Study of a Crude Oil Desalting Plant of the National Iranian South Oil Company in Gachsaran by Using Artificial Neural Networks

H. Kiani, S. Moradi, B. Soltani Soulgani, S. Mousavian

Abstract—Desalting/dehydration plants (DDP) are often installed in crude oil production units in order to remove water-soluble salts from an oil stream. In order to optimize this process, desalting unit should be modeled. In this research, artificial neural network is used to model efficiency of desalting unit as a function of input parameter. The result of this research shows that the mentioned model has good agreement with experimental data.

Keywords—Desalting unit, Crude oil, Neural Networks, Simulation, Recovery, Separation.

I. INTRODUCTION

CRUDE oil contains varying amounts of inorganic salts (NaCl, CaCl2, MgCl2, and so on). The presence of such salts presents difficulties during crude oil processing such as corrosion, plugging and fouling of equipment, and poisoning the catalysts in processing units. In order to mitigate the effects resulting from the presence of salts, it is advantageous to reduce the salt concentration to the range of 3–5mg/L.

At most of the world's oil fields there is considerable water and brine in the extracted oil, with Iran's field being no exception. Desalting of crude oil is necessary due to the relationship between the price of exported crude oil and its quality. An increase of one part per million (ppm) of water and brine reduces the cost of crude oil by approximately 0.85–1.3$ per barrel. Currently, there are several available methods, such as chemical demulsification, gravity or centrifugal settling, pH adjustment, filtration, heat treatment, membrane separation and electrostatic demulsification. Each of these methods has advantages and disadvantages. For example, pH adjustment may be utilized to separate oil–water emulsions, but it is not usually effective in breaking water–oil emulsions. Centrifugation, an effective method for some emulsions, has a high operating cost. This method is used in laboratory and isn't suitable for industrial scale. Heat treatment can reduce the viscosity of the oil, thus allowing any water droplets to fall more rapidly through the oil phase, helping the separation of any trapped gas in the crude oil. This method can reduce API of crude oil in high temperature because of evaporating light hydrocarbon of crude oil in addition it has a high operating cost. However, the heat and chemical treatments are expensive and have a tendency to result in high fuel consumption [1].

Over the past 50 years, many studies have been conducted in emulsions with an aim to understand these complex systems. However, many unresolved questions still remain. Oil–water emulsions contain complex mixtures of organic and inorganic materials, all of which affect their behavior. These mixtures contain surface active materials which are responsible for the stability and integrity of the emulsion. They include asphaltene (bituminous materials), resins, phenols, organic acids, metal salts, mud, clay and wax. The petroleum industry faces the challenge of resolving several types of complex emulsions on a daily basis. Production techniques result in stable crude oil–water emulsions which require aggressive treatment methods. The stability of the emulsion depends on a variety of factors introduced by the production process such as thermal and pressure cycles and energy input [1], [2].

Desalting/dehydration facilities are often installed in crude oil production in order to minimize the occurrence of water in oil emulsions. A typical desalting unit is shown in Fig. 1. The main objectives of installing desalting plants are maintaining production rate in a field, decreasing the flow of salt content to refinery distillation feed- stocks, reducing corrosion caused by inorganic salts and minimizing energy required for pumping and transportation [3], [4].

The desalting process involves six major steps: separation by gravity settling, chemical injection, heating, addition of less salty water (dilution), mixing and electrical coalescing. Gravity separation refers to the primary free settling of water and is related to the residence time that takes place in both settling tanks and desalting vessels. The gravitational residence time is governed by the Stokes' law:

$$v = \frac{2\pi r^2 \Delta \rho\, g}{9\mu} \tag{1}$$

From (1) it is clear that gravitational separation can be intensified by maximizing size of a drop (chemical injection, electrical coalescing), maximizing density difference between two phases and minimizing viscosity of oil phase (heating, dilution). Several studies have been done to analyze and study the affecting parameters on SRE and WRE [5]-[9].

The aim of this study is simulating complicated desalting unit by use of neural networks.

