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An innovative time-saving method of turning for vessels conducting seismic surveys

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Abstract

The paper presents a turning method saving time and energy while conducting seismic surveys and an example of its application. The introduced turning method is based on use of the ocean currents / tidal streams as a supporting factor. The turning technique is applicable for vessels towing streamers and conducting line-change or other maneuvers similar to 180° turn. Chosen forces affecting seismic in-water equipment as well as behavior of the spread are briefly shown and explained. Some advantages over traditional turning techniques are here described. The method was applied onboard the seismic vessel Geo Pacific reducing significantly time required for line-change.

Introduction

Geophysical market analysis shows that complex solutions are commonly used at sea for the exploration of hydrocarbon deposits (and, recently, for hydrate deposits). Nowadays, marine seismic surveys using acoustic waves or electromagnetic waves are in use during geophysical explorations.

Marine seismic surveys are conducted by specialized vessels towing seismic equipment. Part of the equipment comprises of airguns triggering acoustic waves. Acoustic waves reflected by geological structures under the seabed are sensed by hydrophones (acoustic signal receivers) located inside seismic streamers. Ships are also equipped with auxiliary geophysical data processing systems. The size of the towed spread often exceeds 10 km × 1 km (Figure 1).

The survey area is usually wider than the coverage achieved during one pass of the vessel. Therefore, in order to acquire data for a whole project, a ship must tow the equipment back and forth along preplanned lines (Figure 2). Every time one line is finished, the next is approached – normally in the opposite direction. Due to the large size of the towed gear, the turn radius for vessels conducting a 3D/4D survey may vary from 3500 m to 7500 m or even more when an unfavorable current is affecting the spread.

Nowadays, a significant limitation of turning methods is the remote use of currents and streams in order to increase seismic survey efficiency. Ocean currents are considered as an impediment only. The general impression from the literature is that there are very few publications depicting maneuvering with a seismic ship. The dissertation of Pedersen (Pedersen, 1996) is the only comprehensive study existing in the literature, but it did not consider the line-change aspect. The dissertation of Ersdal (Ersdal, 2004) is considering aspects of forces exerted on sources cylinders mainly, therefore it's application is limited. There is also a paper by Pipchenko (Pipchenko, 2013); however, it shows a very simplified model, and there is no information about the possibility of its use. In addition, the concept of the use of ocean current as a helping factor while

