Multi Streamer Seismic Acquisition is a Challenging Task in Congested Mumbai Offshore: Case Study

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KEYWORDS

Seismic interference, SINE, sub-sea installations, swell noise, close passes & dead head shooting, tidal shooting, stake nets.

SUMMARY

The purpose of this abstract is to discuss the different acquisition challenges during streamer mode seismic operation congested oil field in Mumbai offshore and the efforts to overcome this by maintaining the good data quality. The noises from various sources like seismic interference, activities in rigs or platforms, streamer bending or by environmental impact were tested during onboard QC processing to determine the noise elimination parameters. Also special processing effort was driven on vessel itself to remove the seismic interference. The most complicated part of the project was the middle of swath-05 & SW of swath-04 where the rigs/ platforms were closely placed and risky to pass with streamer. Two separate deadhead shooting program and an orthogonal swath were introduced to enhance the optimum coverage around installation complexes. Due to shallow water and presence of unknown position of stake net in NE part of the area, tidal shooting pattern was adopted for smooth & safe operation. The overall project was successfully and safely completed by efficient planning and extra processing efforts to acquire good quality data.

INTRODUCTION

Mumbai High field is the giant oil field in India, discovered in1974. Mumbai offshore basin is a pericratonic rift basin situated on western continental margin in Arabian Sea, India and divided into five tectonic blocks; viz. Tapti-Daman in north, Panna-Bassein-Heera in the east central part, Ratnagiri in the south, Mumbai High-/Platform-Deep Continental Shelf (DCS) in the mid-western side and Shelf Margin adjoing DCS and the Ratnagiri Shelf.

A 3D flat streamer seismic data acquisition campaign in "East of Panna and Central Graben", Mumbai offshore was conducted during 2014-15 to explore the potential of Bassein & Panna formation in the eastern and western periphery of central graben area.

It was a contractual job awarded by ONGC to cover 3680 SKM area in one field season (~6 month) and two seismic vessels were deployed by contractor to complete the target.

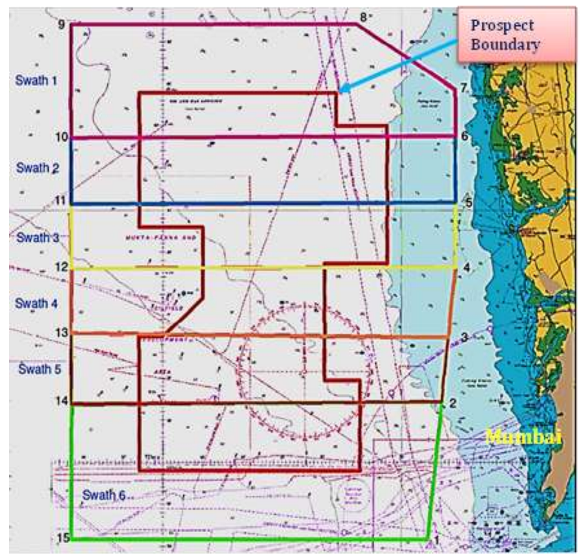


Figure 1: Location map of "East of Panna and Central Graben" with swath wise division.

ACQUISITION SUMMARY:

Project area (Figure 1) is located approximately 42nm North-West from Mumbai, bathymetry gradually increases from 20m to 70m (NE-SW). Whole area was divided into 6 swaths; each contained roughly 36-40 preplot lines heading East-West, total 208 sail lines having average 44 Km length. Production started from south most & deepest swath-06. It was a Q-marine solid streamer survey having with 6000m long 8/6 streamers (separated by 100m) as per sail line operating at 7m water depth. Source arrays are composed of identically tuned bolt air-gun sub-arrays operating in flip-flop mode at 5m water depth with volume 5085 in^3. It was a dense grid seismic acquisition having bin size (6.25m X 25m).

ACQUISITION CHALLENGES:

1. Seismic interference and time sharing:

As two seismic vessels were working together in the same prospect, there was a high probability of seismic interference. Therefore two vessels were operational by maintaining minimum 40-50 Km distance between them or shoot in different time period to avoid seismic interference. But during the last stage of the project, both vessels were operated at NE region of the prospect where the bathometry very shallow (bathymetry 17-25 m) and crowded by unknown stack nets. Therefore both vessels were bound to following same tidal cycle for shooting and became closer (~ 10-15 Km apart). Total 68 sequences (for both the vessels) were affected by interference noise and the strongest one was average of ~20-25 µBar RMS, move out of 310ms/km with duration of 2500ms and time difference of 1500ms (Figure 2 & 3). All the affected sequences were deblended in onboard processing itself with an extra effort of applying WesternGeco SINE (Margaret C. Yu 2011) processing.

