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Casing Strings Sizing Optimization in Patos-Marinza Oil Field and Rock Volume Calculation

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ABSTRACT: Casing strings sizing is a critical phase in the drilling operations, involving the installation of casing strings from the surface to the reservoir to ensure structural integrity and facilitate safe production. This process includes the installation of various types of casing strings, such as conductor casing, surface casing, intermediate casing, casing liner, and production casing. It is a fact that Casing strings represents approximately 20% of the total well cost, optimizing its design to minimize expenses is essential. Achieving cost efficiency requires careful calculation of the minimum possible casing diameters while accounting for several key factors, including the geological cross-section of the well, pressure conditions along the wellbore, well depth objective and the level of drilling technology. Proper consideration of these parameters is vital to prevent operational failures and ensure the well's long-term integrity and efficiency. The selection of casing pipe diameters in the initial phase of well completion plays a crucial role in determining the total volume of rock to be extracted from the wellbore. Considering the weight per linear meter of each casing string, the total load of the casing strings in each interval will be calculated. This information is crucial for determining the maximum hook load that the drilling rig must withstand. Accurate preliminary calculations of the rock volume are essential to ensure sufficient space for its accumulation during drilling operations. Furthermore, these calculations are vital for developing effective strategies for the handling, transportation, and disposal of the extracted material, thereby ensuring operational efficiency and compliance with environmental regulations.

KEYWORDS: oil and gas well, casing strings, rock volume, wellbore diameter.

I. INTRODUCTION

The installation of casing strings is a critical step in completing drilling operations to accomplish geological requirements, and enabling efficient hydrocarbon production from reservoir. The primary purpose of casing installation is to prevent potential complications that may arise during drilling operations. By preventing such issues, the process ensures operational continuity, minimizes non-productive time, and reduces overall drilling costs. (M. E. Hossain, 2015, pp. 433-500)

Patos-Marinza is an oil field in Albania that consists of multiple stacked sands of Upper Miocene (Messinian) Age. The reservoir is made of four formations, known from the surface downwards: Gorani, Driza, Marinza, and Bubullima. Each formation of Patos-Marinza oil field possesses distinct characteristics related to the properties of the oil it contains (Albpetrol). Therefore, it is essential to selectively exploit these formations to optimize production. To prevent interference between formations, it is necessary to implement effective casing installation techniques, ensuring proper isolation and maintaining wellbore integrity throughout the extraction process. (Samuel, 2007, pp. 451-462)

Another potential challenge during the drilling process is the collapse of unconsolidated geological formations, which can obstruct the wellbore and slow down drilling operations. Additionally, there is a risk of contaminating near-surface freshwater aquifers, emphasizing the importance of implementing effective well control measures and environmental protection practices to ensure operational safety and environmental sustainability.

During drilling operations, it is common to encounter geological formations with abnormally high fluid pressures. To prevent the influx of formation fluids into the wellbore, it is necessary to increase the density of the drilling fluid, thereby raising the hydrostatic pressure to a level that effectively overcome the formation pressure. Moreover there is possible to encounter geological formations with abnormally low fluid pressures do that there is a risk of drilling fluid losses from the wellbore into the surrounding low-pressure zones. Proper management of drilling fluid density is

therefore essential to maintain well control, minimize operational disruptions, and ensure drilling efficiency. To prevent abnormally geological formations casing strings are placed and cemented into the wellbore.

The installation of casing strings is crucial for establishing a sealed conduit that enables the deployment of production equipment and facilitates other well operations. The primary objective of this process is to ensure the efficient and controlled production of oil from the reservoir (Larry W. Lake R. F., 2006).

The objective of this study is to determine the optimal dimensions for the casing strings in the Patos-Marinza oil field, by utilizing data related to the production casing diameter and the issues associated with the geological formations from the surface to the reservoir. The selection of the production casing diameter is based on several factors, including the properties of the oil, the technological specifications of the production equipment to be utilized, the geological formation, and the overall cost of the well.

II. LITERATURE SURVEY

During its lifecycle, an oil field progresses through several production phases. In the initial phase, the high reservoir pressure enables the natural flow of crude oil to the surface, representing the most cost-effective production method. However, as reservoir pressure declines over time, the operation transitions into a secondary recovery phase, necessitating measures to maintain reservoir pressure at optimal levels (Larry W. Lake J. R., 2006).