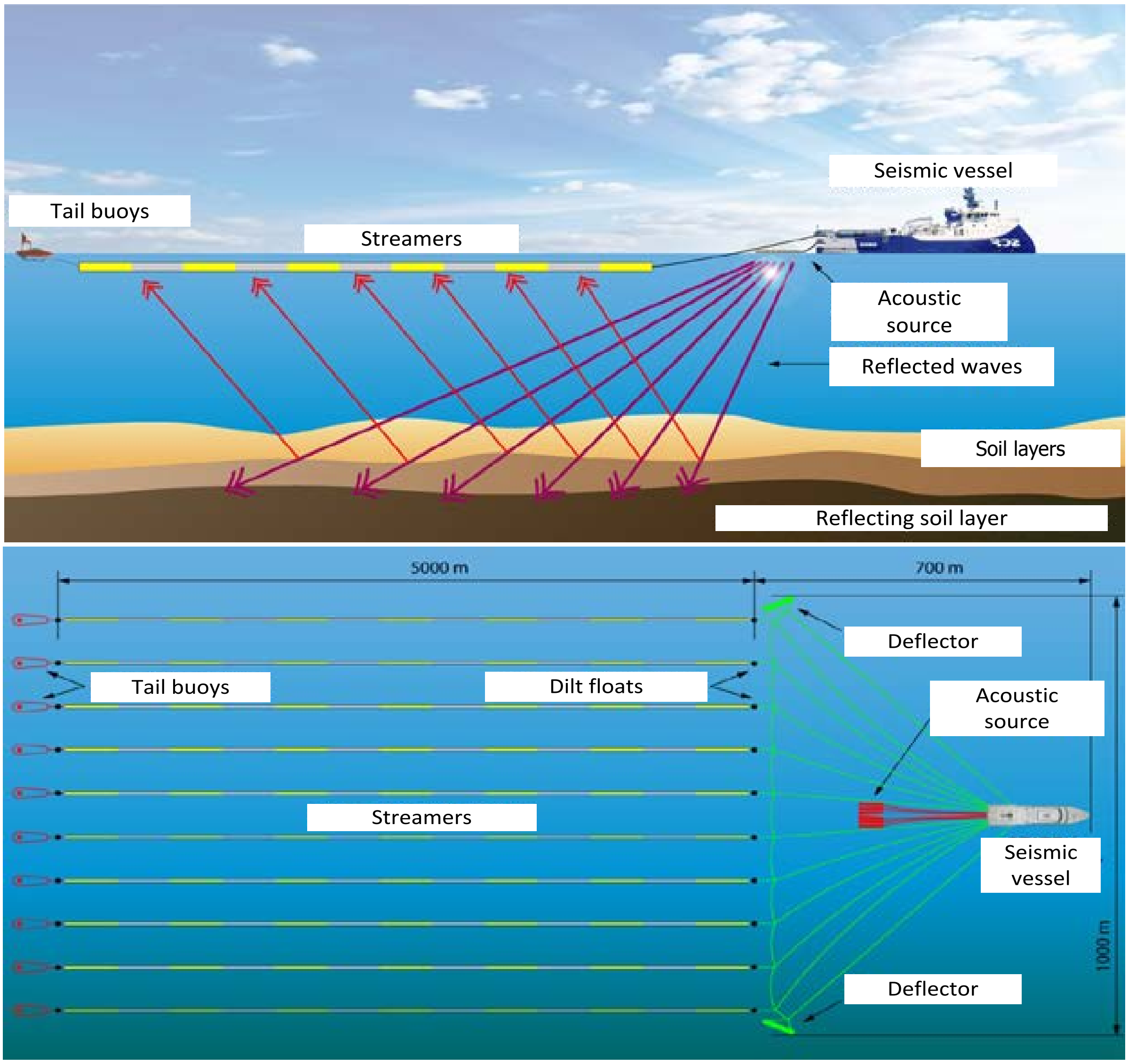

Figure 1. Example of a towed seismic spread and explanation of specific names

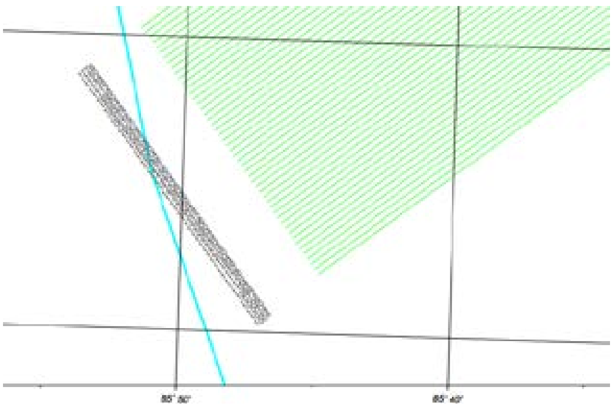

Figure 2. Part of a seismic prospect area with preplanned passage lines

conducting maneuvers with towed in-sea hardware is not mentioned in any publication.

During analyses conducted with the assistance of professional seismic navigators and specialists engaged with geophysical companies in survey planning, it was noted that there are a number of unresolved issues that cause a decrease in efficiency and safety during the line-change process. This convinced the authors to begin working on the study. The main idea is the creation of an efficient turning method to be used if the line-change process is carried out in an area affected by strong currents.

Improvement of turning efficiency

Usually, seismic vessels conduct turns by following a circular track. The turns are preplanned so that they begin and finish at specific points over ground: position of EOL (end of line) and position of SOL (start of line) (Figure 6). Therefore, when conducting a turn, a seismic ship usually follows a circular path with a steady radius over ground. This method of turning is in many cases not efficient because it does not take into account the direction and speed of current. An ineffective method of turning may also increase stress on the gear and affect the geometry of the spread.

We understand an improvement of turn efficiency to be a reduction of the length and time of turning without compromising the safety of the towing set. Apart from SOL/EOL position, at least the following factors should be considered while planning the geometry of the efficient turn of a seismic ship when affected by significant currents/streams:

- speed of streamers through water (especially of the inner and the outer cables);
- tension on the deflector vanes;
- crab angle;
- direction and size of current and swell;
- other circumstances specific for various vessels and configurations (some vessels – i.e. "Ramform V and S class" – may have problems even with traditional turns due to their super-wide rope touching hulls).

The kinematics of deflector vanes

Deflector vanes are used to widen a tow with seismic in-water equipment. This way, the area cowered in one pass is extended.

