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Fuel consumption analysis and cost overview of mechanical vehicles in petroleum drilling rig

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Abstract: During the drilling activities carried out before the use of Petroleum and Geothermal Energy resources, daily fuel consumption occurs depending on the operational diversity of the mechanical components of different types of rigs in our country. In this study, a time-dependent financial analysis of the preferred operating procedure and fuel consumption during drilling operations was performed, both in engineering studies and in order to reach a predictable level in terms of cost, oil drilling operations were mentioned by drilling rig type today, and comparisons of mechanical evenings were made to provide an economically predictable earning environment for daily fuel consumption. As a result of the research and findings, Group Motors/Drawworks, Pump Motor and Generators were actively used during the idling of mechanical evenings, and the average daily diesel consumption of 23.61 lt/h, 45.8 lt/h and 33.3 lt/h was reached, respectively. Maneuver Opr. the average daily diesel consumption of 37.5 lt/h, 0 lt/h and 39.58 lt/h was reached based on the active use of Group Motors/Drawworks, Pump Motors and Generators during the operation. Drilling Opr. the average diesel consumption of 26.24 lt/h, 129 lt/h, 33.3 lt/h and 83 lt/h respectively was reached based on the active use of Group Motors/Drawworks, Pump Motor, Generators and Top Drive.

Keywords: Petroleum, Drilling, Fuel, Cost.

1. Intorduction

Petroleum, neft or ground oil, a naturally combustible mineral oil composed of hydrocarbons, denser than water, dark in color, unrefined, with a distinctive odor, extracted from the ground. It is formed from the Latin words “petra” meaning stone and “oleum” meaning oil. Although petroleum is popularly known only as a specific fuel, the word petroleum actually means unprocessed crude oil that occurs naturally and is extracted from the ground. Petroleum is a mixture of hydrocarbons and does not always have a fixed chemical composition. Crude oil, which is a natural fuel, has different compositions depending on the countries where it is found. There are many types of petroleum with different chemical compositions which are formed by combining hydrocarbons with different chemical contents. Hundreds of millions of years ago, the remains of animals and plants living in the seas or washed into the seas by the waters formed kerogen, similar to crude oil, in an anaerobic environment under the necessary conditions (heat, pressure and the action of microorganisms). Kerogen then gradually changed during its migration to the upper layers and formed crude oil [1]. In this context, oil and natural gas exploration is of great importance in the world. The most basic of the processes carried out before production is drilling operations and these operations are diesel engine or electric drilling rigs. The cost analysis of diesel-powered drilling rigs, which are actively used in our country, and the related income/expense regulation are also important for today’s companies.

2. Overview of Mechanical Vehicles

The production of oil and gas underground is possible by drilling wells into reservoir rocks. The development of a reservoir or field also requires the drilling of a certain number of wells. Drilling is carried out onshore

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and offshore for Exploration, Development, Production and Injection (▶Figure 1).

There are 2 drilling methods that have been used since the beginning.

1. Cable-Tool Drilling

2. Rotary Drilling

The first of these was widely used in the early years of oil discovery. In this method, drilling was achieved by successively striking the formation with a steel drill attached to the end of a steel cable. This method has been completely replaced by Rotary Drilling for the last 60 years.

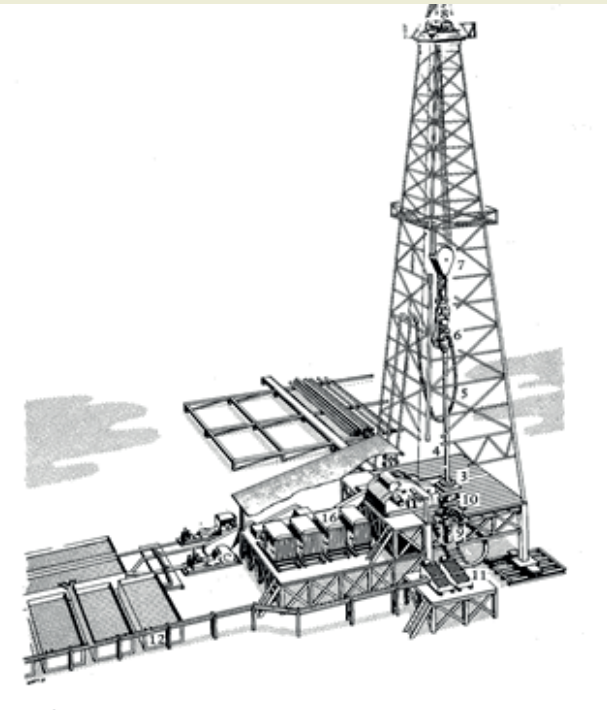

Figure 1. Rotary Drilling Rig [2]

The main components that can be included in the diesel expenses/expenditure category in diesel engine drilling rigs are Drawworks and Transmission (Group Engines), Generators and Pump Engines. Since the kelly system was used in primitive towers, this component, which was not included in the main category most of the time, has been replaced by the Top Drive system in today's technology. Accordingly, Top Drive and the engine to which it is connected can also be included in the fuel expenditure category (▶Table 1).

