MBNA Publishing House Constanta 2021

Proceedings of the International Scientific Conference SEA-CONF

SEA-CONF PAPER • OPEN ACCESS

A Study Regarding the Operation of Seismic Prospecting Ships

To cite this article: Gordeș Alexandra-Nicoleta, Proceedings of the International Scientific Conference SEA-CONF 2021, pg. 341-351.

ISSN: 2457-144X; ISSN-L: 2457-144X

doi: 10.21279/2457-144X-21-042

A Study Regarding the Operation of Seismic Prospecting Ships

Gordeș Alexandra-Nicoleta[1]

Constanta, Romania, e-mail : gordesalexandra14@gmail.com

Abstract. The exploration and exploitation of marine oil and gas fields has developed explosively in recent decades. The year 1950 marks the beginning of the exploitation of oil in marine areas, with the usage of drilling and extraction platforms. As oil reserves in the mainland decline sharply, oil companies are increasingly turning to marine extraction, with these resources estimated at 160 billion barrels of oil and 14 billion cubic meters of natural gas. The evolution of the offshore drilling industry has been rapid. At the beginning of 1974, there were 192 fixed platforms and 239 mobile platforms in operation worldwide. The number of these means has increased enormously in the last decade, today totalling over 6,900 oil installations. According to a report by the United Nations General Secretariat, about 27% of the world's total crude oil and gas comes from the exploitation of marine resources.

1. Exploitation of natural oil deposits from the bottom of the seas

It is considered that the global oil market will continue to be a tight one, in which demand and supply will be appropriated. According to the forecasts of the International Energy Agency, the oil market will grow at an annual rate of 1% by 2035, the growth engine being represented by the transport sector. The situation is similar in terms of the nature of natural gas. It is estimated that this will increase globally by 65% by 2035 and that two-thirds of production will come from unconventional deposits, including offshore deposits of great depth.

It is estimated that oil reserves from the deepest depths would be about 830 billion bep, of which about 70% have not yet been explored. So far, only 75 billion bep have been produced - less than 10% - and another 67 billion bep have been developed. There is a need for considerable investment and effort for the exploration and development of esteemed reserves. It is not uncommon for a project to cost $ 8-10 billion, but only the Petrobras plan for the development of the Sântos Basin field is $ 225 billion. The project to exploit the Tupi field, with reserves of 8-10 billion bep, mentioned above, presupposes a financing of $ 7 billion.

Investments in areas of great depth involve very high costs. While an exploration probe in the onshore sweep area costs between $ 5-10 million, it can reach up to $ 100-180 million in the offshored area of the border, and this is likely to be the case. It is about 20-25% (between 3 and 4 out of 5 drill bits are dry or discover hydrocarbon resources without economic viability). Also, an important role in increasing the costs of deep-water exploration wells (about 50%) was played by and tightening the regulatory framework following the 2010 B flat accident.

However, there are exploration wells that cost more than $ 250 million. An example is the Pitanga probe dug by BP in Brazilian waters, which was abandoned, but which cost the company $ 850 million, according to data from the 2014 report. The increase in exploration cost costs is part of a more general trend in the cost of discovery in the baryl, with an annual rate of 11% between 1999 and 2019.

In areas of great depth to use equipment, platforms or ships are very expensive. An autonomous ship, which can drill 50,000 feet from sea level to the field, can cost around $ 800 million and rent for $ 700,000 a day. There is another market for renting equipment, platforms and offshore drilling rigs that until recently has been extremely tight, with a large supply and a limited supply.

As mentioned, Supermajors are very active offshore de great depths out of a desire to maintain their production and reservice. This requires investment from the largest to the largest, as can be seen from the comparative analysis of the increase in capital expenditures on the three largest oil companies, the Dutch and the Dutch oil companies.

In the following, the main forms of risks associated with the activities and projects of the exploitation of natural deposits on the seabed will be analyzed:

Uncertainty About Resource Potential - With all the technological developments, the probability of drilling a successful probe is between 20-25%, which can be costly, costly, costly. BP, which after the accident in the Gulf of Mexico has become very transparent, mentions in the 2014 annual report no less than 12 examples of failed surveys - more than a half of the country. Other examples include Algeria ($ 524 million), India ($ 139 million), the Gulf of Mexico ($ 500 million), China ($ 112 million), Angola ($ 110 million) and Morocco ($ 83 million).

Technology-Related Risk - Technological evolution in general represents, for the oil and gas sector, both a risk and an opportunity. It is a risk that recent progress confirms that batteries can become a strong competitor in the energy supply sector, and the cost of technology decreases over time. In parallel, the cost of extracting a finite resource, such as crude oil and natural gas, is an upward trend. Technology can be a competitor because it leads to substitutes.