In the analyzed case, deflector vane B46 was used with the following lift/drag capability at 4.5 kn.

The hydrodynamic forces modeling proposed here is based on K. Reite thesis (Reite, 2006).

On Figure 3, the angle of attack on the port side is reduced because the vessel is turning to port. The course through water (CTW) is changing slowly

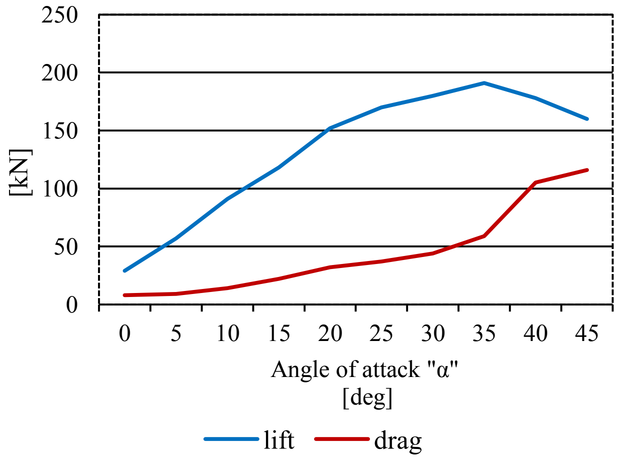

Figure 3. Amount of drag compared to the amount of pulling power (lift) produced by B46

due mainly to the high lift from the starboard deflector (up to 50 tons or more). Also, cross-dragging of streamers significantly reduces ROT; however, this is deliberately not marked on Figure 4. The proportions of forces on the starboard side and the port side vanes change during a starboard turn.

Use of the crab angle in turn planning

Because crabbing cannot be avoided while turning in an area affected by significant currents, it ought to be used purposefully. Figure 5 shows how turn length can be reduced by the effect of the crab angle shifting from one side of the vessel to the other. It also visualizes that even though COG is changing rapidly, the vessel's heading is much steadier. Such turn adjustment results in a significant improvement of turning efficiency, if properly planned.

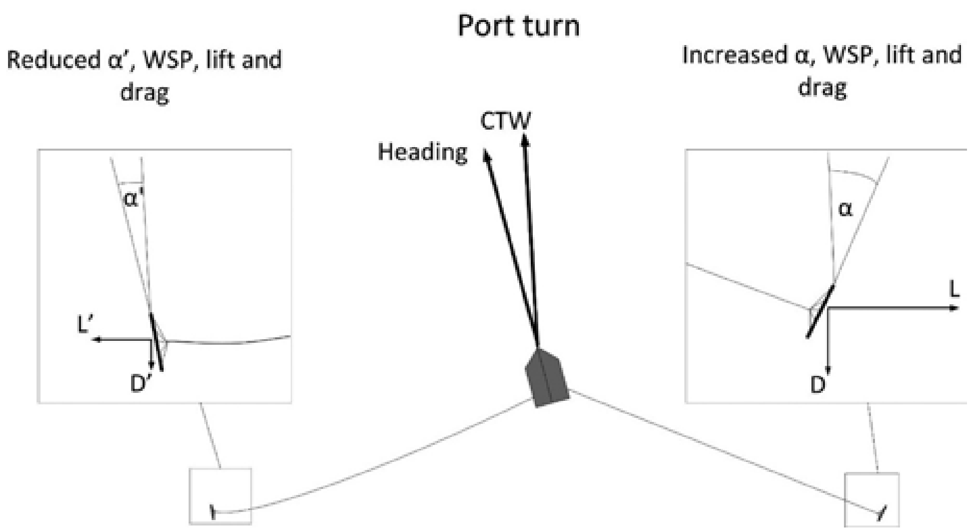

Figure 4. The hydrodynamic forces and angle of attack on deflector vanes during a port turn