3. Mechanical Vehicles for Drilling Rigs

3.1. Drawworks and Transmission

Drawworks, which is the leading basic equipment in drilling rigs, is the component that determines the basic load capacity of the rig. It lifts and tilts the right and left mast of the rig or carries the drill string and transfers it to the rotary table drive unit with the power it receives from the transmission. Drawworks has 5 main sub-equipment. The conventional process of mechanical power transmission system of existing rotary drive system of deep drillingis complicated, involves different mechanisms, consume lot of input power due to various transmission losses in the systems [3]. The band brake system in its structure is used and the brake system is mechanically operated and the brake is a pneumatic system that works in the form of on/off. This system will not be able to apply sufficient force when it is below 7.5 bar. For this reason, in fast maneuvers, the belt brake system has a negative effect on expansion and braking due to wear (▶Figure 2). Pneumatic systems use compressed air to operate the brakes. In pneumatic brakes, there are three different braking systems: service brake (primary brake), secondary brake and parking brake. In recent years, electronically controlled brake systems (EBS) have begun to be used in new model heavy vehicles. EBS has been developed specially to improve brake safety in the latest model heavy-duty vehicles [4].

1. Drawworks Boiler: There is a water reservoir connected to the hydromatic brake. Thanks to the water centrifuge in its structure, it is a boiler system used to provide braking with water in the opposite direction of the rotation direction of the blades [4].

2. Overrunning Clutch: It is located between the drawworks and brake systrem and when it is desired to be pulled in the opposite direction (up), it disables the Hydromatic brake system and allows it to move. It ensures

Table 1. Rig Types and Mechanical Components Number of Charging Stations

Number	Rig Types	Motors	Drawworks
1	F320	2 x CAT398 Group Motors & 2 x FD1600 Mud Pumps & CAT3512 Generation	TF-38 (200 HP)
2	F200	2 x CAT512 Group Motors & 2 x PN700 Mud Pumps & CAT3512 Generation	TF-35 (1350 HP)
3	F125	2 x CAT398 Group Motors & 2 x PN700 Mud Pumps & CAT3512 Generation	TF-20 (1100 HP)
4	NAT80	2 x CAT398 Group Motors & 2 x 8P80 Mud Pumps & CAT408 Generation	TF-20 (1000 HP)

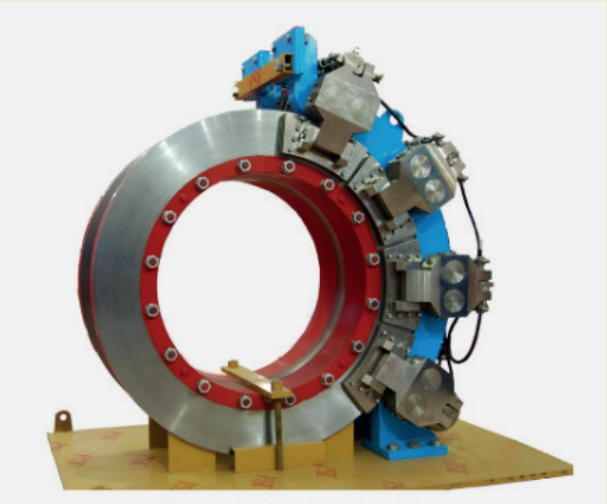

Figure 2. Drawworks and Brake System [5]

Figure 3. Drawworks Transmission System [6]

that the hyromatic brake is activated when the moving pulley goes down [4].

3. Hydromatic Brake Systtem: Drawworks' band brake system is used. The brake system is mechanically moved by means of a pneumatic system (▶**Figure 3**). There is also a water boiler connected to the hydromatic brake and the water centrifuge works. It provides braking with water against the direction of rotation with the blades inside [4].

4. Hook Block Limiting Device (Crown-o-matic): It is a safety system used to prevent the moving spool from hitting the crown spool. It is an automatic braking system that works with pneumatic system [4].

5. It provides communication between Drawworks and Group Engines: It collects the power from the group motors and transmits it to the drawworks, which provides maneuvering and drilling. In addition, it also helps to provide movement to the mechanical compressor and pumps [4].

3.2. Generations

Generators used in drilling rigs are machines that convert rotational force into electrical energy. They work with diesel (diesel) fuel types. They are generally used as a continuous energy source. The cost spent for the formation of energy in generators is higher than the cost of energy. The types of generators used vary according to the installed power and real needs of the towers. Diesel generator systems and batteries automatically supply electricity to maintain the cooling system of the reactors and the spent fuel pools of each unit [7].

Generators, 1750 KVA (1400 kW) Power, Voltage 600 V AC, Phase Number 3P, Speed 1500 rpm. In addition, for the C18 Generator used as backup, 700 KVA (560 kW), Voltage 400 V AC, Phase Number 3P and Speed 1500 rpm (▶**Figure 4**).

The total installed power values of the Drilling Rigs used in Average Oil and Geothermal Drilling are shown as follows.

