Exploring potential applications of Gaussian Ball Filters in Sharpe's Hollow Cavity Model

Christopher C. Petten and Gary F. Margrave
University of Calgary, CREWES Project

Summary

In this study we explore the potential applications of Gaussian Ball Filters (GBFs) in Sharpe's Hollow Cavity Model (SHCM). The dominant frequency of the GBFs decreased with increasing ball width, which was similar to the behaviour observed in the SHCM with cavity radii. Several different wavelets that we had used in the SHCM were used in conjunction with the GBFs to observe the effects of different source activation waveforms. We found that that a Ricker and a minimum phase wavelet produced the most reasonable results that might be expected from a real explosion.

Introduction

The SHCM is a model that was developed by Joseph Sharpe in the 1940s which can be used to predict the nature of elastic waves emitted by a seismic source. Using this model with a series of arbitrary cavity radii, we found that we were able to make accurate predictions of the dominant frequency and amplitude response of the charges used in the Hussar 2011 and Priddis 2012 experiments (Petten, 2012). The charge size is related to the radius of the cavity in the SHCM; in a previous study we found strong evidence to suggest that the relationship between charge size and cavity radius was a cubic function, multiplied by a proportionality constant (Petten, 2012). However, we were not able to determine the magnitude of the proportionality constant. This model could be greatly improved if we are able to determine the relationship between charge size and cavity radii as we would be able to make more accurate predictions. The relationship between cavity radius and charge size is crucial for implementing the model into real data. GBFs, as described by Aldridge, could potentially allow us to determine this relationship as the dominant frequency of the GBF is directly related to the ball width (Aldridge, 2011).

Method

Figure 1 shows an arbitrary pressure pulse in the time domain that has been modified by a GBF; Figure 2 shows this same operation in the frequency domain. Note that the GBF modifies both the phase and amplitude response of the initial pressure pulse in the time domain, and alters the dominant frequency in the frequency domain. Figure 3 shows a series of GBFs with varying width in both the time and the frequency domain. Note that as the width of the balls increases in the time domain, they shrink in the frequency domain. We noted a similar behaviour when we changed the radius of the cavity in the SHCM (Petten, 2012). As the width of the cavity decreased, the frequency spectra appeared to expand. This behaviour suggests that we may be able to implement GBFs into the SHCM if we assume that the ball width corresponds to cavity radius, and can be specified as a Gaussian function.

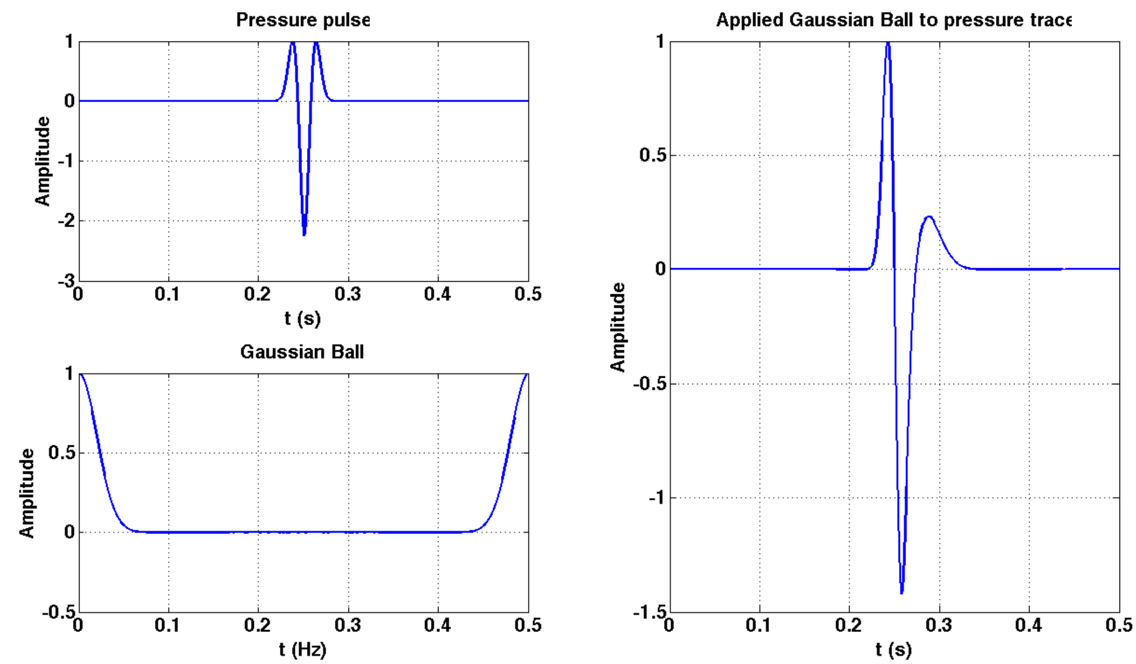

Fig. 1. A pressure pulse in the time domain obtained via a GBF. Note the phase and amplitude change that results after application of this filter.

