ESTIMATING ASPHALTENE PRECIPITATION IN THE PRESENCE OF CO_2 INJECTION IN OIL RESERVOIRS

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To my beloved parents, thank you for always being there for me, supporting me and encouraging me to be the best that I can be.

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ABSTRACT

In this research, use of multi layer perceptron (MLP) and radial basis function (RBF) structures of artificial neural network (ANN) for prediction of asphaltene precipitation were described and the models were contrasted with the modified Hirschberg *et al.*, model. The essential data were gathered and after pre-treating was employed for training of ANN models. The performance of the best obtained model was checked by its generalization ability in predicting 30% of the unseen data. Excellent prediction with Mean Squared Error (MSE) of 0.0018 and Average Absolute Deviation (AAD %) of 1.4108 was observed. However the accuracies of RBF and MLP models may be evaluated relatively similar, it was obtained that the constructed MLP according to Levenberg-Marquardt (LM) optimization exhibited a high performance than RBF structure, and the modified Hirschberg to predict asphaltene precipitation.

ABSTRAK

Dalam kajian ini, penggunaan multi layer Perceptron (MLP), dan fungsi pangkalan jejari (RBF) struktur rangkaian saraf tiruan (JST) untuk keputusan curah hujan aspalten digambarkan dan model dibandingkan dengan diubahsuai Hirschberg dkk., Model. Data yang diperlukan dikumpulkan dan setelah pra-mengubati digunakan untuk latihan model JST. Prestasi model terbaik diperolehi diperiksa dengan kemampuan generalisasi dalam memprediksi 30% dari data yang tak terlihat. Excellent ramalan dengan Mean Squared Error (MSE) dari 0,0018 dan Rata-rata Sisihan Mutlak (AAD%) dari 1,4108 diamati. Namun ketepatan RBF dan model MLP boleh dinilai relatif sama, didapati bahawa MLP dibina sesuai dengan Levenberg-Marquardt (LM) pengoptimuman menunjukkan prestasi tinggi daripada struktur RBF, dan Hirschberg diubahsuai untuk memprediksi curah hujan aspalten.

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LIST OF ABBREVIATIONS

Abbreviation:	
EOR	Number of neurons in hidden layer
EOS	Equation of state
ANN	Artificial neural network
ANFIS	Adaptive neuro fuzzy inferance system
MLP	Multi layer perceptron
ANN	Artificial neural network
ANFIS	Adaptive neuro-fuzzy inference system
RBF	Radial basis function
FCM	Fuzzy c-means clustering
FIS	Fuzzy inference system
AAD (%)	Average absolute deviation(%)
Sub-ANFIS	ANFIS-based subtractive clustering algorithm
MLP	Multi layer perceptron
MSE	Mean squared error
GDX	Gradient decent algorithm
LM	Levenberg–Marquardt algorithm
RP	Resilient back propagation
TSK	Takagi-Sugeno-Kang
ANFIS_FCM	ANFIS-based fuzzy c-means clustering algorithm
NH	Number of neurons in hidden layer
HLT	Hidden layer transfer function
OLT	Output layer transfer function
LR	Learning rate
MSE_TEST	Mean squared error value for testing data
MSE_TRAIN	Mean squared error value for training set
T_T (sec)	Consumed time for training part (second)
NORM_F	Normalization function
MLP_LM	Multi layer perceptron structure trained by trainlm function

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Petroleum consists of a complex mixture of hydrocarbons of various molecular weights, plus other organic compounds. There is a very general classification scheme which is used to define the various component typically found in petroleum fluids. The scheme is specifically designed to address special phase behavior and solid deposition issues. In general, petroleum constituents are classified under two major groups, namely the well defined and volatile C_6^- fraction and the poorly defined and relatively nonvolatile C_6^+ fraction. The C_6^+ fraction is more complex than C_5^- due to the multiple isomer combinations available to hydrocarbon with increasing chain length. This group of component is classified as paraffins (P), naphthenes (N), aromatics (A), resins (R), and asphaltene (A). Among of these constituents, asphaltenes are possibly the most studied and yet least understood materials in the petroleum industry. The word "asphaltene" was coined by Boussingaultin in 1837 when he noticed that the distillation residue of some bitumens had asphalt-like properties. There are many definitions of asphaltenes.

Strictly speaking, asphaltenes are the crude oil components that meet some procedural definition.

A common definition is that asphaltenes are the material that is (1) insoluble in n-pentane (or n-heptane) at a dilution ratio of 40 parts alkane to 1 part crude oil and (2) re-dissolves in aromatic solvents such as toluene, benzene and xylene. Asphaltene aggregation problems are encountered both in the reservoir and during transport and processing of petroleum fluids. Asphaltene can cause reservoir impairment, plugging of walls and flow lines through deposition, separation difficulties, and fouling in facilities. Deposition in the oil wellbore and tubing are identify very difficult and expensive to remove. The main factors that influenced to the deposition are:

i. Temperature drop acidizing
ii. Pressure drop
iii. Action of metallic ions
iv. Rich gas
v. Mixing of crude streams
vi. Incompatible organic chemicals
vii. Miscible flooding-such as CO_2 (EOR)

Enhanced oil recovery (EOR) has been known as tertiary recovery of oil. CO_2 Flooding applied in the EOR system to recover oil. Normally, CO_2 has been flooded as immiscible and miscible form.

