

Formation Strength Estimation From Well Log Data For Sand Cut Analysis in Tapti – Daman Area, Western Offshore Basin, India

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Summary

The study deals with determination of intrinsic formation strength from well log data, to analyse sandcut behaviour of exploratory gas wells in Daman formation of C-24 area of Tapti-Daman, Western Offshore, India. The intrinsic formation strength has been estimated through computation of elastic constants from the acoustic well log data. The dynamic elastic constants viz. shear and bulk moduli and Poisson's ratio are computed from shear and compressional sonic logs. However, when shear sonic log is not recorded an alternative approach is adopted using only compressional log data which is based upon empirical relationship between formation shaliness and Poisson's ratio. The intrinsic formation strength thus computed has been characterized in terms of a parameter which is product of shear and bulk moduli and is termed as formation strength index 'fsi' for sandcut analysis in present study.

Introduction

Sand cut occurrence in flowing wells is influenced by various factors such as loss of mechanical integrity in rock around an open hole or perforation, dissociation of solid particles from rock due to hydrodynamic force and movement of these particles to the surface along with reservoir fluids. It is imperative to understand various reservoir characters of sand such as its in-situ intrinsic strength, fluid flow rates, pressure drawdown, type of fluid production etc. to account for the sand cut behaviour. The in-situ intrinsic strength of the formation depends upon the confining stress, shape and sorting of the grains and the cementation between grains and the shaliness of sand may contribute towards cementation of sand grains. The present study deals with determination of intrinsic formation strength from well log data, to analyse sandcut behaviour of exploratory gas wells in Daman formation of C-24 area of Tapti-Daman, Western Offshore.

Over the years many investigations for the causes and prediction of sand production have been carried out. But no technique has yet proved to be universally acceptable or regarded as accurate and reliable. However, good correlation between intrinsic strength and dynamic elastic constants determined from sonic velocity and density measurements has been reported by various authors. The intrinsic strength can be inferred from shear modulus and bulk compressibility derived from well logs. These dynamic

elastic moduli are computed from sonic shear and compressional velocities and the bulk density logs. In the absence of shear sonic log data an alternative technique has been employed by Anderson et.al.(1973) and Tixier et. al. (1973) in which the elastic constants are related to compressional sonic velocity, bulk density and the shaliness of the sand. It is based upon empirical relationship between Poisson's ratio and shaliness. In the present study the empirical relation between Poissons's ratio and the shaliness has been generated and the computed formation strength index has been used to analyse the sand cut behaviour the of gas producing sands.

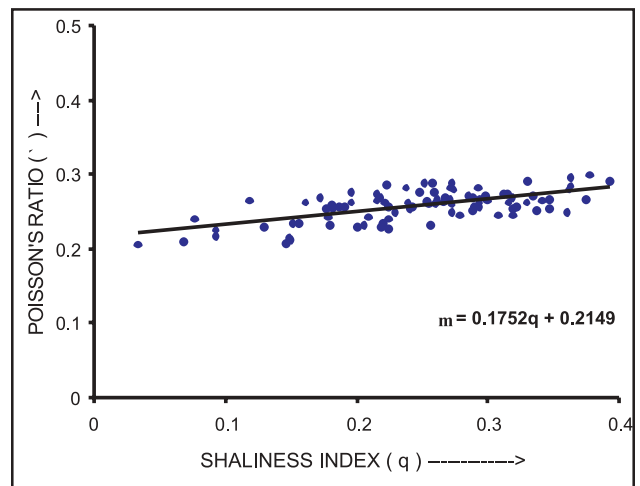


Fig. 1: Poisson's Ratio Vs. Shaliness Plot



Methodology

In rock mechanics two approaches can be adopted for determining the elastic constants. One method involves placing a rock specimen under load to determine elastic constants from stress-strain relationship which are called static elastic constants. The other method is based upon measurements of elastic wave velocities and determination of elastic constants from wave propagation relationships. These are referred to as dynamic elastic constants. The dynamic measurement can be obtained from the well log data which provides a continuous curve exhibiting variations of elastic constants with depth. As these measurements are made under in-situ conditions, these should be fairly representative state of confining stress the formation would experience at the time of completion. From sonic shear and compressional transit time the elastic constants are computed using following basic relationships:

$$\text{Poisson's Ratio, } \mu = \left[\frac{1}{2} \left(\frac{\Delta t_s}{\Delta t_c} \right)^2 - 1 \right] / \left[\left(\frac{\Delta t_s}{\Delta t_c} \right)^2 - 1 \right] \quad (\text{i})$$

$$\text{Shear Modulus, } G = \rho_b / \Delta t_s^2 (1.34 \times 10^{10}) \text{ psi} \quad (\text{ii})$$

$$\text{Bulk Modulus, K i.e. } (1/C_b) = \rho_b [1/\Delta t_c^2 - 4/3\Delta t_s^2] (1.34 \times 10^{10}) \text{ psi} \quad (\text{iii})$$

where, C_b = bulk compressibility, ρ_b = bulk density (gm/cc), Δt_s = shear transit time ($\mu\text{s}/\text{ft}$) and Δt_c = compressional transit time ($\mu\text{s}/\text{ft}$). The coefficient 1.34×10^{10} is a factor to convert bulk and shear moduli in psi units.

If shear sonic log data is not recorded, an alternative approach is adopted for evaluation of elastic constants using only compressional sonic data. It is based upon the empirical relationship which relates shaliness to the Poisson's ratio of the sand as described by Anderson et.al.(1973).

The elastic constants are obtained as follows:

$$G = A \rho_b / \Delta t_c^2 (1.34 \times 10^{10}) \text{ psi} \quad (\text{iv})$$

$$K = B \rho_b / \Delta t_c^2 (1.34 \times 10^{10}) \text{ psi} \quad (\text{v})$$

where, $A = (1-2\mu) / [2(1-\mu)]$ and $B = (1+\mu) / [3(1-\mu)]$

In the present study the empirical relationship between Poisson's ratio and shaliness has been generated from log data of exploratory wells of C-39 area where both shear and compressional logs are recorded. The Poisson's ratio is computed from the shear and compressional sonic log data and the shaliness index is computed, as $q = (\Phi_s - \Phi_d) / \Phi_s$ from sonic and density porosities after applying appropriate corrections for gas and compaction. From the plot of Poisson's ratio (μ) versus shaliness index (q) as shown in Fig.1, the following transform has been obtained

$$\mu = 0.175q + 0.22 \quad (\text{vi})$$

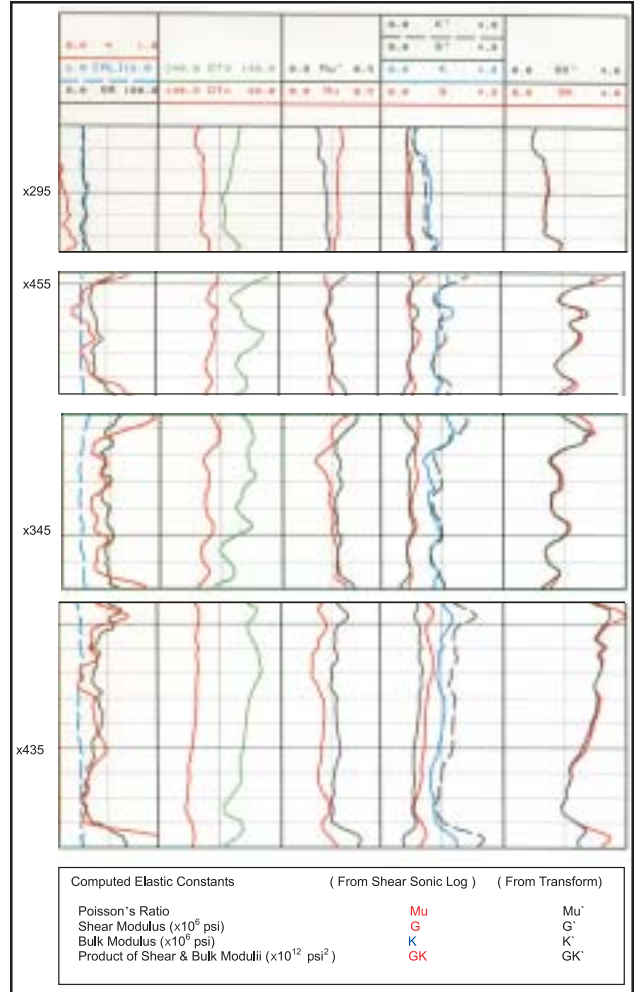


Fig. 2: Comparison of Elastic Constants Computed from (a) Shear Sonic Log and (b) Transform