Secondary recovery techniques include polymer injection directly into the oil-gas-bearing formation and water injection into the aquifer to enhance its pressure. These methods are essential for sustaining production rates, improving overall recovery efficiency, and prolonging the productive life of the reservoir. Cyclic steam injection is another enhanced oil recovery (EOR) method in the Patos-Marinza oil field (Spiro Thodhorjani, 1998), particularly suited for heavy oil reservoirs. This technique involves injecting high-pressure, high-temperature steam into the reservoir to reduce the viscosity of the crude oil, which typically ranges between 5–7API (Albpetrol). By lowering the oil viscosity, the method significantly enhances production efficiency and facilitates the extraction of otherwise challenging heavy oil reserves. Despite its effectiveness, the economic feasibility of cyclic steam injection becomes increasingly challenging in reservoirs with substantially depleted pressures (Riza Aleti, 2005). Implementing this method in newly drilled wells under such conditions often proves financially difficult.

Consequently, there is a pressing need to reduce drilling costs to acceptable levels without compromising operational safety or efficiency. Casing installation, which accounts for approximately 20% of the total well cost (Samuel, 2007), represents a significant opportunity for cost optimization. Selecting the appropriate casing strings plays a pivotal role in achieving this objective. The chosen casing strings must not only fulfill the required physic-mechanical properties to ensure well integrity but also meet technical and economic criteria to minimize expenses. An optimal balance between cost-effectiveness and operational reliability is essential for the successful application of EOR methods in pressure-depleted reservoirs.

III. METHODOLOGY

The methodology applied in this study involves calculating the diameters of the casing strings, beginning with the production casing and concluding the study with the conductor casing. The lengths of the casing strings are determined based on the geological formations traversed by the well. To address the specific challenges encountered in the Patos-Marinza oil field, detailed calculations were conducted to select the optimal casing dimensions.

Following the determination of casing diameters, the mass of the casing strings is calculated, which is a critical parameter for evaluating the load capacity of the drilling rig. This assessment facilitates the selection of an appropriate rig, thereby preventing potential operational failures during drilling. Additionally, the volume of the displaced rock is calculated to ensure adequate planning for its storage and disposal, thus supporting both operational efficiency and environmental compliance.

IV. METHODOLOGY RESULTS

In a well drilled within the Patos-Marinza field, specifically targeting the Marinza formation, geological data were collected to characterize the formations encountered along the wellbore as follows:

1. The upper section consists of an unconsolidated formation 0-300 meter
2. Abnormally high-pressure zones were identified 600-800 meter
3. Gorani and Driza oil formations 1100-1500 meter.
4. The productive formation of Marinza layer 1600-1700 meter
5. Production casing diameter 5" or 127 mm.

V. CALCULATION OF CASING DIAMETERS AND DRILLING BITS DIMENSIONS

Drilling bit diameter calculation D_{d4} , interval 1500-1700 m:

$$D_{d4} = D_{MK4} + 2 * \delta$$

$$D_{d4} = 141.3 + 2 * 10 = 161.3 \text{ mm}$$

Where: D_{MK4} - production casing coupling diameter by OCTG Casing Dimensions and Weight Chart (EnPro) $D_{MK4} = 141.3\text{mm}$. δ - the distance between wellbore and coupling 10-15 mm. The delta depends on a series of factors, including the stability of the geological formations, wellbore deviation, casing diameter, and the placed depth. The properties of the drilling fluid, such as the clayey crust, are also taken into consideration. Using drilling bit standard diameter API manual (Fernandes) $D_{d4ST} = 6\frac{3}{8}" (161.9\text{mm})$

