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

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ABSTRACT

This paper provides a brief investigation of the frequency spectra from the Hussar 2011 and Priddis 2012 test shoots conducted by CREWES and the theoretical predictions in regards to the Sharpe Hollow Cavity Model (SHCM), with the intended purpose of testing the viability of this model to predict the nature of elastic waves emitted by an explosive pressure source. It was found that the overall form of the frequency spectra predicted by the SHCM coincided with that of the data obtained in both Hussar and Priddis. The dominant frequency in each study decreased with increased charge size and there was also a loss in high-frequency content with smaller charges, which were two observations predicted by the SHCM. The data from Hussar however showed significant variation in the high-frequency content for all charge sizes compared to the frequency spectra obtained from Priddis. There was also a low-frequency roll-off in both field studies which was consistent with the frequency spectra resulting from the pressure pulse chosen for the SHCM in a previous study. Overall this data suggests that the SHCM can provide a viable theoretical framework for predicting the nature of elastic waves emitted from explosive pressure sources.

INTRODUCTION

Despite its common use in exploration seismology, the nature of explosive pressure sources are one of the poorest understood phenomenon in Physics. In a previous study it was proposed that the SHCM may provide a theoretical framework for such a phenomenon and may be able to accurately predict the propagation patterns of elastic waves emitted from an explosive source (Petten, 2011). The two main features of elastic waves predicted by the SHCM are the frequency content and the power that result from different charge sizes. Two field experiments were conducted by CREWES, one Hussar in 2011 and one in Priddis in 2012, where a series of test charges ranging in size between one third of a kilogram and four kilograms were detonated and recorded. The data from these experiments, specifically the frequency data, can provide valuable insight as to whether or not the SHCM can predict the frequency content of waves emitted from explosive sources. If this data coincides with theoretical predictions made by the SHCM, it may provide a means of implementing this model such that it can accurately predict the nature of explosive sources which will greatly aid in improving survey design.

THEORETICAL PREDICTIONS OF THE SHARPE HOLLOW CAVITY MODEL

The predictions of the SHCM have been thoroughly derived in Petten et al. so they will not be discussed in great detail here (Petten, 2012). Predictions made regarding the

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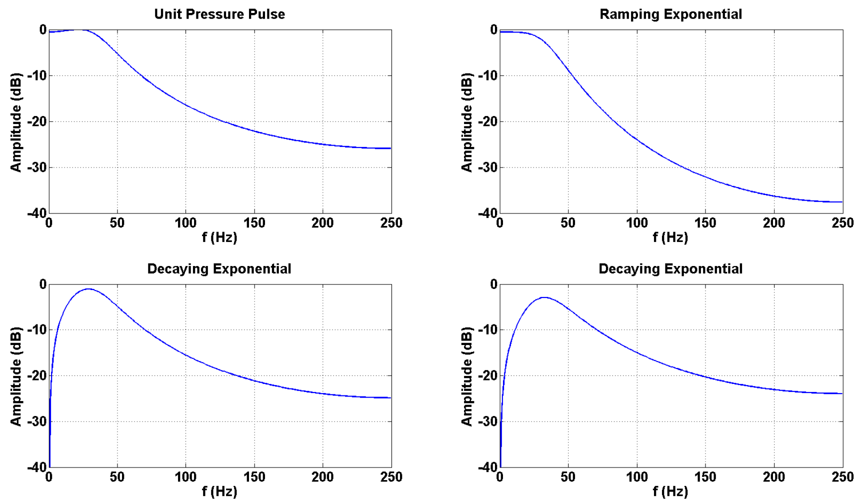

FIG. 1. The frequency spectra resulting from various pressure pulses in the SHCM. In previous works, it has been determined that the decaying exponential shown in III would be a reasonable model for an explosive source. Therefore, it is necessary that frequency spectra obtained from sources deployed in the field must possess the observed low-frequency roll-off in order for this model to be viable.

frequency content are the most important for this particular set of observations and have been shown in Figure 1 and 2. The results shown in these figures suggests that there are four distinct features of the frequency spectra which must be observed in order for Sharpe's model to be a viable means of predicting the nature of waves emitted by explosive sources. These four features are:

I) There must be a low frequency roll-off present due to the choice of pressure pulse for modelling an explosive pressure as discussed in previous work (Petten, 2012).

