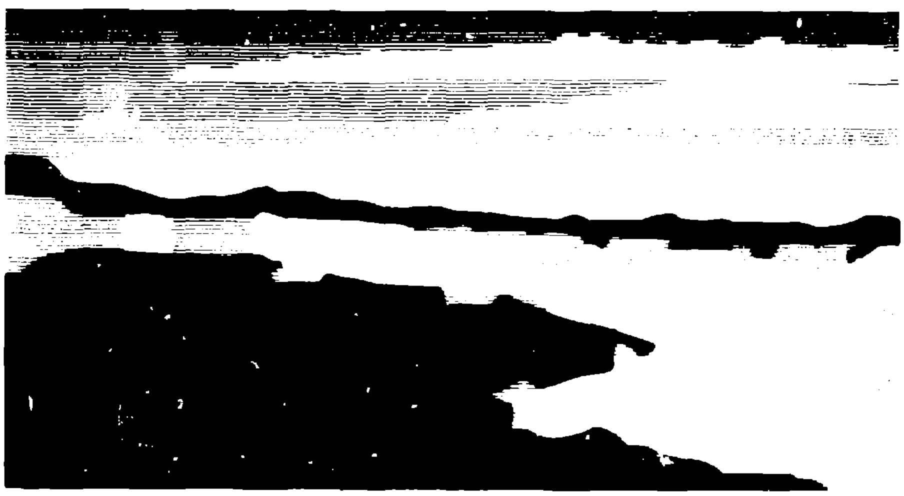
Conf 951157--

LA-UR- 95-922

Title: UTILIZATION OF NEAR-SOURCE VIDEO & GROUND MOTION IN THE ASSESSMENT OF SEISMIC SOURCE FUNCTIONS FROM MINING EXPLOSIONS

Author(s): B. W. Stump, D. P. Anderson

Submitted to: Engineering Blasting Technique, Kunming, China, November 7-10, 1995



Los Alamos
NATIONAL LABORATORY

UTILIZATION OF NEAR-SOURCE VIDEO AND GROUND MOTION IN THE ASSESSMENT OF SEISMIC SOURCE FUNCTIONS FROM MINING EXPLOSIONS

Brian W. Stump
Los Alamos National Laboratory
EES-3, MS-C335
Los Alamos, NM 87545, USA
(505)6671004 FAX (505)6674739 email:stump@lanl.gov

David P. Anderson
Southern Methodist University
Department of Geological Sciences
Dallas, TX 75275, USA
(214)7684290 FAX (214)7682701 email:dpa@io.isem.smu.edu

Abstract: Constraint of the operative physical processes in the source region of mining explosions and the linkage to the generation of seismic waveforms provides the opportunity for controling ground motion. Development of these physical models can also be used in conjunction with the ground motion data as diagnostics of blasting efficiency. In order to properly address the multi-dimensional aspect of data sets designed to constrain these sources, we are investigating a number of modern visualization tools that have only recently become available with new, high-speed graphical computers that can utilize relatively large data sets. The data sets that are combined in the study of mining explosion sources include near-source ground motion acceleration and velocity records, velocity of detonation measurements in each explosive hole, high speed film, video and shot design information.

1. INTRODUCTION

Following the work of Reamer *et al.*, 1992, this paper reports on efforts to document physical processes in the near-source region of mining explosions for the purposes of unambiguously constraining the important characteristics of mining explosions that generate seismic waves. The primary goal of this work is a quantification of the relative and absolute generation of compressional, shear and surface waves by different types of mining explosions. Physical processes that accompany these explosions include the directly coupled energy from the explosive shock, the expansion of gas accompanying the explosion source, spall or tensile failure of the free surface above or in front of the source and material casting.

Mining explosions are designed for a variety of purposes including the fragmentation and movement of materials. The blast design is dependent on the particular application intended and the material properties of the rock. The range of mining applications from hard rock quarrying to coal exposure to mineral recovery leads to a great variety of blasting practices. A common component of many of the sources is that they are detonated at or near the earth's surface and thus can be recorded by camera or video. Although our primary interest is in the seismic waveforms these blasts generate, the visual observations of the blasts provide important constraints that can be applied to the physical interpretation of the seismic source function. In particular, high speed images can provide information on detonation times of individual charges, the timing and amount of mass movement during the blasting processes and in some instances evidence of wave propagation away from the source. All of these characteristics can be valuable in interpreting the equivalent seismic source function for a set of mine explosions and quantifying the relative importance of the different processes.

This report documents an attempt to take standard Hi-8 video of mine blasts, recover digital images from them and combine them with ground motion records for interpretation. The steps in the data acquisition, processing, display and interpretation will be outlined. Two applications, the first a single cylindrical charge at standard burden distances and a small, four-by-four, milli-second delay fired explosion will be used to illustrate the techniques.

