COD Removal Prediction of DAF Unit Refinery Wastewater by Using Neuro- Fuzzy Systems (ANFIS)

(Short Communication)

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Abstract

In this study the Dissolved Air Flotation (DAF) system in oil refinery was investigated for the treatment of refinery wastewater. In order to investigate sytem a labratory scale rig was built. The aim is to remove some of the wastewater pollutant materials and data modeling of COD test.The effect of several parameters on flotation efficiency namely, saturator pressure, and coagulant dose, on COD removal was examined experimentally. Experiments were done by using poly aluminum chloride coagulant (PAC) at pressures 2bar up to 5bar and in three doses 15mg/l ،20mg/l and 25mg/l. After final examination's removal efficiency obtained is close to the performance achieved by the refinery. The data obtained from COD experiments using neuro-fuzzy systems have been modeled. The correlation coefficient (R^2), root mean square error (RMSE) and sum of square error (SSE) of predicted values by using neuro-fuzzy systems are obtained 0.9991, $6.35\times10^{-3}$and 4.04×10^{-5} respectively, which shows the high accuracy of neuro-fuzzy systems.

Keywords: Adaptive neuro-fuzzy inference system, COD, Dissolved air flotation, Refinery wastewater

Introduction

Flotation is an operating unit which is used for separating solid particles or liquid from a liquid phase. These separation in this process was done by entering small gas bubbles (usually air) into the liquid phase, then the air bubbles stick to the solid particles and the collection of particles and gas bubbles floating force is increased which cause the ascent of the particles to the surface. In addition, the particles with density more than the liquid can forced to ascend to surface and the ascent of particles with a density less than the liquid (like oil soluble in water) can also be facilitated [1]. Basically in wastewater treatment, floatation is used to separate suspended solids and concentrated of biological sludge. But in the water treatment, the purpose of flotation was separation of suspended solids [2]. The main advantage of floating over these dimension is that in this method, very small or light particles which are slowly settled can be removed more perfect and in shorter time[3] .

Dissolved air flotation can include vacuum or pressure methods. The vacuum floating is limited to one atmosphere pressure changes and it has limited applications for instance (Sludge dehydration). Herein, the emphasis is on dissolved air flotation under pressure (dissolved air flotation).

Continuous development of industries and processes that are working with hydrocarbons, has been caused to increased pollution and disposal of oil and the environment. Most of industrial wastewater treatment and refining are to be oil in water emulsions. There are different methods for separating oil from water, such as adsorption, coagulation, electrical accumulation and flotation [4, 5]. There are three different ways in floating to create air bubbles: Electrolytic method, Dispersed Air and Dissolved Air [6]. In Dissolved Air Flotation (DAF), air dissolved in water at high pressure and when the water be saturated it enter into the flotation tank at

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atmospheric pressure, and extra soluble air is released as small bubbles. Encounter and contact of tiny bubbles and suspended particles increase the buoyancy force and provides ascent to the surface and floating [7, 8]. The amount of air released into the system can be calculated by using of Henry's law, having saturation pressure and the amount of recycled flow fluid. In the work which done by Zabel and before that by Hyde the maximum possible efficiency for saturation was about 90% [9, 10]. Chung's calculations show that the optimum operating pressure for saturation was about 5bar [11]. Also, Lund showed that the amount of releasing air in a tank with 85% efficiency at 5bar pressure is about 88 mili liter of air based on one liter of liquid [12]. Since floating is a dynamic process, the yield depends on the time that fluid remains in the tank. To analyze the flow regime, in order to design and process control, resident time distribution curve of fluid in the reservoir can be plotted. In many of complex flows, the engineers use a simple flow model for explain the behavior of the system [13]. Tansel *et.al*. examined the effect of various parameters such as adding clotting, the residence time, inlet concentration on amount of floating particles, and also demonstrate that the increase in residence time can increase the separation efficiency till 17% [14]. Parker was used the DAF process in industrial wastewater treatment, the removal efficiency of TVSS and TSS 57% and 58% ,respectively were observed and it also eliminates 74% of the oil from wastewater [15]. Al- Shamrani *et.al*. used dissolved air flotation for separation of oil from oil-water emulsions by aluminum sulfate and ferric sulfate and oil removal efficiency for both coagulants was obtained 3.99% and 94.99% ,respectively [5]. Boyd *et.al*. [16] stated the results of pilot plant studies in the separation of oil from chemically treated wastewater, showing that the effluent with 10–15mg/l oil can be produced by following DAF. Miskovic *et.al*. [17] used DAF to treat oil refinery wastewater although the effluent was still loaded with dissolved oils. Moursy and Abo-Elela [18] have concluded that DAF units are capable of removing most of the oil in emulsions from refinery wastewater that was chemically pretreated.

