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ARTIFICIAL INTELLIGENCE SELECTION WITH CAPABILITY OF EDITING A NEW PARAMETER FOR EOR SCREENING CRITERIA

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Abstract

This paper describes the application of an Artificial Intelligence (AI) technique to assist in the selection of an Enhanced Oil Recovery method (EOR). The structure of an expert systems selection based on a new formulated screening criteria, Artificial Intelligence selection developed by a computer software called ($E^{K}OR^{A}$), with an easily and friendly user interface by using visual Basic-6 environment tools is presented. An additional capability provided by this software is the ability of changing and editing the parameters of EOR methods which emerged or tested in current implementation projects. Other commercial expert systems either offer limited or no capabilities for changing and editing the EOR parameters of screening rule.

Keywords: Oil recovery method; Artificial intelligence; Expert system; Screening criteria; EOR parameters.

1. Introduction

A large number of EOR projects have been utilized in many oil fields around the world. This has led to an increased understanding of the selection and applicability of certain oil recovery methods and has ensured degree of technical and economical success.

The selection of enhanced recovery methods is based on technical and economic standard. In this paper we considered only the application process on a technical level, since economical levels are subject to change from one company to another. Economic standard could be easily added depending on worldwide oil price and account for the strategy of each petroleum company. It is very important

for reservoir engineers to choose the most feasible EOR method for a certain reservoir based on optimizing profits. The entire screening criterions are expensive and typically involve many steps.

There are a number of considerations in selecting the most appropriate recovery method for a certain oil field. A review of published results of several tables and charts of successful EOR projects implemented worldwide are presented in various periodicals by, Dusseault [1], Goodlett [2], Parkinson [3], Taber and Martin [4], Taber et al. [5, 6], Qin and Wojtanowicz [7].

Screening guides conducted in this expert system were developed in more specific criteria to achieve a specific rule. Table 1 formulated new criteria and listed the rules of thumb for picking the proper EOR technique as a function of Maximum-Minimum reservoir and crude oil properties.

Table 1. Reservoir Properties Min/Max Values of Expert System's Rule.

(1)	Nitrogen and Flue Gas Flooding						
Properties	API	Viscosity cp	Saturation of oil %	Permeability md	Depth ft	Temp F	Salinity ppm
Min	35	0.07	59	N/C	6000	N/C*	N/C
Max	54	0.3	80	N/C	18500	N/C	N/C
(2)	Hydrocarbon Miscible Flooding						
Min	24	0.04	30	N/C	4000	N/C	N/C
Max	54	2.9	98	N/C	15900	N/C	N/C
(3)	CO2- Miscible Flooding						
Min	22	0.3	20	N/C	2500	N/C	N/C
Max	40	6	70	N/C	4000	N/C	N/C
(4)	CO2- Immiscible Flooding (Lower Oil Recovery)						
Min	13	0.3	20	N/C	1800	N/C	N/C
Max	21.9	6	70	N/C	2500	N/C	N/C
(5)	Alkaline Flooding						
Min	15	0.1	35	50	1300	80	<100000
Max	30	35	90	10000	9000	200	
(6)	Alkaline/ Surfactant/Polymer Flood						
Min	20	0.1	35	30	1300	80	<140000
Max	100	35	80	10000	7000	180	
(7)	Polymer Flooding						
Min	14	10	50	10	1300	140	<100000
Max	43	100	92	15000	9000	200	
(8)	Thermal – In-situ Combustion						
Min	10	100	62	85	400	100	N/C
Max	27	5000	94	10000	11500	500	N/C
(9)	Thermal – cyclic Steam Injection						
Min	8	1000	40	367	328	N/C	N/C
Max	26	5000000	90	6170	4500	N/C	N/C
(10)	Thermal - Steam Flooding						
Min	8	1000	40	200	344	N/C	N/C
Max	26	214000	90	11600	4500	N/C	N/C

*N/C not critical

Ibatullin et al. [8] mentioned that theoretically, available analytical technologies make it possible to solve the problem of selection of the optimum EOR method, though in practice it is complicated by the similarity of the different methods.

Expert system technology has recently gained an increasing importance in the petroleum industry. Application areas include diagnosis, planning, design, prediction, interpretation, monitoring, debugging, repair, and control of different processes in oil and gas engineering Shindy et al. (1997)[9].