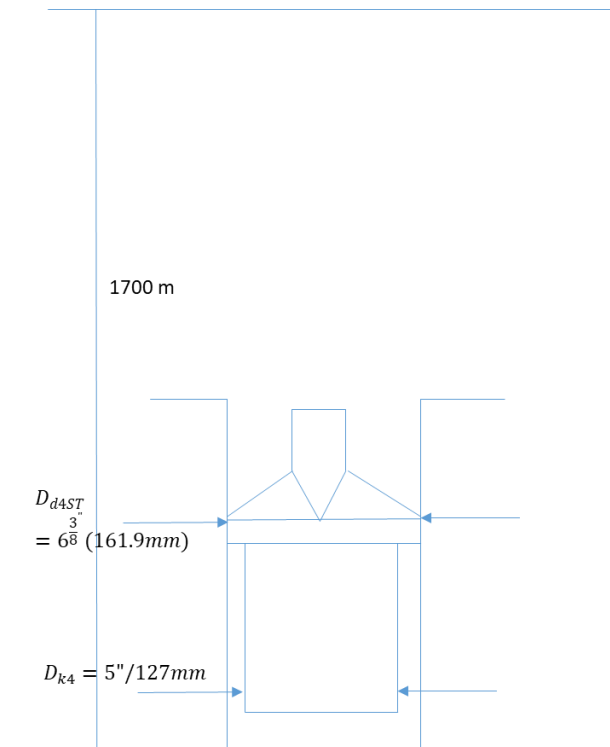


Figure 1. Production Casing and Drilling Bit Diameter

The next step is to calculate the internal diameter of the casing liner, through which will move drilling bit with diameter $D_{d4ST} = 6\frac{3}{8}" (161.9\text{mm})$.

$$D_{K3} = D_{d4ST} + \Delta$$

Where: Δ - is the distance between inside surface of casing liner and drilling bit, approximately 4-8 mm.

$$D_{K3} = 161.9 + 4 = 165.9 \text{ mm}$$

Using OCTG Casing Dimensions and Weight Chart we are going to choose for the casing liner the dimensions as follow: the outside dimensions 7" (177.8mm), inside dimensions (166.06 mm) and wall thickness 5.87 mm. Using OCTG Casing Dimensions and Weight Chart (EnPro) results casing coupling value for casing liner $D_{MK3} = 194.46 \text{ mm}$.

Drill bit diameter calculation D_{d3} drilling interval 800-1500m:

$$D_{d3} = 194.46 + 2 * 10 = 214.46 \text{ mm}$$

Using drilling bit standard diameter API manual (Fernandes) $D_{d3ST} = 8\frac{1}{2}" (215.9\text{mm})$

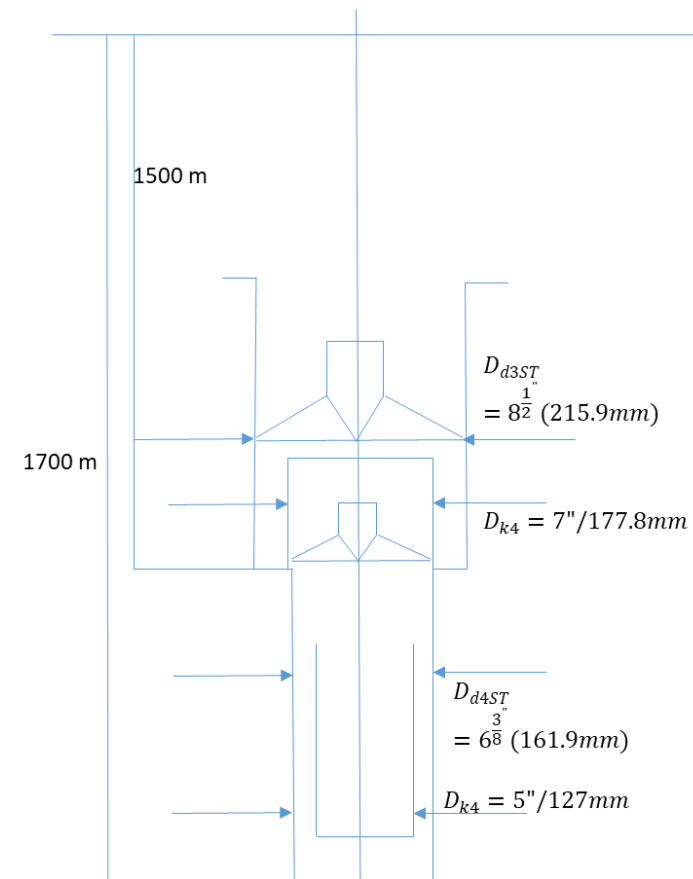


Figure 2. Casing Liner and Drilling Bit Diameter

The same procedure is repeated to calculate the internal and external diameters of the casing strings, their wall thicknesses, as well as the diameters of the drill bits that will perform the interval drilling. The data for each casing string will be summarized in the table below.