II) The dominant frequency must decrease with increased charge size.

III) There must be a loss in high-frequency content with smaller charge sizes.

IV) The amplitude response must increase with charge size.

If these criterion are fulfilled with data obtained from charges deployed in the field it will provide an excellent starting point for implementing the SHCM and verifying that it can reasonably predict the nature of waves propagating from an explosion. Note however that the dominant frequencies predicted in this case cannot be reliably compared to that of the observed frequencies since a link between charge size and cavity radius in the SHCM has yet to be established. This relationship is necessary to accurately predict various features of the frequency spectra and since this information has yet to be obtained, only a qualitative investigation of the forms of the frequency spectra will be attempted in this study.

RESULTS OF THE HUSSAR 2011 FIELD EXPERIMENT

This experiment was conducted by CREWES during the Hussar Low-Frequency Experiment which has been covered in great detail in Margrave et al (Margrave, 2011). Along

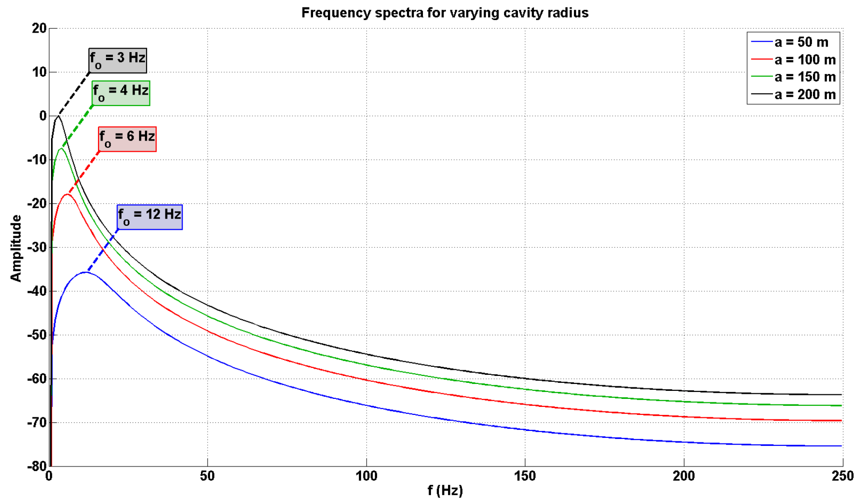

FIG. 2. Frequency spectra predicted by the SHCM. The dominant frequency decreases with increased charge sizes and there is a significant loss in high-frequency content with smaller charges.

with the Vibroseis machine, several test charges ranging in size between one and four kilograms were buried at several locations along the seismic line. Each of these test charges were detonated at various times throughout the day and were recorded by a 3-component geophone. In this particular study, only the vertical component of the displacements were considered during analysis.

The frequency spectra recorded in Hussar can be seen in Figures 3 and 4. Initial observation of these figures show that three out of the four criterion presented previously have been met with this particular data set. In both the Hussar and Sharpe frequency spectra the low-frequency roll-off is present, suggesting that real sources can potentially be modelled with decaying exponential pressures. The dominant frequency decreases with larger charge sizes, which can be more clearly seen in Figure 4, and the biggest charges produce the largest amplitude response. These three observations match the theoretical predictions of the SHCM however, the high-frequency content varies significantly with instances of higher frequencies observed for smaller charge sizes, which does not coincide with Sharpe's predictions.

THE PRIDDIS 2012 FIELD EXPERIMENT

This experiment was conducted by CREWES during the summer of 2012 in Priddis, Alberta. A series of test charges ranging in size between one third of a kilogram and two kilograms were detonated and recorded with similar geophones used in the Hussar 2011 experiment. In this particular case the only the vertical component of the travelling waves were considered during analysis.