In recent years toward the use of Neuro-fuzzy systems a variety research has been done Such as, Adaptive network and fuzzy inference system (ANFIS) approach for overcurrent relay system combined by Geethanjali and Slochanak (2008) [19], a novel approach for ANFIS modeling based on a full factorial design investigated by Buragohain and Mahanta (2008) [20] and elastic constant of rocks estimated with using an ANFIS approach by Singh *et.al*. (2012) [21].

In this paper, by using Neuro-fuzzy systems (ANFIS) COD values which obtained experimentally have been modeled.

2- Materials and methods

2-1- Materials

Experimental rig is include two parts, a part which is made of metal and used as a saturator which has three inputs and one output section. The three entrances considered for the air (via compressor), pressure gauge and the wastewater (as batch); And its output is attached through a plastic tube and a pressure relief valve to a plexiglas column of 9 cm diameter and 80cm height. This plexiglas column was used as a floatation tank. Figure 1 shows a schematic of this rig.

2-2- Methods

The wastewater prepared from the Kermanshah refinery (in Iran, west area, Kermanshah, kermanshah refinery) was combined with poly aluminum chloride coagulant (PAC) and as batch entered into saturator and aerated by the compressor in various pressure from 2 to 5bar. Then the aeration cutted off and for 2 min wastewater was discharged to floatation tank and its COD was measured.

To measure the COD, 5220D method was used [22], (closed reflux, colorimetric method).

