
LITERATURE REVIEW

The chapter presents the literature review done to propose and complete the research work. For the sake of brevity, some of the items those are mentioned elsewhere in this thesis are not mentioned here.

2.1 Emulsion Treating and modelling issues

The problem of water-in-crude-oil emulsion has been observed from the start of the petroleum industry [39]. Historically, after the discovery of crude oil in 1859, various ways were tried to remove the water. In the early days, the crude was put in tanks or in pits and simply let it remained there for a period of time expecting gravity would take its effect on the heavier water and eventually it would separate. Soon it was found that heating the oil would decrease the time required for most of the water to settle out. However, such approaches were make-shift and unreliable. Therefore, in those early days, great quantities of emulsified oil in pits were found around most oilfields in the USA, because the crude oil in which water was tightly emulsified would not separate with time or moderate temperature.

There was a need to separate water from crude oil in more efficient ways. Later, two different approaches became prominent to solve this problem. Monson (1937) [37] highlighted that methods for crude oil emulsion treatment were reduced essentially to two, the chemical method and the electrical method. In the paper, he provided discussion on chemical resolution of petroleum emulsions.

Tsabek, Panchenkov and others (1971) [49] discussed investigations into the theory of emulsions behavior in electric field. The paper was presented based on the theoretical and experimental work. However, equations presented in the paper are pertaining to defining the basic behavior of droplets in the electric field. Such equations are not interesting to the plant operators at oilfield towards optimizing the plant operation.

Cummings and Engleman (1989) [16] presented emulsion treating problem. They highlighted the underlying three basic processes that are needed to treat crude to acceptable BS&W content. These are: (i) weakening and destabilization of emulsifiers, (ii) coalescence of water particles into larger droplets, and (iii) sufficient settling time for the droplets to settle out of the oil. They highlighted that the design should take into account favorable flow pattern, chemicals, heat, electricity or any combination of these to decrease retention time and improve the efficiency of the separating processes. Such observations underscore the complexity involved in developing model for DDP.

Khatib (1996) [26] mentioned about a Pilot-Scale Chem Electric Treater (PSCET). Such pilot scale investigations were used to provide operating guidelines. Content of this paper, also underscored the involved complexity, and thereby, hinted the underlying complications in developing any model which may be used for DDP.

Lee, Sams and Wagner (2001) [28] presented an experimental study, the primary objective of which was to evaluate performance of the coalescence system fed with a well-characterized emulsion. In their discussion, they noted a limitation, “It is well known that electrostatic coalescence is not only influenced by the voltage, oscillating frequency and waveform type of the applied electric field, but also by coalescer geometry, electrode configuration, operating temperature, agitation speed of mixing, volume phase ratio, and physical–chemical properties of the emulsion constituents (e.g., oil-phase density, viscosity, dielectric constant, electrical conductivity, water droplet size, surfactant concentration, etc.). To date, there is no valid

theory that can completely correlate all of these variables with emulsion separation rate, nor is there any easy method to isolate individual factors or to generalize the entire contributions to the whole process". Such observations highlight the involved complexity, and thereby, hinted the underlying complications in developing any model which may be used for DDP if developed using 'first-principles'.

Noik, Trapy and Mouret (2002) [38] described a study conducted to develop a compact electrocoalescer. The study includes CFD simulation through FLUENT software, which is famous software available in the market. Also experiments were performed on droplet coalescence, phase separation and centrifugation using laboratory prototype. This study resulted into patenting of a new concept of compact centrifugal electrocoalescer.

Al-Otaibi, Elkamel and others (2003) [40] presented an experimental investigation to study the effect of five factors namely gravity settling, chemical treatment, freshwater injection, heating, and mixing on the efficiency of the dehydration and desalting process for a Kuwaiti crude oil and a commercial demulsifier. These factors were systematically varied to study variation in SRE as well as WRE. As these factors are representative of DDP employed at oilfield, these were used in this thesis.

Al-Otaibi, Elkamel and others (2005) [41] presented a study in which the performance of DDP was evaluated by calculating SRE and WRE depending upon five process parameters namely concentration of demulsifying agents, heating, wash water addition, settling time, and mixing time. The work involved modelling and optimizing the performance of DDP using the concept of artificial neural network (ANN). According to the authors, ANNs have potential for modelling highly nonlinear relationships of the parameters involved in DDP. Model outputs were stated to be consistent to actual observations. Relevance of process factors used in this study with the real plant, and stated ANN's ability to model highly nonlinear

relationships of the parameters involved in DDP strengthen the idea for further work to be done through the current study for enhancing the applicability of such previous work.