Guerillot [10] presents logic and comments on why one selects an Expert System for EOR method. Ridha [11] developed an expert system that combines EOR screening, simulator input preparation, and parameter selection that optimizes the recovery from selected EOR processes. There are considerable applications in the area of EOR screening and these can be found in Shindy et al. [9], Guerillot [10], Chung et al. [12], Maksimov and Tetelbaum [13], Elemo and Elmtalab [14].

Elemo and Elmtalab [14], Shindy et al. [9], Gharbi [11] and Ibatullin et al. [8] expert systems either offer limited or no capabilities for changing and editing the EOR parameters of screening rule.

Rich [15] defined artificial intelligence (AI) as the study of how to make computers do things that, at the time, people could do better. The field of artificial intelligence (AI) has gained considerable acceptance in virtually all areas of engineering. AI is now being applied in several areas of petroleum engineering, such as drilling operations [16], well testing, economic evaluation, and well logging and interpretation Elemo and Elmtalab [14].

2. Expert Systems Description

In this expert system the EOR rule base has been developed for ten processes, classified in three groups: Gas dissolution processes, chemical processes, thermal processes.

A major problem involved in the screening process is the large number of EOR methods that have an applicable match to the oil field data concerned. The second problem is the need to check the suitability of a particular process in the light of the information available about the reservoir. In this expert system application, reasonable solution of these problems has been conducted by matching all EOR methods and then arranges it from highest to lowest, that is, most suitable to least suitable match percentage (see the flow chart on Fig. 1). In case of lack of available reservoir data, the expert system has an ability to work and analyze with a shortage of some input reservoir parameters, but care must be taken into account that the lack of one or more of input parameters are very sensitive in the screening process and it may result in a totally wrong selection. An example for this case is the input of the water salinity parameters are not saved as an input parameter in the database for the match selection process of some EOR methods because they are not a critical condition in the screening criteria but elsewhere it can be considered as a sensitive parameter in the selection result of chemical flooding methods.

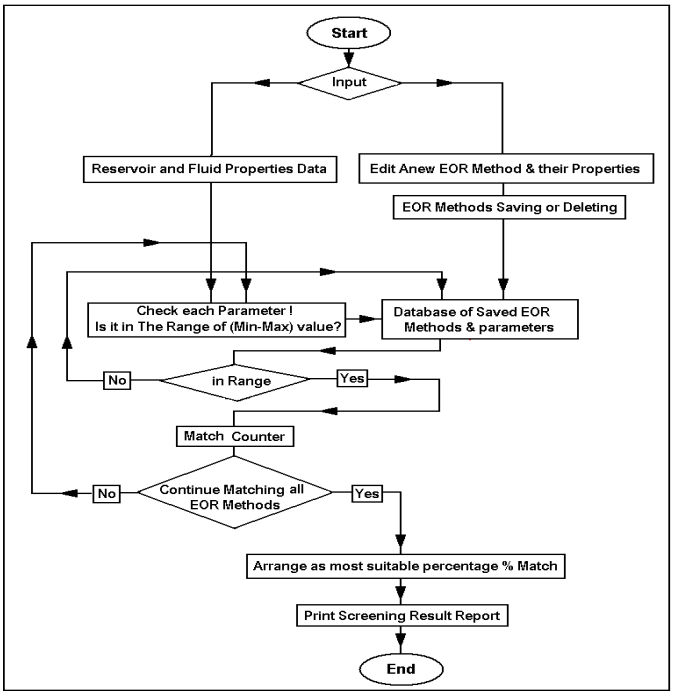

Fig. 1. The Layout view of $E^{K}OR^{A}$ Expert System.

3. The Operational Process of the Expert System

The screening criterion of this expert system has been achieved through a comprehensive literature review of the technical EOR screening studies and successful reported projects [1-7]. A newly generated table provides a wider range with more specific criteria for screening in which the rules of selection have been used and are based on minimum-maximum value range of the reservoir parameters. It should also be mentioned that the selection range of minimum-maximum values have emerged from differently developed screening criteria to incorporate the previous and current research experience. The rule of minimum-maximum value is approved in order to conduct differentiation between all saved EOR methods in which these parameters are the most sensitive ones in the selection processes. The operational steps can be achieved as following:

3.1. Input data

Input parameters are categorized into two types: the reservoir parameters and the crude oil parameters including API gravity, viscosity, reservoir depth, permeability, reservoir temperature, oil saturation, and water salinity also attached with the name of field or the reservoir to be conducted to the screening process. A simple direct input user interface form can be used to import the data as shown in Fig. 2.