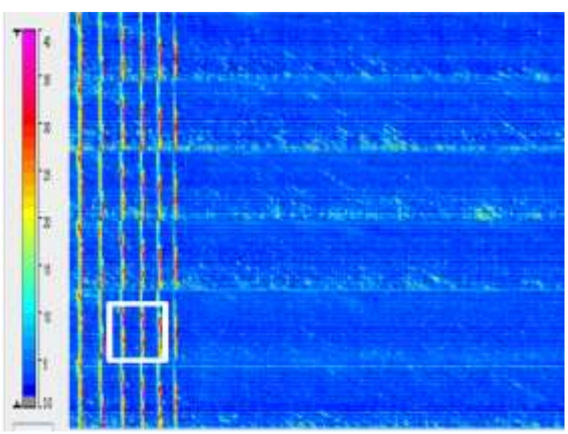
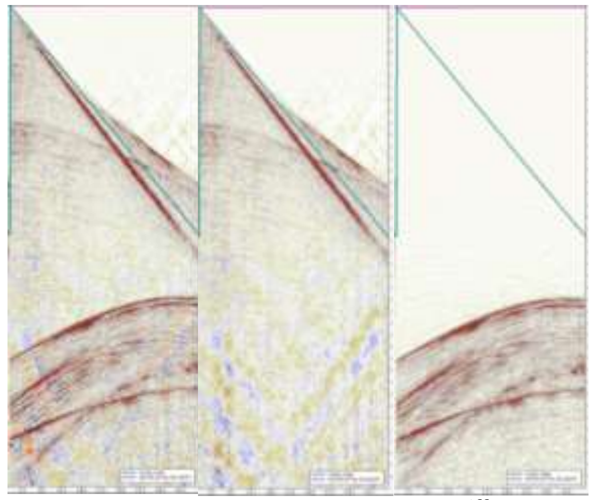


Figure 2: Seismic Interference (red, >25 µBar RMS, move out 310 ms/km), all 6 streamers on background RMS amplitude plot.

To make it smoother & easier SINE application, both vessels were scheduled to move in same heading with similar speed one behind other that will produce interference as beam from behind or front.



Before **After** **Difference**

Figure 3: SINE result, performed in the white box region of figure 2

2. Obstruction due to Installations:

As the prospect area comes under the highly hydrocarbon potential zone, the number of unannounced movements of rigs and installations with some fixed man or unmanned platforms, big barges having their anchor network, buoys, support vessels, etc. was reported from swath to swath, had a great impact on the quantity and quality of data acquired. Total 43 numbers of obstacles was reported during the survey, inside or just outside of the prospect and most of them were located (Figure 4) in the middle of swath-05 and west end of swath-04.

- **Foldage Enhancement in Swath-04 & 05:**

This exclusion zone crowded by large number of installations with associated buoy patterns and support operations, in conjunction with their spacing, nearly 362 SKM area was functionally bisected the swath. Some of these installations covered a footprint that was more than a kilometer wide which severely restricted both the normal 3D operations and the 2-boat undershoot operations. It was very risky to move with streamers between the installations.

To maximize fold coverage on this swath two separate deadhead shooting programs were conducted to cover the both Eastern and Western sides

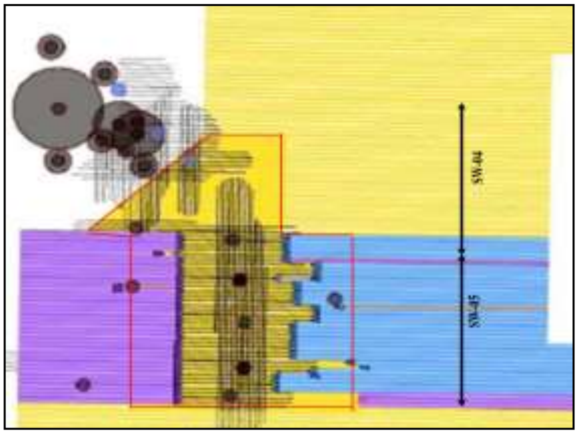


Figure 4: Installation position in swath-04 & 05. Red Block indicates "Orthogonal swath area"

separately where all the sequences of either side were shoot along same heading by same vessel.
In addition to the primary swath operations there was an additional secondary acquisition grid that was referred to as the 'Orthogonal Swath' having NS 34 sail lines (figure 5). This rotation allowed for effective acquisition along the predominant line of Rig & Platform complexes and enhances the coverage. Total 53 orthogonal sequences including infill and undershoot (18) were attempted to cover this region by both of the vessels.