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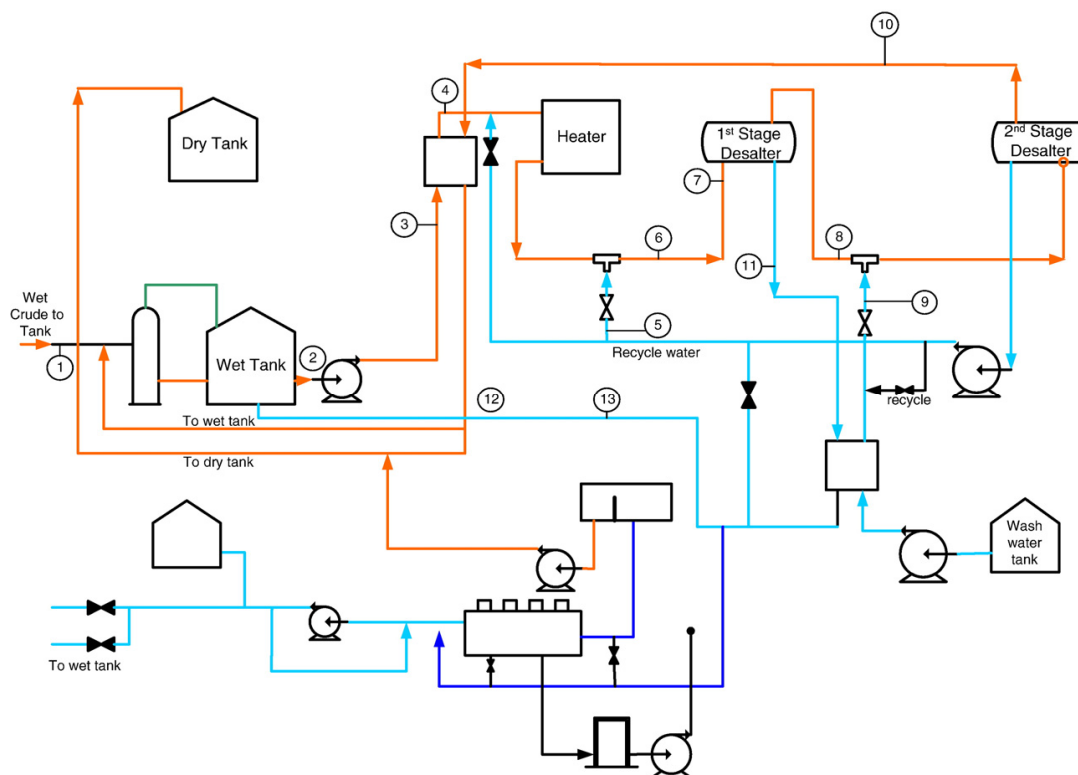
Fig. 1 Schematic of crude oil desalting/dehydration plant

II. NEURAL NETWORKS

Application of an ANN is new and has proven successful in solving problems in a variety of areas. The network consists of at least three layers, namely, the input, hidden, and output. The input layer consists of nodes accepting the input information specified by the user or the plant data. Each of these nodes trigger signals to the nodes of the hidden layer, which may be single or multilayered, consisting of nodes like the neurons of nervous system of human being communicating with the brain. Output signals from each of these nodes are triggered by the signals emanating from the input nodes which can be modeled as a sigmoid relation:

$$f_i(a_i) = (1 + e_i^{-a}) \qquad (2)$$

where f_i is the output signal from the ith node and a_i is the activity of the ith node. The activity of ith node is obtained as the sum of the signals received from the preceding nodes and defined as:

$$a_i = \sum w_{ij} x_i \qquad (3)$$

where w_{ij} are the weights connecting input node "i" to hidden node "j", x_i is the input value (normalized to unity) to input node "i." Signals from the hidden nodes then propagate to the output layer and generate output signal similarly as input did.

Output from the net is the output signal of the controller. During training of the net, back propagation was used for updating the weights. The number of iterations governing the accuracy depends on the number of hidden nodes between the input and output layers. Details of the ANN algorithm are available in literature [10]-[12].

III. EXPERIMENTAL DATA

Experimental data of a desalting plant of the National Iranian South oil company in Gachsaran is given in Table I.

