Experimental Simulation for Shale Oriented Drilling Performance Evaluation

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INTRODUCTION

- Numerous studies emphasized the importance of rock strength on the drilling rate of penetration (ROP), in specific and the drilling performance, in general. Strength can vary and be distributed differently depending on rock types, confined pressure, etc. The studies, also reported the influence of the strength on ROP as a function of strength variation.
- At the most basic level of rock characterization, rocks are either isotropic (ISO) or anisotropic (ANISO). An example of ISO rocks are some granites and some synthetic rocks (concrete)[1]. Shale is an example of ANISO rocks. ANISO rocks are simplified to vertical transverse and horizontal transverse Isotropic (VTI and HTI, respectively). The properties; physical, mechanical, and drilling are direction dependent, where the iso rock properties are not[1].
- Shale, as the main source of data for this work is the most encountered rocks in oil and gas drilling, as well as it is the source rock for hydrocarbons and can be a reservoir rocks by over sealed by impermeable rocks.
- With the advancement of directional and horizontal drilling, mainly in shale, the importance of the controlled laboratory drilling under various conditions and scenarios arise.
- The core of this work is to simulate drilling in Grey Shale (weak and laminated shale newly tested in our laboratory) as a function of its bedding inclination.

OBJECTIVES

- Estimate the influence of shale drilling performance.
- Determine the optimal regions of drilling with respect to the drilling direction related to the bedding inclination.
- Construct relationships between Grey Shale strength anisotropy and drilling parameters, mainly ROP.
- Draw out conclusions, guideline, and suggestions with the associated conditions that could assist in choosing the optimal well trajectory and optimal drilling parameters' intervals.

Apparatus Materials and Scaling

A Fully instrumented lab-scale drilling rig (figure 1-left) was used for the lab experiments. The rock samples used were Grey shale cut and drilled with respect to their lamination plane orientation including vertical as 90 degree, diagonal as 45 degree, and horizontal as 0 degree. Based on the U-Strength curve, the vertical and diagonal have about same high strength comparing to the diagonal, this poster contains only comparison between the diagonal (D) and the horizontal (H) drilling results.

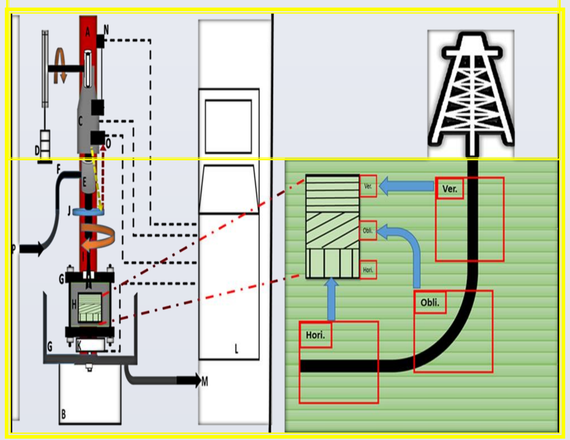

Figure 1. Lab scale rig, left and shale bedding representation in lab and field.

The main materials used as a primary source of data is the Grey shale displayed in different scale size in figure 2. The scale used for drilling laboratory experiments is scale #4 (coring scale).

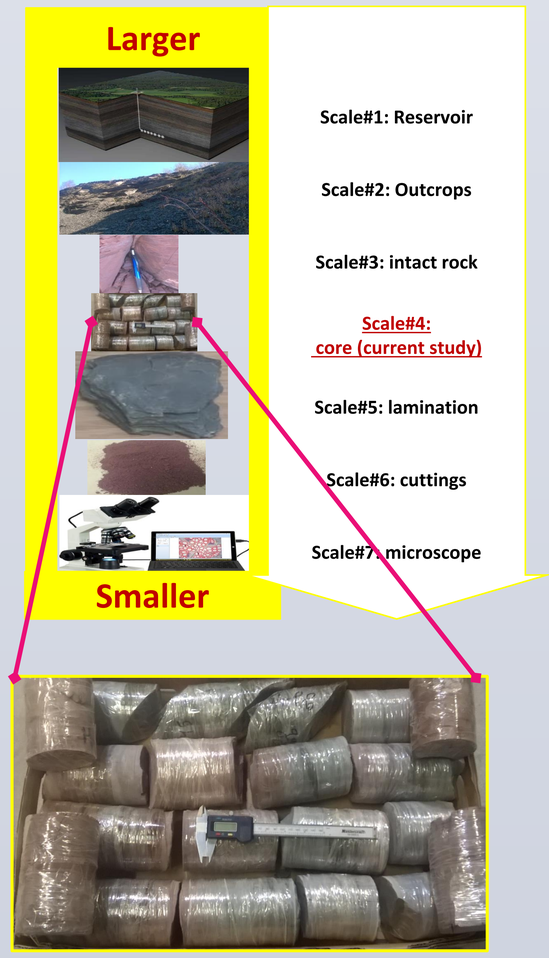

Figure 2. General scaling order (from larger, top to smaller, bottom) with magnification of scale #4 used for current work.