At the same time, it also represents a barrier to the entry on the market. When you master it, you can keep your competitors at bay. With the exception of Petrobras, most national energy companies do not have the necessary technology for large depths. Innovation takes place in economies where competition is high. And finally, technology can be a facilitator.

The way in which it is now explored in the depths of the sea was unthinkable 20 years ago. Navele, drilling rigs, but also processing technology - all have made enormous progress in the last two decades. To understand the technological challenges, it must be said that some deposits are at total depths of 9,000 meters below sea level (in depths of 2,000 meters and 7 meters below sea level).

The equipment located on the seabed must work under a pressure of 200 atmospheres for 20 years. This is in the conditions in which the most performing nuclear submarines do not descend to depths greater than 500 meters. With all the evolutions, the technology can continue to pose problems. Thus, the explorations made by Shell in the Arctic waters have been interrupted twice as a result of the fall of matter. Noble's drilling rig broke its engine, and Kulluk's platform broke the cables with which it was treated and it failed, being behind.

A very recent example of the technology risk is the Chevron project in the Gulf of Mexico called the Big Foot. The deposit is located 225 miles south of New Orleans in the deep waters of about 1,600 meters and would have produced 75,000 barrels of oil and 675,000 cubic meters of natural gas. The production platform, which has a height of 130 meters, will be anchored to the bottom of the sea by 16 foots (steel tubes with a diameter between 61 and 81 centimeters).

Trade Risk and Oil Price Fluctuations - It has already been found that the fall in oil prices has led to the cessation of many offshore projects of great depth. According to a Bernstein analysis, in 2014 only 39 offshore projects were started (similar to what happened in the period 2008-2009, at the height of the global crisis, in the first half of the world, when with an average of 58 in the years 2011 - 2013. In the new market conditions, the essentials are the selectivity of the projects, not the speed of the execution. Many companies risk an important part of their value, and even their existence, with a single project, which is critical to the attention of investment projects. It is not only the volume of discoveries that is important, but also their quality, and this varies greatly depending on the type of deposit. For example, in the Canadian province of Alberta - 13 deposits generate 13 different types of oil, their value being obviously different depending on the quality.

Project Management - Despite the development of advanced technology and management skills, many of the projects are exploring and exploiting 20% of the country. Projects that seemed to have great potential were stopped. An example is the Shtockman project in the Arctic, where Gäzprom, Státoil and the Totâl franchisees were partners. The project envisages the exploitation of a deposit located 600 km north of the Kola Peninsula with an estimated potential of 3,800 billion cubic meters of natural gas and 37 million tons of gas. Discovered in 1988, the development of the project began in 2005, at the time of the signing of an agreement between Russia and Norway. However, for many reasons - misunderstandings between partners, cost overruns, lack of market prospects, the project was stopped in 2012.

Environmental Risks - It is classic now, but not mentioned, the accident of the platform operated by BP - Deepwater Horizon. This has so far cost the company $ 40 billion in damages, and the lawsuits are not closed today. There is talk of compensation that could reach $ 80 billion. This was also reflected in the market value of BP, which was reduced by 20% after the accident, given that the company offered a very high level of dividends. It is speculated that, as a result of this accident, BP could be a target for another Superintendent - either ExxonMobil, or Chevron.

2. Technological Methods of prospecting and discovering new gas and oil deposits

2.2.1 The Towed Streamers Method

Two basic elements included in all these methods are specialized seismic vessels and seismic tools (seismic network), which are to be deployed and towed straight on the sea surface by a specialized seismic vessel. Seismic vessels are usually 75-90 meters long, with a crew size of between 30 and 80 members, with research personnel. During seismic prospecting operations, these vessels advance with a speed around 5 knots, along the predetermined inspection route (scheme).

Seismic operations are sensitive to weather (waves), which means that if the encountered waves are higher than 3 meters, operations are usually stopped and the seismic matrix is recovered onboard the seismic ship. There are two main approaches to seismic topography using these methods: two-dimensional exploration (2D) ore three-dimensional (3D) exploration. The differences between these two methods are shown schematically in the figure below:

