THE USE OF α-AMYLASE AND PULLULANASE ENZYMES IN WELLBORE CLEANING

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I dedicate this thesis especially for

my beloved parents, little brothers, families and friends,

for their full support and endless love.

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ABSTRACT

The α-amylase and pullulanase enzyme treatment solutions were introduced to overcome the issue of formation damage. The laboratory procedures had been conducted under static condition at different temperatures ranging from 75°F to 250°F. The treatment process was performed using two types of concentration, namely by percentage of volume and by enzyme unit activity. Experimental results showed that the optimum degradation efficiency using concentration of enzyme by volume was at 6%, where α-amylase achieved 82% of degradation efficiency at 100°F and pullulanase gave 87% at 150°F. The optimum concentration using enzyme unit activity was at 150U/100 ml where both α-amylase and pullulanase achieved 68% of degradation efficiency at their respective optimum temperatures. Enzyme stabiliser and viscoelastic surfactant were introduced into the enzyme solutions in order to enhance the degradation efficiency of the enzymes beyond their optimum temperatures. The experimental results revealed that the addition of enzyme stabilizer had succeeded in improving the degradation efficiency for both α-amylase and pullulanase enzyme (i.e. 64% and 69% as compared to 58% and 66% at 200°F respectively) while the addition of viscoelastic surfactant had allowed α-amylase and pullulanase enzymes to experience an increase in degradation efficiency of 60% and 67% respectively as compared to 58% and 66% at temperature of 200°F respectively.

ABSTRAK

Rawatan menggunakan enzim α-amilase dan pullulanase telah diperkenalkan untuk mengatasi masalah kerosakan formasi. Prosedur makmal yang terlaksana telah menggunakan keadaan statik pada suhu dari 75°F hingga ke 250°F. Proses rawatan menggunakan dua bentuk kepekatan, iaitu kepekatan berdasarkan peratus isipadu dan kepekatan berdasarkan unit aktiviti enzim. Keputusan uji kaji menunjukkan bahawa kecekapan penurunan optimum kepekatan berdasarkan peratus isipadu adalah pada 6%, dengan α-amilase mencapai 82% pada suhu 100°F dan pullulanase mencapai 87% pada suhu 150°F. Kepekatan optimum larutan enzim apabila menggunakan unit aktiviti enzim adalah pada 150U/100 ml dengan kedua-dua enzim terbabit berjaya menurunkan kek lumpur sebanyak 68% pada suhu optimum masing-masing. Dua jenis bahan tambah, iaitu penstabil enzim dan surfaktan likat-anjal, telah dicampurkan dengan larutan enzim untuk meningkatkan kecekapan penurunan kedua-dua enzim terbabit pada suhu yang melebihi suhu optimum masing-masing. Keputusan uji kaji menunjukkan bahawa penambahan penstabil enzim ke dalam larutan enzim telah berjaya meningkatkan kecekapan penurunan enzim α-amilase dan pullulanase, iaitu masing-masing 64% dan 69% berbanding 58% dan 66% pada suhu 200°F. Penambahan surfaktan likat-anjal pula berjaya meningkatkan kecekapan penurunan α-amilase dan pullulanase masing-masing sebanyak 60% dan 67% berbanding dengan 58% dan 66% pada suhu 200°F.

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LIST OF ABBREVIATIONS

API	-	American Petroleum Institute
HPHT	-	High Temperature High Pressure
VES	-	Viscoelastic Surfactant
WBM	-	Water-Based Mud
HCl	-	Hydrochloric Acid
KNU-B/g	-	Company unit for Alpha Amylase activity
NPUN/g	-	Company unit for Pullulanase activity
V_{max}	-	Maximum Rate
KCl	-	Potassium Chloride
Ca^{2+}	-	Calcium Ions
μ_p	-	Plastic Viscosity
Y_P	-	Yield Point
GS	-	Gel Strength

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

The drilling fluid is an essential part of a successful drilling operation. The drilling fluid runs several important functions and is continuously linking to the bit and borehole. Information such as cuttings, mud colors, circulating pressure, etc. can be obtained from the circulating mud. The drilling practices have been enhanced through the development of drill-in fluids with the aim of maximizing the wellbore contact with productive intervals. The drill-in fluids are invented to give the functionality of drilling mud to drill through the productive zone while at the same time reducing the wellbore damage experienced with conventional drilling fluids (Rabia, 1985).

