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Eliminating Marine 4D Positioning Errors - How Close Are We? A North Sea Case History

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SUMMARY

We present a North Sea 4D acquisition case history that achieved very high repeatability as a result of detailed planning and the use of a new automated and integrated vessel, source and receiver control system. The new control system virtually eliminates source positioning errors. Streamer feather matching to a baseline survey is shown to be highly repeatable through the use of steerable streamers and shooting each line at the appropriate time in the tidal cycle. The combination of these two factors lead to excellent feather matching despite a +/- 7 degree natural feather variation. Results from the survey show that 94% of the co-binned traces had a combined source and receiver positioning error of less than 25m from their planned positions.

Introduction

A new automated and integrated vessel, source and receiver control system has been demonstrated to improve the accuracy and repeatability of 4D surveys. In summer 2007 this system was used to record a 4D monitor survey over an existing 3D survey recorded in 1992. The automated vessel and source steering virtually eliminated source positioning errors (95% of shots within 2m), while tidal cycle matching and streamer steering were used to minimize receiver positioning errors. Post-survey analysis shows that combined source and receiver errors (Δ source + Δ receiver) between the monitor survey and the pre-plot of the monitor are less than 25m for 94% of the survey. This success was achieved despite significant obstacles: the disparity between the acquisition parameters of the old and new surveys; the irregularity of the baseline survey e.g. non-straight source lines; and finally, tidally driven currents giving rise to a $\pm 7^\circ$ feather variation in receiver positions. Only after significant pre-survey analysis and planning was it concluded that these obstacles could be overcome and the survey acquired with the high level of repeatability needed for this field.

This paper reviews the new control system and how it leads to improved repeatability of source and receiver positioning. We then describe the planning process: the steps taken to provide a navigation plan that would minimize the repeatability errors. We present the results of the survey in terms of source position relative to the navigation plan, feather relative to the navigation plan and a set of “bin-based” attributes that describe the repeatability.

Method

Brown and Paulsen (2008) described a new automated vessel, source and receiver positioning system. This system was developed to automatically steer the vessel, the sources and the streamers to achieve the best possible 4D position match. In the development of the system, three important features were identified:

Automation – It is not possible for an operator to accurately predict the behaviour of the towed spread and the vessel in a changing current environment.

Independent source steering – Controlling the source position independently improves the receiver repeatability.

Planning and QC – Planning a 4D survey acquisition is more involved than planning a regular exploration 3D survey. Hence, dedicated software was developed to provide an optimised navigation plan for each 4D monitor survey.

During summer 2007 the above three features of the control system were used to full effect in acquiring a 4D monitor survey over a producing oilfield in the North Sea. The original survey in 1992 was recorded with three streamers, had very irregular shot positioning compared to its pre-plot positions and large feather variations between adjacent sail-line passes. This was the result of a “shoot-for-coverage” policy and no attempt to shoot adjacent sail lines at similar tidal conditions, resulting in a survey with high infill. Pre-survey planning revealed that if streamer feather could be matched, and taking standard shot location accuracy into account, the Δ source + Δ receiver repeatability produced by matching source locations between base and monitor surveys is not significantly better than using straight source lines in the monitor survey. Therefore it was decided to shoot the 2007 survey as a new baseline with straight shot lines, improved spatial sampling of the wavefield and to attempt to repeat the 1992 feather. Feather analysis of the 1992 navigation showed that the feather was controlled by the tidal currents so the acquisition plan had to be recalculated daily during the survey to allow sail lines to be started at their correct point in the tidal cycle whilst minimising time waiting for the correct tidal conditions.

Survey Design and Planning

During planning for the new survey, analysis of the 1992 navigation data showed that the rapidly varying feather strongly correlated with the local tidal currents; a subset is displayed in Figure 1 (left).

