The 19th Iranian Geophysical Conference, November, 2020, pages 1188-1191

Developing an empirical relation among Young modulus (E) and Uniaxial compressive stress (UCS) in a carbonate gas reservoir with petrophysical and geophysical parameters, using regression analysis

Misha Pezeshki[a,b] Imandokht Mostafavi[a], Amin Morshedipour[a], Hassan Eshraghi[a].

[a] *Geology Department of Pars Oil and Gas Company (POGC), Tehran, Iran*

[b] *Department of Petroleum Engineering, Amirkabir University of Technology, Tehran, Iran*

ABSTRACT
As geomechanical testing procedure has cost and time effect and, also in an elastic, isotropic, homogeneous solid the elastic moduli also can be determined from the velocity of compressional waves (Vp) and shear waves (Vs) as well as petrophysical parameters (Zoback M. D., 2007); finding empirical relation in order to calculate elastic parameters could be a key to obtain geomechanical properties of a reservoir. Static Young's modulus (E_{sta}) and uniaxial compressive strength (UCS) are one of the key parameters in geomechanical study in hydrocarbon reservoirs. These are usually estimated based on the empirical models developed to relate the strength and elastic parameters of the rock to their petrophysical properties. In this article the aim is studying the relation of two geomechanical parameters including Young modulus (E) and Uniaxial compressive stress (UCS) with porosity, density, shear wave velocity and compressional wave velocity; and find the best correlated empirical relations by using of regression method for these parameters in a carbonate gas field in southern of Iran, by using of core lab test data extracts from 5 wells in this field. Result of this study shows that the best correlation for UCS is predicted by porosity ($R^2 \approx 0.7$) and for E is predicted by density ($R^2 \approx 0.7$)

Keywords
Geomechanics, Young modulus, uniaxial compressive test, regression, empirical relation, gas reservoir.

Introduction
The field in this study is a gentle carbonate reservoir anticline with minor fractures and categorized in low pressures-temperature reservoirs categories, which implies the idea of smooth change in geomechanical parameters in all over the field, so the test results of all the wells in all around the field should have a similar range in parameters. Although changing in rock strength and other parameters in crest and dip of the structure is natural, but the difference should be minor and predictable, as the available test data has a good diversity all around the field. This hypothesis can lead to find some empirical relations in all around the field.

The mechanical earth model is the core of any geomechanical work and cause data acquisition programs rarely focused on rock mechanics in the past, it often appears that part of the key data required to perform a proper evaluation is not available. In such a case, one may have to use correlations to estimate the missing parameters (Chardac et al. 2005). As a result in this study, have been focused on generating empirical formulas for Young modulus (E) and Unconfined Compressive Strength (UCS) as the main result of Uniaxial Compression Test. As if two parameters of elastic modulus are defined or can be calculated by any methods, three others can be calculated by specified formulas (Feajer et al., 2008) having reliable empirical relations for one of these parameters and one of main geomechanical tests results i.e. UCS, can lead to a better understanding of geomechanical behavior of the field. In order to find empirical relations, at first geomechanical tests has been done over five nominated wells in different part of the field[1]. Then by

[1] The laboratory method is described in "Geomechanical characterization of a south Iran carbonate reservoir rock at ambient and reservoir temperatures", by Mehrgini B, et al. 2016.

use of regression method tries to find some relations which are applicable in all part of the field by acceptable error. In order to verify extracted formulas, a blind well in this experiment has been chosen.

As there are five wells with geomechanical lab test results, four wells are used for formula prediction, and one well has been chosen as a blind well.

Methods and Procedures

As this field is not a high pressure-high temperature reservoir (T≈120°C and P≈5200psi), the result of laboratory data in ambient condition is chosen for further study. In next step porosity, density, shear wave velocity and compressional wave velocity, Young modulus and UCS of each sample of each well extracted into a table in order to drive an empirical relation by using of regression method for each well. The relation between E and each four parameters (Φ, ρ, V_p, V_s) has been driven, then formula is extracted, and R^2 is calculated for polynomial, exponential and power function and the best fit is chosen, then at last the chosen empirical relation is run for blind well data and compared with actual laboratory test results of it. In order to determine the prediction error by generated formula, a correlation chart between predicted data and laboratory data is generated, either. It should be noticed that density has been used here is extracted from petrophysical log, but the other parameters (i.e. Φ, V_p, V_s) are measured from core plugs.

In Table 1, in each row one parameter has been used to predict a formula for predicting E, first row is V_s, the second row V_p, the third row porosity (Φ), and last row is density (ρ). The first column shows all four well data and the predicted formula accompany with R^2 of that formula, the second column is the predicted formulas versus laboratory data of the blind well, and the third column is the correlation between actual data and prediction.

The same procedure has been done for UCS in Table 2.

However it should be mentioned that in order to get a better result the out of range data has been omitted from final predicted formula. As it has been recognizable in Table 1 and Table 2, some data are too high or too low, which would decrease the correlation result, so they have been omitted in formula prediction stage.

Conclusions

As it is shown in Table 1 and Table 2, the calculated R^2 for E by used of porosity and for UCS by used of density data have the most reliable result, which is expectable as the essence of these parameters are integrated with nature of rock. In absence of any density and porosity data using V_p and V_s is suggested if the amount of predicted error would have been calculated in uncertainty analysis of the final geomechanical model or wellbore stability analysis had been run over predicted E and UCS. The predicted formula for each parameter has been shown in tables, either.