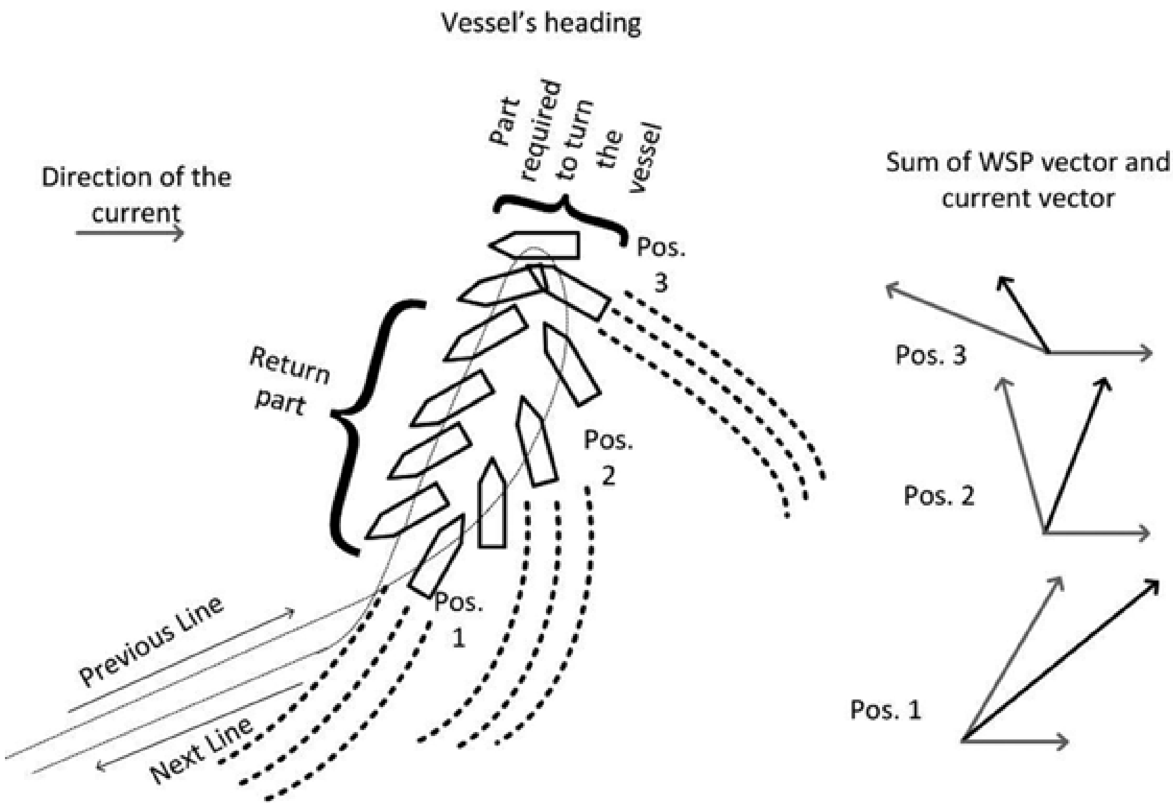

Figure 5. Tow movement and heading of a seismic vessel while conducting a "saving turn"

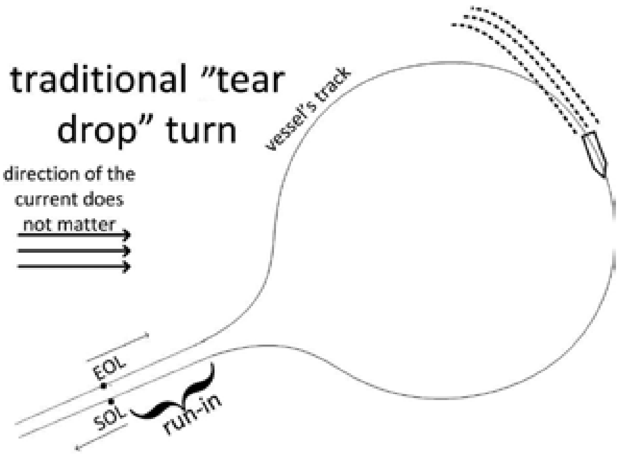

Figure 6. A traditional, unplanned turn wasting time and energy

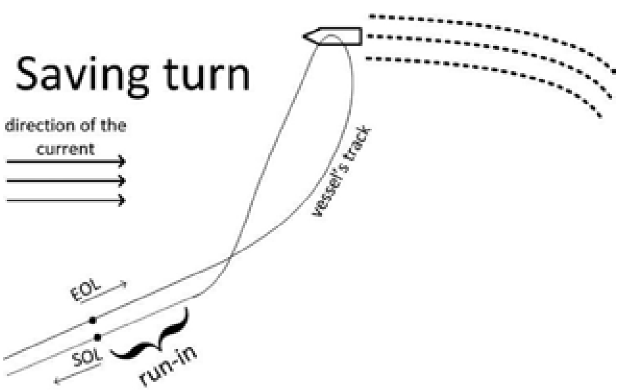

Figure 7. A preplanned turn saving time and energy

Streamers behavior in strong currents

We need to emphasize that movement of the tow is even steadier than the ship's heading due to the natural behavior of the body of the ship while the current is shifting from one side of the hull to the other. Therefore, there is no unusual stress on the tow.