The resulting frequency spectra can be seen in Figures 5 and 6. Comparison of these spectra with that of the SHCM shown in Figure 2 yields strong similarity between the theoretical predictions and the data obtained in the field. Both spectra contain the low-frequency roll-off, both have the same amplitude response for larger charges, both show the same decrease in dominant frequency with larger charges, and the high-frequency content

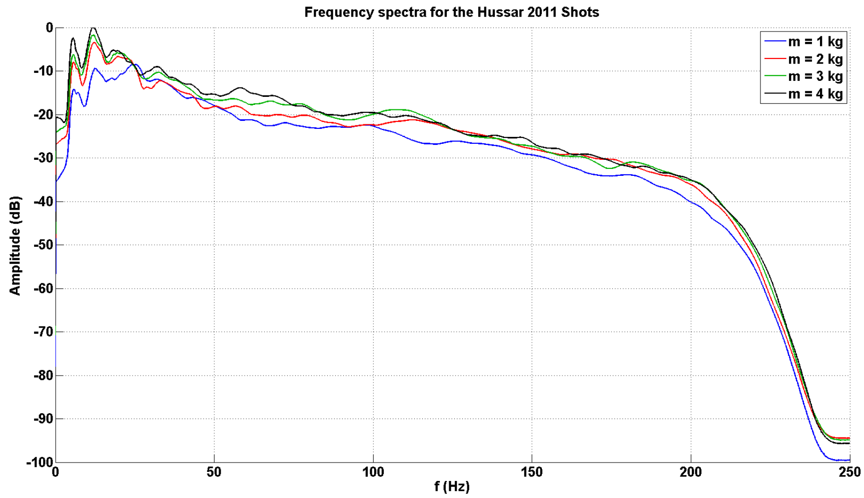

FIG. 3. The frequency spectra of the Hussar 2011 test charges. The dominant frequency decreases with increased charge size as predicted by the SHCM, however, there appears to be significant variation in the high-frequency content which does not coincide with predictions made by this model. Also notice the low frequency roll-off that exists for for all charge sizes which also coincides with the predictions of the SHCM.

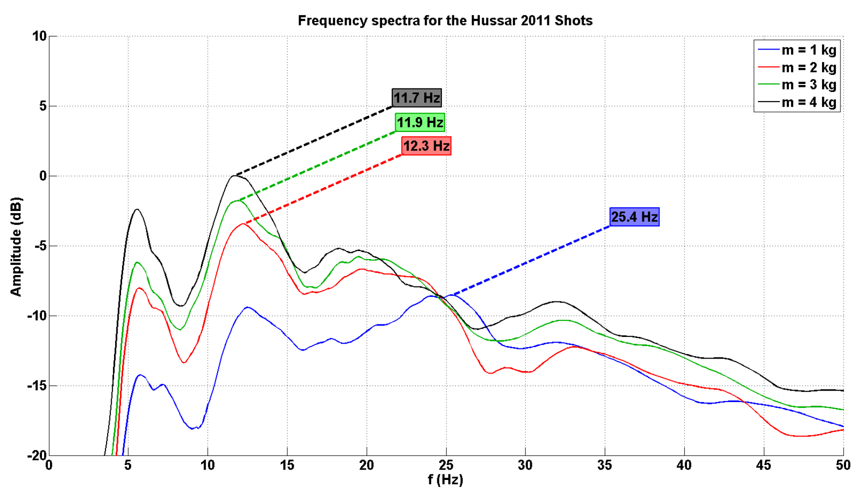

FIG. 4. A closer view of the dominant frequencies of the Hussar 2011 test shoots, where a clear decrease in dominant frequency with increased charge size can be observed.