1. Hopper Motors: 2x75 kW
2. Mud Cleaner: 1 x 75 kW
3. Degasser: 1 x 55 kW
4. Compressors: 2 x 55 kW
5. Closing Unit: 1 x 37 kW
6. Trip Tank: 1 x 22 kW
7 Hydromatic System: 1 x 7.5 kW
8. Screen Motors: 4 x 2.5 kW
9. Mixer Motors: 10 x 7.5 kW
10. Sheds: 12 x 5 kW
11. Lighting System: 10 kW
12. Other: 10 kW

Total installed power is 622 kW (777.2 kVA). Installed power value according to generator power is 1110 kV.

Figure 4. Generation for Drilling Rigs [8]

3.3. Mud Pumps

The selected mud pump should be capable of providing mud flow rates that are high enough to transport drill cuttings to the surface at all stages of drilling. Mud properties that influence the type of pump include mud weight and rheological properties. For Newtonian fluids, viscosity is the only parameter describing fluid rheological characteristics. Plastic viscosity and yield point are the two parameters used to describe the rheological characteristics of Bingham plastic fluids. The minimum required mud flow rate from the mud pump is equal to the minimum required mud velocity times the maximum possible cross-sectional area of annular space during drilling. The minimum required mud flow rate demanded by the borehole geometry from the mud pump is estimated based on the minimum required mud velocity, which should be higher than the drill cuttings slip velocity (▶Figure 5). The selected mud pump should also be capable of providing pressure that is strong enough to overcome the total pressure loss and pressure drop at the bit in the circulating system at the total hole depth [7].

Figure 5. Mud Pumps [9]

3.4. Drilling Rig's Engines (Group Motors)

Excepting the early usage of steam-powered engines, diesel engines have long been the engine of choice for powering drilling rigs. Sturdiness, reliability, and efficiency are synonymous with diesel engines. Located onsite at well pads and platforms, they typically range from 400 – 3,000 hp. As the sole source of power generation at many production sites, these engines are essential to all drilling operations. Renowned for their steadfast performance, diesel engines maintain their status as the dependable internal combustion engine for drilling rigs [10]. The group engines used in the drilling rigs are diesel/motorized and the power they generate enables the operation of the mechanical parts between the drawworks and transmission (▶Figure 6). CAT3512 or CAT398 (1014 HP) type group engines are used in mechanical rigs. In this type of diesel engines, the air is compressed in the cylinder to reach high pressure and temperature and the engine power is the result of the combustion of the fuel sprayed into the compressed air.

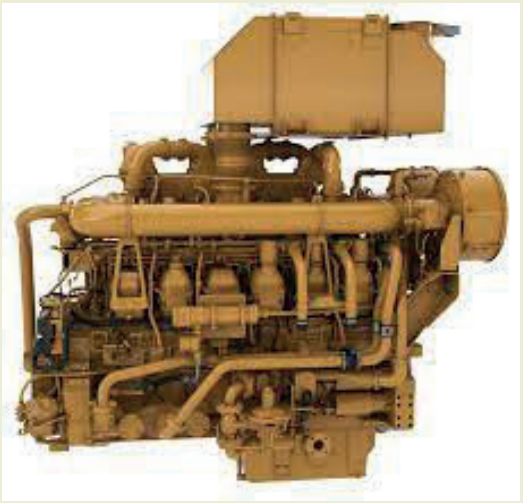

Figure 6. Drilling Rig's Engines [11]

4. Effect of Fuel Consumption

4.1. Idle Fuel Analysis of Consumption

Within the scope of operational-based fuel consumption in Oil and Geothermal Drilling rigs, the average fuel consumption as a result of idling without any load in the evening, such as the preparation phase before the operation or when the rig is on standby with the crew. Before the components work under load, they should be idled for 1-2 hours as a standard before drilling operations (▶Table 2). The data obtained in the appendix are prepared according to the catalog values of the manufacturers of the specified evenings and the comparison of on-site (lt/h) measurements made in the field (▶Table 3).

Table 2. Idle Fuel Analysis of Fuel Consumption

Number	Mechanical Vehicle Types	Avarage Fuel Consumption
1	Drawworks & Rig Engines (C398)	3 x C398 Rig Engines at 520 ROM for 24 hours (total fuel consumption of 1400 liters) – 23.61 lt/h
2	Mud Pumps	3 x C3516 Mud Pumps Motor for 24 hours at 430 RPM (total fuel consumption of 2200 liters) – 45.8 lt/h
3	Generations	1 x C3512 Generation for 24 hours at 390 RPM (total fuel consumption of 800 liters) – 33.3 lt/h

4.2. Fuel Consumption during Wiper Trip Operation

Wiper trips can be short or long for cleaning purpose or for making the wall smoother and more stable. Ashort trip is an action or some operation for tripping out / or in the drill string to a certain planned depth inside the open hole section. Performing a short trip helps to remove the cutting bed and to improve the smoothness of the wall. Sometimes a short trip can be done when there is a long sliding section via a mud motor. It is beneficial to do sobecause sliding with the mud motor creates a lot of cutting beds that are not effectively removed [12]. Although it consists of the integrity of different types of operations in Oil and Geothermal Drilling Rigs, the first type and basic wiper trip operation can be taken as the basis in order to minimize fuel consumption (▶**Table 4**). Travelling Block is the basic type of operation that covers the descent and ascent maneuvers of the string elements by means of the Crown Block wrapped with the drill string. However, in case of an ascent or descent maneuver with circulation, the Pump and Engine also operate. In this study, average fuel consumption is calculated in case of full ascent and circulation (pump and engine are not active) is not performed (▶**Figure 7**).