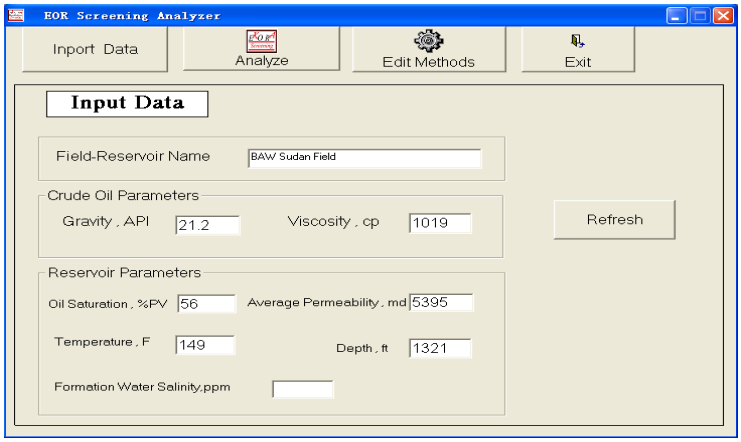

Fig. 2. The Main User Interface Of E^{K}OR^{A} Expert System.

3.2. Edit and save the EOR methods and parameters

This step will be done subjected to the need of Edit and Save Change or Delete of the EOR methods by the user. Therefore, in order to renew or set new EOR methods and their parameters as the database in database file for the selection process, the expert system provides the user with an easy interface captioned Methods and Parameters, and with an additional capability of an optional selection for the EOR parameter's value depending on the evaluation of screening criteria (Fig. 3) including the properties of New, Save, Delete and Exit which can be done automatically by pressing a certain menu of each property.

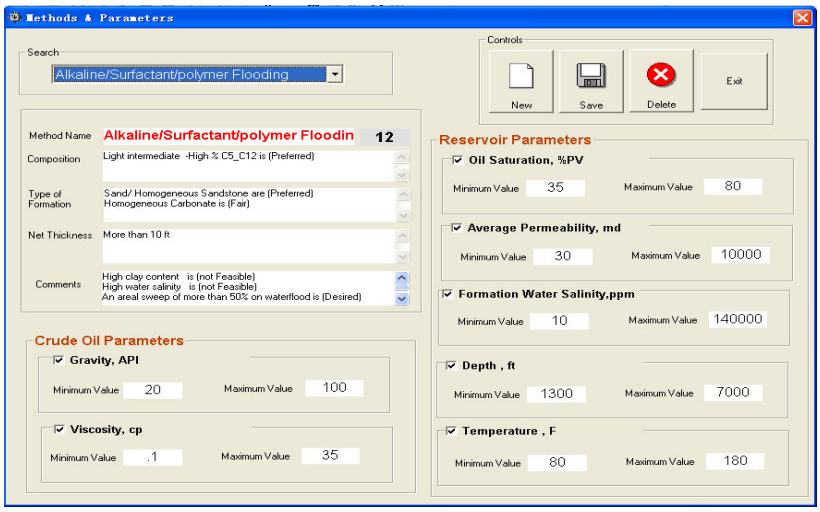

Fig. 3. E^{K}OR^{A} Expert System's User Interface of Editing and Changing EOR Methods.

3.3. An artificial intelligence running of the analyze step

The main analyzing process of this expert system is to provide the user with all the feasible EOR processes as well as the most suitable one for a particular reservoir. This process is done in the following steps:

- For each input parameter of API gravity, viscosity, etc. per each EOR method search to match the minimum ("min") and maximum ("max") values for each saved parameter associated with the application of a successful EOR method, were saved in database file .
- Calculate the total times of match for each method per loop of: total=total +1
- If the value of each parameter is in the range or equal to the minimum-maximum values then Calculate the number of matching times for each method per loop of :Match = Match + 1
- When the Match value is not equal to zero, Then the percentage of matching for each EOR method calculated by: Percent = Match / Total × 100.
- The above four steps can be continually run to identify all explicit search loops and match all saved EOR method databases until all possible solutions are found. In the flow chart in Fig. 1, this step is mentioned by continually matching all EOR methods. When this running step is finished the expert system arranges all EOR methods according to a highest percentage of matching.

The expert system reported the feasible matching percentage of all input parameters and at least three of six or four of seven input parameters must match one of each the EOR method to be considered as feasible matching, otherwise it will considered as not feasible matching, indicated as not a reasonable EOR method.