2. DATA ACQUISITION AND PROCESSING

The blasts were all recorded on a Sony TR101 Hi-8 video camera at 30 frames/s and a 1/10000 shutter speed. The camera was deployed approximately 100 m from the single cylindrical charge parallel with the free face in front of the charge. During the milli-second delay fired explosion, the camera was deployed approximately 250 m behind and above the explosion. In each deployment, there was a near-by ground motion sensor for correlation with the video. The ground motion data was acquired with a 16-bit Refraction Technology Data Acquisition System, Terra Technology accelerometers and Sprengnether S-6000 2 Hz seismometers. The focus of this discussion will be on the video acquisition and processing as the ground motion data was processed in standard ways.

The raw video images were transferred to a Sony CVR 5000 laser disk using the Silicon Graphics Inc. (SGI) Galileo Card for time-base correction, a process which takes a few seconds. 150 frames (i.e., 30 fps * 5 sec) of the video were digitized outside of real-time from the laser disk and transferred to hard disk using the SGI Galileo Video card. This process produces YUV format color images each 640x486 pixels for a total size of 150 MBytes. The files are converted from YUV to RGB format and written as Run Length Encoded (RLE) files using the Utah Raster Toolkit conversion utility (URT tools are available free from the ftp anonymous login cs.utah.edu). At this point each individual frame of the image consist of two interlaced fields sampled 1/60 sec apart. Figure 1 illustrates one of the interlaced frames from the single, cylindrical explosion. The fuzzy nature of the image is due to the rapid speed at which the material is moving and the interlacing of two fields sampled 1/60 sec apart to produce a single video frame.

Fig. 1: Raw, interlaced video frame from the single cylindrical explosion. The frame follows the detonation of the explosive by 500 msec.

The frames are next de-interlaced and interpolated into one even and one odd field which represent two instances in time separated by 0 01667 sec. Additional contrast and image enhancement is performed on the de-interlaced images using RLE public domain utilities. The marked improvement in the image quality after these steps is illustrated in Figure 2.

Fig. 2: De-interlaced and image enhancement of the even field from frame displayed in Fig. 1.

Although not obvious in the single frames and fields displayed in this paper, the camera moves as the P wave arrives at the recording site. This motion degrades the interpretation of the blast and so a simple correction scheme called de-jittering was devised. The location of a stationary distant point or points is noted in each frame and then the field is corrected to this location to remove camera motion. The resulting corrections for all the frames in the video are combined to produce a representation of the camera motion in the plane of the picture. The individual frames are then combined and animated on the SGI to produce a digital record of the blast at 0.01667 sec resolution. *An animated representation of these images will be available for review at the meeting.*

The final step of the process is to combine the digital video images with the digital ground motions so that one can begin to investigate the relationships between the ground motion and the source processes as recorded by the camera. The ground motions are superimposed on the bottom of the video frame along with a vertical cursor that indicates the location in time of the waveform relative to the image currently being viewed. Time correlation between the video images and the ground motion records is made with the P arrival record. The composite animation are next reconverted to RGB format and sequenced one frame at a time back onto the laser disk. The laser disk can then be used to play the animation at speeds from 30 frames per second (1/2 real time after de-interlacing) to a single frame stop motion. We have found that the ability to interact with the animation at various speeds has been one of most important visualization tools. An example of one frame from the composite is given in Figure 3.

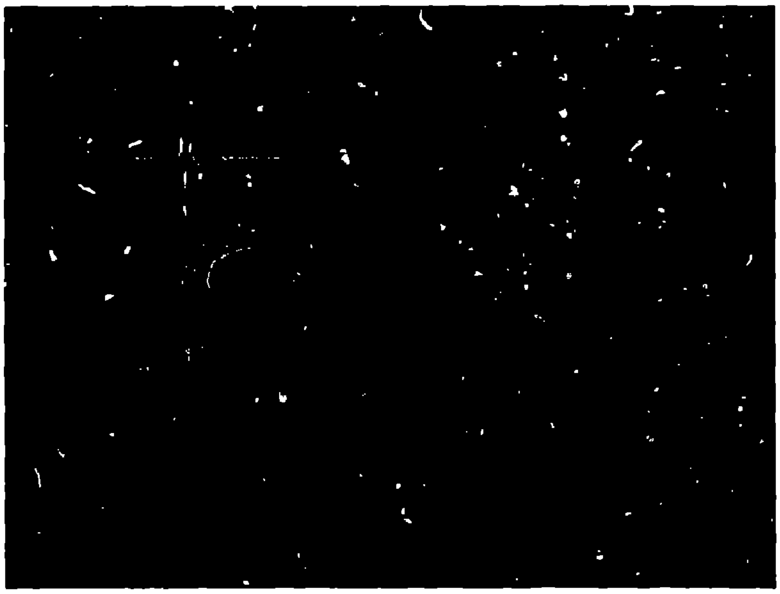


Fig. 3: De-interlaced, de-jittered and composited field from the single, cylindrical explosion. The bottom two time series are the recovered camera displacements from the de-jittering process (x-tangential, y-vertical). The top three time series are ground velocities (vertical, top; radial, second; transverse, bottom) derived from a near-by accelerometer. Time denoted in the figure is elapsed time since the detonation of the surface delay.

