Improving Data Quality and Operational Efficiency through Recent Advances in Acquisition Technology

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Summary

Seismic recording equipment engineering and manufacture has experienced an evolutionary change in the past 20 years. In addition to great strides in channel count and flexibility, the cost per channel has dropped steadily as well.
Seismic contractors utilizing modern equipment can economically shoot in virtually any region that can be accessed with little or no lasting impact on the land and at the same time the quality and utility of the recorded data has increased inversely to the cost.
These evolutionary strides are supported by higher channel counts; lighter more flexible equipment and amazing advances in source technology including operational strategies which produce 20000 or more source points in a single day of shooting. The growing trend of high density single point sources combined with single point sensors is yielding high fold data of unprecedented quality.
This presentation will explore some of the milestones in seismic equipment development and the operational changes that have enabled this evolutionary change in the quality and cost of seismic data.

Introduction

Research and development in seismic recording equipment is often taken for granted since it has always just seemed to happen independent of the rest of the industry. Driven by a competitive market for equipment sales, the advances and milestones along the way may have seemed insignificant to the explorationist. However, looking back at the individual strides in R&D and their impact on current recording a clear picture emerges of the forces that have driven the changes which yield the current results. In some cases with consequences that were never part of the plan outlined by the original efforts.
Vibroseis development has made great strides in the previous 10 years. The current "off the shelf" vibrator can sweep broader band, with better phase control and limited distortion than source units only 10 years old. These improvements are the result of the application of modern engineering methods applied to what is now old technology. Production sweeps starting as low as 1.5Hz have been successfully employed in multiple regions of the world while frequencies as high as 300 Hz have been swept in other areas.
Ultra-high channel count recording systems and cableless technology are providing a degree of flexibility in survey design which is also unprecedented. Traditional group intervals and trace densities are yielding to high density single point acquisitions with group spacing as small as 10 meters. Contractors routinely deploy 20000 to 40000 of live channels in many parts of the world. Discussions regarding the use of wide or narrow azimuth geometries and stacking fold have become obsolete, overwhelmed by the sheer numbers of traces delivered by a modern seismic crew.

What Makes the Modern Vibrator Shake?

Vibroseis technology was first proposed and introduced to the industry by Conoco in the 1950s. R&D since can be summarized by efforts to increase the energy delivered by the vibroseis and to control and understand the energy that is delivered. These efforts yielded bigger, heavier vehicles, better controllers with real time feedback and operational patterns that often had multiple units sweeping simultaneously. Research from a small group of industry experts expanded the understanding of the complexities involved in a seemingly simple process. Yet the production parameters seemed all too familiar and all too common. An 8-60Hz, 10-12 second linear sweep with standard cosine tapers or something nearly identical was the norm. A few mavericks attempted to push the frequency envelope but little in the way of lasting paradigm changes prevailed.

Then in the early 2000's things started to change more quickly. Modern engineering and computer modelling methods began enlighten developers. Building on the works of earlier researchers, the behaviour of individual vibrator components could be analysed, understood and corrections implemented. Among those advances are software and firmware controls to the servo valve, improvements to the hydraulic controls and a better understanding of the baseplate-earth coupling that has prompted stiffer more ridged baseplates. Combined, these improvements have created a vibrator which sweeps the common 8-60Hz sweep with better control, but more importantly, better consistency across a broad range of surface types. The key to better vibroseis data will always be a better understanding of what energy the vibrator puts into the ground.

Understanding the mechanics and hydraulics of the modern vibrator have led to other advancements like better controllers and sweep design. Controllers play a key role since they interface with the vibrator through firmware, software and respond to feedback loops in real-time attempting to adapt to changes and drive the vibrator to achieve specific energy delivery goals. The controller feedback is supplied by accelerometers usually on the baseplate and mass of the vibrator shaker assembly, and current engineering has even demonstrated optimal placement for those accelerometers.

In the past 2 years it has become common the start sweeps as low as 1.5-2Hz extending the energy by octaves in the low frequencies. This was enabled because of the improvements outlined above, and the understanding of the performance characteristics. Designing custom sweeps which drive a vibrator within its theoretical performance profiles has made it possible to start sweeps in these very low frequencies and perhaps more importantly, to understand the potential outcome and set the expectations for what is possible.

The higher frequencies have also benefited from these advancements. Small sized vibrators can sweep as high as 300-400Hz when frequencies in those ranges are expected in programs with shallow targets or VSP operations while maintaining phase and energy goals.

Higher density shooting with single, better controlled and understood vibrators is changing the way seismic data is shot. Desert operations in the Middle East employ huge fleets of vibrators and high productivity shooting methods to achieve fantastic source production rates, but more importantly better seismic data. The observed trend is that those technologies and operational methods will find their way into every region of the world and produce similar improvements in data quality. We already see signs of these trends in areas like

Figure 1 shows a small sized vibrator working in a national park in Uganda. Picture courtesy of the oil sands of Athabasca which 10 years ago was believed to be a dynamite only region.

Figure 2 shows a compact cableless node with a connected battery and 3C sensor.

RECORDING SYSTEMS

Ask anyone that has been around seismic data recording a while and the thing that is most amazing is the increase in equipment and channel counts. In the early 1990's when 3D seismic was picking up, distributed cable systems could field 2000-4000 channels live. As demands for wide azimuth and denser receiver geometries increased, channel counts on crews began to grow. A second, simultaneous technology was 3C geophones and the prospect of full wave field recording which increased the demand on channel count by three times. While 3C recording today remains a special case, recording system development has delivered. 20000 to 40000 channels live are now common and 200000 channels and up are possible. System components have grown lighter, are less power hungry, more reliable and most importantly, cheaper. Old issues like system timing and filter response have taken a back seat to channel count because high fidelity, low noise systems with precision timing is a standard capability of the current available systems.

In the early 2000's cableless system technology was introduced. Made possible by the availability of off-the-shelf precision A/D converters virtually anyone with the resources and a few good engineers could submit a contender in the system market. Today in North America, cableless equipment has all but totally replaced cabled seismic equipment as the method for collecting data. This evolutionary change was driven by two main factors. The primary reason is development and availability of cost effective reliable gear. The second reason is because modern cableless systems are comprised of remotely deployable nodes, each of which is a standalone recording system. By virtue of this architecture, the systems are fully scalable and can be deployed at any group interval and in virtually any setting were access is possible. It is this flexibility of the equipment which has made the concept popular with the contractors and explorationists alike. Survey design is no longer constrained by cable lengths or connections and virtually any geometry is possible with any type of sensor configuration.

CONCLUSIONS

Many changes in source and system development have led to the current modern seismic equipment. Improvements in vibrator technology have led to more accurate and better understood source which can sweep a very broad range of frequencies. Recording systems provide a level of flexibility and capability which is unprecedented.