Figure 7. Wiper Trip Operation Fuel Analysis of Fuel Consumption (2023)

4.3. Fuel Consumption during Drilling

It is a type of operation that is defined as the basic operation in Oil and Geothermal Drilling rigs and must be

Table 3. Idle Fuel Analysis of Fuel Consumption (lt/h)

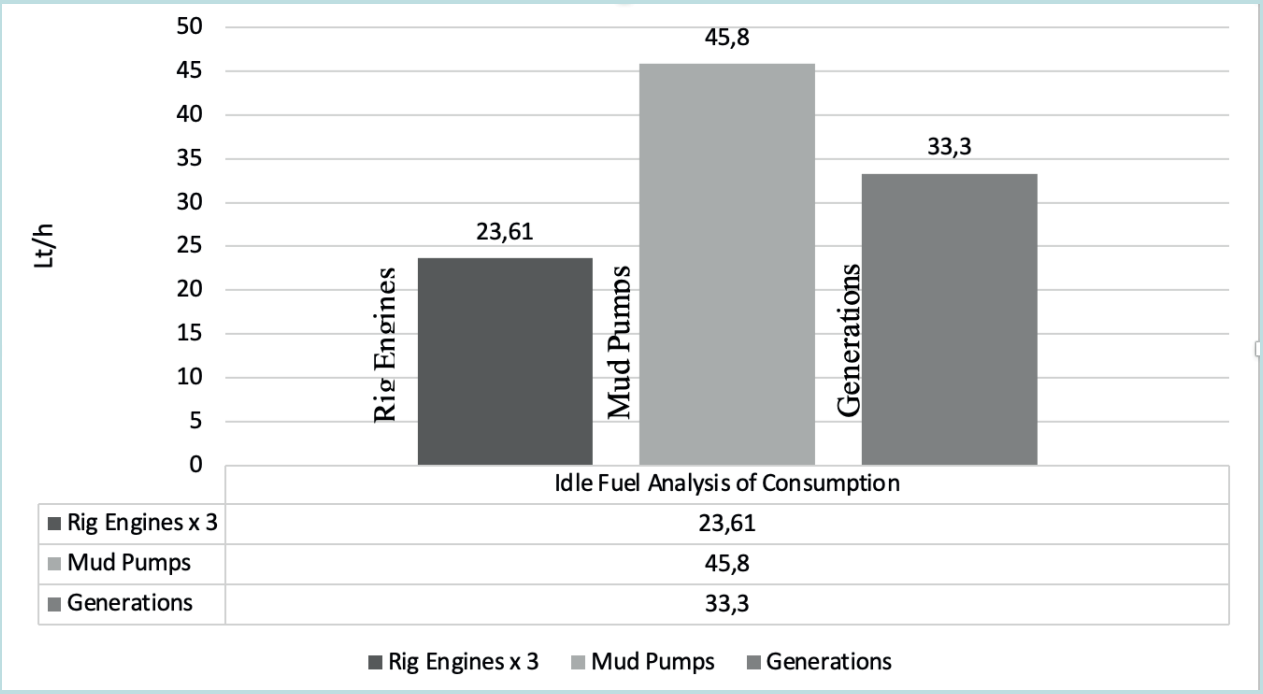

Table 4. Wiper Trip Operation Fuel Analysis of Fuel Consumption

Number	Mechanical Vehicle Types	Average Fuel Consumption
1	Drawworks & Rig Engines (C398)	It runs at 1000 RPM for 24 hours with 3 x C398 Engines (total fuel consumption of 2700 liters) – 37.5 lt/h
2	Mud Pumps	Wiper Trip is realized by deactivating the mud pumps during operation
3	Generations	2 x C3512 Generations for 24 hours at 1300 RPM (total fuel consumption of 1900 liters) – 39.58 lt/h

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performed to reach the target depth. There are many parameters that affect and differentiate the drilling operation (▶Table 5). These parameters are WOB (Weight on Bit), Rotary (Speed), SPP (Pressure), Torque, Mud

Weight and Viscosity, Drill Type and Flow Rate (Q). According to the change of these parameters, there will be load and power differences on the mechanical evenings and the parameter values based on the study are shown below. Drawworks (Rig Engines), Pumps and Engines, Generators are actively working during the Drilling Operation. Parameters of Drilling are WOB: 10-13 Tones, Rotary: 110 RPM, Q: 375 gpm, SPP: 900 psi, Torque: 3-4 klb-ft, MW: 65 ppcf (Table 6).