The vertical bar in Figure 3 denotes the time in the waveforms that correlate with the video field from the explosion. Comparison of the ground motion record with the camera displacements illustrates the under damped pendulum response of the camera tri-pod. The near-source ground motions are completed many msec prior to this video image. The image also illustrates that there are still many dynamic processes taking place in the source region despite the lack of ground motion. Careful review of the animation reveals the importance of the initial shock from the explosive in generating the near-source ground motions. The P wave as it propagates from the initial shock to the camera can be seen as a reflectance change in the near-surface materials. These two observations indicate that for the recorded near-source ground motions that late time explosion phenomena including the material that is cast out into the pit do not contribute to these waveforms.

The same processing scheme was applied to the ripple-fired explosion. In this case, one can identify the non-electric detonating system as it operates, the detonation of the individual charges, the interaction of the motion between the individual charges and the spall of the material. The frame rate of the video is not fast enough to constrain the exact detonation time of all the surface delays. High speed film or video with frame rates as high as 500 frames/s are more appropriate for this task. Figure 4 illustrates one field from the ripple-fired explosion.

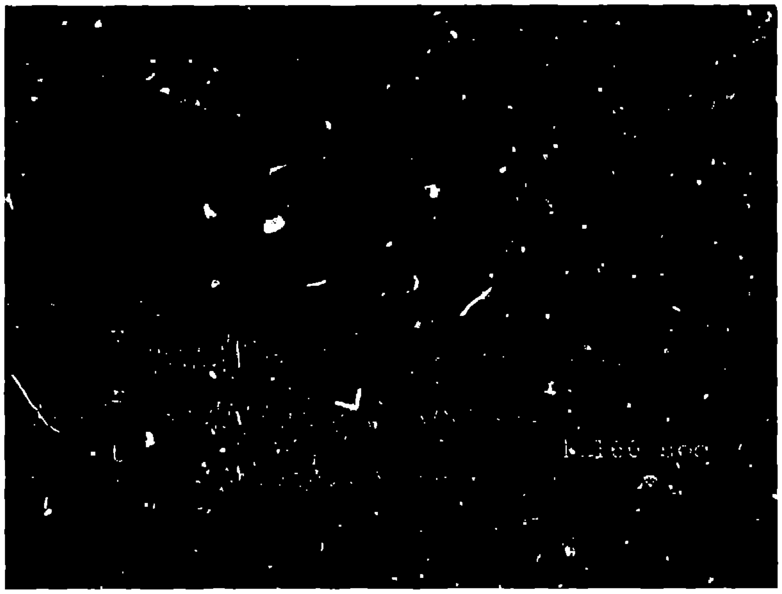


Fig. 4: De-interlaced, de-jittered and composited filed from the ripple-fired explosion. The ground velocities and the camera are at a range of approximately 250 m from the explosion.

3. CONCLUSIONS AND RECOMMENDATIONS

The utility of combining video records and ground motion records from the near-source region of mining explosions has been demonstrated. This tool provides a unique opportunity for investigating the physical properties important in generating seismic waveforms. The simple examples presented in this paper argue that direct shock coupling of energy from the explosion is of primary importance in the generation of near-source waveforms and that the material cast by such explosions is of secondary importance. Analysis of the ripple-fired explosion documents the firing sequence and the cylindrical interaction of the individual charges in the source array. Spall processes quantified by the video occur at late time relative to the near-source motions.

Simple Hi-8 video with its improved resolution provides the starting point for this analysis procedure. The key to the work is the digitization of the video, the de-interlacing, the de-jittering and the animation with the recorded waveforms. A modest priced desk top computer such as a SGI Indigo-2 coupled with a video capture card provides the basis of the analysis system. A read/write laser disk system is needed as well for both the processing steps and the final assembly of the images.

This preliminary study has begun to explore the utilization of different types of data in the interpretation of the seismic source function. Additional work with multiple cameras intended to provide three-dimensional characterization of the source is planned. These images can be used to provide detailed temporal and spatial quantification of material motion in the source region. These same images in combination with sparsely sampled ground motion records can be used to provide some understanding of the two and three dimensional aspects of the seismic wavefield. We intend to explore the utilization of the video images as an interpolating tool between the point ground motion records.

An important key to these visualizations is the linking of temporal and spatial aspects of the problem in a logical way so that the scientists can interpret the important physical processes in the source. *Processed video records of the tests discussed in this paper will be displayed at the meeting for those interested in investigating the temporal and spatial relations in the video and ground motion data sets.*

REFERENCES:

Reamer, S. K., K.-G. Hinzen and B. W. Stump, Near-source characterization of the seismic wavefield radiated from quarry blasts, *Geophys. J. Int.*, *110*, 435-450, 1992.

ACKNOWLEDGMENTS: Some support for BWS was made possible by the Department of Energy and the Source Region Program at Los Alamos National Laboratory. Support for DPA was made possible by the Department of Energy and Air Force Office of Scientific Research under Grant F49620-93-1-0146. John Smith, John Wiggins and R. Frank Chiappetta are thanked for their support in the field. D. Craig Pearson, Meredith Ness and Ben Smith were responsible for the data acquisition.