ANALYSIS ON PARAMETERS INVOLVED IN 2-D FRACTURE GEOMETRY DESIGN

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To my beloved parents and selfless wife

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ABSTRACT

During past decades, the depletion of oil and gas reservoirs and increasing of the hydrocarbon price, major companies in oil and gas industry endeavor to enhance the recovery of hydrocarbon from the present reservoirs as well as marginal reservoirs. One of the most successful ways to improve oil and gas recovery is to perform Hydraulic Fracturing technique. Modelling of fracture geometry (width, length, and height) is an aspect, specifically in the interest of hydraulic fracturing as a stimulation technique. To have an accurate and optimum fracture design, it is important to evaluate the influence of design parameters on the dimension of an induced fracture in fracture design models. The classical models for fracture geometry in two dimension are the PKN (Perkins–Kern–Nordgren) and KGD (Kristianovitch–Geertsma–Daneshy) models. Effect of each parameter on the fracture geometry is important in order to know which one has positive or negative effect. A sensitivity analysis will be performed in order to find out the impact of each parameter on the fracture geometry by employing Microsoft Excel® 2013. The input data have been extracted from previous successful treatment that have been done in a Malaysian gas condensate reservoir named Angsi. Parameters that may affect the fracture geometry and going to be assessed are related to the mechanical rock characteristics and fracturing fluid specification. They are Poisson's ratio, Young's Modulus, fluid pumping rate, fluid viscosity and fracture height. Based on KGD model, it is observed that value of fracture width will improve by increasing the values of fracturing fluid pumping rate, Poisson's ratio and Young's Modulus and decreasing the values of fracturing fluid viscosity and fracture height. In terms of fracture length due to KGD model, same trend is present for pumping rate and fracture height, however, a reverse trend obtained for variations of Poisson's ratio, Young's Modulus and fluid viscosity. A similar analysis was performed based on PKN model. Furthermore, a comparative analysis has been done to compare these two design models in order to find the sensitivity of the design parameters on the fracture geometry.

ABSTRAK

Dekad yang lalu, kerana simpanan minyak dan gas semakin berkurang dan harga hidrokarbon semakin berkurang, syarikat-syarikat utama dalam industri minyak dan gas memikirkan resolusi untuk meningkatkan pemulihan hidrokarbon dari takungan kini dan juga takungan kecil. Salah satu cara yang sangat berkesan untuk meningkatkan pemulihan minyak dan gas adalah dengan melaksanakan teknik Hydraulic Fracturing. Permodelan keretakan geometri (lebar, panjang, dan ketinggian) merupakan satu topik yang menarik, khususnya bagaimana pemecahan hidraulik sebagai teknik rangsangan. Untuk mempunyai reka bentuk keretakan yang tepat dan optimum, ia adalah penting untuk menilai pengaruh parameter reka bentuk pada dimensi retakan yang dibuat dalam model reka bentuk keretakan. Model klasik untuk geometri retak dalam dua dimensi adalah KGD dan model PKN. Analisis kepekaan akan dilakukan untuk mengetahui kesan daripada setiap parameter ke atas geometri retak dengan menggunakan Microsoft Excel ® 2013. Data masukan telah dipetik daripada rawatan sebelumnya yang berjaya yang telah dilakukan di dalam takungan peluwapan gas Malaysia bernama Angsi. Parameter yang boleh memberi kesan kepada geometri retak dan akan dinilai adalah berkaitan dengan ciri-ciri mekanikal batu dan spesifikasi keretakan cecair. Parameter tersebut adalah nisbah Poisson, Modulus Young, kadar mengepam cecair, kelikatan cecair dan ketinggian retak. Berdasarkan model KGD, pemerhatian yang dilakukan adalah nilai lebar retak akan meningkat dengan meningkatkan nilai kadar mengepam keretakan cecair, nisbah Poisson dan Modulus Young dan mengurangkan nilai-nilai keretakan kelikatan cecair dan ketinggian patah. Dari segi panjang retak kerana model KGD, corak yang sama berlaku untuk kadar dan ketinggian retak mengepam. Walau bagaimanapun, satu corak yang terbalik diperolehi untuk variasi nisbah Poisson, Modulus Young dan kelikatan cecair. Analisis yang serupa telah dilakukan berdasarkan model PKN. Tambahan pula, analisis perbandingan telah dilakukan untuk membandingkan kedua-dua model reka bentuk untuk mencari sensitiviti parameter reka bentuk ke atas geometri retak.