It is observed that the ROP value between 1281-1385 meters is 4.5 m/h at the end of the 24-hour period in which drilling activities actively continued in the parameters stated in the ▶Table 6. Considering that the Top Drive system is also actively working in the tower assembly, it is also observed that the TD engine consumed 1985 liters of diesel fuel at the end of 24 hours (▶Table 7). In this context, it is also observed that the Generator, Group Engines and Pump Engines consumed a total of 10041 liters of diesel fuel (Total 12241 liters) (▶Figure 8).

Figure 8. Drilling Operation Fuel Analysis of Fuel Consumption (2023)

Considering the different parameters and quantity ranges of the drilling operation, with the activation of the double mud pump, it was observed that the highest

Table 5. Wiper Trip Operation Fuel Analysis of Fuel Consumption (lt/h)

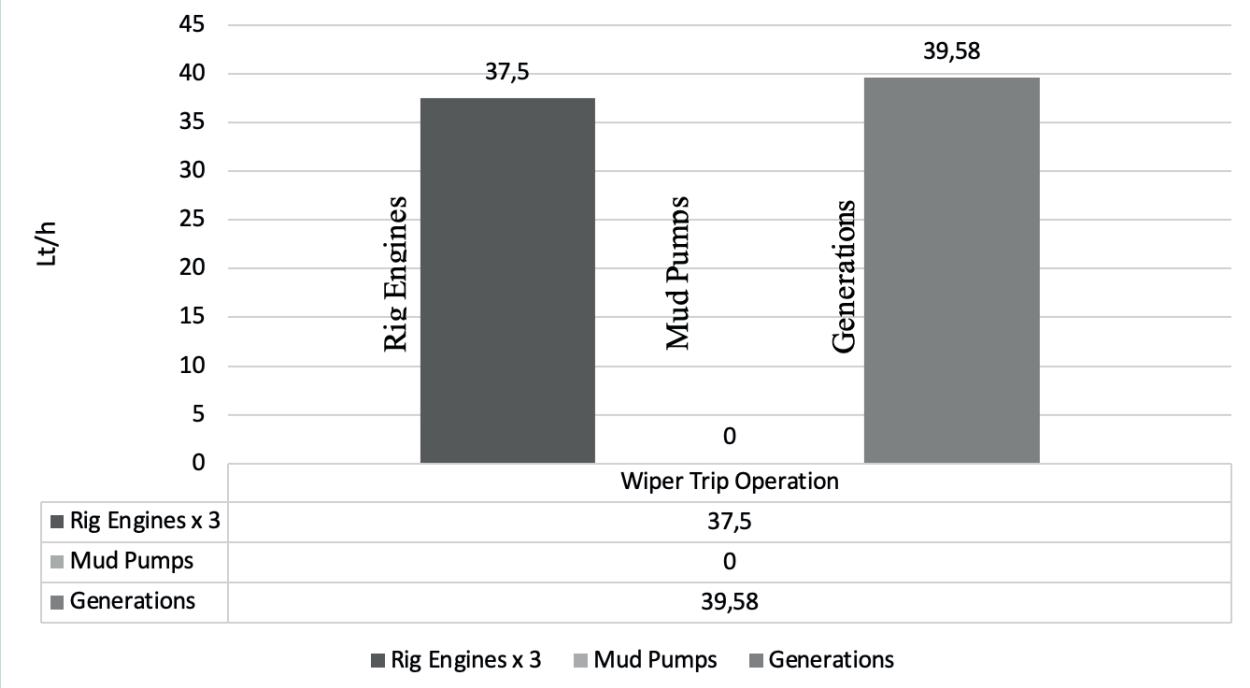


Table 6. Wiper Trip Operation Fuel Analysis of Fuel Consumption

Number	Mechanical Vehicle Types	Avarage Fuel Consumption
1	Drawworks & Rig Engines (C398)	It runs at 1000 RPM for 24 hours with 3 x C398 Engines (total fuel consumption of 2700 liters) – 37.5 lt/h
2	Mud Pumps	Wiper Trip is realized by deactivating the mud pumps during operation
3	Generations	2 x C3512 Generations for 24 hours at 1300 RPM (total fuel consumption of 1900 liters) – 39.58 lt/h

fuel consumption was observed in the pump and motor, while the lowest fuel consumption was observed in the group motors and Drawworks system. In this context, it is understood that unlike the wiper trip operation, less group motors provide labor to the drawworks through transmission. In addition, in the rigs with TD connection, it was observed that TD and its Engine burned the most fuel in the second place due to the power that the torque, wob and rotary functions brought by the drilling, wob and rotary functions received from the engine itself. Considering the different parameters and quantity ranges of the drilling operation, with the activation of the double mud pump, it was observed that the highest fuel consumption was observed in the pump and motor, while the lowest fuel consumption was observed in the group motors and rig engines system.

