Acquisition of high shot density blended seismic data: a WAZ sea trial
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Summary

In this paper, we present the results of a high shot density sea trial recently performed in the Gulf of Mexico. The seismic data are acquired over an existing wide-azimuth and extra-long offsets survey. The higher shot density acquisition is achieved by reducing the shot point interval and taking full advantage of the continuous recording technology. The resulting blended seismic data are up to three times denser than the reference data without extra acquisition cost. Comparisons between blended and reference datasets show encouraging preliminary results.
**Introduction**

In the past decade, the benefits of wide azimuth (WAZ) acquisitions over conventional narrow azimuth (NAZ) surveys have been demonstrated in complex geology area (e.g., Gulf of Mexico); WAZ techniques provide better subsurface illumination and better seismic resolution (Howard, 2007). However, one of the known limitations of multi-vessel WAZ designs is the constraints imposed by the relationship between the number of seismic sources, the speed of the vessels, the shotpoint interval and the length of the seismic records. As a consequence, adding extra seismic sources to improve the illumination generally results in a loss of shot sampling in the inline direction. A way for increasing the shot point density while controlling the acquisition cost (i.e., the acquisition time) is to allow temporal overlap of the seismic shot records (blended acquisition) by firing the seismic sources more often (e.g., Berkhout, 2008).

Different shooting strategies are available for acquiring blended seismic data. A first strategy is to activate nearly simultaneously a combination of seismic sources. Long *et al.* (2013) present a method using a dual-vessel configuration, a streamer vessel and a source vessel, with dithered firing times of simultaneous sources for acquiring long offsets data. Dragoset *et al.* (2009) describe a sea trial in WAZ context with four seismic vessels involved and where the sources are simultaneously fired by pairs. As in the previous cases, simultaneous shooting with randomized firing delays is used to increase the shot density allowing a better seismic image of the subsurface. However in the case where more than two source vessels are involved in the survey, this shooting strategy is questionable. Should we activate more than two seismic sources simultaneously? What would be the impact from a processing perspective? For instance, Peng *et al.* (2013) have shown on synthetic dataset that the de-blending difficulty increases with the number of blended sources.

An alternative strategy for increasing the shot density is inspired from seismic land acquisition. Berkhout (2008) proposes abandoning the condition of non-overlapping shot records by moving to densely sampled source distributions with various time intervals between consecutive shots. In this paper, we describe a high shot density field test performed in the WAZ context and implementing the following shooting strategy: actuating sources sequentially as usual, but more often by increasing the shooting rate and taking full advantage of the continuous recording technology.

**High density (HD) seismic data acquisition**

The HD seismic dataset was acquired during summer 2013 in the Gulf of Mexico along an existing acquisition line of a wide-azimuth and extra-long offsets survey. The staggered marine acquisition geometry (Mandroux *et al.*, 2013) is shown in Figure 1: five seismic vessels are deployed, including two streamer/source vessels and three source vessels. The inline shot point (SP) interval, i.e., the inline distance sailed by the acquisition spread between two successive shots, is 30 m. The variety of kinematics in the seismic data obtained with this geometry is illustrated by shot gathers panels corresponding to inner seismic cables of front and rear streamer vessels.

From an operational point of view, shooting sequentially five independent sources every 12 seconds (30-m SP interval) leads to actuate each source every minute, which is far from the minimum required time for refilling the seismic airgun source. In fact, there is room to actuate each source more often. Indeed, reducing the shotpoint interval is a natural approach for increasing the inline shot sampling. In practice, the minimum possible shotpoint interval depends on the speed of the vessels and the minimum required time for refilling the source airguns between two successive activations. In the context of continuous recording, for a considered record length, firing faster leads to blended seismic data: recorded wavefields generated by successive shots overlap in time.

The present field test consists of acquiring high density seismic data over an existing reference sail line. All acquisition parameters remain similar to the reference survey, only the inline shotpoint...
interval is changed. The first test-line is acquired with a SP interval of 15 m and the second test-line is shot with a SP interval of 10 m.

