COMMUNICATIONS IN COMPUTATIONAL PHYSICS
Vol. **3**, No. 1, pp. 33-51

Commun. Comput. Phys.
January 2008

REVIEW ARTICLE

Numerical Modeling of Elastic Wave Propagation in a Fluid-Filled Borehole

Arthur C. H. Cheng[1,*] and Joakim O. Blanch[2]

[1] *Cambridge GeoSciences, 14090 Southwest Freeway, Suite 300, Sugar Land, TX 77478, USA.*
[2] *Nexus GeoSciences, 14090 Southwest Freeway, Suite 240, Sugar Land, TX 77478, USA; previously at SensorWise, Inc., 2908 Rodgerdale, Houston, TX 77042, USA.*

Received 8 March 2007; Accepted (in revised version) 6 June 2007

Available online 14 September 2007

Abstract. We review the methods of simulating elastic wave propagation in a borehole. We considered two different approaches: a quasi-analytic approach using the Discrete Wavenumber Summation Method, and the purely numerical Finite Difference Method. We consider the special geometry of the borehole and discuss the problem in cylindrical coordinates. We point out some numerical difficulties that are particularly unique to this problem in cylindrical coordinates.

AMS subject classifications: 86-08

PACS: 47.11.Bc, 43.35.+d, 91.60.Lj
Key words: Acoustic, borehole, numerical modeling.

Contents

*Corresponding author. *Email addresses:* arthurcheng@alum.mit.edu (A. C. H. Cheng), jblanch@NexusGeo.com (J. O. Blanch)

1 Introduction

Full waveform acoustic logging is a method of obtaining the acoustic properties of the subsurface by lowering a tool into the borehole. The tool generates an acoustic signal inside the fluid-filled borehole. The acoustic wave then propagates in the earth formation around the borehole and is recorded by an array of receivers located on the same tool a short distance away. A schematic diagram of the acoustic logging process is shown in Fig. 1. A detailed description of the process can be found in Tang and Cheng (2004).

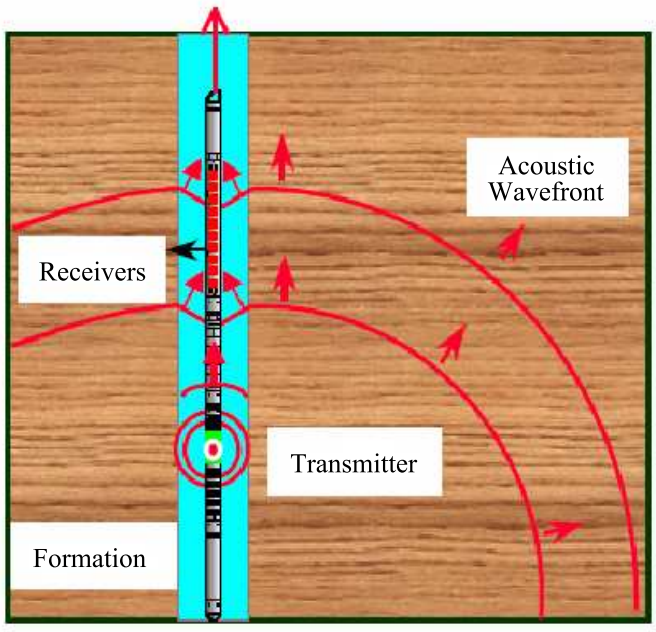

Figure 1: Schematic of the acoustic logging process, from Tang and Cheng (2004).

Because of the particular geometry of the logging process, and the frequencies involved, modeling the acoustic wave propagation is a complex process. In this paper we will describe two frequently used methods for modeling the wave propagation. One is the quasi-analytic method known as the discrete wavenumber summation method, and the other is the finite difference method. We will also discuss other approaches briefly, and the advantages and disadvantages of each under different circumstances.

2 Theory

We will first briefly review the basic analytic formulation of elastic/acoustic wave propagation in a borehole. Let us consider the simple example of a cylindrical borehole of radius R, filled with fluid, in an infinite elastic formation.