In the most of the drilling operations it is obvious that a considerable amount of money is spent for drilling related problems; including stuck pipe, lost circulation, and excessive mud cost. In order to decrease the percentage of non-productive time (NPT) caused by these kinds of problems, the aim is to control annular frictional pressure losses especially in the fields where pore pressure and fracture pressure gradient is too close which is called narrow drilling window.his context, it is understood that unlike the wiper trip operation, less group motors provide labor to the drawworks through transmission. In addition, in the rigs with TD connection, it was observed that TD and its Engine burned the most fuel in the second place due to the power that the torque, wob and rotary functions brought by the drilling, wob and rotary functions received from the engine itself [10].

5. Effect of Cost

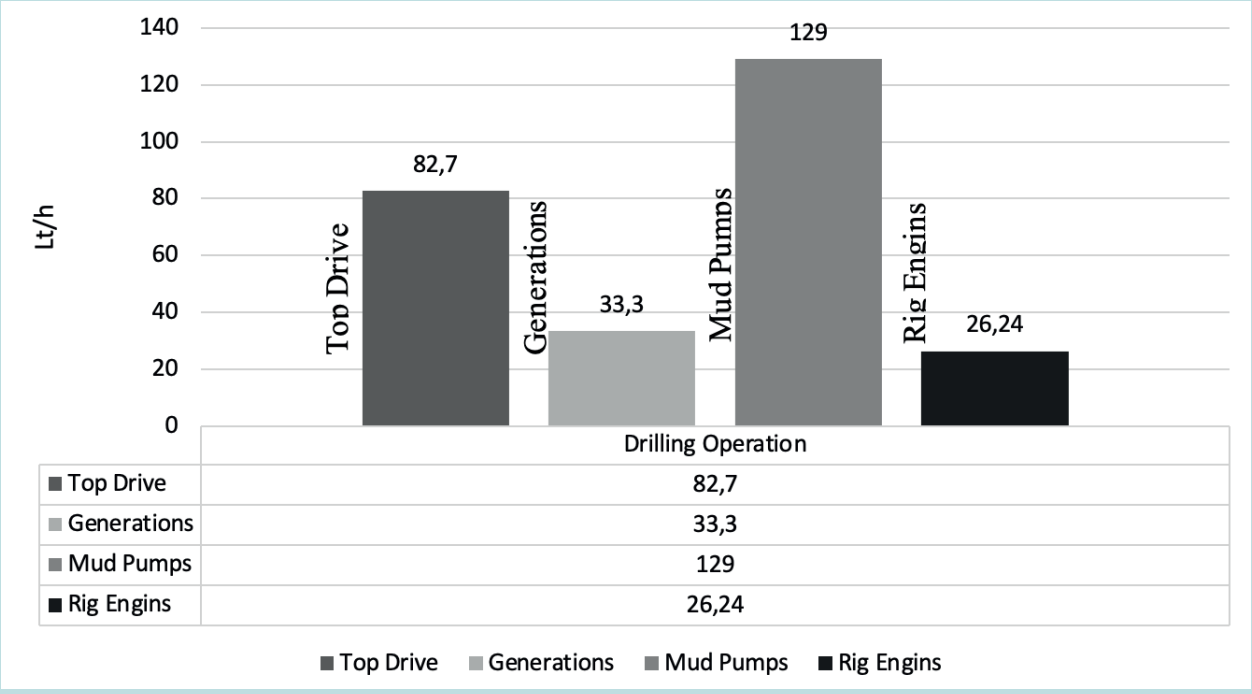
5.1. Fuel Cost of Consumption

Unlike electric towers, roman towers have daily consumption and stock amounts depending on the diesel fuel. According to the amount of stock calculated on a daily basis, the next diesel supply is made and accordingly, daily costs are formed. Correct analysis of daily diesel cost tables on operational basis (idling, maneuvering and drilling) is important in the oil drilling sector. (*The exchange rate is calculated so that 1 dollar is equivalent to 28 Turkish liras, 12.08.2023*)

The global economy has changed in significant ways during the past several decades, and these changes are rooted in how the global economy is organized and governed [12]. For this reason, cost management is important.

When the idle cost analysis of the oil drilling rigs was calculated, it was observed that the cost of the group engines, generator and pump engines and circulation was calculated on the basis that the generators were 33.3 liters, the pump and engine 45.8 liters and the group engines 23.61 liters per hour. In this context, according to the current diesel prices, when a financial analysis is made specifically for each mechanical component, the hourly cost of the generators is calculated as 25$, the pump and motor as 34$ and the rig engines as 17,6$ (▶**Table 8**).