The examples of elastic constants computed using transform (eqns. iv - vi) and from shear sonic log data eqn. (i to iii) for the same sand intervals are shown in Fig.2 which indicates a good correlation between elastic constants computed using two approaches. It has been observed by Tixier et.al. (1973) that the product of shear and bulk moduli permits greater range of sensitivity than either the shear modulus or bulk modulus taken alone for defining threshold criteria for sand cut analysis. In present study the product of shear and bulk moduli has been termed as formation strength index 'fsi' for the sand cut analysis.

Examples

During initial production testing in exploratory wells of C-24 area, moderate to heavy sand cut was observed in

many tested zones having porosity range of 15-25%. Testing with increasing choke size resulted in sand free gas & condensate till it resulted in sand cut in a zone corresponding to its critical choke size. It varies from 8/64" in zone C1 to 48/64" in zone A1 (Table-1). However, some of the sands in these wells also resulted in sand free production even at large choke size of 40/64" in zone A2.

The sand cut behaviour in these gas producing zones has been analysed on the basis of 'fsi' computed from the well log data. The shear sonic log data was not recorded in these wells therefore, the 'fsi' has been computed using compressional sonic data, density log and the Poisson's ratio derived from the q vs. μ transform of eqn (vi). The fsi is plotted as a continuous curve such that the variations of fsi along the perforated zones can be observed. Examples of computed elastic constants in some sand cutting and sand

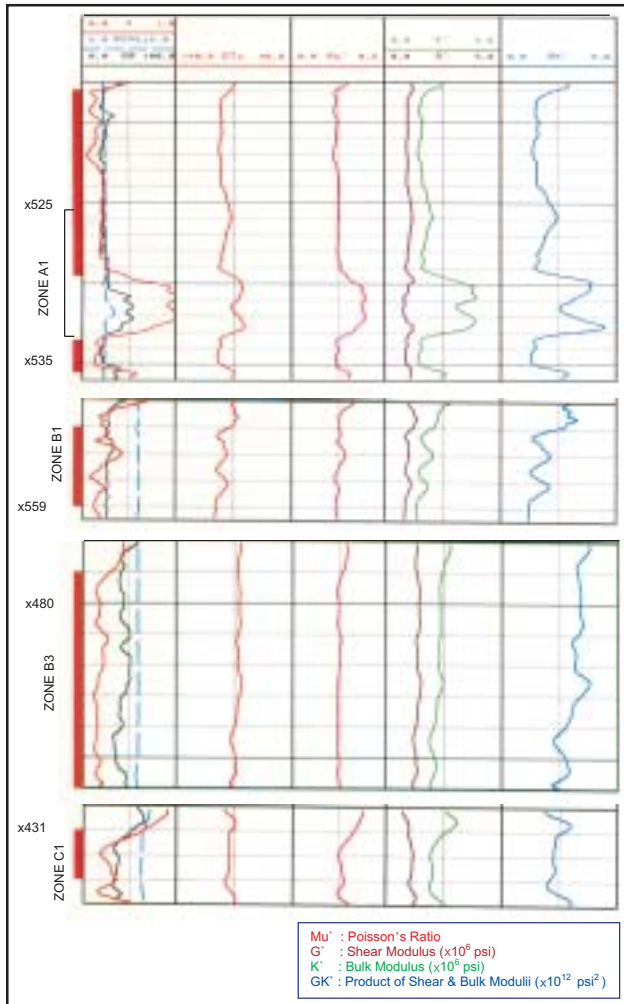


Fig. 3: Examples of Mechanical Properties Log In Gas Producing Zones With Sand Cut

free producing zones are shown as mechanical property logs in fig.3 & fig.4 respectively. The minimum and maximum fsi observed in each perforated zone is given in Table-1. The fsi ranges from 1.2 to 3.7×10^{12} psi² in the zones having sand cut and for sand free producing zones a relatively higher range of 2.9 to 4.0×10^{12} psi² is observed.