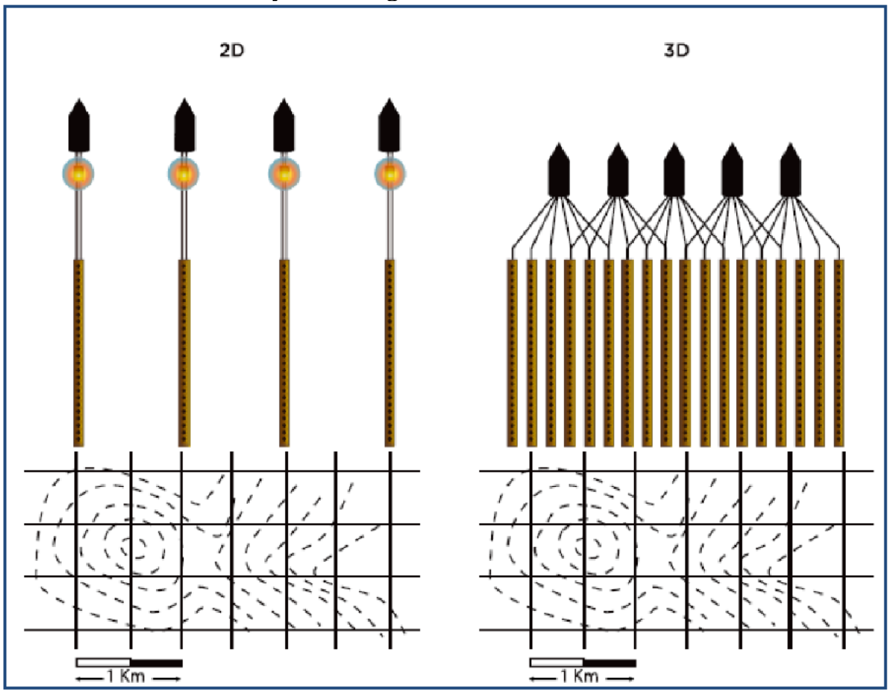

Figure 1: Essential differences between the two-dimensional (2D) and three-dimensional (3D) seismic exploration method [2]

2D is a less expensive method that uses a simple seismic matrix, with a single streamer. The acquired data compose a bidimensional view of the seabed section (expressed in specific values of length and depth). 2D prospecting involves procedures that usually involve 3D or 4D prospecting.

In the meantime, 3D topography is a more complex and efficient method of seismic topography involving a more sophisticated approach using a complex seismic matrix, ie several streams are used at the same time. The data received generates a 3D view of the bottom o the sea (expressed in effective numerical values of length, width and depth).

Figure 2: The configuration of a modern seismic ship [4]

Air pistols/guns are launched at a distance about of 50 meters from each other, which allows the propagation of shock waves through the water to the bottom of the sea and beyond. Sent shock waves change their speed depending on the density of the environment encountered in the subsoil (different layers of rocks, liquids, gas and oil bags or empty spaces). In the area where different underground layers meet, one part of the wave is reflected to the surface, while the other is further refracted into the Earth. The speed of sound waves generated by air pistols is about 2,500 m/s through the water column and between 3000 and 5000 m/s through the ground.

A hydrophone is a sensor designed to detect pressure fluctuations caused by reflected shock waves. The recordings are transformed into visual images. The hydrophones are spaced 1 meter apart and coupled in electrical groups. Electronic modules are used to digitize and transmit seismic data, while steel or Kevlar voltage elements provide the necessary power to the streamer. All the components mentioned above are housed in the streamer shell. Streamers have additional external devices, such as: birds, magnetic compasses, acoustic positioning units and end / tail buoys.

Seismic vessels are limited in their maneuverability, which is particularly important when operations are carried out in coastal areas, in areas with heavy traffic or near existing oil or gas exploitation platforms. One of the most advanced modern prospecting methods is MAZ (or the Multi Azimuth method), which is a 3D projection on the same underwater area with multiple azimuth passages (or orientations). The specific area is monitored several times, but using different navigation directions. With the MAZ technique it is possible to obtain an improved seismic image of the rather small specific area:

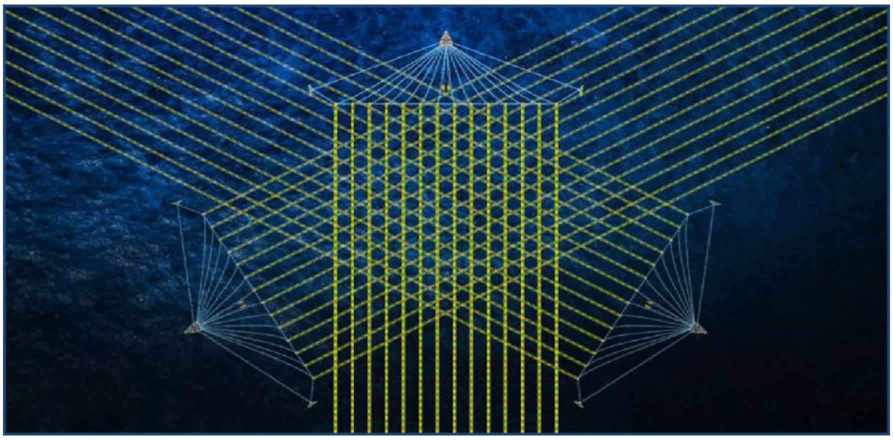

Figure 3: Exemplification of a seismic prospection application using the MAZ method [4]

