New Technique for Modeling Movable Water Saturation Distributions: Application in LII Reservoir of Mumbai High

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Summary

Movable water saturation has been estimated making combined use of Flow Zone Indicator (FZI) concept and non-parametric regression technique. FZI has been derived from the porosity and permeability data of cored wells. Thus obtained FZI is integrated with log motifs (RHOB, PHIN, GR, RLLD) and transform for this has been generated to obtain FZI for uncored intervals/ wells. FZI for uncored interval has been estimated and further being used for determining the irreducible water saturation which in turn gives movable water saturation. S_{wir}-values vertical profile has been generated which will be helpful for precise determination of perforation interval. One well of L-II reservoir has been taken up for this study. The present approach provides depth continuous values which can be made spatially continuous by making the use of geostatistcal techniques. This approach can also be useful in managing producing reservoirs to develop by-passed pay and to establish presimulation performance predictions

Introduction

Recently, Amaefule et.al. (1). has given a new concept of hydraulic unitization. This study show that magnitudes and distribution of flow units, as calculated by the flow zone indicator (FZI), influence fluid saturations and their distributions, fluid flow and sweep and recovery efficiencies in reservoir. Each flow unit has an average FZI value related to core-derived permeability (k) and porosity (ø) value by the following relation.
FZI = 0.0314 " (k / ø)

Where
FZI (µm) = flow zone indicator
ø = Effective fractional porosity
k = Absolute permeability

Amaefule et.al. (1) has also observed that irreducible water saturation is robustly correlatable to FZI. Therefore FZI can be used to distribute fluid saturations within the reservoir's 3-D space as a function of height above FWL (free water level).

The Brooks-Corey (2) capillary pressure model has been accepted widely for normalizing measured capillary pressure data .Amaefule (1) realizes that Leverett J- function can not satisfactorily correlate capillary pressure data in heterogeneous reservoirs. Udegbunam & Amaefule (3) reinterpreted the model given by Brooks and Corey (2)

$$(S_{wI} - S_{wir}) / (1 - S_{wir}) = (P_d / P_c)^{\ddot{e}} \quad \text{———— (1)}$$

They have converted the capillary pressure to height in the following manner

$$h_{FWL} = 12.7 \; P_d \quad \text{———— (2)}$$

$$\frac{(Swi - S_{wir})^{1/\lambda}}{(1 - S_{wir})^{1/\lambda}}$$

The parameters S_{wir}, P_d , λ are then correlated with FZI with the following relations

$$S_{wir} = 1 - \frac{1}{1.02636 + 0.604\, FZI^{0.77}} \quad \text{———— (3)}$$

$$\lambda = \frac{1.9146}{FZI^{0.5031}} \quad \text{———— (4)}$$

$$P_d = \frac{3.18375}{FZI^{0.93}} \quad \text{———— (5)}$$

Method

To obtain FZI for uncored interval /well a transform for FZI has been constructed integrating core derive FZI with various log parameters such as GR, PHIN, RHOB, RLLD making use of Alternating conditional expectations , a technique given by Xue G and Akhil Dutta Gupta(4)

$$GR\_Tr = 4.7860E\text{-}03GR^2 - 1.7320E\text{-}01\, GR + 1.0614E\text{+}00 \quad \text{——— (6)}$$

$$PHIN\_Tr = -8.1102E{+}00\ PHIN^2 + 9.6676E{-}01\ PHIN + 1.7170E{-}01 \tag{7}$$

$$RHOB\_Tr = 7.1926E{+}00\ RHOB^2 - 3.6727E{+}01\ RHOB + 4.5873E{+}01 \tag{8}$$

$$RLLD\_Tr = -1.6859E{-}04\ RLLD^2 - 3.8016E{-}02\ RLLD + 4.3712E{-}01 \tag{9}$$

$$SUMTr = GR\_Tr + PHIN\_Tr + RHOB\_Tr + RLLD\_Tr \tag{10}$$

$$FZI = 4.4306E\ {-01}\ SUMTr^2 + 6.0857E{-}01\ SUMTr + 3.8229E{-}01 \tag{11}$$

Equation(6-11) have been obtained with the help of Alternating conditional expectation technique given (3).Equations (6-9) depict the transform for gamma ray(GR),neutron porosity(PHIN),density (RHOB),deep resistivity (RLLD) respectively. SUMTr is the sum of all transform given by equations (6-9).Equation (11) gives the relation between the log motifs and FZI and it has been used for estimating the irreducible water saturation

