A field test and performance evaluation of accelerated weight drop (awd250 v1.0) for shallow seismic survey

Alfian Bahar, Fatkhan*, M. Rachmat Sule

Geophysical Engineering Study Program, Institut Teknologi Bandung, Jalan Ganesha 10, Bandung 40132, Indonesia

E-mail: fatkhan@gf.itb.ac.id

Abstract. The acquisition of seismic reflection involves generating and recording seismic wave field on/near the surface of the earth. Success of producing high quality seismic data depend on choice of seismic sources. There are commonly seismic sources for land seismic surveys such as explosive sources, vibrators and Accelerated Weight Drop (AWD). In some cases, the use of explosive sources often faces many problems, especially related to the costs, permission and environmental issues. The use of vibrators is also similar, facing problems such as the availability of access roads, permits and the environment impact. The use of AWD seems to be a solution as an alternative seismic sources when explosive or vibroseis cannot be used for some reasons. In this research, we have designed and built a mechanical seismic source named AWD250V1.0. This hand-made AWD prototype was developed for shallow seismic surveys. To evaluate the performance of this tool and to improve the design of the prototype, a field tests have been carried out. The test was conducted in Ciparay village, Bandung Regency, West Java. The survey area is mostly paddy field with the near surface covered by clay and highly seismic attenuation. The purposes is simply whether AWD can work properly or not while maintaining data quality and safety standards. In addition, the test is intended to find out how deep penetration of seismic waves using this source. Seismic recorders used were 96 channels with interval between receivers was 10 meters. Findings showed that the deepest reflection can be seen around 450 milliseconds or approximately 400 meters. To sum up, the device is work well and is able to produce good quality of seismic sources. The prototype can also meet design criteria that are repeatability, portability, economical and environment friendly.

1. Introduction

Seismic survey are often used in petroleum and gas exploration to map or delineate such as stratigraphy formations, lateral continuity of geologic layers, faults in sedimentary layers, and others. These can be deduced through analysis of the nature of reflections and refractions of generated seismic waves from interfaces between layers within subsurface formation.

A seismic energy source is used to produce seismic waves that travel through subsurface of the earth and are eventually reflected back by various subsurface formations to the earth's surface. As the seismic waves reach the surface, they are detected by some array of seismic detection apparatus that are known as geophones. These transduce waves are detected into representative electrical signals. The electrical

* To whom any correspondence should be addressed.
signals produced by such the array are collected and analyzed to permit deduction of the nature of the subsurface formations at a site.

There are several types of seismic energy sources that have been used in seismic survey methods for petroleum, gas, coal, other mining exploration operations and geotechnical investigation, such as explosives, vibrator and impact sources. The nature of output seismic energy depends on the type of seismic energy source that was used to generate it.

Seismic acquisitions can be regarded as success if they can generate high quality of seismic data. There are two kinds of parameters to make high quality of seismic data those are signal to noise ratio (S/N) and resolution. These two parameters rely on seismic energy sources used [1][2]. Present day, there are several kinds of seismic energy sources that have been used in seismic acquisitions on land, such as dynamite, vibroseis and Accelerated Weight Drop (AWD). Selection of the seismic energy sources depend on many aspects, such as purposes of survey, cost, operational obstacles and environmental impacts.

The use of explosive sources such as dynamite have been widely used for land seismic surveys for many decades, generating high-energy high-bandwidth source. However, it often experiences many problems, for instance the operational in the field, environmental impact and regional government permission process. In addition, the use of dynamite is too expensive since it needs to drill a hole in the ground to place the explosive before initiating the explosion.

As an alternative to explosives, a mechanical-hydraulic vibratory sources e.g. a vibroseis truck has been used for petroleum and gas exploration. However, the vibroseis truck as a seismic energy source is not extensively used on land in Indonesia since it is often not suited to certain types of terrain or area. For example, it can be difficult to use in rough relief of topographical condition and dense population or vegetations. Hence mobilization of the vibroseis truck cannot be easy to operate.

We have to compromise between dynamite (cost and time consuming) and vibroseis (bulky, need much space). Therefore to overcome the problems of seismic energy sources for land seismic data acquisition, the utilization of AWD sources is one possible alternative solution. We design AWD to meet criteria that accommodate all problems faced for shallow seismic survey in Indonesia. AWD systems have been used from early days in seismic data acquisition, but in the last two decade, many improvements have been made in term of mechanisms to produce more reliable and repeatable source [3].