Another advanced 3D prospecting technique is WATS (Wide Azimuth Towed Streamer) and is used to obtain an improved seismic image of a larger area. This prospecting technique involves the use of two or more ships in a single configuration, where one or more ships are used to generate shock waves (called source ships), while other ships are used to obtain data (called streamer ships). Typically, the target area should be monitored two or more times, with a different lateral separation between the streamer vessels and the source vessels, as shown schematically in the figure below:

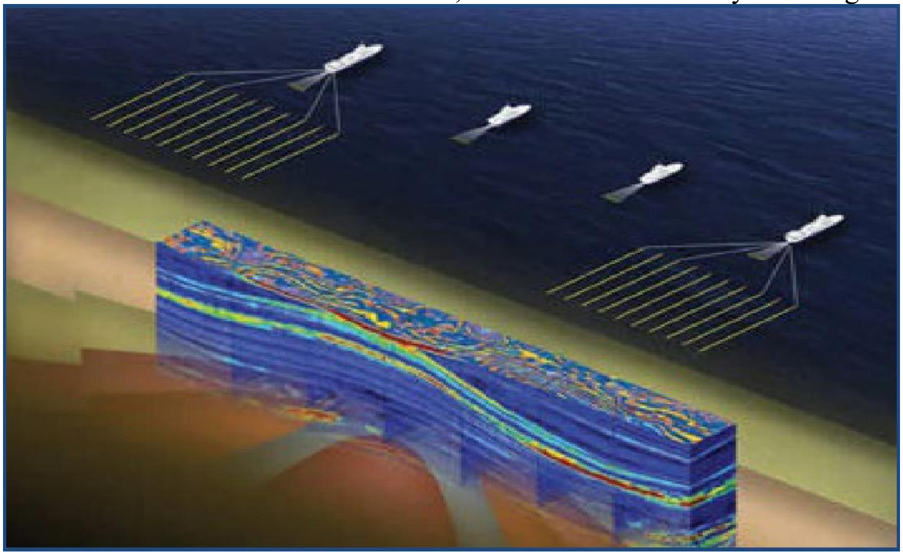

Figure 4: Exemplification of a seismic prospection application using the WATS method [4]

2.2.2 Ocean Floor Cable (OFC) Method

This is a seismic prospecting method that uses a series of seismic cables that are fixed and laid or buried on the seabed. There are usually two main OFC configuration approaches: with two components (abbreviated 2C) or with four components (abbreviated 4C).

The 2C method uses a geophone and a hydrophone, while the 4C method uses three geophones and a hydrophone. The hydrophone detects seismic waves on or below the solid surface of the Earth and turns them into electrical impulses proportional to the movement, speed and acceleration of waves. A hydrophone then detects changes in water pressure.

This method can also be used for a 2D survey with a single seismic cable or 3D and 4D surveys with a multi-cable configuration. In this case, a 5- or 6-kilometer-long cable is laid in rows every 25 to 30 meters.

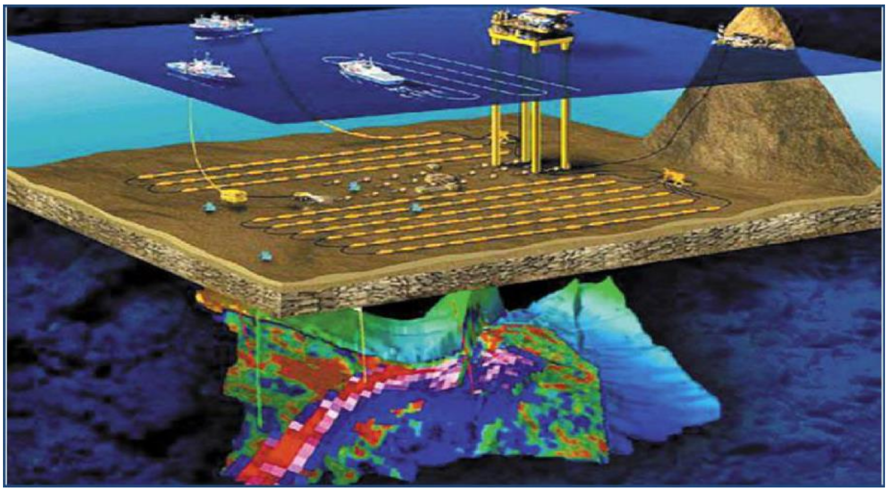

Figure 5: Schematic representation of the OBC prospecting method [3]

OFC specific operations include the use of an earthquake vessel to conduct one or more cables, record data, and recover cables. In the process of generating seismic waves, a source vessel periodically triggers seismic waves, following a pattern determined over the deployed cable configuration. The use of multiple vessels increases the cost of OBC operations compared to the method of towing streamers. On the other hand, the OBC method generates better quality and higher resolution images of potential sites or locations compared to the much more widespread method with towed streamer. OBC is usually used in areas with existing exploitation in the vicinity.