Purposeful use of feathering is an important part of turn planning. In order to achieve the expected streamers behavior, the sum of the vectors of ship velocity and current velocity (Figure 5) has to be planned by turn adjustment. Figures 5 and 7 show how helpful a strong current may be for "sweeping" streamers around compared to the traditional method of turning (Figure 6). Feathering, when used consciously, sets the cables against the current. As a result, the speed of cables through the water is increased and the turn radius can be reduced without affecting the geometry of the spread.

Application of the "separation coefficient" while conducting a line-change maneuver

In order to improve overview on streamers geometry, the "separation coefficient" was used. The coefficient is based on the average and the minimal separation between two successive cables. An exact description of the coefficient can be found in "The Concept of Marine Seismic Research Quality Coefficient to Improve its Accuracy and Efficiency" .

Application of the model for turn adjustment

Apart from steering devices such as "Nautilus" or "Digifin" (which are helpful to some extent only), an increased turn radius is normally used to improve control over streamers during a line-change. Naturally, it also increases the time required to carry out the maneuver because, normally, the speed of a seismic vessel during a turn does not exceed 5 kn. A saving turn can reduce the time required to carry out a line-change maneuver. Thanks to the use of the presented turning method, the current is not such an impediment anymore because it is used to increase STW of towed gear in the second and the third part of the turn (Figure 5). It is also used to 'sweep' streamers around in the first stage of the turn.

The reduction of time required to conduct a turn by adjustment of its shape to the direction and the speed of the current has been exercised onboard the seismic vessel Geo Pacific in the vicinity of Cuba. The time required to carry out the turn was significantly reduced (by approximately 50% including "run-in" time). It was also carried out in a safe manner without any unusual stress on the gear. An additional advantage of a saving turn is that in many cases it shortens the length of "run-in" because streamers are nearly straight astern of the vessel before the "run-in" even starts.

A saving turn (Figure 8) was exercised with the close cooperation of the bridge and the instrument room crew. A vital part of the turn is when the side of the hull exposed to the current is changing (Figure 5). At this moment, the rate of turn can be increased rapidly because the crab angle is shifting (i.e. from 15 degrees negative to 15 degrees positive, giving a 30 degrees course change in just a few minutes). Surprisingly, there is no tool for planning an efficient turning track that considers currents, tow and the vessel's limitations. Vital for this operation is the experience of both the seismic and the bridge crew. An additional benefit may be achieved by using seismic research quality coefficient proposed by authors of this paper.

Conclusions

The paper presents a model of an innovative, time-saving, turning method and the results of its application onboard a seismic vessel. A quantitative

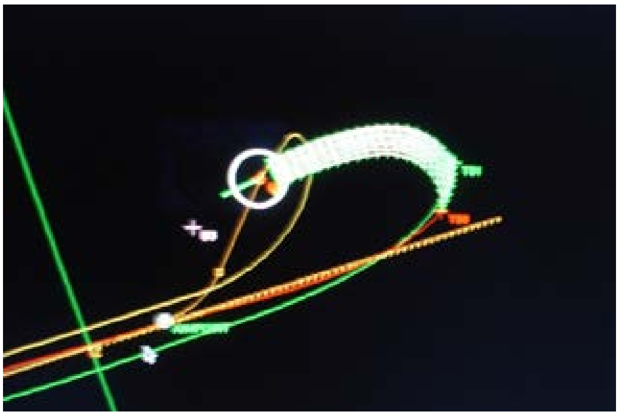

Figure 8. A real example of turn adjustment (current direction approx. 95 degrees, speed approx. 1.7 kn)

indicator was used to improve the assessment of the position of the towed gear in relation to the desired value while conducting the turn. The coefficient indicates the streamer parallelism and the streamers' real separation related to the desired separation. A saving turn was introduced to prove that time and energy can be saved while conducting maneuvers with a tow in an area affected by significant currents.

The application of a saving turn shows that a reduction in length of turn is possible and worth implementing on a large scale.

In order to reduce the risk of unnecessary stress on in-sea equipment, the creation of a computer program able to configure an efficient turning track that considers currents, towed gear and the vessel's limitations is planned.

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