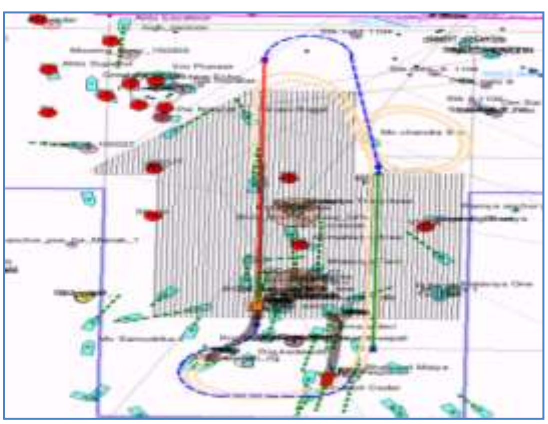


Figure 5: One by one simultaneous shooting using two vessels along orthogonal lines

To minimizing the risk of seismic interference during dead-head or orthogonal shooting (Figure 5), both the vessel sheared shooting time, means one was shooting and another was changing line in same time.

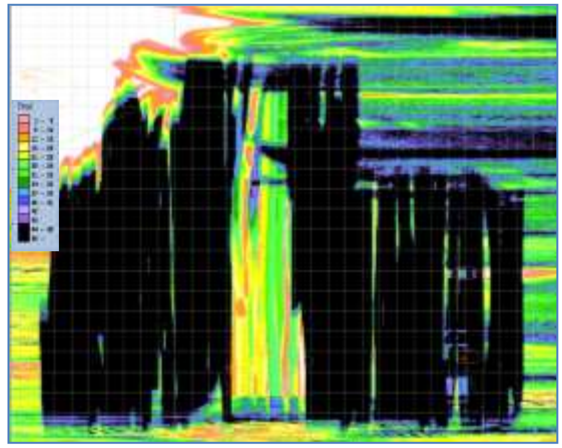


Figure 6: Total coverage map (all offset range) for orthogonal swath.

- **Rig Noise:**

Sequences, mainly middle & southern part of prospect which were located near to the platform or rigs were suffered with high frequency rig noise (5-20 µBar; depending on the distance), generated due to the activities in the installation. The affected sequences were passed through some testes (figure 7) during QC processing to evaluate a best way of rig noise elimination parameters of possible residual noise and thus an acceptability of data.

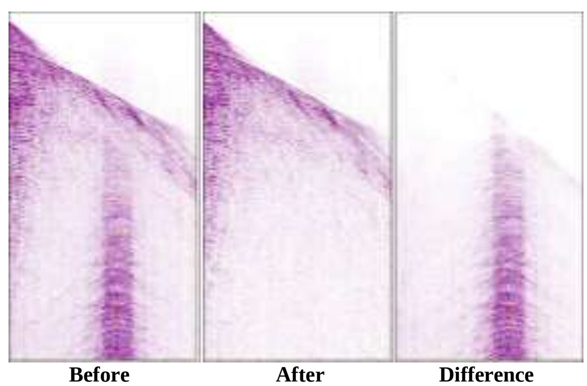


Figure 7: Example for Rig noise elimination test.

- **Turn Noise:**

Turn noise was observed as on when streamers bending, caused by vessel deviations from shooting track due to field obstructions or fishing boats. However it was variable in the number of traces affected, was consistently severe in terms of amplitude (>25 µBar). Strongest turn noise (>35 µBar) was observed in western end of swath-04 (figure 8) due to shortening of run-in/out for the presence of a large number of sub-sea infrastructure. Turn noise mainly affects the data at start and end of line. On-board QC processers conducted turn noise removal test in shot domain by applying SVD, cascaded AAA, LNA and RNA.

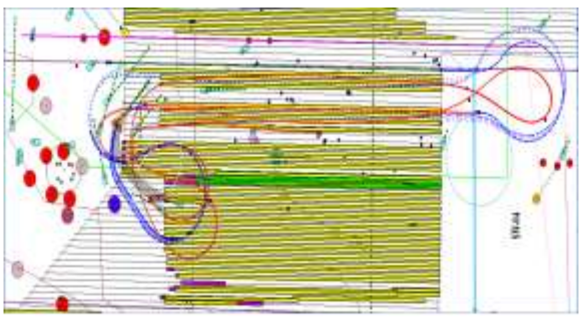


Figure 8: Streamer bends at western end of swath-04 due shorter run-in for the presence of installations.