The expert systems pointed out the degree of matching, which is evaluated as follows:

Matching Percentage	Degree of Matching
< = 50%	Not Feasible ,
51% to 70%	Poor
71% to 86%	Possible
87% to100%	Preferred

All the results of the selection process are transferred to a final designed report with the matching information and comments for each EOR method. Recommended reservoir parameters include the oil composition, type of formation, reservoir thickness and other comments are directly attached to each of the certain EOR Method without needing to be run in the matching process.

The operational steps can be achieved by pressing the analyze menu, then an automatically generated report will appear in real time using VB data report tool as shown in Fig. 4. The data report is a powerful tool and it's easy to build complex reports by dragging and dropping fields out of the data processing environment window. Figure 1 shows the layout flow chart of all the artificial intelligent systems.

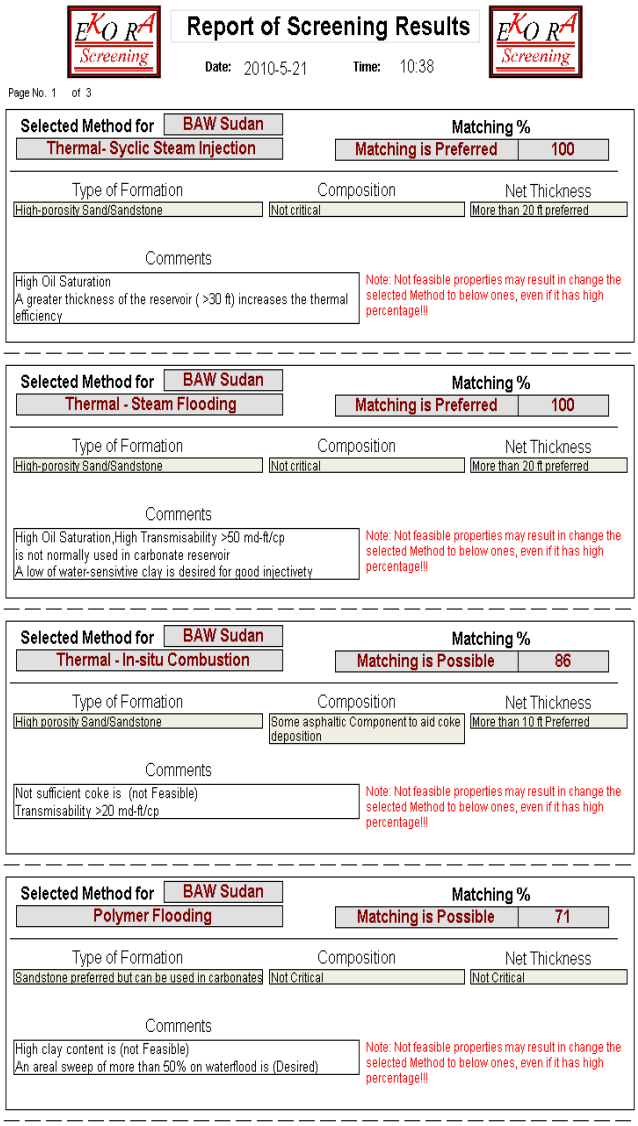

Fig. 4. Expert System Generated Report for BAW Oil Field.

4. Example Applications for Verification and Validation

In this section we present the results of sample runs made to test the reliability and consistency of this developed expert systems using actual data. In this paper we deal with a Sudanese oil field called BAW as an example. The investigated reservoir in BAW-Field is assumed to have already been produced to its economic limit and is potential candidate for an EOR process. The reservoir properties shown in Table 2 are carefully studied in order to assess the applicability of selecting the appropriate

EOR methods using the way a human expert's choices. The result of the screening study show the thermal steam injection methods are a feasible selection to be implemented in BAW oil fields. The generated screening result by the expert system's report is shown in Table 3, which presents the Thermal Steam injection (Cyclic steam and steam flooding) as the most suitable EOR method with a preferred matching percentage of 100%, which, as indicated above agrees well with the human experts' selection mentioned.

Table 2. BAW Sudanese Oil Field Data for EOR Screening.

Formation Type	Sand	
Bottom Water Present	Strong Bottom Water Drive	
Reservoirs Properties	Range Value	Average Value
Net Pay Thickness, m	1.7-8.8	5.25
Reservoir Depth m	1321	1321
Permeability, md	2140-8650	5395
Initial Oil Saturation	0.39-0.72	0.56
Initial Pressure, psi	1785	1785
Current Pressure, psi	1400	1400
Temperature, ^{o}F	149	149
Fluid Properties		
Oil Viscosity, cp	78-1019	548.5
Gravity of Oil, ^{o}API	17.4-25.0	21.2

The expert system matched all EOR methods saved in the database file and yielded the feasible EOR methods with their degree of matching as shown in Fig. 4 which are summarized in the Table 3.