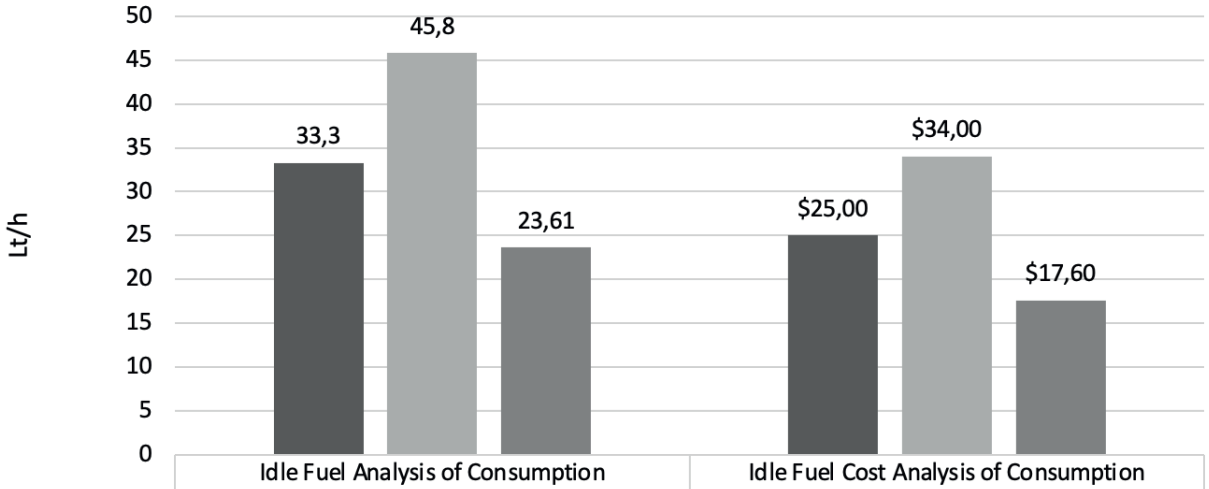
Table 7. Drilling Operation Fuel Analysis of Fuel Consumption (lt/h)



When the cost analysis was calculated during the maneuvering operation of the oil drilling rigs, it was observed that the generators were calculated as 39.58 liters, the pump and motor as 0 liters and the group motors as 37.5 liters per hour when the cost was calculated on the basis that the group motors, generator and pump motors were not circulated. In this context, according to the current diesel prices, when a financial analysis is made specifically for each mechanical component, the hourly cost of the generators is calculated as 29,67$, the pump and motor as 0 $ and the rig engines as 28,10$ (▶Table 9).

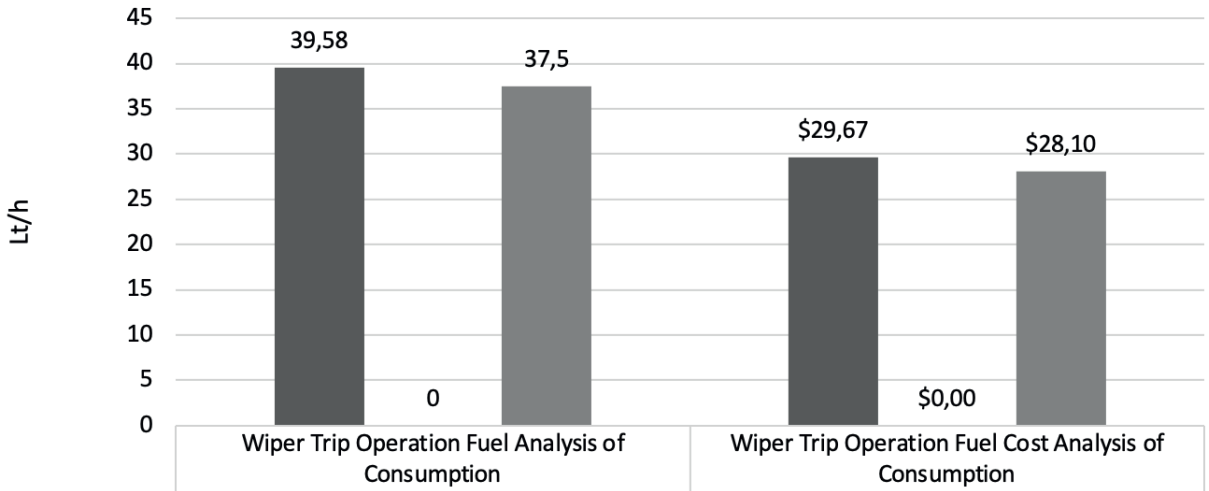
When the cost analysis of the cost of oil drilling rigs during the drilling operation is calculated on the basis of group engines, generator and pump engines and circulation, it is observed that the generators are calculated as 33.3 liters, the pump and motor 129 liters and the group engines 26.24 liters per hour. In this context,

Table 8. Idle Fuel Cost of Consumption (l/h and $)



