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STUDENTS' NOTES

MINING MACHINERY

TOPIC-DRILLING

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Jamal Sir (1st Class)

Activities Before Start of Drilling operation:-

1.) Release of location
2.) Survey of surface / subsea location. Sometimes the cost can be reduced by a small change in surface location
3.) Civil works and foundation for onshore drills site and soil coring/sea bed survey in case of offshore well.
4.) Preparation of Geo-technical order
5.) Preparation of complete well plan / programme
6.) Preparation of bill of material and initiation of purchase procedure, if required
7.) Procedures from obtaining sanction for purchase to receipt of material
8.) Rig allocation and its shifting to the new location.

Input Data For Well Planning:-

The informations required for planning of a well are:-

1.) The objective of the well

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2.) Well data package consisting of seismic data, location map, structural map, expected pore pressures, offset and correlation logs and information on formation type, top and thickness.

3.) Offset and correlated drilled wells data consisting of bit record, mud reports, mud logging data, drilling reports, well completion reports, complication reports and production / injection histories

4.) Proposed logging, testing and coring programmes.
5.) Government reflection and Company's policy

Geo-Technical Order

G.T.O. furnishes the following details:-

(a.) General data like well name, well number, area, location, water depth, elevation, well type, category, objectives of well etc.

(b.) Geological data consists of following

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details:
(1.) Depth
(2.) Age
(3.) Formation
(4.) Lithology
(5.) Interval of coring
(6.) Electro-logging
(7.) Collection of cuttings
(8.) Angle of Dip
(9.) Oil/gas shows
(10.) Formation pressure
(11.) Formation temperature
(12.) Mud loss/caving

(c.) Mud parameters consist of:-
(1.) Type of mud
(2.) Specific gravity
(3.) Viscosity
(4.) pH
(5.) Percentage of sand
(6.) Filtration loss

(d.) Drilling Data includes:-

(1.) Casing policy and rise of cement
(2.) Type of drilling
(3.) Type and size of bit
(4.) Number of bits expected
(5.) Meterage per bit
(6.) weight on bit
(7.) RPM of rotary
(8.) Stand-pipe pressure
(9.) pump discharge
(10.) Bit nozzle details
(11.) Drilling time
(12.) Remarks, if any.

Drilling Programme Preparation

The preparation of good Drilling programme is very vital for safe and effective drilling operation. Drilling programme can be broken down into 12 main sections:-
(1.) Well details
(2.) Well objectives
(3.) Casing policy
(4.) Wellhead selection
(5.) BOP requirements
(6.) Cementing programme
(7.) Deviation programme
(8.) Survey requirements
(9.) Mud programme
(10.) Bit and hydraulics programme
(11.) Evaluation requirements
(12.) Estimation of well cost

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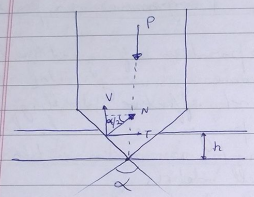
Syllabus of 1st Ct (SKS Sir)

Chapter 2 → KVM Rao Drilling Book

5/2/2015 SKS Sir

Percussive Drilling (G.B. Mishra surface mining book)



$P = 2V + 2W\cos\alpha/2$

$V = N\sin\alpha/2$

$W = N\mu$ = force of friction between bit and rock

μ = coefficient of friction

$N = \dfrac{\sigma_c \cdot D \cdot h}{\cos\alpha/2}$ D = Diameter of bit, σ_c = Compressive strength

$P = 2N\left\{\sin\alpha/2 + \mu\cos\frac{\alpha}{2}\right\}$

$= 2Dh\sigma_c\left\{\tan\frac{\alpha}{2} + \mu\right\}$

$h = \dfrac{P \cdot \eta}{2D\sigma_c\left\{\tan\frac{\alpha}{2} + \mu\right\}}$

η = Coefficient of blunting (1 for sharp and 2 for blunt)

Resisting force on a wedge shaped bit

$T = N\cos\frac{\alpha}{2} = \frac{P}{2}\left\{\tan\frac{\alpha}{2} + \mu\right\}$

If bit makes n_0 impacts per revolution, the area of rock on the face of the hole between 2 impacts is given by:

$(\text{Area})\ F = \dfrac{\pi D^2}{2n_0}$

then $T = \dfrac{\pi D^2 \sigma_s}{2n_0}$

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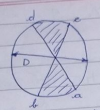
σ_s = shear strength



combining equations we have required no of impacts per revolution of bit, n_0, to bore a penetration h over the entire hole face :- $n_0 = \dfrac{\pi D^2 \left\{ \tan \alpha/2 + \mu \right\} \sigma_s}{P}$

The required speed of rotation of bit is n, and n' is the no of impacts per second.