In order to achieve clean drill-in fluids, it is usually comprises of starch, cellulose or xanthan polymer and sized calcium carbonate or salt particulates (Suhy and Harris, 1998). Although drill-in fluids are naturally less damaging than the conventional drilling mud, but the relative impermeable filter cakes still deposited on the borehole wall. The filter cake deposited on the formation can be classified into external and internal filter cakes. External filter cake is deposited on the sand face whereas the internal filter cake occurs inside. The filter cake will seal the wellbore and minimize fluid leak-off into the formation. It is assumed that the filter cake can be removed by the natural clean-up and from sufficient drawdown during production.

Insufficient degradation of the filter cake can inhibit flow capacity at the wellbore wall where it may result in sizeable reduction of the well productivity. The part of the wellbore that has been exposed to drill-in fluids for the longest period is the most damaged which could result in reduction of well productivity. As a result, it will lead to a poor production profile and reduce the efficiency of the completion. Therefore, the formation damage is totally unacceptable by reservoir and production engineers.

Since the clean-up of the drilling fluid filter cake is not an easy task especially in long horizontal and multilateral wells, numerous methods have been used to remove the damage with the intention to increase the well productivity (Siddiqui *et al*., 2006). There are mechanical techniques which include the circulation of completion brine at a relatively high rate to induce sufficient erosion to the external filter cake (Aslam and Alsalat, 2000). Also there are chemical techniques, such as hydrochloric acids, oxidizing agents, combination of acids and oxidizing agents, chelating agents, enzymes or combination of chelating agents with enzymes. However, all of these methods have their own advantages and limitations.

1.2 Problem Statement

Throughout the drilling and completion operations in petroleum industry, the main aim is to enable a well to produce oil within the targeted time and cost. However, the operation can be interrupted when the filter cake on the surface of the well bore is not properly degraded. Historically, various methods have been used as clean-up treatments, such as strong acids and oxidizing materials so as to boost polymer degradation and removal. Nevertheless, field experience has shown that the use of acids and oxidative solutions to remove filter cake have proven somewhat ineffective based upon well performance (Samuel *et al.*, 2009). When these treatments are applied in extended length open hole intervals, the problem becomes obviously proven.

Enzymes have been suggested as one of the remedial treatments amid the advances in biotechnology research. The application of enzyme in the petroleum industry can be one of the major solutions if the strength and capability of an enzyme is well covered. However, the use of enzyme has a serious limitation; unstable at high temperatures. Samuel *et al.* (2009) had mentioned that enzyme activity decreased as the temperature increased from 122°F to 140°F. Thus, the enzyme solution needs a stabilizer which could sustain its activity exceeding the optimum temperature.

As in heterogeneous formations where there are high permeability streaks, it will require a large volume of the treatment fluids. A serious problem may arise as it will lead to poor performance due to higher rate of absorption of the treatment fluid. Consequently, many jobs may needed monitor and retain the permeability of the formation. In order to reduce leak-off rate, the viscosity of the enzyme solution must be increased and this can be done through the use of polymers or viscoelastic surfactants. The addition of the viscoelastic surfactant to the enzyme solutions will reduce the surface tension and increase the viscosity of the enzyme solutions which will shorten the time required in transporting treatment fluids to the formation due to its elastic properties (Nasr-El-Din *et al.*, 2007).

Normally the amount of an additive to be used in a certain formulation is determined based on a percentage level. Every enzyme has its own unit of activity that eventually verifies its point of strength in accomplishing a job. Equal dosage of enzyme used will produce different results of by-product. Hence, it will be more useful to take note on the level activity of an enzyme so that it will be much easier to handle and applying them in a given job.

1.3 Objectives of Study

The objectives of this study were:

(1) To analyze the effectiveness of pullulanase and α-amylase as a treatment fluid in degrading and removing filter cake.
(2) To analyze the effect of enzyme stabilizer and viscoelastic surfactant in the treatment fluid at various temperature ranging from 75°F to 250°F.

1.4 Scopes of Study

(1) This study focused on degrading and removing the filter cake that generated by water-based mud in a system with temperature ranging from 75°F to 250°F. Three main equipments were used in the static conditions: High Pressure High Temperature (HPHT) filter press, rheometer, and Du Nuoy tensiometer.

(2) The rheological properties of the drill-in-fluid were tested according to the API-RP-13B-1, 2009 (American Petroleum Institute Recommended Practice Standard Procedure for Testing Water-based Drilling Fluids).

(3) There were three types of treatment fluids prepared from two different enzymes, namely α-amylase and pullulanase. The solutions were observed according to the enzyme unit activity and concentration based on the percentage ranging from 6% to 8%.

(4) Benchmarking the enzyme treatment solution against the conventional treatment solution.

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