Abdul-Wahab, Elkamel and others (2006) [1] described the development of simple inferential estimators for product quality of the DDP. They constructed inferential estimators to capture the relationship between the product quality of the plant (in terms of SRE and WRE) and the process input variables, namely temperature, settling time, mixing time, chemical dosage, and dilution rate. Both multiple linear and principal component analyses as well as non-linear regression were used to construct the inferential estimators. They remarked that actual dependence of the performance of DDP on process parameters could not be described only by linear relationships; addressing the non-linearity of the process variables overcame the problem of inaccurate predictions. Their recommendations for future studies include use of computational intelligence techniques that is applied in this thesis. Moreover, above mentioned models, though involve some bulk operating conditions of interest for process engineers at oilfield, but are prone to be applicable only for the case it was developed for, because the constants of the model were attained for a given set of data generated for a particular geometry / make of the equipment subjected to a specific experimental set-up.

Alves and Oliveira (2006) [5] described development of a semi-empiric mathematical model for simulating performance of an electrostatic desalting process based on experimental studies conducted at a lab pilot plant. The mathematical model is as follow:

$$T_{wo_f} = \left(\alpha + \beta \cdot \frac{K_P}{T_{RP}} \right) \cdot G_T^\gamma$$

Where,

T_{wo_f} : water cut in the treated crude oil.

α, β, γ : constants that depend on the characteristics of the crude oil.

These were calculated through non-linear regression, using STATISTICA software

and data collected from the pilot plant.

K_P : depend on viscosity of the oil and the difference of specific masses, at processing temperature.

T_{RP} : Residence time between electrodes

G_T : Gradient Tension

It may be noted that K_P , T_{RP} , G_T were determined experimentally.

Evidently, such phenomenological model built through semi-empirical approach using statistical tools, is prone to be applicable only for the case it was developed for, because the constants of the model were attained for a particular geometry / make of the equipment subjected to a specific experimental set-up; whereas, idea behind the current work is to develop a versatile process model which may be used for various operating parameters of interest for different DDPs irrespective of their different design / construction. Also, the model lacks broad correlation between several bulk process parameters that are of interest for a plant operator.

Noik, Chen and others (2006) [39] presented a review on electrostatic demulsification of crude oil. They mentioned that the problem of water-in-crude-oil emulsions accompanies with the dawn of petroleum industry and it will become more and more challenging. They listed several possible separation methods of water-in-oil emulsions that include gravity or centrifugal settling, thermal treatment, chemical demulsification, pH adjustment, electrostatic demulsification, freeze/thaw method, filtration, membrane separation, microwave radiation and ultrasonic energy etc. They noted, “The principles underlying the process of electrostatic demulsification, once considered very simple and obvious, are actually very complex, and that there exist different opinions regarding the theoretical explanation of some phenomena involved.” This observation underscores the associated problems of any model built for DDP

as ‘white model’. Duly considering such point, black-box modelling technique has been proposed for modelling DDP in this thesis.

Zeidani and Bahaduri (2006) [58] described development of new equations to estimate the treating rate and treating temperature for dual polarity electrostatic desalters and AC conventional electrostatic desalters at Iranian oilfields. They mentioned that the dehydration system in Iranian oil fields employs chemical demulsifiers, heat, and an electrostatic field to dehydrate the crude. According to them time and specific gravity are the two key factors involved in the process and are directly related to treating rate (q , cubic metres oil per day per square meters) and treating temperature (T , °C). They presented q and T as separate polynomial of oil specific gravities, deduced as best fitting curve, with a minimal deviation from all field data using the method of least square. They listed major factors that affect desalter’s performance as oil flow rate, wash water injection rate / type / temperature, mixing intensity, demulsifier type and amount, process temperature, process pressure and desalting voltage. However, no correlation was found in their paper which could relate the above factors with desalter’s overall performance.

Bai and Wang (2007) [9] described a new process of crude desalting that was based on hydrocyclone technology. They presented effects of several dimensionless units, such as Reynolds number, Euler number and pressure drop ratio on the performance of their designed desalting unit. Though this work encourages development of new type of equipment for accomplishing desalting but does not provide modelling solution for the conventional DDP generally installed at oilfield.