One interest question of oil industry is “how much” asphaltene will precipitate under certain condition. By answering this, a proper solution may take to prevent this problem. Of course “prevention is better than cure”. Consequently, using an appropriate model is unavoidable.

Taking into account the dissimilar approaches, different models have been developed; thermodynamic molecular solubility model (Hirschberg *et al*., 1984; Yang *et al*., 1999), thermodynamic colloidal model (Leontaritis and Mansoori, 1987), thermodynamic micellization model (Pan and Firoozabadi, 1998; Pan and Firoozabadi, 2000) , solid line model (Nghiem *et al*., 1998), statistical association theory (SAFT) (Chapman *et al*., 2004; Paricaud *et al*., 2002).

Although there are a lot of models to estimate asphaltene precipitation, the predictive capabilities of these models are poor especially in the presence of CO_2 . Established models suffer from the difficulty in characterizing asphaltene fraction (Hammami and Ratulowski, 2007).

1.2 Problem Statement

Carbon dioxide (CO_2) flooding has been used as a commercial process for enhanced oil recovery (EOR) since the 1970s (Yin, 2000). Significant amounts of residual oil can be recovered by this procedure. Normally, CO_2 has been flooded as immiscible and miscible form. The miscibility of CO_2 depends to the reservoir pressure. Reservoirs pressure which higher than Minimum Miscibility Pressure (MMP) of CO_2, could formed CO_2 miscible with oil. Although, CO_2 flooding bring a good recovery, but miscible CO_2 flooding have to handle with carefully to avoid asphaltene precipitation in the production systems. It known that, asphaltene will be precipitated if occur any changes in pressure, composition and some other factors. Miscibility of CO_2 will make asphaltene to precipitate, due to changing the crude oil composition and making oil to be acidic (changing in PH). As a result, a special investigation is needed to control CO_2 concentration in the systems during flooding. This investigation can lead to a robust model to monitor asphaltene behavior.

1.3 Purpose of Study

CO_2 Injection is one of the most common enhanced oil recovery methods. In this process, CO_2 acts as a solvent, lowering the viscosity of the oil and making it mobile. Thus significantly it can lower the irreducible oil saturation. However, CO_2 flooding processes cause many changes in the flow and phase behavior of the reservoir fluids and can significantly favor the precipitation of asphaltenes. Even though the literature is considerable on the subject, few studies have been reported on the simulation of asphaltene phase behavior changes caused by CO_2 addition.

1.4 Significance of the Study

Although there are many models to predict asphaltene precipitation but most of them have an error to some extent, to predict phase behavior of asphaltene. Because of the difficulty in characterizing asphaltene fraction, the predictive capabilities of most models are poor.

In enhanced oil recovery (EOR) projects by CO_2 flooding, predicting asphaltene precipitation will be more complicated because another strange component has been added to the oil. Carbon dioxide has its own unique behavior and shows an extraordinary performance to enhanced oil recovery in compare with other substances like N_2 and some chemical materials, when they are in contact with crude oil. In this project ANN approach has been examined to predict asphaltene precipitation. It will be well worth employing these methods to catch good result, because this type of modeling is independent of understanding characterization of asphaltene.

1.5 Objectives

The objective of this study is to examine ANN approach to find a robust model, to predict asphaltene precipitation weight percent in the presence of CO_2 in oil reservoirs. The model should be able to predict the output of the model as a result of changing in pressure, temperature, mole fraction of CO_2 in liquid, and oil composition.

1.6 Scope of Study

Scope of this study is described as below:

i. Choice of inputs and output of the black box. Based on literature review, 33 parameters were chosen as inputs of the model and asphaltene precipitation weight percent examined as output variable.

ii. Data collection. The data sets were collected from the six samples of the oil.

iii. Development of different models of ANN. These structures have been built based on different types of multi layer perceptron algorithms and radial basis function of ANN. The complete process model is programmed and simulated in MATLAB R2010a.

iv. Training and validation of each model by using experimental data. From the experimental data file, seventy and thirty percent of all data observations were selected for training and estimating the generalization ability of the model, respectively.

v. Comparing result of best models with a solubility model. After finding the best model of each structure, their prediction ability will be compared by a solubility model. Their performance has been evaluated based on a statistic criterion and the best one was chosen for future investigations.

vi. Analysis on best model sensitivity towards changes in process input variables, like temperature, pressure, mole percent of CO_2 in liquid, and component of the oil.

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