Results and discussions

Precise determination of ideal perforation can be carried out with the help of $S_{wir} - S_{wi}$ plot which defines the zone of least and maximum movable water. This can also be of help in case of specific solution of certain sick wells showing high water cut where source o1f influx of water is not precisely known. This will also help in attaining long relatively water free production life of the wells/field and . Results have been presented in Table-1 which depicts the movable water saturation, mean FZI, free water level FWL and height h_{FWL} above free water level along with the depth. Fig.1 shows the movable water saturation and total initial water saturation. Further equations (6-11) can be used for evaluating movable water saturation for other wells of LII reservoir of Mumbai high.

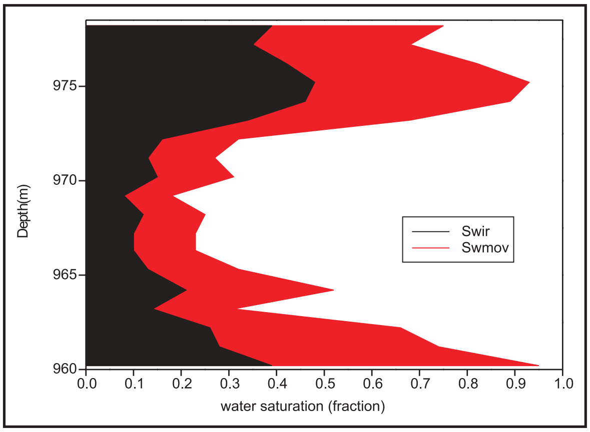

Fig.1 : Depth vs water saturation

Table-1 : Estimation of mean FZI,free water level and movable water saturation

Depth (m)	S_{wi}	S_{wir}	FZI_{mean}	S_{wmov}	FWL(m)	hFWL
960.2	0.95	0.39	0.89	0.56	974.5	14.35
961.2	0.74	0.28	1.03	0.46	976.5	15.30
962.2	0.66	0.26	0.99	0.40	979.3	17.13
963.2	0.31	0.14	0.70	0.17	998.3	35.14
964.2	0.52	0.21	0.94	0.31	984.9	20.77
965.3	0.32	0.13	0.87	0.19	994.7	29.42
966.3	0.23	0.10	0.76	0.13	1004.8	38.52
967.2	0.24	0.10	0.75	0.13	1005.4	38.21
968.2	0.25	0.12	0.62	0.13	1010.5	42.32
969.2	0.18	0.08	0.73	0.10	1013.8	44.68
970.2	0.31	0.15	0.61	0.16	1008.9	38.73
971.2	0.28	0.13	0.59	0.14	1012.6	41.39
972.2	0.32	0.16	0.52	0.16	1014.2	42.07
973.2	0.69	0.34	0.54	0.34	1001.4	28.18
974.2	0.89	0.46	0.50	0.43	999.8	25.55
975.2	0.92	0.48	0.50	0.45	1000.3	25.06
976.2	0.82	0.42	0.50	0.40	1003.3	27.11
977.2	0.68	0.35	0.49	0.33	1007.8	30.58

Nomenclature:

C	Constant [2.3/ (ρw - ? o)]
h	Height, corresponding to the pressure, P
λ	Pore - size distribution index
ø	Porosity
Swi	log derived initial water saturation
Swir	irreducible water saturation
Swmov	movable water saturation
hFWL	height above the free water level
? w	water density
? o	oil density

Conclusions

This technique can simulate many of the desired parameters of core studies in uncored sections such as k, S_{wir} & V shale etc. This is found to be an important tool to bridge the data gap. Precise determination of ideal perforation can be carried out with the help of $S_{wir} - S_{wi}$ plot which defines the zone of least and maximum movable water saturation This can also be of help in case of specific solution of non producing wells ceased to flow due to high water cut where source of influx of water is not precisely known. This will also help in attaining long relatively water free production life of the wells/field.

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