$$n = n'/n_0$$

n' = No. of impacts per second

$$v = 2hn = 2hn'/n_0$$

$$v = \frac{2Phn'}{\pi D^2 \left(\tan\frac{\alpha}{2} + \mu \right) \sigma_s}$$

During the process of penetration the value of P increases from 0 to maximum when depth reaches to h. Hence the work of each blow is A :-

$$(\text{work})A = \frac{Ph}{2} \quad \text{or} \quad P = \frac{2A}{h}$$

$$V = \frac{4An'}{\pi D^2 \sigma_s \left\{ \tan\frac{\alpha}{2} + \mu \right\}}$$

σ_s = shear strength

From this equation, the speed of drilling is directly A and n' and it is inversely proportional to square of bit diameter and shear strength of rock. It is also seen that rate of drilling increases with reduction in α. These equations are did for shallow drilling but for deep drilling, confining pressures are also taken into account.

The whole process of penetration takes only one to three milliseconds depending on the energy of blow and rock breaking is mainly by propagation of tensile cracks in the rock. Upense postulated that rock is broken partly of compression and partly by shear (i.e. compressive shear and tangential shear).

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Types of diamond drills

Diamond bits are classified according to the type of setting of the diamond grains on the matrix.

1.> Surface set bits.

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2) impregnated bits

Even though the mechanism of drilling operation is same for both type of bits but their performance varies widely.

Surface set diamond bits → Diamond grits are distributed in a systematic pattern, as the size of diamond grits is large, hence limited no. of grains are required. These bits are used for soft and medium hard rock drilling because in hard rock formations, magnitude of weight on the bit is enormously high. Because of this, surface set bit grains either get sheared or dislodged from the matrix.

Impregnated diamond bits →
In impregnated diamond bits, diamonds are evenly distributed throughout the matrix material of the bit. These bits utilize a synthetic diamond of high quality with natural diamond stone sizes ranging from 18 US to 50 US mesh. The concentration of diamond is given in terms of carrets. One carret is equivalent to 0.2 grams. A Concentration of 100 conventionally represents approximately 0.88 gms of diamonds per cubic cm of impregnation and these 0.88 gms of diamonds are made of different proportions of 20 to 80 US mesh. Impregnated diamond are used for hard and fractured rocks because the matrix wears away uniformly, continuously exposing sharp cutting diamonds particles throughout the life of the bit and this process continues until the complete matrix has been worn out.

The overall effectiveness of drilling is measured by the cost of drilling. Various factors affecting costs are:
1.) initial cost of drill bit
2.) normal operating cost

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3.) Cost due to loss of drilling time
4.) Bit replacement cost
5.) Salvage value of worn out bits, if any

Surface set bits are costlier than the impregnated bits although their rate of penetration is faster compared to impregnated bits. The overall cost of drilling per meterage is comparatively much lower in case of impregnated bits. Surface set bits require frequent replacements but have salvage value.

There are 4 major types of core barrels:-
1.) Single tube core barrel.
2.) Double tube rigid type core barrel
3.) Swivel type double tube core barrel with core lifter located in the bit.
4.) Swivel type double tube core barrel with core lifter mounted on inner tube.

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There is another type:-
wire line core barrel which consists of double tube core barrel so designed that inner tube can be raised to the surface through the rod string.

Single tube core barrels is composed of a tube acting as an extention of the bit body as well as a core reciever. The assembly is made of a head, an outer tube, a reaming cell, a diamond bit and core lifter located in the bit.

The basic components of a double tube rigid type core barrels are ~~the~~, the outer tube acting as an extension of the bit body and inner tube acting as a core reciever. The complete assembly consists of a head, an outer tube and an inner tube which are connected and rotated simultaneously, a reaming cell, a bit and a core lifter located in the bit.

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Swivel type double tube core barrel with the core lifter located in the bit. This assembly consists of a swivel head, an outer tube and an inner tube connected to swivel head, a reaming ~~bit~~ shell ~~and~~, a bit and a core lifter located in the bit.

20/2/2015 SKS Sir

Wireline Drilling Technique:

Drilling with conventional equipments in medium, soft and hard formations usually encountered in load areas, it was observed that in deeper holes, extensive time spent in hoisting and lowering the drill string due to necessity of removing core samples every 3 m depth. Wireline drilling is developed specially to reduce ~~it~~ this time. The rod outer diameter varies from 44.5 mm to 88.9 mm and categorized into AQ, BQ, NQ, PQ and HQ series.