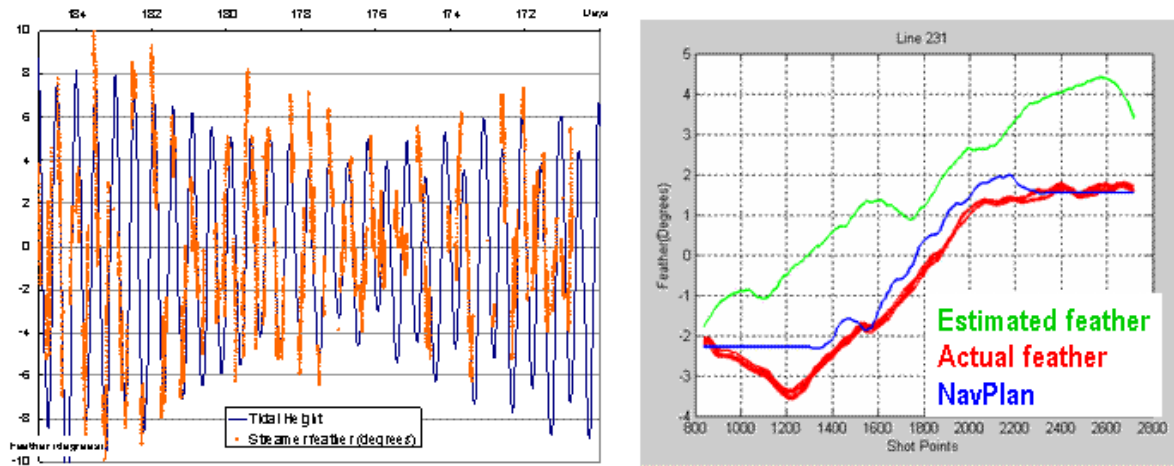


Figure 1 - Base survey streamer feather overlay on tidal heights during recording, showing strong correlation between feather and tide (left) and (right) planned, estimated and actual feather for one line in the new survey. The green line is the feather predicted by the onboard current meter and is the feather that would have been recorded if streamer steering was not used to control the spread. The red line is the actual feather recorded against the navigation plan shown in the blue line.

The 1992 3D survey used three streamers at 100 m spacing and dual sources with 50 m spacing to deliver 25 m x 6.25 m bins. The sail-line spacing was 150 m. The 2007 survey was designed with an eight streamer configuration at 50 m spacing and dual sources with 25 m spacing to deliver 12.5 m x 6.25 m bins. The sail-line spacing was again 150 m. This geometry gave finer cross line sampling and the additional streamers were used to provide a four CMP overlap between adjacent sail lines. Although the sail-line spacing would be identical to the 1992 survey, the different source spacing meant that repeating source locations would not be possible.

To evaluate Δ source + Δ receiver between the base and the proposed monitor survey, the feather profile for each sail line from the 1992 survey was assigned to the corresponding monitor sail line and a full synthetic navigation dataset was produced. This was then used with the base navigation to co-bin and produce Δ source + Δ receiver maps for all offsets. Different acquisition geometries were tested and it was found that the chosen acquisition configuration gave an average Δ source + Δ receiver of 50 m. Not including the previous feathering in the modelling produced an average Δ source + Δ receiver of 130 m; which would not be acceptable. It was therefore decided that shooting different shot locations would be acceptable but that streamer feather would need to be repeated as accurately as possible.

Delivering the acquisition plan required the 2007 survey to have each sail line starting at the same point in the tidal cycle compared to the 1992 lines with an allowed error of ± 30 minutes. This was calculated by interrogating the 1992 navigation data and then using the predicted 2007 tide tables to produce a start of line time for each 2007 sail line. The small time window for the start of each sail line within a tidal cycle and the amplitude variation within the monthly tidal cycle, combined with the requirement of minimising downtime, produced an irregular sail line shooting sequence that had to be recalculated every day as factors such as weather, fewer lines being left to shoot and technical downtime invalidated the previous shooting plan.

Operations and Onboard QC

To ensure that the project was delivered to the required specifications and within budget required careful and rapid quality control. On board QC for seismic and navigation data quality control was collated and reviewed on-shore to revise the shooting plan. The major external control on the receiver repeatability was the tidal currents; the tidal predictions were calibrated using the z component of the DGPS on the gun string, which showed that the tidal model was accurate. The major control on the

source location was the integrated navigation system which immediately showed exceptionally good source positioning. Each sail line was evaluated to see if the line had begun in the allotted time window, if the acquired feather matched the modelled feather (shown in the right-hand side of Figure 1), how close the acquired source was to the pre-plot, the 3D fold coverage and the 4D measure of Δ source + Δ receiver. Once a line was accepted then the shooting plan was recalculated to minimise any time waiting for the correct tidal conditions.

Positioning Repeatability

Source positioning proved to be very accurate: 95% of the source locations were within 2 m of the planned positions. This is an accuracy that cannot be achieved without the aid of steering control as described above. Conventional systems typically deliver shot repeatability of 12 m to 20 m accuracy. Feather repeatability was also good: 95% of the survey had feather differences less than 3.75° from the planned feather. While shot repeatability is a good measure of the quality of the survey, feather repeatability is less so because it does not directly show receiver repeatability.

To demonstrate combined source and receiver repeatability we analysed the navigation data using a 4D bin-based method. For a single offset group, data are binned and within each bin the best pair of baseline and monitor traces is selected. The pair selected has the lowest Δ source + Δ receiver value. Areal plots are then generated showing various attributes of the selected pair e.g. distance between source locations, distance between receiver locations, the sum of the source and receiver differences Δ source + Δ receiver and the difference between the source and receiver azimuths.

As the navigation plan called for the shot locations to follow the straight line pre-plots and not the legacy shot positions, there were two types of repeatability QC to evaluate: firstly, the shot positions relative to the 1992 baseline and secondly, the shot positions relative to the navigation plan.

Figure 2 shows the results of the Δ source + Δ receiver values for an offset group of 2500 m: 94% of the traces are less than 25m from the navigation plan positions. This is an exceptionally low value and, assuming the next 4D monitor survey is acquired to similar repeatability, will provide a 4D dataset with very high repeatability.