The basic principle of a weight drop is a mass of weight dropped from a certain height to hit the base plate at the ground. During the fall, the mass accelerates and when the mass hits the base plate, the momentum will be transferred to the ground. This momentum transfer occurs in a very short time. The force acting on the ground during this time interval will produce shock pulses which then propagate as seismic waves to subsurface of the earth. Various mechanisms have been developed to increase the speed of the mass when hitting the base plate so that the resulting seismic energy increases and the shape of the seismic pulses becomes sharper, including using elastomer rubber bands, high pressure air (pneumatic system). This system is then better known as Accelerated Weight Drop (AWD) or sometimes called seismic Thumper. By using this basic AWD principle and considering several design criteria, one AWD product has been designed and built by hand made. The prototype of the design of this tool is named AWD250v1.0.

2. AWD Design and Specifications.

The AWD is basically a surface “impact” type seismic energy source. The impact source is a weight striking ground surface to a metal baseplate placed on the earth's surface, generating seismic energy. There are several criteria and specifications in designing the AWD seismic source:

1. Energy impact : minimum or equivalent to 0.25 kg of dynamite or 2000-8000 Joule and penetration of reflected signal to 1000 m depth.
2. Strike consistency : energy and frequency content have to be consistent every strike.
3. Repeatability : source signature has to be consistent from one shot to others. It means that repetition of energy source requires amplitude, phase and spectral content are as similar as possible.
4. Transportability & Protability: it is easy to carry and to assemble in the survey area.

5. Complexity: simple and easy to operate.

6. Economics: commercially viable to build and to operate. Also it is relatively inexpensive for routine maintenance.

7. Maximum size (W x L x H) 1.2m x 2.0m x 1.7m, maximum total weight of AWD (trailer, frame, baseplate and hammer) must be less than 500 kg.

After selecting several alternative mechanical solutions, the rubber belt elastomer has been chosen as the mechanism for accelerating the hammer mass. Elastic latex rubber material is stretched when the hammer mass (250kg) is lifted up to a height of 0.5m, so that it has potential energy from the gravitational force and tension of the rubber band. Then, the hammer mass is dropped until it hits the baseplate on the surface. This mechanism will produce a higher impact energy than the free fall mass. The kinetic energy released is proportional to the hammer mass and the final velocity squared when mass strike to the baseplate.

3. Prototype of the AWD source

The construction of this prototype of the AWD seismic source was conducted by hand made. Some components use used material whilst others, such as latex rubber, use new factory made material. The lifting system consists of 5 HP gasoline engine equipped with electromagnetic coupling, sprocket and chain. The hammer weight is made from solid steel. The AWD source system is mounted on a designed trailer that is able to move agile in small and bumpy road. The designed trailer has four wheels, each two in front and rear. The front wheel is slightly smaller in diameter than that of real wheels. This will make the trailer can be easy to move around the survey area even there is no access road available. Figure 1 shows the model and prototype of the AWD seismic source and Figure 2 shows operating the AWD in the field.

4. Field Data Acquisition

This field test would lead to the development of new source method which hopefully would be of the same quality of data as dynamite, but would also lead to easier permitting procedure through more environmentally friendly. In order to evaluate future application of the AWD as complimentary source to shallow seismic acquisition, we had to test its performance in the field. The objective is to evaluate the efficiency of AWD source capable of generating signals that can be observed in consolidated sedimentary rocks. Moreover it also has to maintain data quality and safety standards. The target is shallow at around 100 ms to 500 ms two-way time (TWT) and the AWD sources were situated on the surface. Location of field test survey is Ciparay district, Bandung regency in which mostly paddy field with weathering zone, mostly clay. More over, the near surface is highly absorbent for high frequency and fairly high seismic attenuation rate. Figure 2 shows operating the AWD source in the field area.