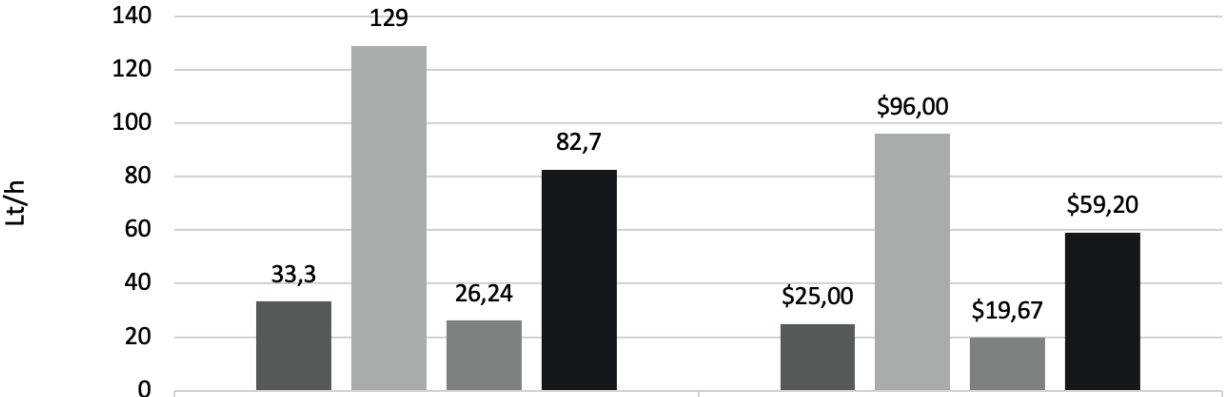
	Idle Fuel Analysis of Consumption	Idle Fuel Cost Analysis of Consumption
Generations	33,3	$25,00
Mud Pumps	45,8	$34,00
Rig Engins	23,61	$17,60

Table 9. Wiper Trip Operation and Fuel Cost of Consumption (l/h and $)



	Wiper Trip Operation Fuel Analysis of Consumption	Wiper Trip Operation Fuel Cost Analysis of Consumption
Generations	39,58	$29,67
Mud Pumps	0	$0,00
Rig Engins	37,5	$28,10

Table 10. Drilling Operation and Fuel Cost of Consumption (l/h and $)



	Drilling Operation Fuel Analysis of Consumption	Drilling Operation Fuel Cost Analysis of Consumption
Generations	33,3	$25,00
Mud Pumps	129	$96,00
Rig Engins	26,24	$19,67
Top Drive	82,7	$59,20

according to the current diesel prices, when a financial analysis is made specifically for each mechanical component, the hourly cost of the generators is calculated as 25$, the pump and motor as 96$ and the rig engines as 19,67$. 38.24 tl-28 TL/dollars. *(The unit liter price of diesel is 38.24 Turkish liras and 38.24 Turkish liras is equal to 0.73 dollars, 12.08.2023)* (▶**Table 10**).

As a result of these analysis, petroleum is the most important resource for global energy production, far exceeding the role of coal and natural gas, the role of river energy and wind energy, and also the role of nuclear fuel [13]. And also, it is found all over the earth, usually in places where oceans were once present, because petrol produces a lot of energy, people have been using it to fuel their cars and generate electricity [14].

6. Conclusion

Cost analysis is of great importance in the Oil and Geothermal Drilling sector. Different operational techniques are used until the well program created according to the planned drilling depth and reaching the target depth/reserve, and depending on these techniques, the daily fuel amount and cost of diesel/motorine-based mechanical evenings are formed. In accordance with standard practices, the daily fuel amount is calculated as a result of sometimes manual and sometimes digital measurements. Regardless of the measurement method, the main goal is to ensure the integration of minimum consumption and maximum gain. The aim of this study is to determine the average daily fuel amount according to different operational variations of oil rigs with diesel-based mechanical nights and to present a predictable cost analysis accordingly. As a result of the research and findings, the average daily diesel fuel consumption of 23.61 l/h, 45.8 l/h and 33.3 l/h were obtained based on the active use of rig engines, pump engine and generators when the mechanical nights were idling. During the wiper trip operation, rig engines, pump engine and generators are used actively and average daily diesel fuel consumption is 37.5 l/h, 0 l/h and 39.58 l/h respectively. During the drilling operation, rig engines, pump engine, generators and top drive were used actively and the average diesel consumption was 26.24 lt/h, 129 lt/h, 33.3 lt/h and 83 lt/h respectively.

Due to the high-cost results of the petroleum drilling exploration sector, it has always been aimed to keep the failure hours at a minimum level and accordingly to realize the type of operation in a minimum time. In line with this goal, it is of great importance that the cost analysis based on the average fuel consumption and the official working in the field can deduce the average cost as a foresight. In this study, it is aimed to prevent possible problems that may occur in line with the data to be obtained. For example, it is to reveal the possibility of theft as a result of the detection of high fuel amount or the possibility that the operation has not been carried out correctly/efficiently as a result of the detection of low fuel consumption amount.

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Research Ethics

Ethical approval not required.

Author Contributions

Conceptualization: [Muhammed İkbal Yıldız], Methodology: [Adem Yılmaz], Formal Analysis: [Muhammed İkbal Yıldız], Investigation: [Muhammed İkbal Yıldız], Resources: [Muhammed İkbal Yıldız], Data Curation: [Adem Yılmaz], Writing – Original Draft Preparation: [Muhammed İkbal Yıldız], Writing – Review & Editing: [Adem Yılmaz], Visualization: [Muhammed İkbal Yıldız], Supervision: [Adem Yılmaz], Project Administration: [Adem Yılmaz]

Competing Interests

The author(s) declare that there are no competing interests.

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