Mahdi, Gheshlaghi and others (2008) [31] presented experimental investigation of effect of five parameters, namely demulsifying agent concentration, temperature, wash water dilution ratio, settling time and mixing time on performance of DDP. They mentioned in the paper that parameters affecting SRE and WRE have been analyzed in several studies which denoted

that the effect of process variables is very complicated. According to them, conducting experiments to evaluate and study the effect of parameters on the performance of a real plant is costly and time consuming, and the governing laws usually prohibit changing parameters in a real plant and normally it is difficult due to operational limitations. In their work, SRE was expressed by a statistical model for the whole range of variables while WRE was expressed with two statistical models, each valid in a part of variable domains. However, such model though involved some bulk operating conditions of interest for process engineers at oilfield, but is prone to be applicable only for the case it was developed for. Any other case would require fresh work to attain new constants for the new model utilizing the indicated concept.

Ye, Lu and others (2008) [55] presented a study of ultrasonic-electric united desalting and dewatering of crude oil. Though this work encourages development of new type of equipment for accomplishing desalting but does not provide modelling solution for the conventional DDP generally installed at oilfield.

Alinezhad (2010) [2] noted that because of the many parameters to be examined, e.g. operating conditions (voltage, frequency, temperature) and emulsion properties (density, viscosity, water drop size, hold up), a complete rate equation which could take into account all these factors was not yet presented. They investigated some of the main characteristics of crude oil emulsions, and the effect of some factors such as type of the electrode, degree of API, volume fraction, temperature and voltage on the separation rate of water from crude oil (as the separation efficiency) by a glass batch electrostatic dehydrator in a non-uniform electric field. Finally, a model was derived from the experimental results using regression and Mont Carlo technique. Evidently, such model is prone to be applicable only for the case it was developed for, because the constants of the model were attained for a particular geometry / make of the equipment subjected to a specific experimental set-up.

Shvestov and Yunusov (2010) [47] presented limitations of electrical dehydrators widely used in Russia and proposed better electrode system for retrofitting. For analyzing performance of the existing dehydrators they noted equations for dipole-dipole attraction force involving parameters / constants that are not interesting for day-to-day plant operation but can be beneficial for suggesting modification in the particular existing equipment.

Ye, Lu and others (2010) [54] described an experimental investigation of the enhancement of ultrasound irradiation on desalting and dehydration process. Though this work encourages development of new type of equipment for accomplishing desalting but does not provide modelling solution for the conventional DDP generally installed at oilfield.

Bresciani, Mandonca and others (2010) [13] described a study in which, the concept of cellular automata is applied in an innovative way to simulate the separation of phases in a water/oil emulsion. However, the described model contains “white elements” that required focusing on certain specific aspects, namely kinetics of the coalescence of water droplets in crude oil emulsions subject to an electric field and not the entire DDP system. It includes parameters / constants that are not interesting from production operations point of view, and also some parameters depend on the specific geometry and flow conditions. Thus, it may be beneficial in developing a new product or for enhancing a product design; but may not be practically able to serve the afore-mentioned need of a process engineer at oilfield.

Rayat and Feyzi (2011) [45], in reference to fundamental modelling of oil water separation in electric dehydrators in oil industry, mentioned in their paper that in spite of various kinetic models, thermodynamic aspects are frequently neglected. They quantified the effect of external electric field on the interactions among water droplets in water-in-oil emulsion taking into account thermodynamic aspect. Such model deals with a narrow aspect and not the entire DDP. It may be beneficial in developing a new product or for enhancing a product

design; but may not be practically able to serve the afore-mentioned need of a process engineer at oilfield.

Less and Vilagines (2011) [29] presented some theoretical as well as experimental investigation on electrocoalescence. They listed basic equations with the focus on electrocoalescence which is one of the underlying aspects of DDP. However, no broad correlation between several bulk process parameters that are of interest for a plant operator is found in the paper. Those equations and conclusions may provide great information for developing a new product or for enhancing a product design; but are not interesting for operators at oilfield.

Vafajoo, Ganjian and Fattahi (2012) [51] presented the result of a study conducted regarding the impact of several operational parameters including temperature, chemical injection and pH on the desalting process. Modeling of desalting was done using fuzzy logic method from MATLAB fuzzy logic toolbox. This study underscores the use of artificial intelligence techniques for desalting process. In this thesis also, another artificial intelligence tool is utilized, to model DDP in a manner that is expected to enhance model's applicability.