2.2.3 Permanent Seismic Installation Method

This kind of installation is, in fact m a method in which a series of seismic sensors are arranged one meter deep in the seabed, and its scheme is generated by a predefine patterns based on similar studies made on a certain area. This method is used for a fairly small number of existing and producing hydrocarbon fields for continuous 4D measurements (behavior of hydrocarbon fluid and gas in the tank during operation). This method requires the presence of a single ship, a "source ship" equipped with air pistols to generate seismic waves and collecting data. A disadvantage of this system is the relatively high initial cost due to underwater works which include the preparation (excavation) of the seabed and the deployment of sensor cables.

2.2.4 Vertical Seismic Profiling (VSP)

This is a method in which a number of geophones are lowered on the seabed through a borehole. The source of seismic waves is still on the ship or on a platform on the sea surface, which can produce seismic wave above the borehole or other positions around the area (VSP compensated). Prospecting usually lasts one or two days and is used for a fairly small target area. The main advantage of this method is that the seismic wave moves in one direction through the seabed and the distance traveled by the seismic wave is relatively short. Due to this, the energy of the waves is less absorbed in the structure of the Earth, therefore the image has a higher resolution, ie a high quality.

3. Study of a modern seismic prospection vessel

The SSV Bourbon Petrel was designed by *Offshore Ship Designers*, a Dutch company based in Hoofddorp. As a basic technical feature, the ship is equipped with a hybrid propulsion system, which allows it to function as a "mother" seismic research ship and can be operated using three main modes of propulsion:

- Diesel - mechanical - is used in normal driving and navigation conditions;
- Diesel - electric - is used when the ship operates as a research ship;
- Boost - when the ship is operating in tow.

The ship is designed can perform the following main missions:

- Arrangement and towing of seismic research equipment;
- Fuel delivery (MDO and HFO);
- Transport of general supplies, with equipment stored on deck;
- Transport and food supply;
- Loading / unloading of waste and oil residues;
- Accommodation and transfer for a maximum number of 12 passengers;
- Emergency recovery of seismic equipment;
- Activity to follow the seismic research process;
- Collection of data characteristic of prospecting for seismic study.

The main dimensional characteristics of the ship are:

- Total length: 53.80 m;
- Maximum width: 13.00 m;
- Draft: 6.30 m;
- Deadweight: 1,360 dwt;
- Bollard pulling capacity (in diesel-mechanical mode): 40 dwt;

- Bollard pull (boost mode): 50 dwt;
- Gross/net tonnage: 1,358 dwt or 407 register tons.

Figure 6: *SSV Bourbon Petrel* seismic research vessel [2]

The specific load capacities of the Bourbon Petrel SSV are:
- Deck area: 5 metric tons per m^2 on an area of 23.00 × 10.20 m (approximately 230 m^2);
- Maximum storage capacity of goods / equipment on deck: 205 metric tons;
- MDO fuel for own consumption (at a capacity of 97%): 271 m^3;
- MDO/HFO fuel for research at 97% capacity): 895 m^3;
- Total MDO / HFO transfer capacity: 950 m^3;
- Fresh water tank capacity: 121 m^3;
- Capacity of ballast tanks: 519 m^3;
- Oil tank capacity: 10 m^3;
- Waste transport/transfer capacity: 10 m^3.

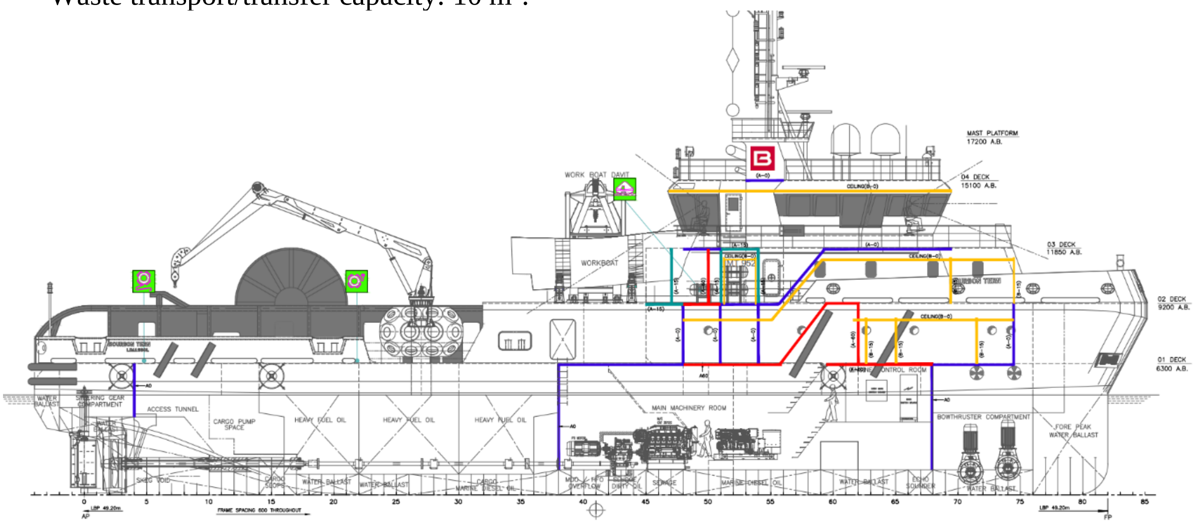

Figure 7: *SSV Bourbon Petrel* Deckplan [5]