- **Close pass/ Deadhead shooting:**

Safety distance (500m) from rigs & platforms was maintained during close pass. Production was planned so that acquisition around the many platforms in the prospect was made during the neap tides giving lower feather to achieve bin coverage closer to these structures. Also lines over the obstacles were covered by the deadhead sequences operated from opposite direction to improve near offsets coverage around the installations.

- **Undershoot:**

Two-boat undershoot operation as also conducted to fill the coverage gap nearby the rigs, platforms or their associated barges which was left by normal shooting. Total 51 undershoot sequences were attempted to complete 38 pre-plot lines.

3. FISHING ACTIVITIES:

The prospect area was situated close to many fishing villages along the north coast of Mumbai. Dense fishing activity was observed during the campaign. The most challenging part of the survey was dealing with the fishing vessels; gill netters, trawlers and the most problematic by far are the stake netters.
A flotilla of 39 chase vessels were acting as scout and guard each vessel, the effectiveness of this has been limited and it has been a hard job making any production during the periods of higher fishing activity.

Stake net: Stake net was the typical challenge for streamer mode seismic acquisition in especially shallow water in west coat of India. It usually wooden (bamboo) or steel pipe driven into the seabed, to these are attached two polypropylene ropes. This stake netting occupied mainly the NE side of the survey (approximately 35-40% area), as a rough approximation the fishing stakes are laid everywhere inside the sea of the 35m water depth. Stake ropes will surface when currents are low and if the streamer is at shooting depth, the rope will catch onto it and will damage.
To avoid stake net hazard some dynamic approach was adopted during the survey.

- The streamers were surfaced when currents are <0.5 knts in the area where water depth is less than 35 m
- Offshore Mumbai, in particular the shallower areas towards east, the tidal currents are clearly defined as semidiurnal. The tidal tables (refer to figure 9) from Mumbai port were used to roughly calculate the slack water periods, spring and neap cycles which dictated the fine tuning of the planning. The idea was to use the slack water periods for line change and the high current period to shoot. Keeping a diligent eye on the ~6 hour cycle and close attention to the area (shallows or deeps) were the key to successfully implement tidal shooting plan.

4. ENVIRONMENTAL OBSTACLES:

- **Tidal Shooting:**

Because of the need to raise streamers on slack water due to shallow water (20-30 m) & stake-net, all the production lines in the northern 3 swaths had to be split into two so that the line lengths were achievable within the tidal slot. Taken in racetrack this had the advantage of shooting adjacent lines with similar feather conditions over successive tides. This reduced the overall infill requirement but introduced additional line changes which accounted for 10.1% of the survey duration. Also fan mood shooting (50% fan) approach adopted in this region to minimize the infill probability.

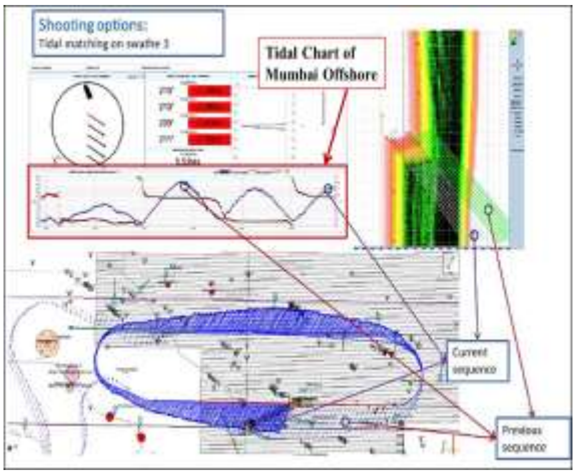


Figure 9: Tidal shooting to minimize father miss match.

- **Damage Control:**

The seawater in this area is also known to cause an accelerated corrosive effect. This was verified when the one vessel had to pull off the survey to repair the front end of a streamer and it was notices that 20-30% of the steel of monowing (main towing bridle) corroded only in 65 days of survey. This necessitated a full front end recovery to replace the towing chains, at the same time the spread was reduced from 8 to 6 streamers to increase maneuverability in amongst the multitude of stake fishing vessels. High corrosion was also witnessed on gun arrays and all other in-sea gear.

- **Swell Noise:**

Throughout the survey period sea was almost favourable for seismic operation except in the last month, June when SW monsoon arrived at the prospect and it lead noise level sometimes more than 30-35 µBar due to sea swelling.