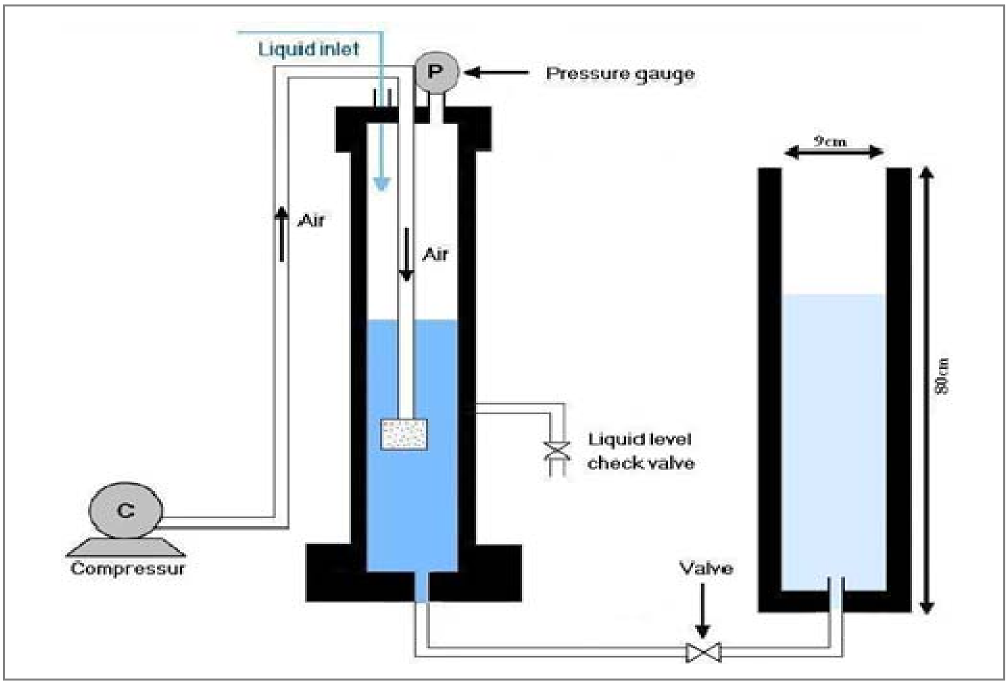

Figure 1: Schematic of DAF experimental rig

Table 1: Charactrization of the DAF unit of Kermanshah refinery wastewater input and output

	COD (mg/l)
Input to DAF unit	252
Output of DAF unit	105

2-3- Adaptive Neuro-fuzzy inference system (ANFIS)

One of the popular artificial intelligence techniques is ANFIS. The abbreviated form of ANFIS taken its name from adaptive neuro-fuzzy inference system. ANFIS is accomplished of fuzzy inference systems (FIS) to adaptive networks for developing fuzzy rules with appropriate membership function to the needed input and outputs. Neuro adaptive learning technique works like the neural network. Neuro adaptive learning method prepares a technique for the fuzzy modeling process to learning the details of a set of data. Fuzzy Logic Toolbox software calculate the membership function parameters that the best allows participant. The fuzzy inference system to track input/output data. The Fuzzy Logic Toolbox function which implements this membership function parameter setting is called ANFIS. The ANFIS function can be available from order line or the ANFIS editor GUI.

A general structure of ANFIS is shown in Figure 2, Where a circle represents a fixed node, where as a square represents an adaptive node. For comfort, it was considered that the FIS has two inputs x and y and one output z. The ANFIS used in this article runs first order Sugeno fuzzy model. For this model, a common rule adjusts with two fuzzy if the rules can be explained as:

Rule 1: If x is A_1 and y is B_1 then $z_1 = p_1 x + q_1 y + r_1$

Rule 2: If x is A_2 and y is B_2 then $z_2= p_2 x + q_2 y + r_2$

Often using ANFIS systems with a Takagi–Sugeno–Kang (TSK) fuzzy system as a progressive network structure. If the output of each layer as O_k^i (k *th* output node of layer i), The ANFIS model structure with two rules and two inputs x, y, each with two membership functions are described, which formed by five layers as follows:

Layer 1: Each node i in this layer is a square node with anode function.

$$o_i^1 = \mu_{A_i} \quad (1)$$

In which X is the entrance to node I, A_i is a linguistic feature label, and O_i^1 is the membership function of A_i. Parameters in this layer are specified as hypothesis parameters.

Layer 2: The nodes in this layer multiply the entrance signal and Post the product out. This demonstrates the fire power of a law.

$$\omega_i = \mu_{A_i}(x) \times \mu_{B_i}(y) \quad i=1,2 \quad (2)$$

Layer 3: The nodes in this layer, compute the average ratio of *I* th rule's firing power.

$$\varpi_i = \frac{\omega_i}{\omega_1 + \omega_2} \quad i=1,2 \quad (3)$$

Layer 4: Every node *i* in this layer is a square node with a node function.

$$o_i^4 = \varpi_i f_i = \varpi_i (p_i x + q_i y + r_i) \quad (4)$$

In which $\overline{\omega}_i$ is the output of layer 3 and parameters p_i, q_i and r_i will be referral to as resultant parameters.

Layer 5: the node in this layer calculates the overall output as the sum of all entrance signals:

$$o_i^5 = \sum_i \varpi_i f_i = \frac{\sum_i \omega_i f_i}{\sum_i \omega_i} \quad (5)$$

In the figure 2 there is a simple structure of function and relationship between layers at Neuro-fuzzy models.