Results & Discussion

The results were as expected and theoretically reported by many authors. The strength has a noticeable influence on the shale drilling performance. Having in mind that shale has strength variations called Strength Anisotropy that varies with shale bedding inclination. Figure 3 shows the general oriented shale strength curve along with the targeted curve for the current study. Figure 4 shows the relationship between strength for six shales under zero confined pressure (from literature review) and seven different weight on bit values with ROP in one tested shale using the rig shown in figure 1-left.

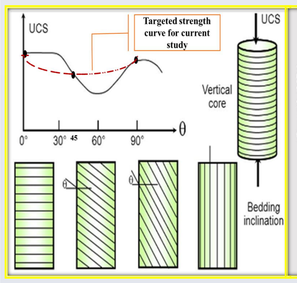

Figure 3. General U-Strength curve for anisotropy rocks as a function of lamination orientation.

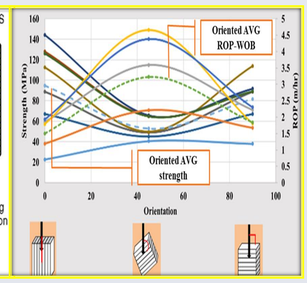

Figure 4. Relationship between oriented shale strength anisotropy and oriented ROP variation.

Deeper Investigation was carried out implementing more drilling parameters that have direct and more impact on ROP (m/hr) such as depth of cut of bit cutter (DOC, mm/rev.), rotary speed (RPM), and torque (TRQ, N-m). Such study was conducted on Grey Shale.

Figure 6 shows a double parameter analysis. Such analysis is based on comparing two parameters at same inclination (degree) of the shale lamination. The results show good agreement in both directions.

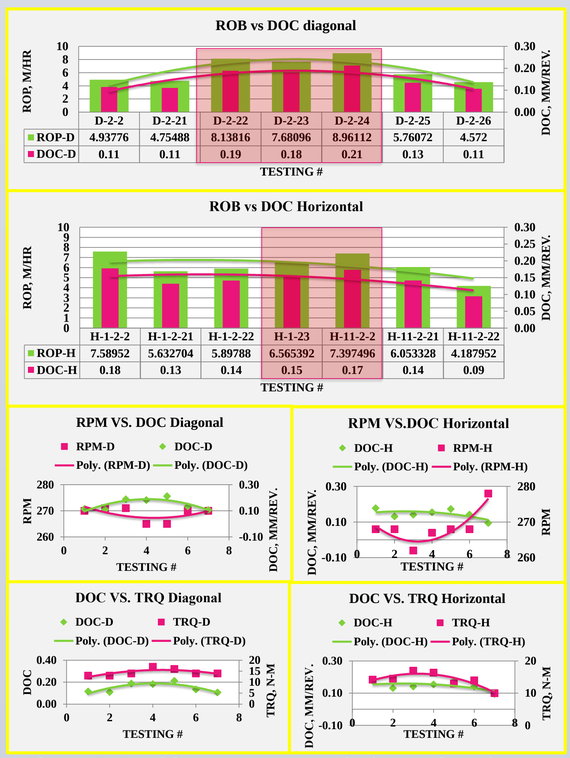

Figure 5. Double parameter analysis as a function of the lamination inclination.

The result further clear out when comparing the drilling parameters (horizontal vs. diagonal) as shown in figure 6a to 6d. For selecting the optimal region for data comparison, we took the DOC as a guideline. The chamfer depth of the used dual-cutter PDC bit is about 0.015mm.

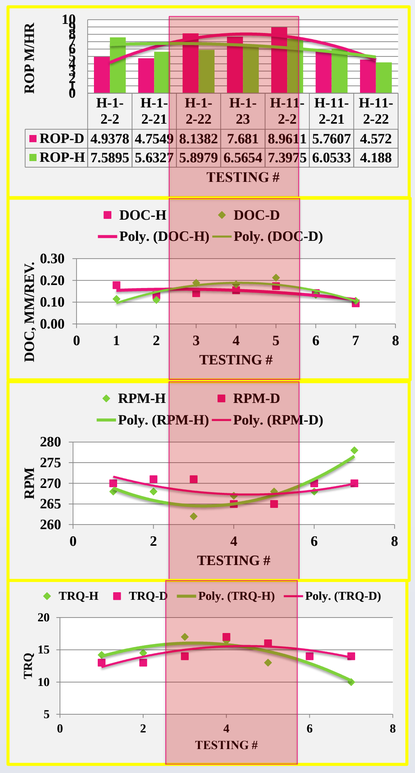

Figure 6. All 4 figures show relationships in diagonal verses horizontal. The shaded areas identify the valid data and the optimal region for comparison. a (ROP, 1st top). b (DOC, 2nd). c (RPM, 3rd). d (TRQ , 4th).

Conclusions

- Shale drilling performance can be best estimated with the involvement of the controlled laboratory experiment outcomes and conclusions.
- The various conditions and scenarios that can be applied and manipulated in the laboratory tests provide credits and more importance to the inclusion of laboratory experiments for ROP determination and for better estimation for field scale drilling.
- The result of this work showed relationships between the bedding inclination and the well trajectory, based on which best drilling direction can be selected.
- The result of this work, also showed the influence the anisotropy of shale properties (including strength ANISO) on ROP.

References

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