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LIST OF ABREVIATIONS

KGD	-	Kristianovitch–Geertsma–Daneshy
PKN	-	Perkins-Kern-Nordgren
2-D	-	Two dimensional

LIST OF SYMBOLS

σ	-	Stress
F	-	Force
A	-	Area
ε	-	Strain
L	-	Length
L_0	-	Original length
υ	-	Poisson's ratio
$\varepsilon_{latitudinal}$	-	Latitudinal strain
$\varepsilon_{longitudinal}$	-	Longitudinal strain
Δd	-	Diameter change
ΔL	-	Length change
d_0	-	Original diameter
E	-	Young's modulus
w	-	Width
P_{net}	-	Net pressure
h_f	-	Fracture height
E'	-	Plane strain modulus
q_i	-	Fluid flow rate
μ	-	Fluid viscosity
$w_{(x)}$	-	Fracture width in x direction
x	-	Horizontal distance from wellbore
w_w	-	Maximum fracture width
t	-	Treatment time
S	-	Maximum horizontal stress
$P_{(x)}$	-	Fluid pressure along the fracture
G	-	Shear modulus

CHAPTER 1

INTRODUCTION

1.1 Background

During the past decades, regarding to depletion of oil and gas reservoirs and increasing of the hydrocarbon price, major companies in oil and gas industry thought about how to enhance the recovery of hydrocarbon from the present reservoirs as well as marginal reservoirs. One of the most successful ways to improve oil recovery of a reservoir is to perform Hydraulic Fracturing technique. Hydraulic fracturing has a significant influence on enhancing petroleum reserves and daily production.

Hydraulic fracturing treatment comprises mixing of some special chemical additives to make a proper fracturing fluid and pump it to the pay zone at an appropriate pressure and rate to initiate and expand a fracture. Figure 1.1 illustrate a simplistic schematic model of hydraulic fracturing equipment (Cleary, 1988).

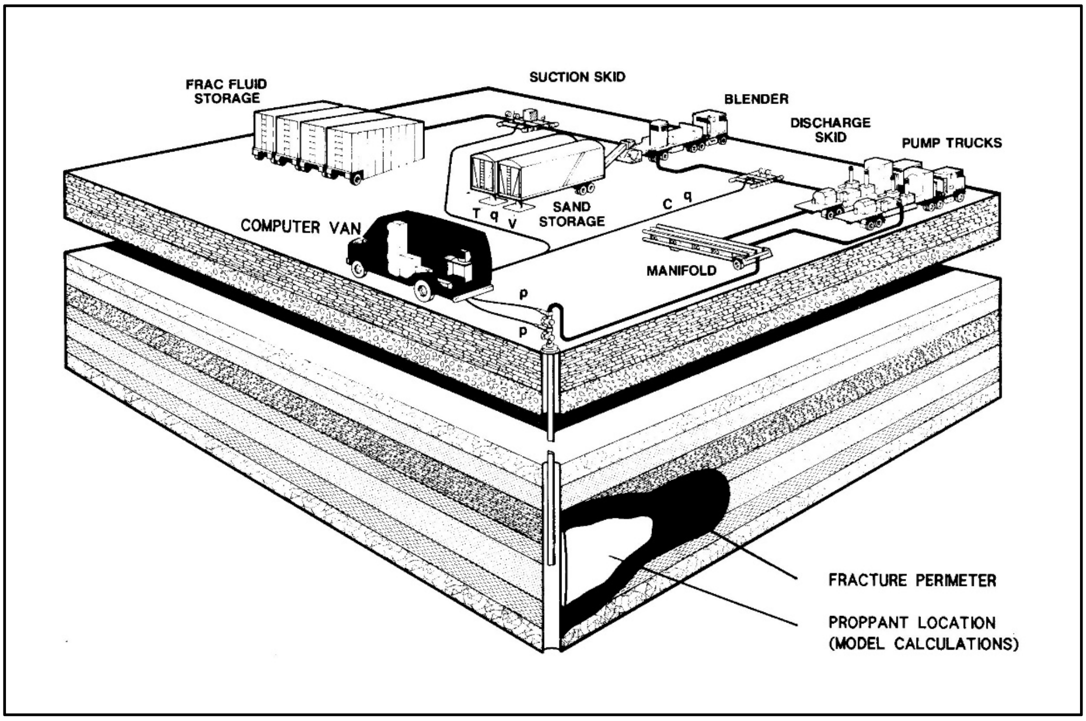

Figure 1.1 A simplistic schematic model of hydraulic fracturing equipment needed to perform a treatment.

One of the stimulation techniques which has been used commercially in the petroleum industry since the early fifties is hydraulic fracturing. Such fracturing treatments are designed to stimulate and increase production from low permeable formations. This is being done by pumping of fracturing fluid and solids (proppants), therefore creating long fractures filled with proppants. Hence, the fracture generates a high-permeability flow channel towards the wellbore which has a large drainage area towards the low-permeability formation. Solid materials used for filling the created fracture, prevent the fracture from closure induced by fluid pressure drop (Fjær *et al.*, 2008).

