a flexible tool modeling software designed for regression, logistic regression, classification, time series prediction, and logic synthesis.

The fitness value was calculated using the R-square value in Eq. (6-8). R-square value measures the fit of the model. Therefore, a high R-square indicates that the regression model fit is good.

$$R^2 = 1 - \frac{SSR}{SST} \tag{6}$$

$$SSR = \sum_i (y_i - f_i)^2 \tag{7}$$

$$SST = \sum_i (y_i - \bar{y})^2 , \bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i \tag{8}$$

where y_i demonstrates experimental results and f_i demonstrates actual results.

4. EXPERIMENTAL RESULTS

In computer science, the depth of a tree is, the number of edges from root node to the furthest leaf node. The depth of initial sources are set as 6 as recommended at Ref 22 [22]. The root node is selected from operator set randomly. All operators have the same probability of selection. For non-terminal nodes, the operation is determined as an arithmetic operation with probability p, or a function with probability 1-p. Terminal nodes are selected from variables randomly with equal probability.

After initialization, functions are generated using information sharing mechanism as described in Fig. 4. Since candidate resources are generated by the crossover process, it will result in very deep trees if not restricted. For a symbolic regression problem, as the depth of the tree increases, the complexity of the equation increases. Getting tree with less in depth without compromising the accuracy of the model will increase applicability. Therefore, the maximum depth value determined experimentally. Fig. 8 (a) and (b) show the convergence graph for depth of tree for Dt/D=0.75 and Dt/D=0.90

respectively. It is clear that, there is no difference between trees with a depth of 15 and 6 trees in terms of R^2 value. A 5-depth tree also can model the problem with high value. However when the depth of the tree is less than 5, the R^2 value decreases. Therefore, max depth value was set as 5 for both of datasets. If algorithm generates deeper tree then 5, it is pruned.

ABCP is an iterative algorithm and the stopping criteria of such an algorithm is either to reach a certain number of iterations or to consume a certain number of fitnesses. Stopping criteria is an important parameter for an iterative algorithm and it is a problem dependent parameter. If this value is too large, it causes over training and cannot generalize the problem. If it is too small, the model cannot learn the problem. Taking this into consideration, we determined this parameter experimentally. Fig. 9 (a) and (b) shows the

Table 1 Parameters of ABCP

Parameter	Value	Parameter	Value
Initial max depth of tree	6	Colony Size	300
Max depth of tree	5	Limit Value	300
Non-terminals	+, -, *, /, sin, cos, tan, log, exp	Max Fitness	50000
Terminals	Reynold (Re), Beta (β), Length (L)	Number of runs	10
		Probability (p)	0.5