Figure 1: Staggered marine acquisition geometry (left) and recorded shot gathers (right). 2 source/streamer vessels (blue, red) and 3 source vessels (green, yellow, purple) are staggered inline. The geometry is representative of a $10 \times 120 \times 9,000$ m spread configuration providing an overall pattern of about 6 km by 18 km. Seismic records of inner cables of each streamer vessels: front streamer vessel at the top, and rear streamer vessel at the bottom. Each shot gather corresponds to an activated source.

Figure 2: Continuous 60 s inner streamer shot records for different SP intervals: 30 m (reference), 15 m (HD) and 10 m (HD). For each panel, the left column corresponds to the records from the front streamer vessel and the right column to the rear streamer vessel.

The continuous recorded seismic data are shown in Figure 2: traces with 60-second record length are displayed. In the conventional seismic survey the five successive shots allow 12-second unblended records, the water bottom appearing around 2.5 seconds. By shooting more frequently and reducing the SP interval to 15 m and to 10 m, the 12 seconds of unblended data are no longer available. However, reducing the time delay between two successive shots increases drastically the amount of reflected seismic energy of those records. The extra recorded energy will provide denser illumination and additional fold for better signal to noise ratio. Moreover, HD-blended acquisition provides a more uniform distribution of the recorded energy in the seismic gathers comparing to quasi-simultaneous
shooting strategy. This aspect of the blended data could be more favorable for model-based deblending algorithms as well as for migration algorithms customized for blended data.

**Preliminary results of high density seismic data processing**

Increasing the shot density allows enhancing the seismic fold. This is illustrated in the NMO-corrected CMP gathers displayed in Figure 3. These gathers are built from the reference 30-m SP interval data and the HD 10-m SP interval data, respectively. It is obvious that the HD gather is significantly less subject to aliasing than the reference data. The strong free-surface related multiple reflections appearing in the bottom part of the gather will naturally stack out on the final image thanks to its un-aliased behavior.

![Figure 3: NMO-corrected CMP gathers built from the reference 30m SP interval data (left) and from the HD 10m SP interval data (right).](image)

A fast track prestack depth migration using only a small percentage of the raw seismic data (i.e., no active deblending applied) is performed in order to assess the amount of cross-talk noise generated by the blending interferences of the HD data in the image domain. Figure 4 shows a comparison of the time-converted images obtained by the depth migration of acquired HD-blended data with the reference unblended data of the same sail line. The incomplete images of a single navigated line are quite similar and the imprint of cross-talk noise is rather limited. The coherence of interfering blended shots is destroyed quite well, even through the use of a standard migration algorithm not customized for blended data. Moreover, the extra fold or illumination of HD data (three times denser) seems to bring more reflection at the upper part of the section (a) and attenuate some deeper migration artefacts (b). Further investigations on the benefit of active deblending and/or imaging with migration customized for blended shots are in progress. Nevertheless, those preliminary results encourage the use of an HD approach to blended multi-vessel acquisitions.

**Conclusions**

Blended Wide Azimuth data have been recently acquired in the Gulf of Mexico with a high shot density. The proposed HD strategy allows us to significantly increase the amount of source density, up to a factor of three, without extra acquisition cost or additional equipment; the approach consists of speeding up the firing sequence by reducing the inline shotpoint interval and taking advantage of the available continuous recording technology to acquire the seismic data. The extra fold and illumination of blended seismic data, uniformly distributed along the continuous records, lead to migrated images with limited crosstalk noise. The preliminary processing, without any dedicated deblending technique, shows very encouraging results. HD wide-azimuth acquisitions are a powerful approach for denser illumination and additional fold.
Migration of one sail line of reference data
(un-blended)

Migration of one sail line of HD data:
three times more shots than reference (blended)

Figure 4: Seismic images obtained through the migration of reference sail line with 30 m SP interval (left) and the migration of HD test line with 10 m SP interval (right). No any active deblending has been applied. Migrations of full reference data indicate that (a) corresponds to the geology and (b) to artefacts.

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References