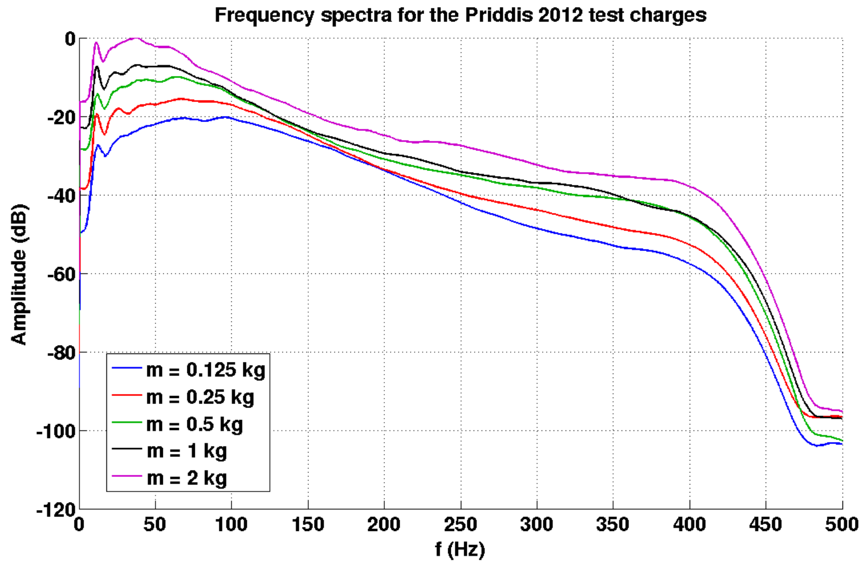

FIG. 5. Frequency spectra obtained in the Priddis 2012 experiment. The dominant frequency decreases with increased charge size and the low-frequency roll-off is present. Additionally, the high frequency content appears to decrease with smaller charges which is predicted by the SHCM.

appears to also decrease with smaller charge sizes. Due to the the fact that all four of the previously mentioned criteria of the SHCM have been observed in this field experiment there is a good possibility that this model can be used to predict the behaviour of waves emitted from explosive sources in other experiments as well.

DISCUSSION

In both field experiments the SHCM was able to reasonably predict the nature of the frequency spectra obtained from the test charges deployed in the field. The only exception in this case was the high-frequency content in the Hussar 2011 experiment, which did not necessarily agree with the predictions proposed the Sharpe model. Figure 7 shows how the frequency spectra in the SHCM is predicted to vary with changing medium rigidity. As rigidity increases the overall frequency content should decrease. However, it can also be seen in Figure 2 that the frequency content should increase with larger charge sizes. Therefore, it may be possible that in the Hussar 2011 case there was significant variation of rigidity within the medium which could account for this inconsistent behaviour of the high frequency content with the SHCM. Additionally, one of the major assumptions involved with the derivation of the SHCM is that the Lamé parameters are equal, in other words, $\lambda = \mu$. This would normally be a safe assumption however, in the presence of anisotropy this assumption is would most definitely be violated. Therefore, it may also be possible that the subsurface conditions in Priddis more strongly favour this assumption compared to Hussar 2011. Despite this deviation from theory however, the remainder of the spectrum appears to coincide with the other predictions, suggesting that this model may still be able to accurately predict the nature of waves in this setting.