The technique is mechanically associated to three phenomena, 1-Pressure parting in water injection wells in secondary-recovery operations, 2-lost circulation during drilling, and 3-the breakdown of formations during squeeze-cementing operations. They appear to involve the formation of open fractures by pressure applied in a wellbore. The most popular interpretation of this mechanism has been that the pressure had parted the formation along a bedding plane and lifted the overburden, notwithstanding the fact that in the great majority of cases where pressures were known they were significantly less than those due to the total weight of the overburden as determined from its density (Hubbert and Willis, 1957).

Modelling of fracture geometry (width, length, and height) is an interesting topic, specifically in the interest of hydraulic fracturing as a stimulation technique. The classical models for fracture geometry in two dimensions are the so-called PKN (Perkins–Kern–Nordgren) (Perkins and Kern, 1961) and KGD (Kristianovitch–Geertsma–Daneshy) models (Geertsma and De Klerk, 1969). The former assumes strain to be confined to the horizontal plane, while the latter assumes plane strain vertically. In common assumptions for both of the models are:

- The fracture height is constant and has a direct relationship with fracture length.
- The net pressure at the fracture tip is zero (Actually a net pressure must be available to overcome the tip resistance and start the propagation of the fracture, so this is assumed to simplify the model).

A schematic illustration of the two models is given in Figure 1.2 (Fjær *et al.*, 2008).

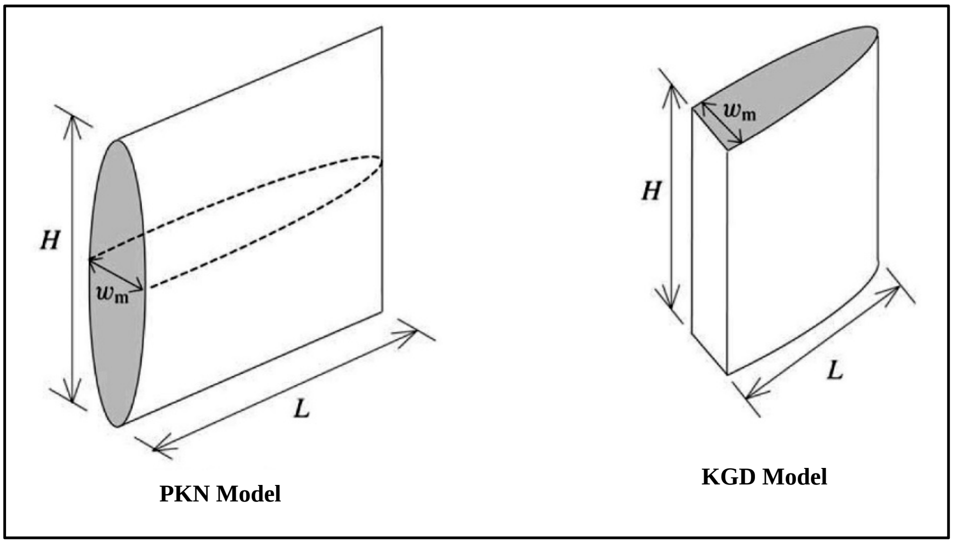

Figure 1.2 Simplistic illustration of 2-D fracture models

1.2 Problem statement

Several principal parameters must be considered in the design of hydraulic fracturing including propagation characteristics and dimension of a hydraulic fracture. The dimension (opening width, length, and height) of hydraulically created fracture can be precisely predicted for a specific time and pumping rate, knowing the properties of reservoir rock, fracturing fluid and the magnitude and direction of in-situ stress (Yew, 1997). Mechanical rock properties consist of Poisson's ratio and Young's modulus. Viscosity and pumping rate of the fluid are considered as fracturing fluid properties.

In order to have an accurate and optimum fracture design, it is necessary to evaluate parameters affecting the dimension of the fracture. Effect of each parameter on the fracture geometry is important in order to know which one has positive or negative effect.

1.3 Objectives of the Study

Objectives of this study are:

i. To investigate the impact of design parameters on the fracture geometry.
ii. To study the relative significance of these parameters between two classical fracture propagating models.
iii. To compare the values of fracture width and length calculated by above-mentioned models.

1.4 Scope of Study

This study concentrates on two basic constant height linear models which are applicable to vertical fractures propagating from a wellbore over the full height of a productive interval. Due to this limitation, only vertical wells will be considered.

The parameters that can affect the fracture geometry and analyzed are related to the mechanical rock characteristics and fracturing fluid specification. They are Poisson's ratio, Young's Modulus, fluid pumping rate, fluid viscosity and fracture height. Fracturing fluid will be considered as a Newtonian fluid, meanwhile it is presumed that no fluid leak off exists to the formation.

The input data that is used in this study have been extracted from previous treatment that have been successfully done in a Malaysian gas condensate field named Angsi.

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