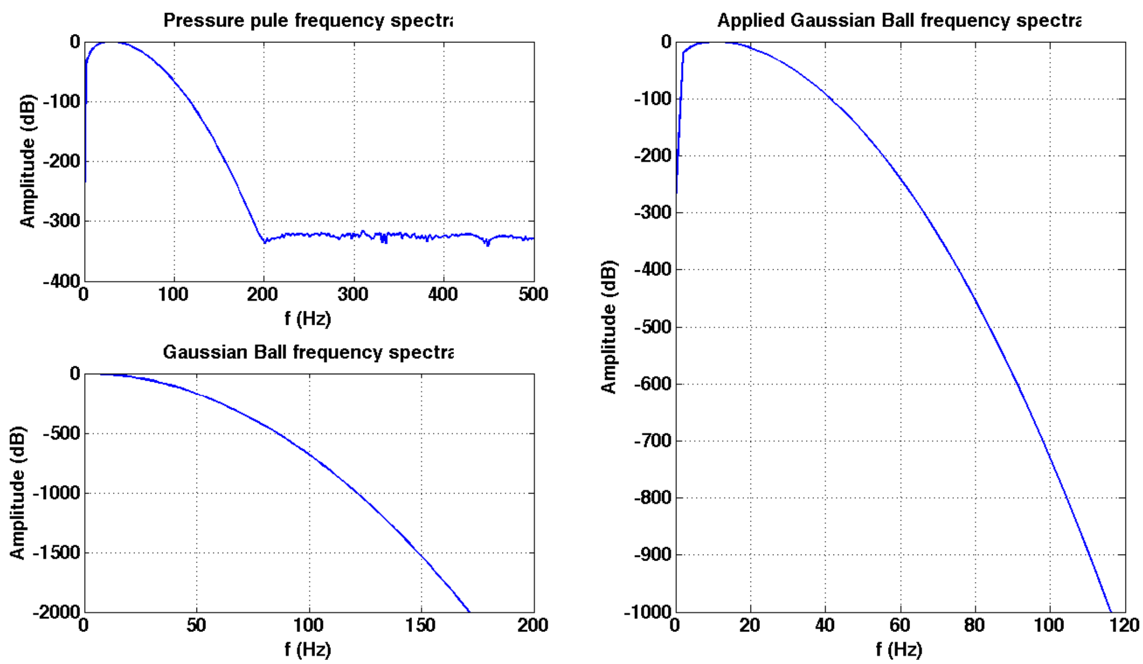

Fig. 2. The frequency spectra for the pressure pulse and GBF that is shown in Figure 1. Note that the GBF changes both the amplitude response and the dominant frequency of the pulse.