TABLE I
EXPERIMENTAL DATA OF A DESALTING PLANT OF THE NATIONAL IRANIAN SOUTH OIL COMPANY IN GACHSARAN

Voltage	Oil Temprature (°C)	Water injection (%)	Chemical injection	Input Oil Flow	Salt in input oil	Output Oil Flow	Water in input oil (%)	Output water (%)	Salt in output oil	Recovery
12500	60	2	5	46000	2200	45124.248	2.1	0.2	56	0.97503006
12500	60	2	5	45000	2450	44066.353	2.3	0.23	70	0.972021363
12500	60	2	5	47000	2180	46109.831	2.1	0.21	65	0.970748204
12500	60	2	5	46500	1995	45670.475	2	0.22	70	0.965538219
12500	60	2	5	47000	2430	46058.116	2.2	0.2	65	0.97378708
12500	60	2	5	46000	2370	44883.674	2.7	0.28	82	0.966240494
15000	60	2	5	44300	2520	43359.146	2.3	0.18	42	0.983687304
15000	60	2	5	45800	2150	44868.677	2.2	0.17	42	0.98086235
15000	60	2	5	45500	2360	44496.994	2.4	0.2	51	0.978866207
15000	60	2	5	46000	2045	45115.207	2.1	0.18	47	0.977459182
15000	60	2	5	45800	2267	44794.869	2.4	0.21	56	0.975839868
15000	60	2	5	45900	2320	44842.184	2.5	0.2	51	0.978523858
17000	60	2	5	38000	2186	37067.601	2.6	0.15	37	0.983489415
17000	60	2	5	38500	2094	37632.449	2.4	0.15	33	0.984595805
17000	60	2	5	38500	2268	37613.614	2.4	0.1	28	0.987938556
17000	60	2	5	37000	1972	36222.222	2.2	0.1	23	0.988581888
17000	60	2	5	38400	2085	37554.354	2.3	0.1	23	0.989211754
17000	60	2	5	39200	2054	38258.258	2.5	0.1	33	0.984319763
19000	60	2	5	39000	2125	38043.065	2.6	0.15	28	0.987146838
19000	60	2	5	39000	2098	38144.103	2.4	0.21	28	0.98694685
19000	60	2	5	39500	2180	38747.996	2.1	0.2	37	0.983350646
19000	60	2	5	39800	2320	39022.734	2.1	0.15	42	0.982250099
19000	60	2	5	38700	2260	37827.942	2.4	0.15	28	0.987889799
19000	60	2	5	38600	2210	37672.673	2.5	0.1	28	0.987634694
23000	60	2	5	39000	2645	37945.946	2.8	0.1	28	0.989700097
23000	60	2	5	38600	2520	37633.066	2.7	0.2	42	0.983750835
23000	60	2	5	39000	2470	37956.299	2.9	0.23	28	0.988967337
23000	60	2	5	38800	1980	37886.83	2.5	0.15	37	0.981752932
23000	60	2	5	39000	2210	38180.18	2.2	0.1	28	0.987596646
23000	60	2	5	39000	2145	38179.359	2.3	0.2	42	0.980831593
17000	30	2	5	39000	2670	38002.007	2.9	0.35	145	0.947082579
17000	30	2	5	39200	2920	38019.277	3.4	0.4	176	0.941541508
17000	30	2	5	39100	2610	38071.672	3	0.38	127	0.952620725
17000	30	2	5	39000	2780	37907.42	3.2	0.41	196	0.931471551
17000	30	2	5	38700	2120	37907.668	2.4	0.36	141	0.934852261
17000	30	2	5	39100	2430	38131.032	2.8	0.33	132	0.947025183
17000	40	2	5	39100	2150	38038.373	2.9	0.19	87	0.960633576
17000	40	2	5	39000	2325	37827.655	3.2	0.2	74	0.969128795
17000	40	2	5	39200	2680	38131.837	2.9	0.18	65	0.97640716
17000	40	2	5	38700	2515	37582.983	3.1	0.22	86	0.966792151
17000	40	2	5	39000	2163	38057.366	2.7	0.29	97	0.956238788
17000	40	2	5	39100	2345	38085.179	2.8	0.21	84	0.965108818

Input oil flow and output oil flow are expressed in bbl/day
Salt in oil is expressed in terms gr/m^3
Water injected is a percent of input oil flow

The recovery calculated in Table I are calculated by the following equation

$$Recovery = \frac{\left(Input\ oil\ flow \times Salt\ in\ input\ oil\right) - \left(Output\ oil\ flow \times Salt\ in\ Output\ oil\right)}{\left(Input\ oil\ flow \times Salt\ in\ input\ oil\right)} \tag{4}$$

IV. RESULTS AND DISCUSSION

Artificial neural networks model (ANNM) with different layer and different neurons in each layer was examined. ANNM with 38 neurons in one layer has the best fit. Fig. 2 shows accuracy the mentioned model.
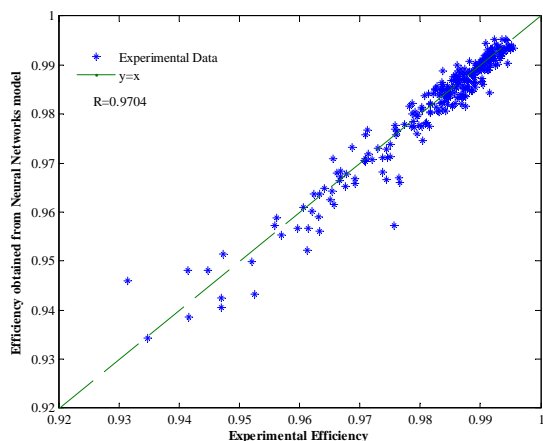

Fig. 2 Neural networks estimation of efficiency versus experimental efficiency

Fig. 2 shows that one layer neural network model with 38 neurons has good agreement with experimental data especially in upper efficiency. This model can be used to optimization crude oil desalting process.

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