Theory of Abrasive Drilling:-

Work done by diamond drill bit is 2-fold:-

1.) ~~Due to~~ thrust (F_v)

2.) ~~Due to~~ Tangential (F_t)

$$W = W_1 + W_2$$

$$W_1 = F_v \cdot \delta$$ δ = advance per revolution

$$W_2 = (F_t - R) \cdot 2\pi r$$ $$r = \frac{D_1 + D_2}{4}$$

$$R = \mu \cdot F_v$$

Final:- (Specific Energy of Drilling)

Influence of rock properties on types of bits:

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Rotary Roller Drilling: | Rotary Blast Hole Drilling

AJ Sir 24/02/2015

Considerations for planning of a horizontal Well

Sufficient knowledge, information and planning is required for drilling a horizontal well. The main elements which are considered for planning of a horizontal well are as follows:-

1.) Offset Well Data → The 1st step in planning a horizontal well is to analyse the well logs, drilling reports, Borehole assembly (BHA), mudlogs, geological maps, creation of well ~~for evaluation of drip~~, inclination and direction of the well etc. Horizontal wells can be ~~made~~ drilled more efficiently by knowing which processes work in the offset wells, how different formation responded to mud system, how various borehole assembly work and what actions ~~taken~~ are taken by the driller and their results.

2.) Well profile selection → The well profile is dictated by reservoir (payzone) trajectory, nature of reservoir structure and the payzone fluid distribution.

These features are the deciding factors to determine:
- whether pilotholes are necessary
- Rig location
- Kick-off points (Pointers the direction of well changes)
- Build radius (Initial and final radius)
- The curvature of turn required for the profile
- the number ~~and~~ of tangent sections
- the length of the horizontal section

3.) Torque and Drag → Torque and drag are the most important factors that can disturb the drilling of horizontal well. Its analysis is to predict the total torque that can develop during drilling and the hook load required during trip in and trip out of the hole.

4.) Bore hole assembly response → This optimises bore hole design by accounting for drill pipe type; no. and placement of heavy

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weight and conventional drill collar; motor design; stabilizer shape, size and placement.

5) MWD consideration (Measuring while drilling) → The foremost consideration for measurement while drilling lies in its reliability and due to higher cost of long trip to change the tool. The other point is the consideration of cost benefit analysis.

6) Horizontal tools → These include the variable blade stabilizers and specially designed stabilizer to avoid excessive drag and hanging, double blade motors and motors with custom blade stabilizer to perform at a specific build tendency and many other devices.

7) Placement and Setting of Jar → An analysis of shockwave transmission through the drill string and the bore hole ~~An analysis~~ assembly in terms of impact force for Jar.

8) Casing program → Torque and drag analysis help to determine whether casing can be run in hole and if it can be reciprocated or rotated while cementing.

9) Hydraulic Computation → Horizontal wells cutting tends to form a bed on the lower side, this can be removed by ensuring the mud is in turbulent flow in the annulus and by keeping the pipe moving. Also selection of type of mud, drilling equipment and mud pumping rate are to be considered to optimise bit consumption, annulus cleaning.

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Directional Drilling is a technique where the planned ~~course~~ course is deviated at pre-determined angle in order to intersect a sub-surface target with a lateral distance and direction from vertical. Directional drilling has evolved from the oil and gas drilling to the geothermal industry. In beginning, directional drilling was used primarily for remedial operations either for side tracking around struck tools, bringing the well bore back to vertical or in drilling relief wells to kill blow outs. To date the ~~devil~~ directional drilling technique find wide applications. Some applications are given below:

- drilling of inaccessible locations
- Multiple wells drilling from a single platform
- Relief well drilling
- Multiple well drilling
- Multiple targets
- Side tracking

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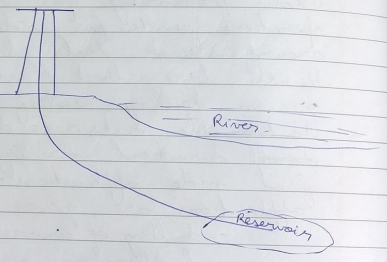
- Troublesome geological conditions

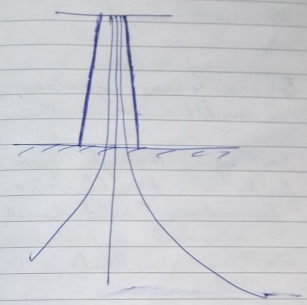
Drilling of inaccessible locations:-

A target zone lying vertically beneath a surface location that is impractical to be used as a rig site (residential locations, river beds, harbours, etc.) can be penetrated by drilling a directional well.



Multiple wells drilled from a single platform:-

Offshore platforms are the most common application of directional drilling where multiple wells can be drilled through various slots installed in the same platform. Cluster drilling is also an ~~applicable~~ application on onshore due to the land limitations.