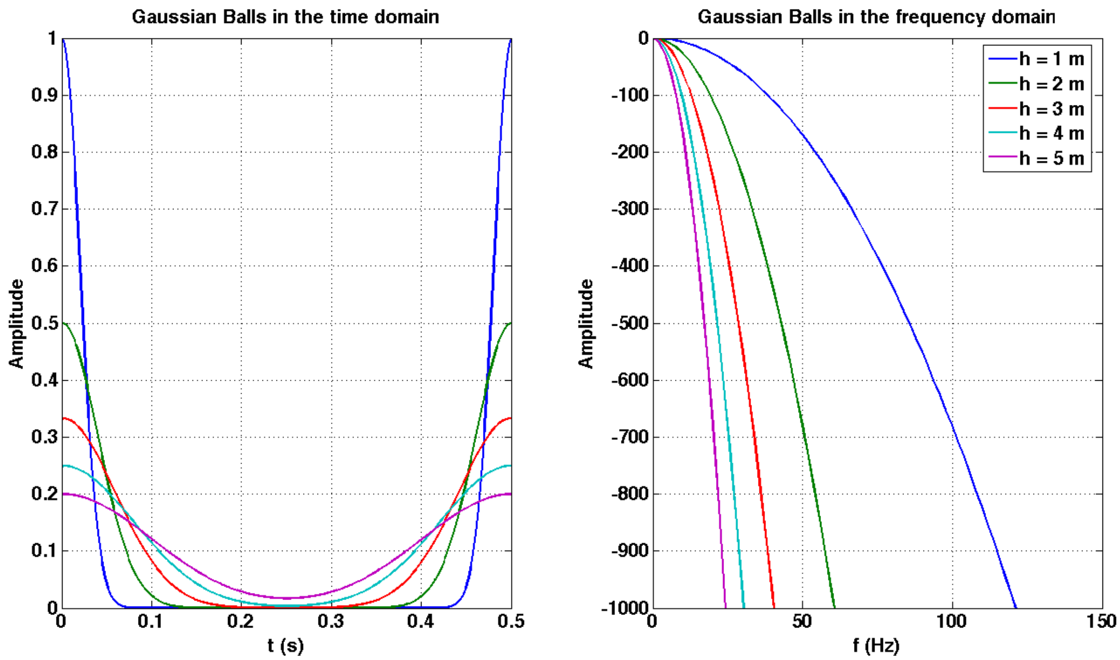

Fig. 3. A series of GBFs with varying ball width. Note that as the width of the Gaussian balls decrease in the time domain, their respective frequency spectra broaden. We observed a similar effect with cavity radius in the SHCM.

Examples

In a previous study we determined that in order for the SHCM to be applicable to real dynamite data, the source activation waveform that is used must produce a spectrum that has three main features. These features include: (1) a low-frequency roll-off in the frequency spectra, (2) the overall amplitude response must increase with larger charge sizes, and (3) the dominant frequency must decrease with larger charge sizes. Note that all of these features were observed in both the Hussar 2011 and Priddis 2012 field experiments, which is why we chose this set of criterion (Petten, 2012).

GBFs are associated with a scalar magnitude as well as a width (Aldridge, 2011). In this study we assumed that the magnitude of the Gaussian ball could be reasonably approximated as the cube of the ball width, which was based on the relationship between power and charge size that was determined in the Hussar 2011 study (Petten, 2012). The choice of source activation waveform when using this model is completely arbitrary; we decided to use a Ricker and a minimum phase wavelet with this model in order to investigate the effect that the wavelet has on the frequency spectra. The results of this experiment can be seen in Figures 4 and 5. In both cases the criterion mentioned previously has been met. This suggests that it may be possible to implement GBFs into the SHCM provided that the proper source activation waveform is used.

For each wavelet shown in Figures 4 and 5, the dominant frequency decreases with increased magnitude, which is similar to what we observed in the SHCM (Petten, 2012). We determined that the decrease in dominant frequency with larger charges was crucial in the SHCM; since a similar effect occurs with the Gaussian ball width, we may be able to use this model to improve the accuracy of the SHCM.