Al Hutmany (2013) [25] presented modelling of desalting process for Libyan crude using ANN. His presented model correlates SRE with seven process variables, namely production rate, salt in, salt out, temperature in, temperature out, chemical addition and fresh water addition. Such model, built through black-box technique using ANN, does have somewhat inherent flexibility, in order to be implemented for different DDP at different locations without depending on specific physical / geometrical aspect of any unit, and does correlate bulk process parameters of operational interest. However, he developed ANN model using MATLAB software. This would inhibit its usage by operating personnel at oilfield. Applicability of previous such work done for modelling DDP using ANN is aimed to be enhanced through this research by combining versatility of ANN and MS Excel.

2.2 Modelling capability of ANN and benefits of MS Excel

Mohaghegh and Ameri (2000) [36] presented review on application of ANN in first article of a three-articles series on virtual intelligence and its applications in petroleum and natural gas engineering. They mentioned, “Neural Networks should be used in cases where mathematical modeling is not a practical option. This may be because all the parameters involved in a particular process are not known and / or the inter-relation of the parameters is too complicated for mathematical modeling of the system.” In this thesis, also, ANN is used to developed a model for DDP in which inter-relation of various operating parameters is too complicated to be practically expressed as a mathematical equation.

Meireles, Magali and others (2003) [35] presented a comprehensive review of industrial applications of Artificial Neural Networks (ANNs) in 12 years previous to their review. They noted that ANN history began in the early 1940s; however, only in the mid-1980s these algorithms became scientifically sound and capable of applications. They added, since the late 1980s, ANN started to be utilized in a plethora of industrial applications. They quoted a study wherein approximate percentage of network utilization is mentioned as: MLP (Multilayer perceptron) - 81.2%; Hopfield - 5.4%; Kohonen - 8.3%; and others - 5.1%. That is, MLP is one of the most used ANN types, which is also used in this thesis.

Yusof, Idris and others (2003) [57] presented the application of ANN models for steady state chemical engineering systems. They mentioned that ANN had generated much interest in the chemical engineering community since late eighties. They mentioned increasing trend of diverse application to ANN to steady-state processes, quoting others' works, e.g. ANN model for estimation of contaminant composition in Xylene distillation column, ANN model for a hydrocracker outlet gas separation unit, ANN fitted to vapor-liquid equilibrium (VLE) data, ANN fitted to experimental data to predict the enthalpy of vaporization. After listing such previous works, they described ANN models for three processes that were developed in

MATLAB environment and utilized neural network toolbox. These include ANN model for calculating physical properties (e.g. density, specific heat and viscosity) for several palm oil components. The ANN model chosen was the multi-layer perceptron (MLP) feed forward network having one hidden layer with 5 nodes and sigmoid activation function. It was trained using the Levenberg-Marquardt algorithm. Levenberg-Marquardt (LM) algorithm implemented through MATLAB software is often used. However, Solver in MS Excel, which utilizes GRG2 algorithm is proposed to be used in thesis; and also 10 nodes (in contrast to 5 nodes) in the hidden layer is used in this present work in order to facilitate wider use of the developed ANN as modelling framework / decision support tool.

Bravo, Saputelli and others (2012) [12] presented analysis of a survey conducted on a broad group of professionals related to several E&P operations and service companies regarding penetration and impact of Artificial Intelligence and Predictive Analytics (AIPA) technologies in E&P industry. Regarding neural network it was noted that this is one of the most widely used AI techniques with many journals and book dedicated to its study and numerous related conferences. They highlighted that the main use of a neural network is as an all-purpose nonlinear function approximator, for modelling and classification tasks. Utilization of this feature of ANN for developing a versatile process model has been described in this thesis. Also, they mentioned that there are several artificial neural network software tools for developing applications and MATLAB tool box is amongst these. However, in this thesis, development of an ANN modelling framework is described using widely available MS Excel.

Arce-Medina and Paz-Paredes (2007) [6] highlighted that a neural network can be thought of as an advanced simulation technique. They demonstrated modelling and simulation of Hydrodesulfurization (HDS) process, which is a key process in most petroleum refineries

used for sulfur removal. Above described power of ANN for process simulation is demonstrated in this thesis to perform modelling for DDP, which is a key process in oilfield. Sarafian and Dooley (2012) [46] have presented benefits of MS Excel towards deployment of model-based decision support for plant optimization, even for using rigorous Hysys models through MS Excel. It reinforces the significance of the work presented in this thesis.