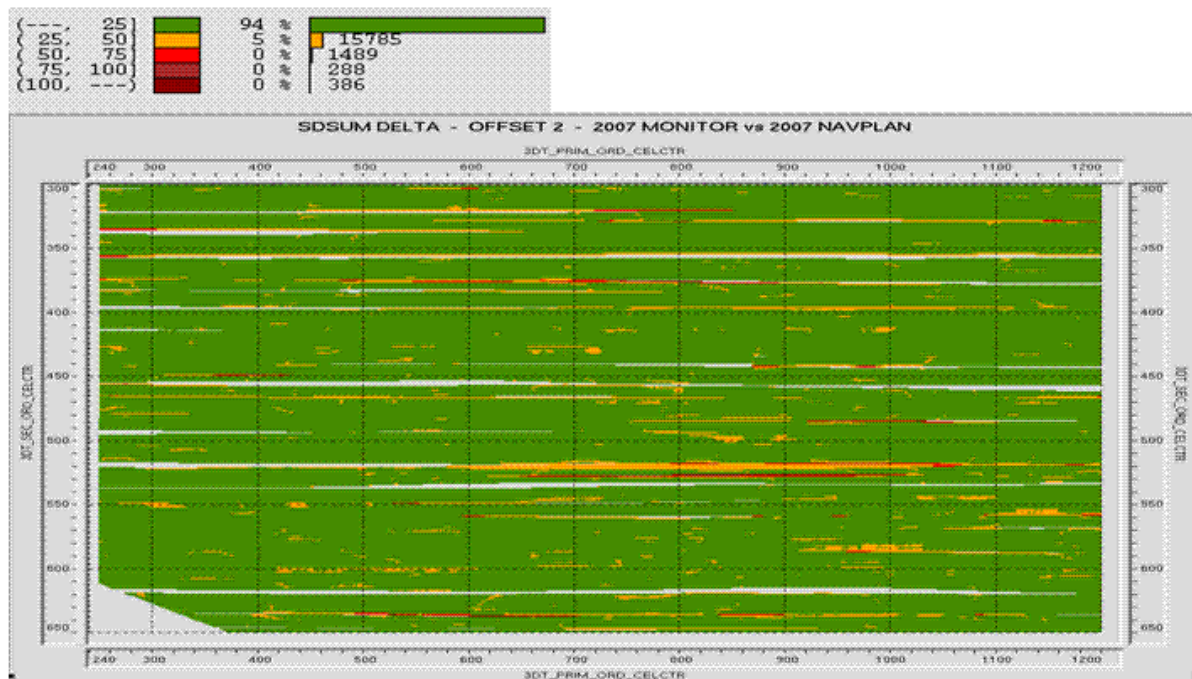


Figure 2 - Areal plot of CMP bins showing Δ source + Δ receiver values (in metres) for traces in the 2500 m offset group: 94% of traces have an error of less than 25m between the planned versus achieved positions.

By comparison, the results for the monitor-versus-baseline analysis show that 75% of the traces had a Δ source + Δ receiver less than 51 m. Even so, fast-track 4D processed results show there is a clear 4D signal. The value of improved repeatability in any future monitor surveys is that any subtle 4D signals, e.g. resulting from a smaller production interval, would be seen more clearly against the 4D noise.

Discussion

Improved steering control, detailed planning and robust operational execution have delivered a 4D dataset with exceptional positioning repeatability characteristics. This repeatability was achieved in an area of high tidal current variations giving natural streamer feather of up to $\pm 7^\circ$. One question that arises from these results is: How much of the success is due to planning i.e. shooting at the optimum time of the tidal cycle and how much is due to the compensating effect of streamer steering. Figure 1 demonstrates that streamer steering correction was significant for the line in question. Analysis of all other lines in the survey is ongoing. In Brown and Paulsen (2008) we showed that steering devices with maximum force delivered between 2° to 3° of feather correction. Analysing streamer horizontal forces allows us an alternative method to estimate average feather correction throughout the survey duration.

Conclusions

This marine 4D case history has shown how exceptional positional repeatability can be achieved through the use of a novel steering and control technology coupled with streamer steering, detailed survey planning and in-field execution. These results were achieved in the presence of strong (but predictable) tidal current fluctuations which, on the baseline survey, gave rise to feather variations of $\pm 7^\circ$. Tidal cycle matching was used to minimize the streamer feather difference between the baseline and monitor surveys. A further reduction of streamer feather differences was achieved through streamer steering correction. The automated vessel and source steering virtually eliminated source positioning errors (95% of shots within 2 m) compared to the desired source locations. This exceptional source positioning has proven very beneficial: Δ source + Δ receiver between the monitor and pre-plot of the monitor are less than 25 m for 94% of the survey, while Δ source + Δ receiver between the monitor and base was less than 55 m for 75% of the survey. The new control system successfully allowed the project to accurately acquire a very complex survey design on schedule and under budget.

Acknowledgements

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References

Brown, G., Paulsen, J-O., (2008) Improved marine 4D repeatability using an automated vessel, source and receiver positioning system, 70th EAGE Ann. Mtg., Rome, Abstract B028