In this study saturator pressure value and coagulant dose considered as input data at ANFIS and COD values were considered as the output. Membership functions were considered for inputs as Gaussian and for output as constant. Membership functions and structure of the model are shown in Figures 3 and 4. A relationship between inputs and output was considered at ANFIS as relevant rules which is shown in Figure 5.

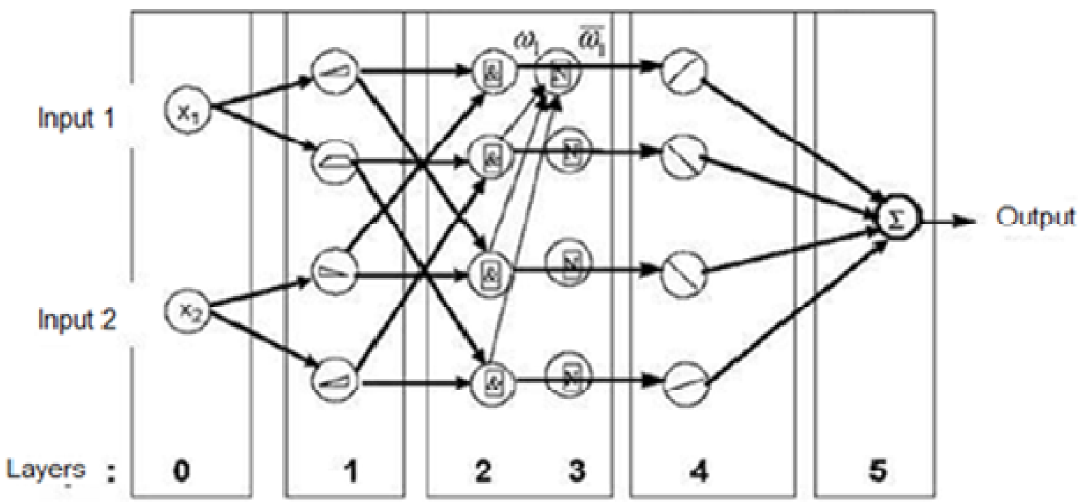