Suggestion and recommendation

As the calculated R^2 shows in this study, using other methods such as optimization algorithms or neural networks might decrease the amount of uncertainty in the final predicted formula

References

Chardac O., Murray D., Carnegie A., & Marsden J. R., 2005, A propsed data acquisition program for successful geomechanics projects, SPE 93182, 1-16.

Fjær E., Holt R.M., Horsrud P., Raaen A.M., & Risnes R., 2008, Petroleum Related Rock Mechanics, Elsevier, 2nd EDITION, 1-491.

Mehrgini B., Memarian H., Dusseault M. B., Eshraghi H., Goodarzi B., Ghavidel A., Qamsari M. N., Hassanzadeh M., 2016, Geomechanical characterization of a south Iran carbonate reservoir rock at ambient and reservoir temperatures, *Journal of Natural Gas Science and Engineering*, Vol. 34, 269-279.

Zoback M., 2007, Reservoir Geomechanics, *Cambridge University Press*, 1-505.

Table 1: Determining E from Vp, Vs, porosity and density

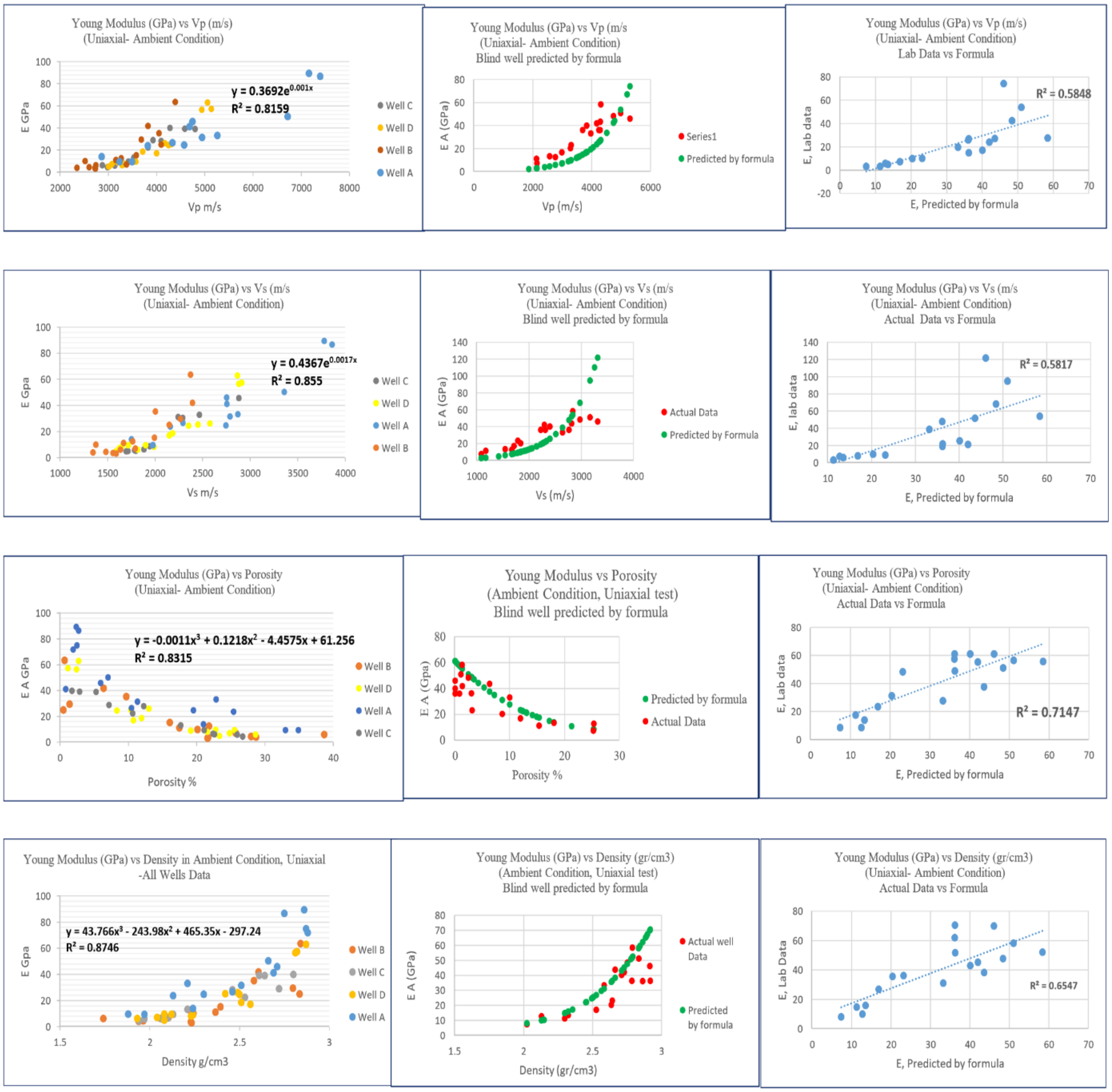

Table 2: Determining UCS from Vp, Vs, porosity and density