Table 1. Casing Strings Characteristics

The general characteristics of the Casing Strings.						
Casing Strings	Placed Depth		Casing Dimensions		Drilling Bit Dimensions	
	From	To	Inch	Mm	Inch	Mm
Conductor Casing	0	300	16	406.4	18 ^{1/2}	469.9
Intermediate Casing	0	800	10 ^{3/4}	273.05	13 ^{1/4}	336.5
Casing Liner	800	1500	7	177.8	8 ^{1/2}	215.9
Production Casing	0	1700	5	127	6 ^{3/8}	161.9

VI. CALCULATION OF THE MAXIMUM HOOK LOAD

Following the determination of casing diameters, drill bit sizes, and the weight per linear meter for each casing string, it is essential to calculate the total weight of the casing strings for each drilling interval. This calculation is crucial for evaluating the load-bearing capacity of the drilling rig and ensuring it can withstand the maximum hook load during casing installation. Accurate estimation of these parameters is fundamental to preventing operational failures, optimizing rig selection, and ensuring the overall safety and efficiency of the drilling process.

Maximum hook load is calculated with the formula below:

$$Q = g * L_i * q_i$$

Table 2. Maximum Hook Load

Maximum Hook Load for each Interval						
Casing Strings Type	Placed Depth (m)		Casing Strings Diameter	Casing Strings Length	Nominal Weight	Total Weight
	from	To	("mm)	L _i (m)	q _i (kg/m)	*10 ³ DaN
Conductor Casing	0	300	16/406.4	300	124.53	36.65
Intermediate Casing	0	800	10 ^{3/4} /273.05	800	97.28	76.34
Casing Liner	800	1500	7/177.8	700	25.6	17.58
Production Casing	0	1700	5/127	1700	27	45.03

VII. TOTAL ROCK VOLUME FOR EACH INTERVAL

Accurately determining the volume of the destroyed rock is crucial for ensuring adequate storage capacity and selecting appropriate handling methods. Proper management of the displaced material is essential to prevent operational challenges during the drilling process and to mitigate potential environmental impacts. This approach contributes to both the efficiency of drilling operations and the protection of the surrounding ecosystem.

$$V_{shi} = K * \frac{\pi}{4} * D_{di}^2 * L_i$$

Where: K - The rock disintegration coefficient, which is accepted as a constant value of 1.25.

Table 3. Total Rock Volume

Rock Volume for each Interval						
Casing Strings Interval	Placed Depth (m)		Casing Strings Diameter “/mm	Casing Strings Length L_i (m)	Nominal Weight q_i (kg/m)	Total Rock Volume m^3
	from	To				
Conductor Casing	0	300	16/406.4	300	124.53	48.62
Intermediate Casing	0	800	10 ^{3/4} /273.05	500	97.28	36.58
Casing Liner	800	1500	7/177.8	700	25.6	21.71
Production Casing	0	1700	5/127	200	27	3.16
The Entire Well						110.07

VIII. CONCLUSION

Casing string sizing plays a vital role in ensuring the structural integrity, safety, and efficiency of drilling operations, particularly in complex oil fields like Patos-Marinza. This study highlights the importance of selecting optimal casing dimensions by considering geological conditions, fluid pressure variations, production equipment specifications, and cost efficiency. Effective casing installation not only prevents operational complications such as wellbore collapse, formation fluid influx, and contamination of freshwater aquifers but also ensures proper isolation of distinct reservoir formations, thereby enhancing production efficiency. By optimizing the production casing diameter based on oil properties, geological challenges, and economic factors, operators can minimize drilling costs while maintaining well integrity and operational sustainability.

The application of this method in the Patos-Marinza oil field, which has transitioned into the enhanced oil recovery (EOR) phase, highlights the need for studies aimed at reducing drilling and well completion costs. The approach presented focuses on selecting casing pipes with the minimal diameter that still meets the safety requirements for production operations. This method has been successfully implemented in the field, resulting in extended field life and improved crude oil production.

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