Table 3. The Expert System Generated Result for BAW-Oil Field.

Order	Selected Method	Matching Percentage	Degree of Matching
1	Thermal- Cyclic steam injection	100%	Preferred
2	Thermal-steam flooding	100%	Preferred
3	Thermal in-situ combustion	83%	Possible
4	Polymer flooding.	71%	Possible
5	Alkaline/Surfactant/polymer	71%	Possible
6	Alkaline flooding	71%	Possible
7	CO_2 Immiscible Flooding	50%	Not feasible
8	CO_2 Immiscible Flooding	40%	Not feasible

The viscosity is a very sensitive parameter in the selection process of EOR methods. In the BAW-Field the viscosity range is too large where this oil field is generally characterized by high viscous crude oil. By applying 1019 cp, the expert system reported that the thermal methods are preferred with a matching percentage of 100% for both cyclic steam and steam flooding and a possibility for Thermal in-situ combustion by 83%. The following methods are chemical methods which are possible with a matching percentage of 83%. By applying low viscosity of 78 cp, the expert system reported that the chemical methods is the suitable one, but referring to the reservoir properties the presence of strong

bottom water aquifer may create adverse effect on the retention of polymers and may also enhance the degradation of polymers. We should mention that the appropriate selection process for this oil field must take into account the specific behavior or the arithmetic mean of reservoir fluid properties that can reflect the actual behavior in the reservoir. Therefore, concerning the study of oil gravity and viscosity mentioned as a general average behavior, it indicated that chemical processes are not feasible in BAW.

5. Objective and Achievement of E^KOR^A

A number of Sudanese oil fields are expected to implement one or more the EOR methods in the near future. However, the implementation of any of the EOR methods involves high capital expenses. A large gain in oil recovery by the Enhanced Oil Recovery processes is rather complicated and has high operational risk. Therefore it is necessary to fulfil the requirements to ensure the successful selection of the proper EOR method for specific reservoir.

As a result, these oil fields face the problem of identifying all the EOR methods applicable to the candidate oil field in order to pick up the most appropriate method that matches the reservoir characteristics. The problem of selecting the most suitable EOR method has induced a crucial need for an expert system to achieve a quick analyzing process and at the same time verify the selected results that are achieved through manual analytical information of the reservoir data.

The (E^KOR^A) software generates a full scale report of the most feasible selected methods and their recommend parameters in order to confirm the decision of selecting the most appropriate EOR methods for a certain reservoir. The outcome, shown through an application example of actual reservoir data, verifies that the developed software is reliable and consistent and is confirmed through a human expert who obtained results by a sensitivity analysis of EOR screening criteria.

6. Conclusions

- The application of emerging expert-system technology to select EOR method is very important and useful. The development of this expert-system shows that expert systems are powerful Artificial intelligence applications that help experienced reservoir engineer users save time and effort while selecting an appropriate EOR process on the basis of the reservoir characteristics. A reasonable solution has been conducted by matching all EOR methods and then arranging it by highest suitable match in which a major problem involved in the screening process, that is, a large number of EOR methods have applicable match to the oil field data concerned.
- The E^KOR^A software is designed to accommodate new recommended parameter ranges of current and future implemented EOR Projects that helps to transfer the expert's knowledge to the users of the software. Moreover, estimations of additional field cases make it possible to continuously refine the screening procedure that may emerge and become available in the future.

- The expert systems exhibit tremendous effort in improving the process of screening now and in the future. This allows for a new additional capability of changing and editing new parameters of EOR methods which emerged or tested in current implementation projects. However, considerable effort is required to develop the expert systems by additional Non-numeric characteristics involve an improving AI techniques for more specific selection.
- In the Sudan oil fields, the role of Enhanced Oil Recovery has assumed a prime importance as most of the fields are gradually stepping into the stages of needing the EOR processes. Therefore the Sudanese's oil reservoirs are considered to be an excellent candidate for applying a screening EOR technique by using this expert system. An example of BAW oil field using this new developed expert system gives a reasonable classification of the most feasible EOR by their best suitable percentage and it was found that the thermal methods are the most suitable EOR technique.
- A reasonable advantage of this expert system is to provide reasoned comments on the applicability of each method that has been selected based on the non-numeric reservoir characteristics where it leads to optimization studies in selected EOR method.

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