Swell noise analysis (figure 10 & 11) was performed for every sequence which had > 25 µBar RMS noise, affecting more than 5% of traces and it was removed in shot domain by the same processing approach of turn noise. Total 3 sequences were totally scratched as it test result was not upto the mark. Later on, to reduce swelling effect streamers were allowed to deep 1-2 m more.

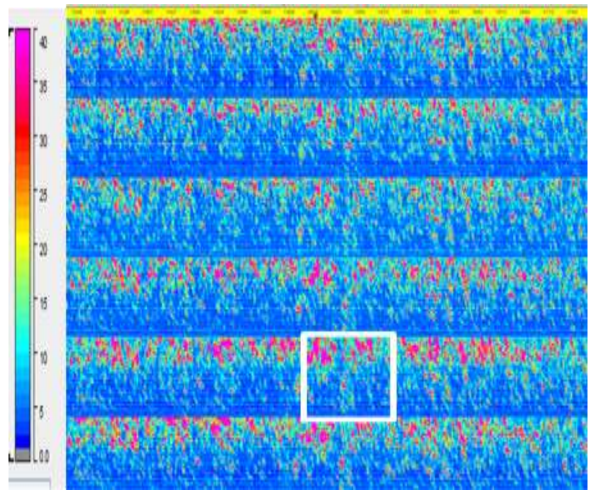


Figure 10: Effect of swell noise (red, >25 µBar RMS) for all 6 streamers on background RMS plot.

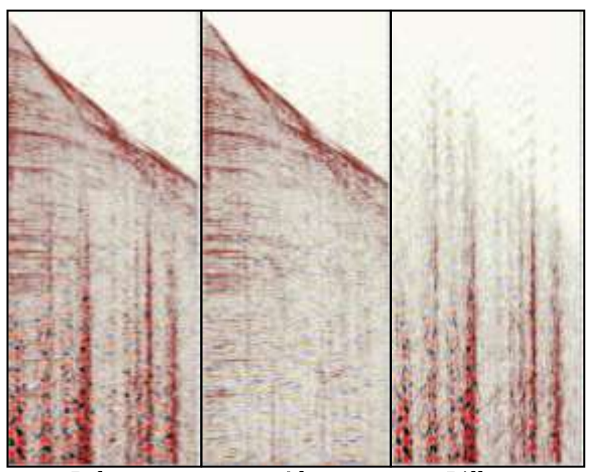


Figure 11: Example of swell noise attenuation test, performed in the white box region of figure 7.

- **Great Nepal Earthquake:**

All streamers for 37 consecutive shots were affected by 7.8 magnitude mega earthquake, originated in Nepal on 25th April, 2015. The noise was on an average of 15 µBar RMS having low frequency (0-8 Hz). 3D AAA in Tau-P domain tool was able to reduce this noise in field processing.

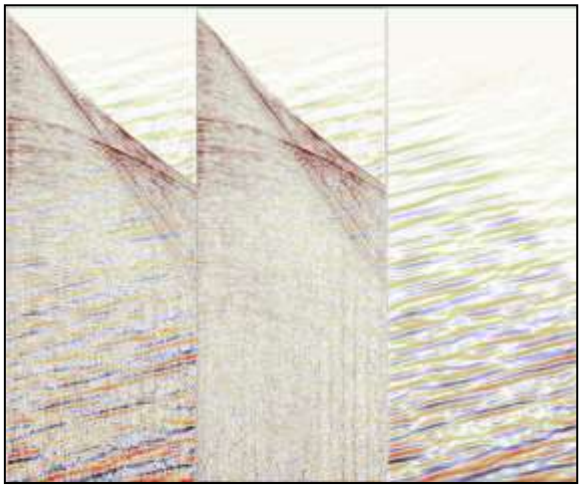


Figure 12: Nepal earthquake noise attenuation result.

CONCLUSION:

Streamer mode seismic data acquisition in potentially reach and matured oil field like Mumbai offshore was a challenging task. Not only different noise but also coverage was hampered by number of installations. Also the stake nets in wide shallow water (< 35 m) region demands a separate acquisition planning. It was tried to avoid seismic interference throughout the project as much as possible, but the affected data were processed in vessel itself to recover the original data. Finally, the intense planning & extra processing efforts made it possible to overcome all challenges without compromising the data quality. The work standard of this project sets a reference for feature projects in this region.

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ABBREVIATION OF WORDS:

SINE- Seismic Interference Noise Elimination
SVD-Singular Value Decomposition
AAA- Anomalous Amplitude Attenuation
LNA- Linear Noise Attenuation
RNA- Random Noise Attenuation

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