Figure 2: Simple schematic of ANFIS model

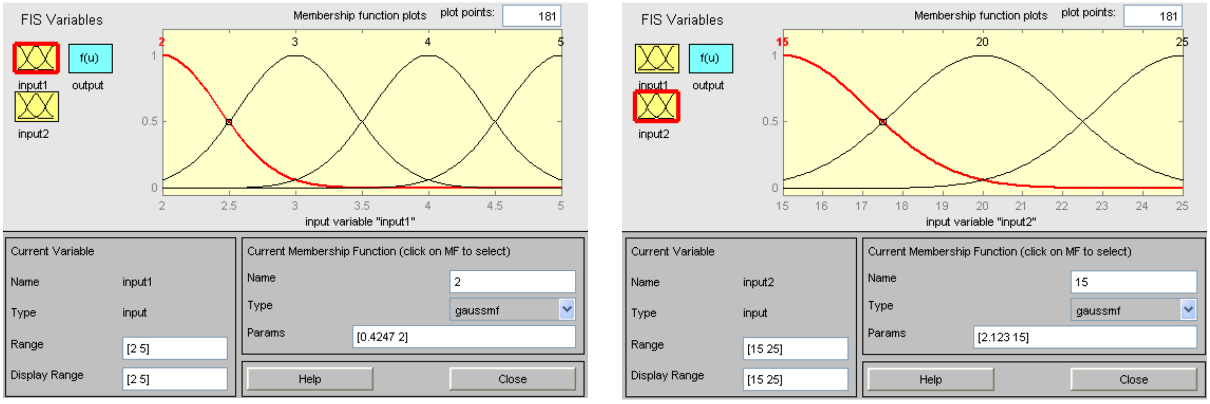

Figure 3: Membership functions

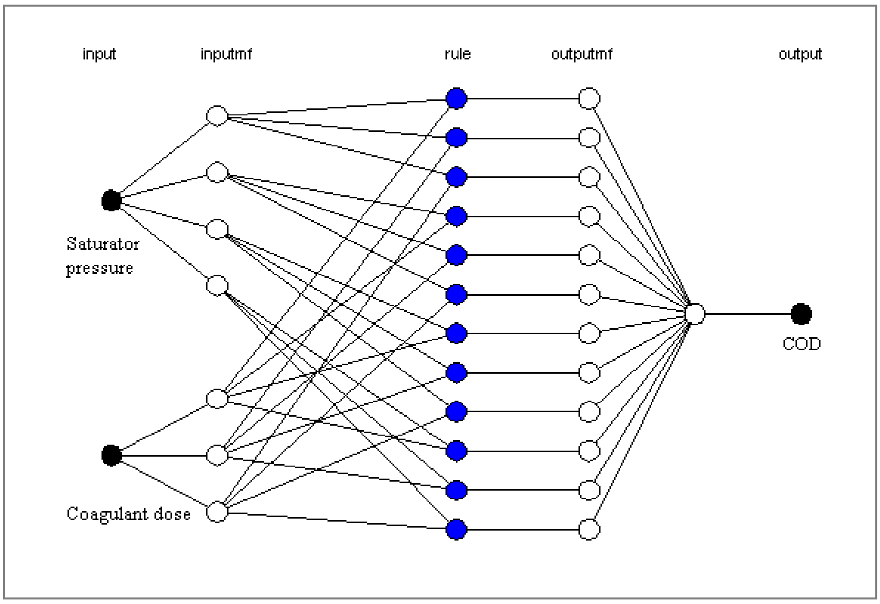

Figure 4: Geometric structure of model at ANFIS

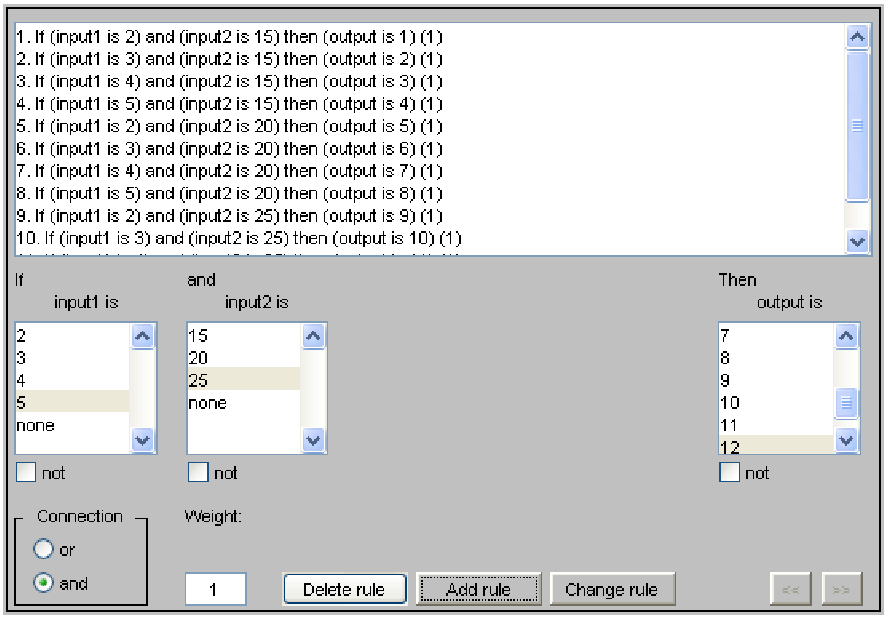

Figure 5: Defined rules at ANFIS

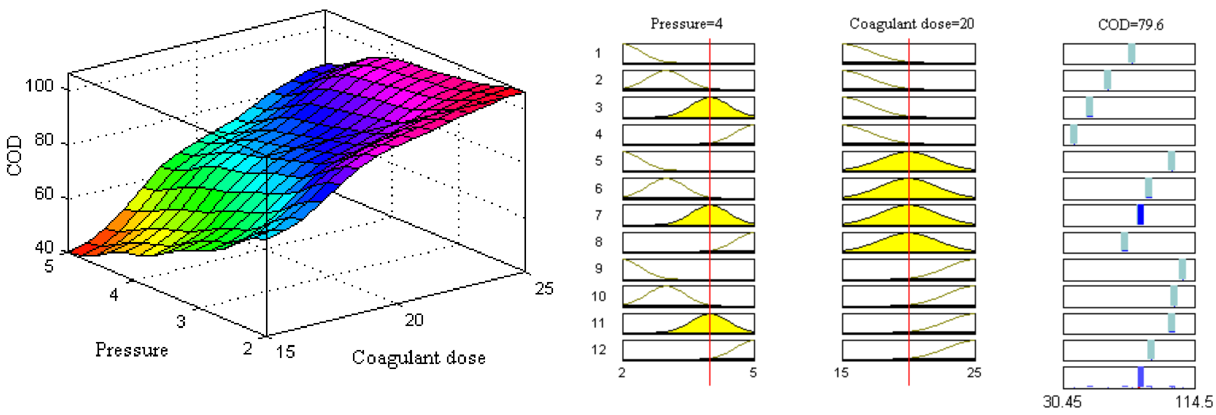

Figure 6: The result of ANFIS

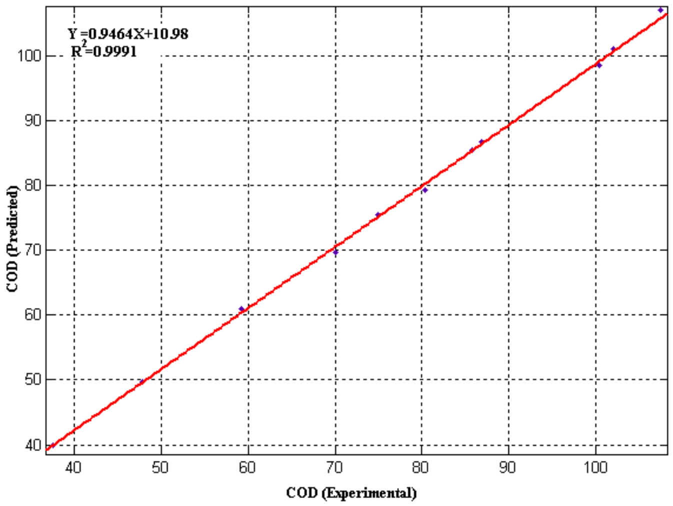

Figure 7: The correlation coefficient between experimental and predicted values