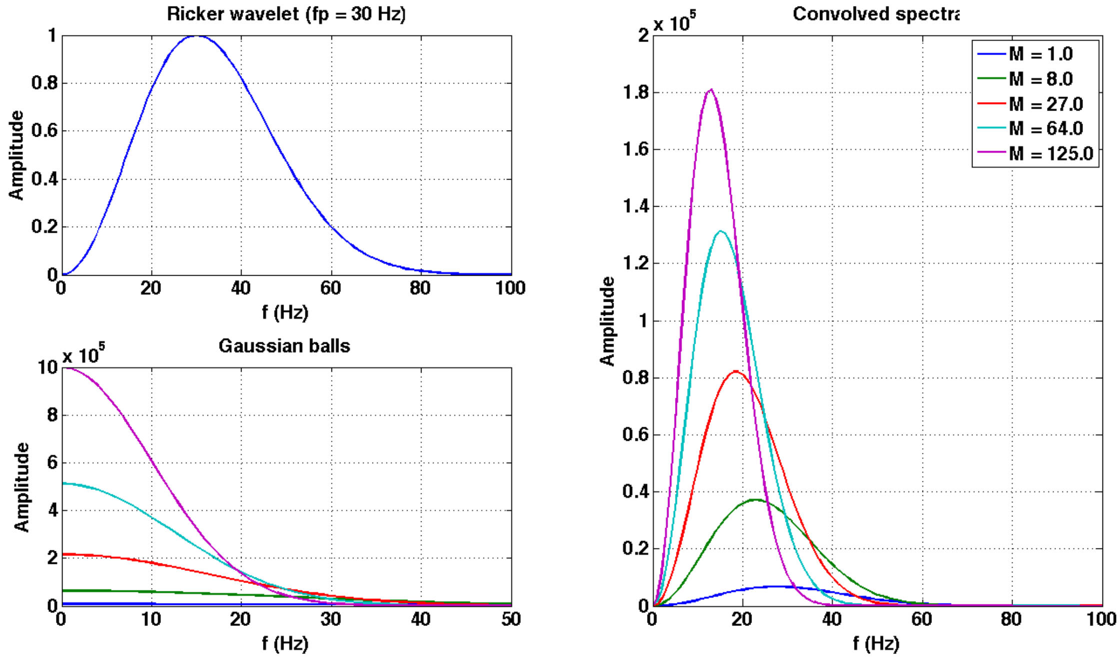

Fig. 4. A Ricker wavelet that has been convolved with a series of GBFs with varying ball width. This wavelet produces a frequency spectra that fulfils the criterion that was established in a previous study involving the SHCM.

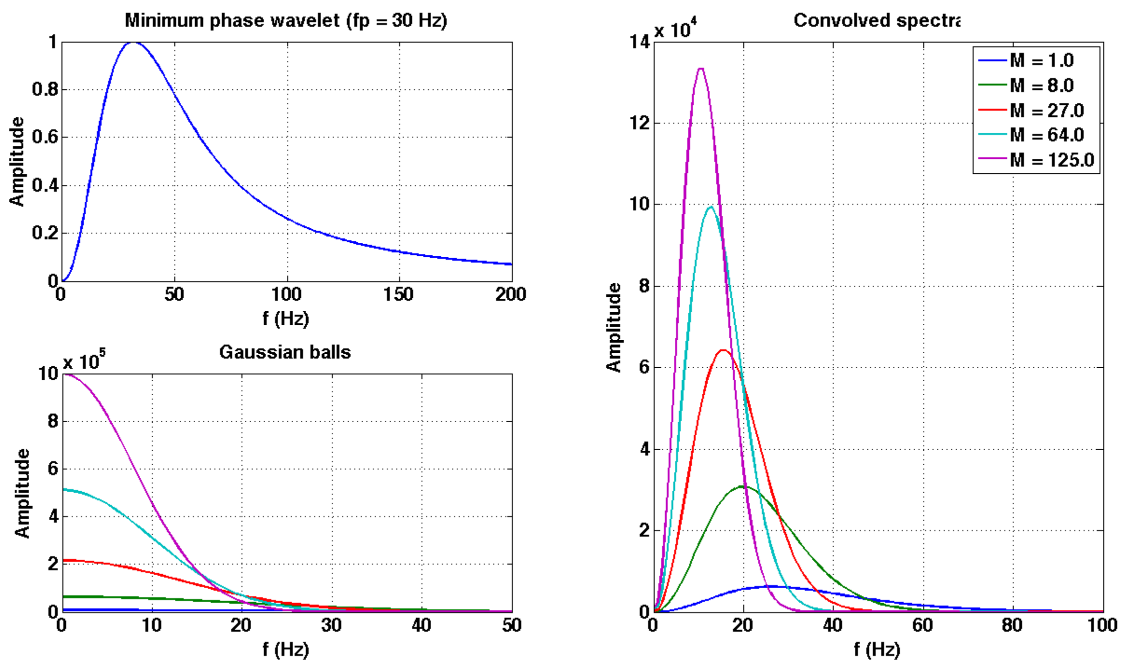

Fig. 5. A minimum phase wavelet that has been convolved with a series of GBFs of varying ball width. This frequency spectra that results from this wavelet also fulfils the criterion that was established in a previous study involving the SHCM.

Conclusions

Based on the results of our investigation, we can conclude that it may be possible to implement GBFs in the SHCM to further establish a relationship between charge size and cavity radius. The choice of source activation waveform used is arbitrary, however, based on results from a previous study we know that it must fulfil the criterion that has been established in our study of the Hussar 2011 and Priddis 2012 data.

Acknowledgements

I would like to thank my supervisor Dr. Gary Margrave for his continuous support and guidance.

References

Aldridge, D. F., T. M. Smith, S. S. Collis (2011), *A Gaussian explosion seismic energy source:* SEG Technical Program Extended Abstracts, pp.2997-3001.

Petten, C. P., G. F. Margrave (2012), *A brief comparison of the frequency spectra from the Hussar 2011 and Priddis 2012 test shoots and the theoretical predictions of the Sharpe Hollow Cavity Model:* CREWES Research Report, Vol. 24, No. 76.

Petten, C. P., G. F. Margrave (2012), *Using the Sharpe Hollow Cavity Model to investigate power and frequency content of explosive pressure sources:* CREWES Research Report, Vol. 24, No. 75.