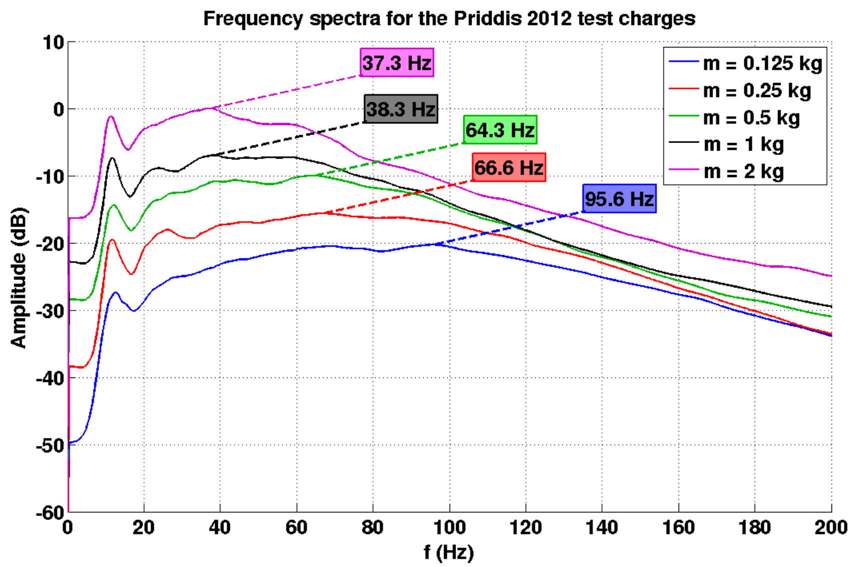

FIG. 6. A closer view of the dominant frequencies obtained in the Priddis 2012 test shoot. A clear decrease in dominant frequency with larger charges can be seen here.
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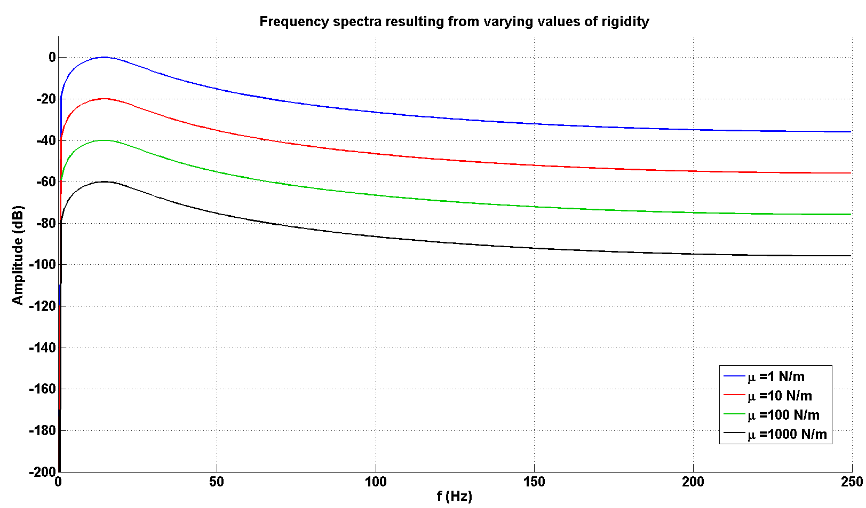

FIG. 7. The frequency spectra that result from varying rigidity with a fixed cavity radius, and thus in theory, a fixed charge size. Increased rigidity in the SHCM appears to decrease the overall frequency content throughout the entire spectra provided the charge size does not change.

CONCLUSIONS

Since both frequency spectra obtained from the charges deployed in the field both contained the low frequency roll-off that results from the decaying exponential it would be a reasonable to conclude that a decaying exponential is a reasonable model for pressures that result from explosive pressure sources. Due to the similarities in the frequency experiments obtained from the test charges and the SHCM it can also be concluded that the dominant frequency decreases with increased charge size and that high-frequency content is lost with smaller charge sizes. Since the SHCM can provide reasonable predictions of these observed features it can also be concluded that the Sharpe model provides a viable means for modelling the frequency content of explosive sources.

Due to the fact that the SHCM could not accurately predict the high-frequency behaviour of the Hussar test charges it would not be reasonable to make any sort of conclusive claims about the viability of the Sharpe model in this situation. The model was able to predict each aspect of the frequency spectra in Priddis suggesting that it as least functional in some settings. That being said however, it is important to note that this model may be unreliable in the conditions present at Hussar. Future work on this project will include gathering data in a different setting with more charge sizes to see if the SHCM can predict the nature of the frequency spectra in other settings as well.

The next stage of this project will be a determination of the relationship between cavity radius in the SHCM and the charge size. The method for doing so has been outlined in Petten et al. and will involve a close examination of both the power and the dominant frequency of each charge size studied. Additionally, a numerical solver will also be implemented to solve the Sharpe model using numerical methods instead of calculus to see if it produces more accurate results. In this setting it may be possible to avoid the assumption that the Lamé parameters are equal, making the model more robust and more viable in subsurface conditions such as Priddis.

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REFERENCES

[1] Petten, C. P., and Margrave, G. F., 2012, Using the Sharpe Hollow Cavity Model to investigate power and frequency content of explosive pressure sources: CREWES Research Report, Vol. 25.