CHAPTER I

INTRODUCTION

Natural gas has been widely used as fuel to generate electricity and heat for homes and industries over the decades. The reason is that it is cleaner, emits less pollutant than coal, and is safer to operate than nuclear energy. The major component of natural gas is methane which is highly combustible and produces high amount of heat to the power generation unit. It also comprises CO_2, H_2S, N_2, O_2 and trace of He, Ne, Xe in which their compositions depend on reservoir location.

Natural gas is a fossil fuel, like oil and coal. These fossil fuels are formed when organic matter (such as the remains of a plant or animal) is compressed under the earth crust, at very high pressure for a very long period of time. This compression, combining with high temperatures found deeply underneath the earth surface, breaks down the carbon bonds into the organic matter. The reservoir temperature increases as the depth from the earth crust increases. At low temperatures (shallower deposits), an amount of oil produced is higher than that of natural gas produced whereas natural gas is highly produced compared to oil at high temperature. Natural gas is trapped under the earth in the sedimentary rock which can be recovered by drilling a hole through the impermeable rock. Gas in this reservoir is typically kept under extremely high pressure. Therefore, it can be released from the reservoir to earth surface easily.

The exploration for natural gas begins with examining the surface structure of the earth, and determining the certain areas where geological information indicates that petroleum or natural gas deposit might exist. Most of natural gas has been discovered in the anticline slope reservoir because the impermeable rock forms a 'dome' shape. The natural gas moved or migrated upward through the porous layer where it was trapped by the sealing cap rock and shape of structure. The biggest breakthrough in petroleum and natural gas exploration comes through the use of basic seismology. Seismology refers to the study of how energy, in the form of seismic waves, moves through the earth's crust and interacts differently with various types of underground formations. It helps to locate formations of natural gas underneath the earth surface. This information assists the geologists to predict fluid content, porosity, permeability, age, and formation sequence of the rocks underneath the surface of a particular area. The exploratory wells are only drilled in areas where confirmed data has indicated a high possibility of petroleum formations. These data consist of a variety of tests that figure out the true composition and characteristics of the different rock layers the well passing through.

Afterwards, the reservoir simulation model is developed based on the actual reservoir geometry to predict the amount of natural gas in the reservoir, reservoir lifetime, the effects of reservoir uncertainties and continuity of pore space and fluids on production rate and the platform location. In addition, during gas production period, the reservoir simulation model also assists production engineer to predict the location of production well and the production rate from the pressure profile in the reservoir. A good reservoir simulation model requires good geological input, accurate reservoir geometry with porosity trends, permeability trends, layer and shale distributions, and so on. In the reservoir simulation model, the transient material balance coupling with porous media flow equation is formulated into partial differential equations, which can be solved by computer. Nowadays, there are a few reservoir simulators commercially available but they are very expensive and not flexible to use. Consequently, development of reservoir simulation model based on fundamental physics in this thesis work will help reduce the cost of buying reservoir simulator and increase usage flexibility.

This thesis work will focus on development of the validated reservoir simulation model for natural gas. The model mainly composes of reservoir and wellbore where natural gas is withdrawn or injected. The developed model determines wellbore and reservoir pressure as a function of time and also predicts the reservoir lifetime. The governing equations in this model formulation are transient mass transport and Darcy's law. One of the main purposes in this thesis work is to apply two numerical methods for solving the governing equations, those of which are finite difference (FDM) and finite element (FEM) methods. FDM uses alternating-direction implicit (ADI) concept to discretize the governing equations. Thereafter, the system of discretized equations is solved by coding into FORTRAN program. In case of FEM, the commercial finite element software package, 'FEMLAB®' is chosen to solve the equations. This is because it provides flexible platform to solve any partial differential equations using finite element analysis. The performance comparison of these methods for calculating reservoir pressure and its lifetime is performed.

The thesis is organized into five chapters. Chapter I presents an introduction to the thesis which includes the thesis motivation and objectives. Chapter II reviews the background of natural gas reservoir, simulation process and mathematical methods and literature review. Chapter III describes the mathematical modelling which includes the information of model description, model assumption, model formulation and model algorithm in finite difference and finite element methods. Chapter IV illustrates the model validation which compares the simulated results with historical data from a real reservoir and simulation results. Finally, chapter V presents conclusions and recommendations of numerical modelling.