The main power installations on board the ship have the following technical characteristics:

- Main engine: 2 × 1175 kW;
- Diesel generators: 3 × 550 kW;
- Electric motor installation: 2 × 350 kW;
- Main propulsion: 2 × sets of hybrid propulsion on CP propellers;
- Bow thruster engines: 2 × 300 kW;
- Emergency generator: 1 × 95 kW.

For the equipment listed above the ship shall record the following specific consumptions, indicated for one day of operation, depending on the operating regime of the ship:

- Diesel-mechanical module: 11.8 t / day at an average speed of 11.0 knots;
- Diesel - electric mode: 3.0 t / day at an average speed of 6.0 knots;
- Boost mode: 15.4 t / day at an average speed of 11.5 knots.

Considering the particular operating specifics of the ship of the studied ship, it has a series of special equipment:

- The storage cable of the research cable with a size of 180 m X 4", which is connected by means of a quick - coupling connection;
- Storage drum for the 120 m long distance research line made of polypropylene;
- A series of buoys and beacons for seismic instruments, storage gutters, other drums, a tow rope basket with a length of 200 m and a diameter of 80 mm, at MBL 137 t, operated by a TS DIP winch;
- Yokohama type fenders:
  - o 2 of 2.00 m diameter at a length of 4.00 m;
  - o 2 of 1.00 m diameter at a length of 2.00 m.
- Streamer type winch (for the disposal/recovery of research equipment) with standard power supply system at 440 V, 3P, 250 A and 60 Hz;
- Foundation support system for a 20" ISO container and a standard weight of 40 tons.

The main technical characteristics of the gears on board the *SSV Bourbon Petrel* are listed below:

- Weight (without oil): 3600 kg;
- Reduction ratio: 7,333:1;
- Rotation at input shaft: timetable for the starboard engine, counterclockwise for the port engine;
- Rotation t output shaft: timetable for the port engine, counterclockwise for the starboard engine;
- Oil volume: 110 liters;
- Type of oil used: SAE 30 (ISO VG 100);
- Working pressure of the oil: 21 - 25 bar;
- The operating temperature range of the oil: minimum 10 0C - maximum 65 0C;
- Vessel band gap interval: 15 0C (static), 22.5 0C (dynamic);
- Type of heat exchanger: Bloksma;
- Water temperature: 34 0C;
- Necessary water flow interval: minimum 9000 l / h - maximum 13,000 l / h;

The elastic coupling mentioned above is of Vulkan type, the model being Vulastik L.

With the custom control system of the propulsion system it is possible to switch directly between any of the modes mentioned above. For example, it is possible to switch from search mode to navigation/boost mode without switching to any of the other modes. The control system is equipped with indicators for the most appropriate operational mode in the current situation. However, the initiation of the mode change must be done manually, for safety reasons. In the following paragraphs a simplified description of the transfer sequences from one module to another is presented:

Further, the propulsion system on board the studied vessel is designed and installed by the Swedish company Berg Propulsion, being of the type Berg Controlable Propeller (elice with adjustable pitch), is shown below:

From Prospection/Navigation to Economic Mode - This change in operating mode suggests that the ship has been set to the survey mode, which means that it is advancing at low speed and that the required speed has now increased. Preliminary conditions:

- The propulsion system is in escort mode with electric motor in operation;

- Caterpillar diesel engine also works;
- The diesel engine has been engaged;
- The propeller pitch was set (optimal projection point) in escort mode;

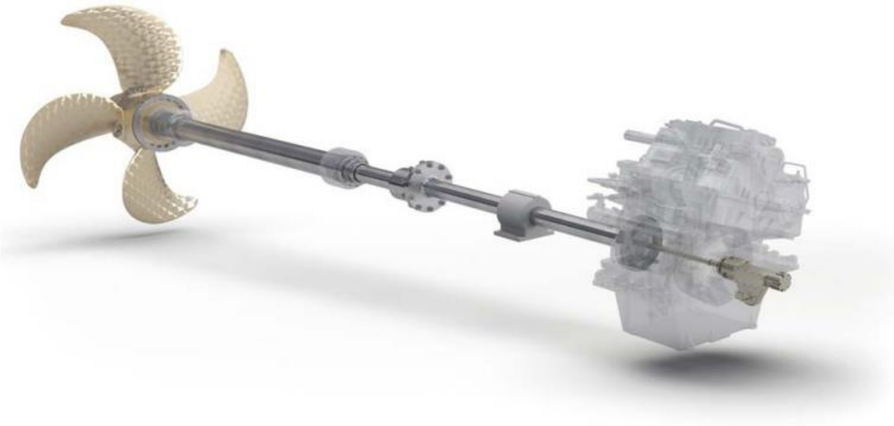

Figure 8: Reduction gear system onboard *SSV Bourbon Petrel*

Sequence of mode change:

- The diesel engine is set to engage the gearbox;
- Electric motor speed adjusted to the same speed;
- The diesel engine is engaged;
- The maximum possible gear setting has been changed to the Transit Economy setting;
- The electric motor is switched off;
- The combinatorial curve has been modified to the Transit Economy section;
- Pitch and speed are controlled from the control lever;
- The control lever on the control panel is in a position proportional to the speed of the vessel.

From Navigation/Economy to Navigation/Boost mode - This change suggests that the ship is running at the maximum speed achievable by diesel engines and additional power is required. Preliminary conditions:

- System set in Transit Economy mode with the diesel engine running;
- The electric motor is switched off;
- The electric motor is switched off;
- The propeller pitch and engine speed are at maximum settings.

Sequence:

- The electric motor is started;
- The speed of the electric motor is adjusted to the same speeds as the diesel engine;
- The electric motor is switched on;
- Make the maximum possible setting of the reducer at Transit Boost;
- The combinatorial curve has been modified to the Transit Boost setting;
- Pitch and speed are controlled at the control lever on the control panel;
- The position of the control panel lever is proportional to the speed of the ship;
- Load sharing is done in operation, automatically, between the diesel engine and the electric motor.

From Navigation/Economy Mode to Towing - This change suggests that the ship will switch from economical transit to towing mode. The principle of the command will change proportionally from the speed to the traction, ie that it will lose in terms of the value of the speed and will gain in terms of the towing force. Preliminary conditions:

- The system is in navigation / economical mode with the diesel engine running;
- The electric motor is switched off;

- Disconnection of the electric motor;
- Propeller pitch and engine speed are set to maximum values;

Sequence:
- The electric motor is started;
- The speed of the electric motor is adjusted to the same speeds as the diesel engine;
- The electric motor is switched on;
- The maximum possible gear setting is changed to the towing gear;
- The engine and engine speed are changed to constant speed;
- The propeller pitch is controlled from the control lever;
- The position of the control lever on the control panel is proportional to the speed of the vessel;
- Load sharing is in operation, automatically, between the diesel engine and the electric motor.

The figure below shows the relative efficiency of the three main modes of operation of the ship from the point of view of operating the propulsion system (diesel, electric and boost). The figure below describes the optimum point or breaking point at which the ship passes in the combined mode of operation of the propeller at a variable speed, with the propeller in the mode of operation with variable pitch, locked at the step of design in low speed. as a fixed-pitch propeller.

Based on the projected curve of the ship's main engine, shifting from transit/economical mode to escort or reverse mode, the transition will be made at approximately 1200 rpm, corresponding to a propeller rotation of approximately 164 rpm. In escort mode, the propeller pitch will be set to the design step (ensuring that the propeller is as high as possible) and will function as a fixed pitch propeller with a variable rotational speed. The blades are located so that they can absorb the power transmitted to the main engine and its boost, but the starting point of the projection will be at a value of approximately 0.85% of the power of the main engine. In addition, it will be ensured that there is a sufficient stroke of the propeller to increase its pitch and to absorb all the power installed in the state transit mode. This means that in transit mode, using the PTI electric motor, the maximum speed of the propeller will be 245, but the step will be increased to absorb all the installed power.