Relief well drilling:-

This is one of the most important application of directional drilling to intersect a blow-out well near the bottom so that the mud and water can be pumped

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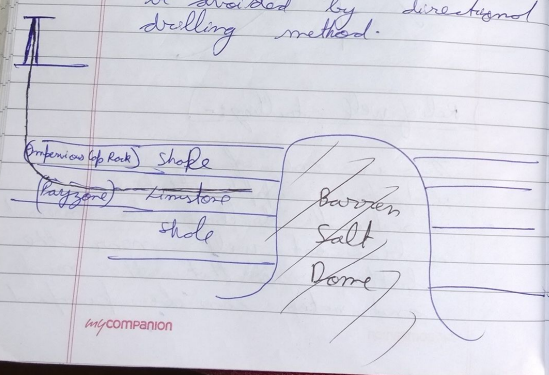
into the blowing well..

Multiple targets :-

Some times it may be necessary to drill through one target and alter the direction of the well to reach the next target.

Troublesome geological conditions :-

Drilling through geological faults or troublesome formations (salt domes) can be avoided by directional drilling method.



Practically the well planning is made in such a way that these problematic structures are avoided from the drilling path.

Side Tracking :-

Directional drilling can be used to deviate the well bore around and away from an obstruction in the original well bore.

ex:) Struck drill string left in the hole

Considerations For planning a Directional Well

The following considerations have to be taken into account while planning a directional well

1- Target locations
2- Target zone
3- Formation characteristics
4- Availability of Deflecting Tools
5- Location of adjacent Well bores

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6- Choice of Build-up rate
7- Type of profile

Target Locations → For the purpose of planning and monitoring, all the measurements must be taken from a common reference point. This point is usually chosen to be the center of the platform in offshore locations. All depths are measured from the elevation of the platform/rotary table. If the target co-ordinates are known, all the measurements will be made with respect to target locations. The true north is also being fixed.

Target zone → The point to be penetrated is called target and the area around the target is the target zone. This allows the directional driller, some tolerance in the final positioning of the well. A radius of 50 m is commonly used as a target zone.

12/3/2015 SKS Sir

Wireline Drilling Techniques:-

While drilling with conventional equipment in the medium-hard and soft formations usually encountered in local areas, it was observed that in deeper holes excessive time is spent in hoisting and lowering the drill string due to the necessity of removing core samples every 3m depth. The wireline system of drilling was specifically developed as a means of reducing this time lost. In this system, drilling rig and other accessories are same but hoisting of core barrel is different. Only the inner tube containing the core is hoisted to the surface by lowering the entire drill string. In wireline

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drilling, the string has only to be hoisted out of borehole while the diamond bit wears out and requires replacement. After removal of core sample, the inner tube of wireline core barrel is dropped back through the drill rods, moves to bottom of hole by gravity where it attaches itself inside the barrel for further drilling.

Hole stability in Wireline Drilling:

During Hoisting and lowering, many disturbances leads to cave-in ~~to~~ giving rise to difficulties for further drilling.

1) Scrapping of borehole walls by rubbing of drill rods and core barrel in the process of their being hoisted out or lowered into borehole. The loosened material falls from the sides to the bottom of the borehole creating drilling problems. With wireline drilling equipment, the assemblies are removed from the borehole comparatively very few times thereby reducing the friction to the borehole walls.

2) The drilling fluid causes pressure surge in the borehole which disturbs the borehole valves in poorly consolidated rock. The formation materials from the borehole walls fall into the borehole creating drilling problems and this kind of problem are less in wireline drilling system.

Wireline Drill rods:-

Wireline Drill rods are slightly bigger in their outside diameter compared to the same used in conventional drilling. They also have larger inner diameter through which the inner tube of core barrel can pass freely. These rods are of flush joint design means box thread

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at one end and pin thread at the other end. There are 4 kinds of wireline rods which falls in Q series

AQ – 34.9 mm	32.5 mm
BQ – 46 mm	42.9 m
NQ – 60.3 mm	65.6 m
HQ – 77.8 mm	73.0 m
outside dia	inner dia

Wireline core bits:-

The bits are made of industrial diamonds to ensure higher metarage of drilling before the bit wears out. The longer the bit life, better is the performance of wireline equipment. Fewer the no of full outs of the entire drill string to change worn out diamond bits. The diameter of the core obtained from wireline drilling is slightly lower in comparison to conventional diamond bits. The core bit of the shape of

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stafe design, the kerf is comparably thicker but set with more number of diamond buttons

Figure of core barrel from KUM Roo

Retractable System:-

A separate winch hoist is provided for lowering the overshot through the drill rod for the removal of inner tube from the wireline core barrel after the completion of 3 m run. The winch is separately driven by gasoline or diesel engine and has wirerope wound on it equal in the length to depth capacity to which the overshot is to be lowered. ~~Generally it is lowered under~~

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