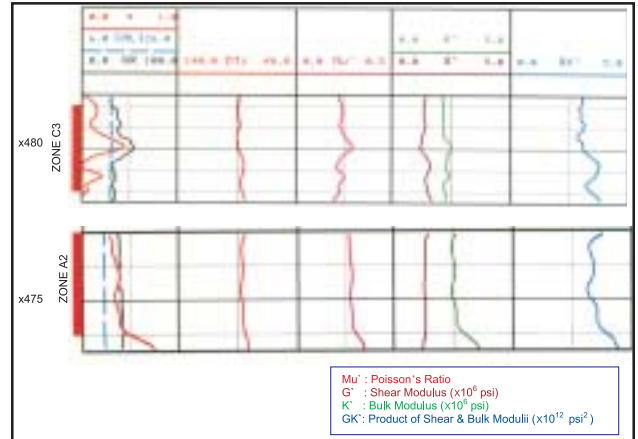


Fig. 4: Examples of Mechanical Properties Log In Gas Producing Zones Without Sand Cut

It is indicated from the data that maximum value of 'fsi' in a sand cutting zone is 2.4×10^{12} psi² in zone A1. The minimum value of 'fsi' in a zone with sand free gas production is 2.9×10^{12} psi² in zone C3. Thus it can be implied that if 'fsi' is less than 2.4×10^{12} psi² within a zone it is candidate for possible sand cut. On the other hand if 'fsi' is greater than 2.9×10^{12} psi² the zone would be sand free gas producer. Thus the zones within which 'fsi' falls below threshold of 2.4×10^{12} psi² need completion with appropriate sand control measures.

Conclusions

Sand cut analysis of Daman sands in exploratory wells of C-24 area of Tapti-Daman has been carried out based upon computation of formation strength index 'fsi' from the well log data.

Poisson's ratio versus shaliness index transform has been generated and used in computing elastic constants from compressional sonic and density logs in the absence of shear sonic log data.

Thresholds values of 'fsi' less than 2.4×10^{12} psi² for gas production with sand cut and 'fsi' more than 2.9×10^{12} psi² for sand free gas production can be taken for Daman formation sands of C-24 area.



Table-1 : Formation strength properties of gas producing zones

| Well No. | Tested Zone(m) | Zone No. | Porosity(%) | GxK ($\times 10^{12}$ psi ²) 'fsi' | Critical choke size for onset of sandcut |
|----------|----------------|----------|-------------|--|---|
| A | X518.0-X529.5 | A-1 | 25 | 1.3 - 2.4 | 48/64" |
| | X533.0-X535.5 | | | | |
| | X473.0-X476.0 | A-2 | 14 | 3.2 - 4.0 | No sandcut |
| | X442.0-X450.0 | A-3 | 24 | 2.0 - 3.5 | 24/64" |
| | X430.0-X435.5 | A-4 | 23 | 2.1 - 3.5 | 24/64" |
| B | X556.0-X559.0 | B-1 | 22 | 1.2 - 2.1 | 32/64" |
| | X496.0-X501.0 | B-2 | 15 | 2.5 - 3.5 | 16/64" |
| | X479.0-X486.0 | B-3 | 15 | 2.2 - 3.7 | 16/64" |
| C | X431.0-X433.0 | C-1 | 20 | 1.9 - 2.3 | 8/64" |
| | X407.0-X410.0 | C-2 | 18 | 1.7 - 1.8 | 24/64" |
| | X478.0-X482.0 | C-3 | 20 | 2.9 - 3.7 | No sandcut |

Acknowledgement

The authors express their sincere gratitude to ONGC Ltd., for permission to publish the work. The authors are grateful to Sh.R.P.Verma, DGM(Wells) & Head, Petrophysics Division, KDMIPE, Dehradun for his critical suggestions during the study.

Views expressed in this paper are that of the author(s) only and may not necessarily be of ONGC.

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