![Figure 1: The model and prototype of AWD250V1.0.](image1)

![Figure 2: Operating the AWD seismic source in the field.](image2)
Seismic recorders used were 96 channels system with 10 meter receiver interval. Whilst interval between shot point was also 10 meters. The distance between shotpoints is 10 m with the number of shot are 5 times each point. AWD works well and was able to produce data from 80 shotpoints location in less than 5 hours. The movement of this tool in the survey area is quite agile, both on asphalt/concrete and rocky dirt roads. The consistency and similarity of the source recorded signal from one firing point is quite good, except for the first records as shown in Figure 3.

Shots were carried out 5 times each point that can be used to further increase the S/N ratio of the recording signal. The regularity of the source wavelet is a very valuable characteristic for seismic acquisition. All recordings of 5 repeating shots were then summed to produce one stacked shot record. The frequency content recording signal yielded was up to 80Hz, despite this characteristic depends much on base plate coupling with the ground surface.

5. Data Processing and Results

In this field test, a 1.1km seismic line has been successfully acquired. Total of 110 shotpoint locations have been recorded, where each shotpoint position was recorded 5 times. The five records of each shotpoint are then stacked to get single record each shotpoint. All stacked shot records are then processed to produce stacked seismic section section. A very significant increase in s/n ratio can be seen in data shot records after stacking (Figure 4) compared to single shot records. Noise due to traffic activity that is quite dominant in the single shot records looks reduced by the stacking process of five shot records.

Seismic data were processed with the sequence:

- a. Data input
- b. Geometry assignment
- c. Refraction static
- d. Surface wave attenuation
- e. Deconvolution
- f. Bandpass filter and AGC
- g. Velocity Analysis
- h. NMO correction
- i. Stacking & Display

The result of seismic data processing are present in two way time seismic section (Figure 5). The horizontal axis shows mid point number (coinside with shotpoint number), while the vertical axis is the two way travel time in miliseconds. The datum of this section is the average surface elevation along seismic survey line. The seismic horizon (reflector) can be seen up to the depth of 450ms.
Figure 4. Shot records from one single shot (upper) are compared to records of 5 shot after stacking (below).

Figure 5. Stacked seismic section along survey line. Reflection signals are only visible up to a depth of 450ms TWT.
6. Field Test Results
After evaluating and analyzing field data and data processing results related to the performance and characteristic of AWD seismic sources, there are several results that can be summed up as below:

- Compacting effects at the source point have a strong influence on the data quality.
- The stability of the source signal waveform is critical things related to the improvement of the signal-to-noise ratio by vertical stacking of pulse sequences at each source point. Figure 4 shows examples of field records from single shot and after stacked five shot.
- One of the main shortcomings of surface sources is the presence of strong coherent noise waves (e.g. surface and air-coupled waves).
- Near surface conditions strongly influence the signal bandwidth (resolution) and signal energy
- There is an overall tendency that the content of higher frequency signals decreases with increasing source power. Figure 4 shows examples of repeatability tests and their frequency contents, whilst Figure 5 shows final result of seismic sections after data processing.

7. Conclusions
The performance of the AWD for use as a seismic energy source was examined on the basis of the results of the field test. A few significant findings of investigations can be pointed out:

- Alternative seismic energy source of the AWD convinces us that it has almost no environmental impact.
- The first prototype of the AWD source seems work well. In addition it is able to deliver good data quality as seen its reflectivity response is fair to good.
- The AWD source meets requirements needed, such as repeatability, portability and economic, provided the geology is not too complex. Moreover, it may be ideal for areas with limited access and sensitive environmental issue.
- From stacked section, maximum reflection signals are only visible up to a depth of 450ms TWT that is still below design criteria. Therefore it still needs improvement since it is not able to give reflected signal up to 1000m depth. Though impact energy also depends on subsurface condition in which field survey takes place.
- Future field tests are more focus to improve and to develop the AWD source so that reflector signals can still be identified up to the depths tested (1000 m). Hence the next version of AWD prototype hopefully will meet all criteria needed.

References
[1] Feroci M, Orlando L, Balia R, Bosman C, Cardarelli E and Deidda G 2000 Some considerations on shallow seismic reflection surveys Journal of Applied Geophysics 45 127-139.
[2] Knapp R W and Steeples D W 1986 High-resolution common depth-point reflection profiling:field acquisition parameter design Geophysics 51 283–294.
[3] Monk D, Ross J and Mooney B 2004 Using thumpers as a seismic source, Why an old technique is now ready for use SEG Int'l Exposition and 74th Annual Meeting