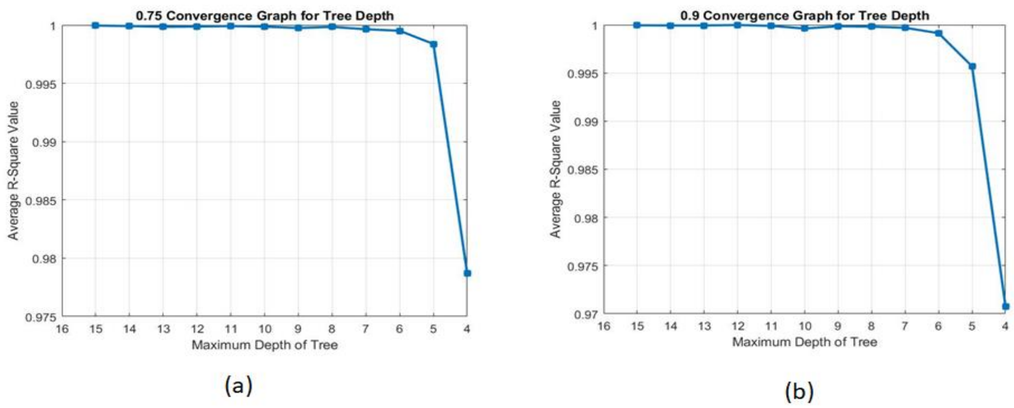

Fig. 8. The convergence graphs for maximum depth of trees

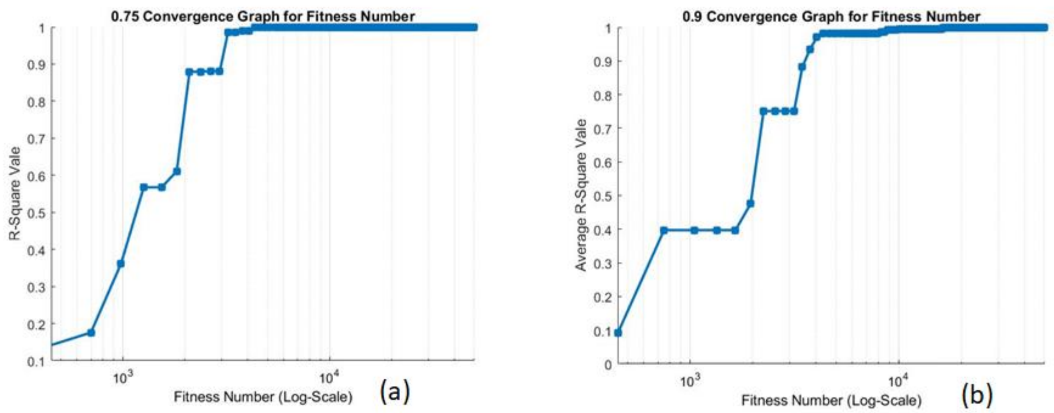

Fig. 9. The convergence graphs for consumed fitness number

Table 2 Results of ABCP

Dataset (Dt/D)	Mean R^2	Standard Deviation	Best R^2	Worst R^2	RMSE
0.75	0.998	0.04	0.999	0.986	1.64
0.90	0.995	0.067	0.999	0.978	2.66

convergence graphs according to maximum fitness number for Dt/D=0.75 and Dt/D=0.90 respectively from a randomly selected run. According to these graphs, R2 value increased for a while and then remained stable. After reaching the maximum point, it was run for a while to see if the success happened by chance. It is clear that, consuming 50000 fitnesses is enough for the model to become stable.

Due to the stochastic nature of the ABCP algorithm, to get statistical validity, the algorithm was run 10 times for both datasets and the results were averaged. Table 2 shows best, worst, mean R^2 results these 10 runs and their standard deviations. The RMSE values for worst case are shown at the last column. For each dataset, 0.99 R^2 values demonstrate, generated functions by ABCP, fit well to target values. Additionally, the small difference between best and worst runs and small standard deviation values proving that the proposed method is proficient in modelling this problem.

The results obtained by ABCP is compared with the genetic algorithm based GEP results and ANN according to R2 value. ANN results are taken from the study at [30] and compared with ABCP results as shown in Fig. 10. Authors used same data and divided it as train (70%) and test (30%). Differently, the data for the 2 ventures are trained separately, but in the study they are given by taking the mean of the squared result. Therefore, it is given by taking the average of the ABCP results. Accordingly, it was seen that ANN was also successful in modeling the data, even though the R2 value was lower than ABCP.

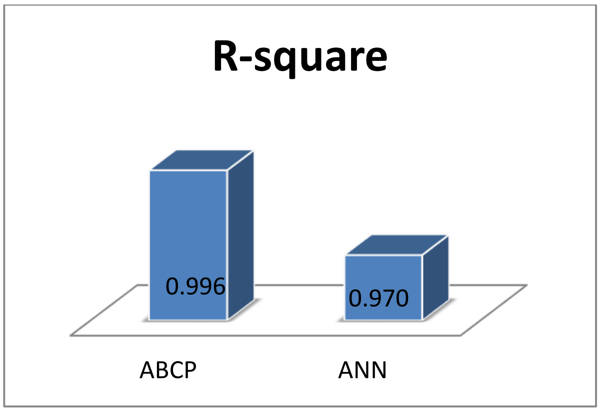

Fig. 10. Comparison with ANN

The results obtained by ABCP is compared with the genetic algorithm based GEP results and ANN according to R^2 value. ANN results are taken from the study at [30] and compared with ABCP results as shown in Fig. 10. Authors used same data and divided it as

train (70%) and test (30%). Differently, the data for the 2 ventures are trained separately, but in the study they are given by taking the mean of the R^2 result. Therefore, it is given by taking the average of the ABCP results. Accordingly, it was seen that ANN was also successful in modeling the data, even though the R^2 value was lower than ABCP.