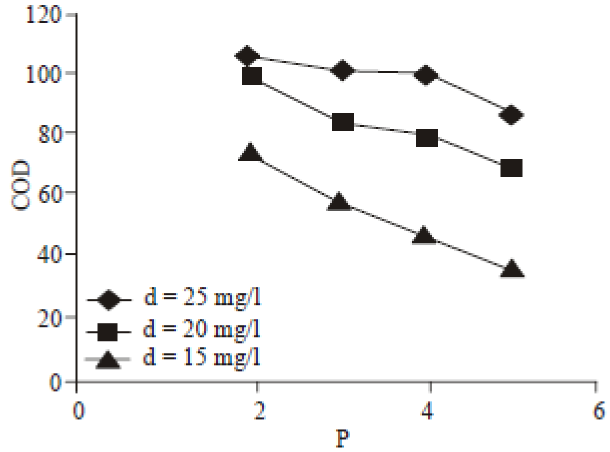

Figure 8: COD values of wastewater for different conditions of pressure and coagulant dose (P= pressure, d= coagulant dose)

3- Result and discussion

After using ANFIS to modeling the inputs, COD levels considered as the outputs. Result of defined rules was shown in figure 6. These results can easily predict the COD values at various pressures and doses with a correlation coefficient of 0.9991 (Figure 7).