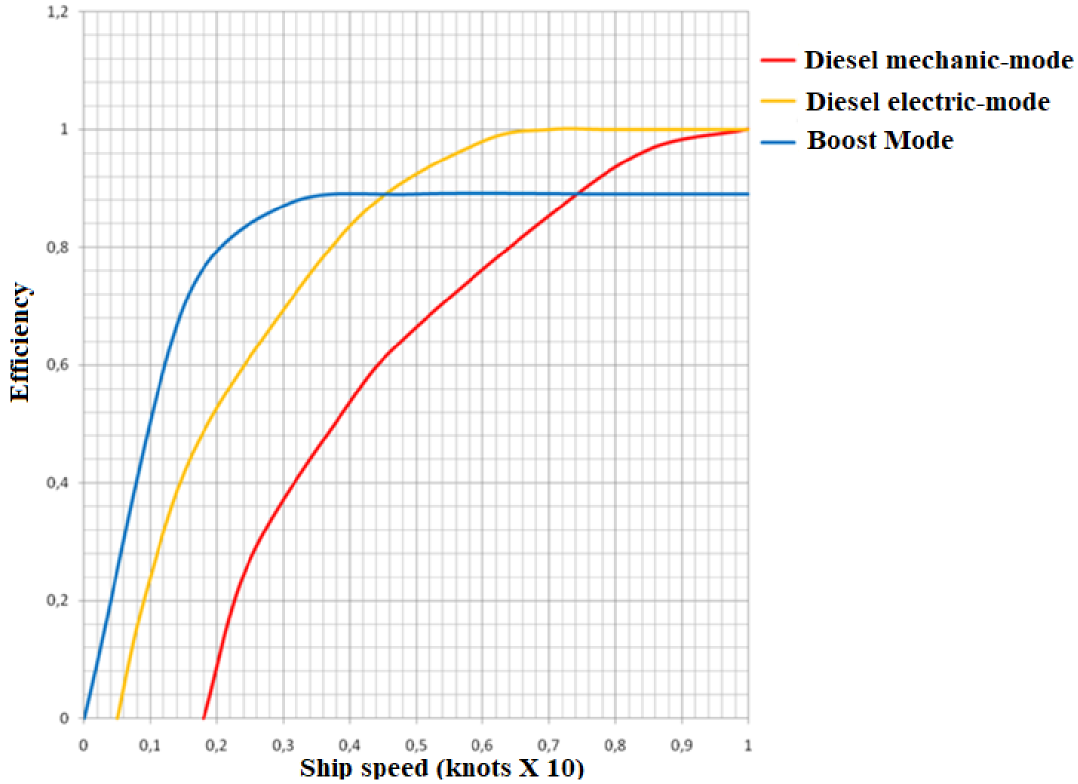

Figure 9: Analysis of the efficiency of the ship in the three modes of operation for the propulsion system, in the speed range of 0 - 10 knots

4. Conclusions

As presented, there are several new methods of marine seismic exploration and development, two of which should be mentioned in the form of general conclusions. One of the new techniques for acquiring seismic data is FreeCable developed by the French company "Kietta". This method is based on the usual seismological analysis of reflection. The system consists of a commanding vessel, one or more source vessels and a series of self-contained submersible cables equipped with seismic sensors for detecting and measuring the reflectors. The standard set includes 20 cables of 8 km length, which are independent and autonomous. The cables are controlled by a series of small autonomous ships (RAV), used to adjust the exact position of the cable, as well as to collect, record and transmit valuable data. All operations are supervised from a control room aboard a seismic vessel. The cables are separated in parallel at each 400 m and each cable is equipped with 4C sensors at each 25 m. The cables can be moved from the autonomous vehicle at a very low speed, about 0.1 knots per area.

Another new method being developed is WiMUST (Highly Scalable Mobile Underwater Sonar Technology). The method is based on the operation of several autonomous underwater vehicles (AUVs) which operate in a synchronized manner. It pulls significantly shorter (but still stretchable) cables forming an underwater acoustic network. This method, like all the others, is still needed for a seismic surface vessel for the deployment and recovery of AUVs and cables, but also for the generation of seismic waves.

Therefore, marine seismic prospecting is the most efficient approach for assessing the quality of the geological structure of the seabed. As a result of seismic research and data collection, it is possible to estimate the location and size of hydrocarbon deposits on the seabed. The most accepted and used commercial method at this moment is a method of towing the stretches applied by the studied ship, SSV Bourbon Petrel. Other marine seismic operations used at the commercial level are the cable deployed on the ocean floor, the permanent seismic installation and the vertical seismic profiling.

References

[1] Birin I., Maglic L., 2020, *Analysis of seismic methods used for subsea hydrocarbon exploration*, University of Rijeka, Faculty of Maritime Studies, Croația;

[2] IAGC, 2002, *Marine seismic operations*, An overview producesd by IACGC to provide a reference to other marine operations in general;

[3] Oil & Gas Producers (OGP), 2011, *An overview of marine seismic operations*, report No. 448;

[4] The Dynamic Positioninc Center, 2014, *Failure Mode & Effect Analysis for Redundant Propulsion & Steering Gear System 50T BP Seismic Support Vessel*, Bourbon Offshore, Londra;

[5] Bourbon SSV, 2014, *BOURBON SSV Seismic Vessel Hybrid propulsion Technical Specification*, Bourbon, Marseille;

[6] Berg Propulsion, 2012, *BCP 620 with HDX Manual*, Berg Propulsion Technology AB, Oekero, Suedia;

[7] Di Carluccio A., 2017, *Structural Characterization and Seismic Evaluation of Steel Equipment in Industrial Plants*, PhD Thesis in Seismic Risk.