The aim of this study is, to define functions that estimate aeration performance of ventures with different reynold, beta and length values. Therefore, ABCP was used which handle the problem as symbolic regression. Genetic programming is also a method which is used for symbolic regression. To compare ABCP results with genetic programming, GEP tool was used. As shown in Fig. 11, for both ventures, ABCP outperformed to GEP. These results prove that the functions that produced by ABCP are better fitted the data.

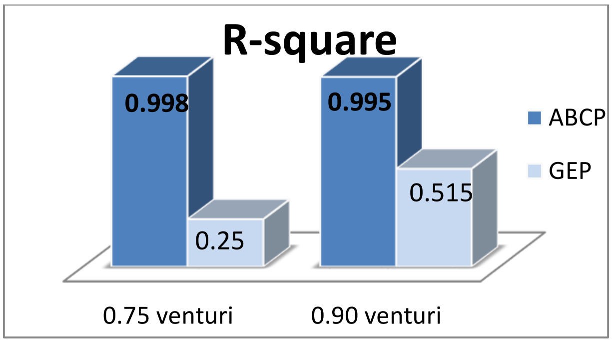

Fig. 11. Comparison with GEP

4. DISCUSSION

The ventilation performance of venturi conduits was experimentally measured in the laboratory environment. However, this is a time-consuming process. The aim and contribution of this study is to develop a computational system that can predict the aeration performance with high accuracy for different Re, β and L values without the need to set up an experimental setup. In a previous study [30], the same data was treated as a simple regression problem and ANN was applied. ANN can model the data with an average R^2 value of 0.97. However, when it is considered as a simple regression, the equation that will fit the data cannot be obtained. It is aimed to obtain functions that can model the data with ABCP. Thus, using these functions, the outputs of different input values can be calculated without the need for a training step. Similarly, genetic algorithm-based GEP program was also applied to the data in order to obtain functions, but considering the R^2 values, it was not successful in modelling.

After each run algorithm generates an optimized function. As an example, 3 functions produced by the algorithm are given at Table 3 and their regression trees for 2 datasets are given at Fig. 12 and Fig. 13. Limiting the depths of trees to 5 prevented the generation of complex functions.