As it's clear from Figure 7, Experimental and predicted values have high and acceptable correlation coefficients, this indicates the reliability of Neuro- fuzzy systems (ANFIS) at predicting of removal COD in refinery wastewater.

3-1- Description of experimental aspects

In figure 8 COD values for Kermanshah refinery wastewater at different operating conditions for the saturator pressure and coagulant dose are shown.

As it's clear from Figure 8; with increase saturator pressure the COD value of wastewater decreases. It is seen that with decreasing coagulant dose to a certain amount, the COD value decreases; with respect to the figure 8 the highest COD removal obtained at operating pressure 5bar and at dose equivalent 15 mg/l.

As we know, three operating configurations have been described for DAF systems [7]. These are:

a. Full- flow pressure flotation: where the influent is pressurized and then released in the flotation tank where the bubbles are being formed. This is generally used for particles, which do not need coagulum but require large volumes of air bubbles.

b. Split-flow pressure flotation: where a part of the influent is pressurized and directly introduced to the flotation tank. This is used in applications where suspended particles are susceptible to the shearing effects of pressure pump, also where suspended particles are at low concentration and thus have a low air requirement.

c. Recycle-flow pressure flotation: where a segment of treated wastewater is pressurized and recycled to the flotation tank. This is generally employed where coagulation and flocculation are needed and the flocculated particles are mechanically weak. Recycle-flow pressure flotation is used more often than the others for usages including oil removal [4, 23].

In the latter configuration small air bubbles of less than 100 μm are formed when air saturated recycle water is injected into the flotation tank through needle valves or specially designed nozzles. The bubble formation process is a two step process, first nucleation and the development [24]. The first step commences automatically after the pressure reduction at the nozzle and the bubble nuclei are produced in the super-saturated water. After the excess air in the saturated water is transferred from the dissolved to the gas phase, the second step of bubble development begins. During this step, the total air volume remains constant but bubbles develop due to coalescence and the decrease in the hydrostatic pressure as they uprise through the flotation tank [25]. The production of micro bubbles is considered to be important as the rising velocity of the bubbles is less than for larger bubbles. This guarantees a longer residence time in the flotation tank allowing more opportunities for encounter between bubbles and particle. In order to produce micro bubbles in the flotation tank, a saturator pressure of 400– 600kPa are recommended [26]. Also, the recycle flow, or the saturated water flow must be high enough to provide a rapid pressure drop and to prevent back flow and bubble develop in the vicinity of the injection system. The concentration of the supplied air bubbles resulting from mixing the pressurized recycle flow, or the saturated water flow, with the influent wastewater affects bubble– particle encounters and consequently the removal of the bubble– particle accumulates. This is considered to be an important design and operating parameter in the DAF process [27, 28]. The air supplied for the DAF process applications can be described in terms of the recycle ratio, the mass concentration of the air released in flotation, the air bubble volume concentration and the number concentration of air bubbles [26].

Higher percentage of COD removal will be obtained, if a recycle flow was added to main set-up such as (c) section and recycle flow was aerated, subsequently.

4- Conclusions

In this work by use an experiment scale DAF and a poly-aluminum chloride coagulant (PAC) 42% COD removal was obtained. As can be seen these values is closed to the values obtained by refinery, however these data obtained without considering the impact of the flowrate, with respect to the high influencing of flowrate parameters at removal. By considering this parameter at experiments and changes on the set-up higher levels of removal at various parameters will be obtained.

In addition, at this paper using ANFIS and experimental data; COD removal of Kermanshah refinery wastewater was predicted. Considering that the proposed model has a correlation coefficient (R^2), RMSE and SSE of 0.9991, 6.35×10^{-3} and 4.04×10^{-5}, respectively. The theoretical results have good agreement with experimental results which confirm high accuracy of model. So, by this model approximate values of COD could be gained at various conditions with high accuracy.

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