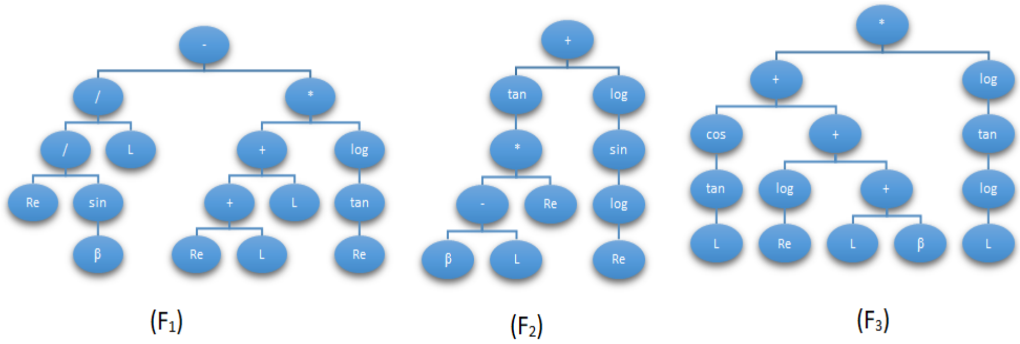

Fig. 12. Regression trees for Dt/D=0.75 dataset

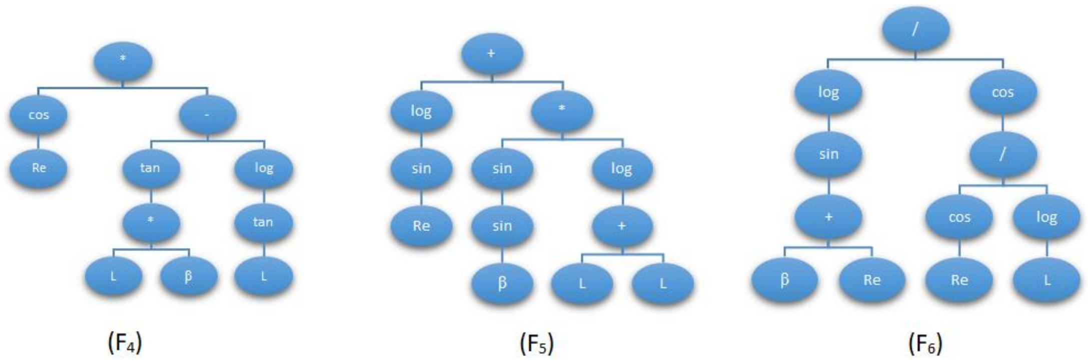

Fig. 13. Regression trees for Dt/D=0.90 dataset

Table 3 Functions generated by ABCP

	Function
F1	$\left(\left(\frac{\frac{\mathrm{Re}}{\sin(\beta)}}{\mathrm{L}}\right)\right) - (((\mathrm{Re}+\mathrm{L}) * (\log(\tan(\mathrm{Re})))$
F2	$\left((\tan((\beta-\mathrm{L}) * \mathrm{Re}))\right) + (\log(\sin(\log(\mathrm{Re}))))$
F3	$\left(\left((\cos(\tan(\mathrm{L}))) + \left((\log(\mathrm{Re})) + (\mathrm{L}+\beta)\right)\right)\right) * (\log(\tan(\log(\mathrm{L}))))$
F4	$\left((\cos(\mathrm{Re}))\right) * ((\tan(\mathrm{L} * \beta)) - (\log(\tan(\mathrm{L}))))$
F5	$\left((\log(\sin(\mathrm{Re})))\right) + ((\sin(\sin(\beta))) * (\log(\mathrm{L}+\mathrm{L})))$
F6	$\dfrac{(\log(\sin(\beta+\mathrm{Re})))}{\cos\left(\frac{\cos(\mathrm{Re})}{\log(\mathrm{L})}\right)}$

5. CONCLUSION

The dissolved oxygen concentration is very important for water quality. In particular, the required dissolved oxygen concentration for rivers should be provided to ensure ecological balance. For this purpose, the oxygen in the air must be transferred to water. The physical process of oxygen transfer or oxygen absorption from the atmosphere acts to replenish used oxygen. This process is termed re-aeration or aeration. Many hydraulic structures are used successfully for aeration. In this study, aeration performance of venturi-conduit was modeled by Artificial Bee Colony Programming (ABCP). With a symbolic regression task, it is aimed to define a function to predict the ventilation performance of conduits with venturi without the need to build an experimental setup. The functions to model the values for 2 different sizes of venturi were generated by ABCP. The performance of the algorithm was measured with r-square and it was run 10 times in 2 datasets. The average R^2 values of the functions produced in both datasets is 0.99 with small RMSE. R^2 results also compared with genetic programming and artificial neural network. According to comparative results ABCP showed better performance then genetic programming and artificial neural network and it can be used to model aeration performance of venturi-conduit.

DECLARATION OF ETHICAL STANDARDS

The authors of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

AUTHORS' CONTRIBUTIONS

Zeynep Banu ÖZGER: Performed the analysed and wrote the manuscript.

Ayşe Ece YAĞCI: Performed the experiments and wrote the manuscript.

Mehmet ÜNSAL: Analysed the results.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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