THE USE OF DURIAN RIND AS LOST CIRCULATION MATERIAL

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"My dearest husband, mum, dad, family and friends"

This is for all of you

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ABSTRACT

Worldwide oil and gas operators are expecting service companies to deliver integrated techniques for minimizing drilling problems, if not prevented. Lost circulation or lost return is known as the total or partial loss of drilling fluid while drilling. The significant and continuing loss of mud to a formation affects the oil industry. Numerous solutions and drilling practices are applied in the field to prevent or cure lost circulation. In this research work, an extensive laboratory works were conducted to investigate the feasibility of sealing fractures using durian rind as a lost circulation additive based on the American Petroleum Institute (API) Recommended Practice 13B for API Specification of Bridging Materials for Regaining Circulation (2009). In this experimental work, three types of samples were used, i.e., untreated durian durian rind (with pectin), treated durian rind (without pectin), and fibro seal. Chemical treatment was done on durian rind to remove natural pectin. FTIR analysis shows that NaOH is the most effective solvent for pectin removal. The experimental results revealed that 30 lb/bbl of untreated and treated coarse durian rind in water-based mud samples show an outstanding performance in combating lost circulation with slot widths from 1 to 3 mm as compared to coarse fibro seal which only shows an outstanding performance for 1 mm slot disc and also in marble bed test with lost mud volume of 10 and 25 ml respectively compared to 30 lb/bbl of coarse fibro seal with mud loss volume of 150 ml. TGA analysis shows that alkaline treatment has improved thermal properties of durian rind. Besides that, the rough surface of treated durian rind fibers has successfully interlocked them over the fracture and subsequently formed a tough bridge which results in the prevention of lost circulation.

ABSTRAK

Syarikat minyak dan gas di seluruh dunia mahukan syarikat servis menghasilkan teknik yang bersepadu bagi meminimumkan masalah penggerudian, jika tidak mampu mencegahnya. Kehilangan edaran ialah kehilangan total atau kehilangan separa bendalir gerudi ketika berlangsungnya operasi penggerudian. Kehilangan lumpur secara ketara dan secara berterusan menjejaskan industri minyak. Pelbagai penyelesaian dan amalan penggerudian digunakan di medan untuk mencegah atau menangani kehilangan edaran. Dalam kajian ini, kerja-kerja makmal telah dilaksanakan bagi mengkaji kemampuan kulit durian sebagai bahan tambah kawalan kehilangan edaran bagi mengedap retakan berdasarkan Amalan 13B yang disyor Institut Petroleum Amerika (API) untuk Spesifikasi Bahan Perapat bagi Mengembalikan Pengedaran (2009). Dalam uji kaji makmal ini, tiga jenis sampel digunakan, iaitu kulit durian yang tidak dirawat (mengandungi pektin), kulit durian yang dirawat (tanpa pektin), dan palam fibro. Rawatan kimia dilakukan pada kulit durian untuk menyingkir pektin. Analisis FTIR menunjukkan bahawa NaOH ialah pelarut yang paling berkesan bagi penyingkiran pektin. Keputusan uji kaji mendedahkan bahawa 30 lb/bbl kulit durian kasar yang tidak dirawat dan dirawat dalam sampel lumpur gerudi dasar air berjaya menunjukkan prestasi yang cemerlang dalam menangani kehilangan edaran bagi retakan dengan kelebaran dari 1 mm hingga ke 3 mm berbanding palam fibro kasar yang hanya menunjukkan prestasi yang cemerlang untuk retakan 1 mm dan juga dalam ujian lapisan marmar, dengan isi padu lumpur yang hilang masing-masing bernilai 10 dan 25 ml berbanding 30 lb/bbl palam fibro kasar dengan jumlah kehilangan lumpur sebanyak 150 ml. Analisis TGA menunjukkan bahawa rawatan alkali berjaya meningkatkan sifat haba kulit durian. Di samping itu, gentian kulit durian dengan permukaan yang kasar selepas rawatan telah saling mengunci sesama sendiri pada permukaan retakan, lalu menghasilkan suatu palam yang padat dan kukuh sehingga berjaya menghambat kehilangan edaran.

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API	-	American Petroleum Institute
LCM	-	Lost Circulation Material
FTIR	-	Fourier Transform Infrared Spectroscopy
SEM	-	Scanning Electron Microscopy
LC	-	Lost Circulation
PV	-	Plastic Viscosity
YP	-	Yield Point
AHR	-	After Hot Rolled
BHR	-	Before Hot Rolled
TGA	-	Thermogravimetric Analysis

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Lost circulation is defined as the loss of the drilling fluid into the formation. It is one of the most challenging operational problems which should be controlled, mitigated, or prevented during drilling operations (Mortadha *et al.*, 2014). In oil and gas drilling operations, the loss of drilling fluid occurs when it flows into one or more geological formations instead of returning to the surface. The causes of lost circulation are based on simple physics of the overbalance pressure which forces the migration of the drilling fluid from the wellbore to the formation (Samuel *et al.*, 2014). Besides that, this problem can also be induced by poor drilling practices such as induced fractures caused by high mud weights or pressure surges (Eric *et al.*, 2000). Usually, lost circulation occurs in highly permeable, cavernous, or fractured zones. The significant and continuing losses of drilling fluids into formation can affect the productivity of an oil well and thus profitability of oil companies. When lost circulation occurs during a drilling operation, it would affect the drilling progress by halting or slowing it down. Circulation loss is said as one of the major issues that lead to non-productive time (NPT) and costly problem experienced by drilling engineers (Sandeep *et al.*, 2012; Alexander *et al.*, 2012; Sharath *et al.*, 2014). According to Brandli *et al.* (2014), lost circulation becomes one of the oil industry's main drilling challenge because on average every second well drilled faces the said problem.

The severity of the drilling fluid losses to formation can be categorized based on the loss rate barrels per hour where 1 to 10 bbls/hr as seepage loss, 10 to 500 bbls/hr as partial losses, and over 500 bbls/hr as severe. According to Shamsa *et al.* (2014), these problems contribute negative impact to well integrity, economics, and well's life cycle. Moreover, this problem may also lead to other potentially costly drilling issues such as stuck pipe, increased non-productive time, etc. (Mark *et al.*, 2010). Therefore, it is important to consider the loss circulation problem during the well planning stage.

High demand of hydrocarbon is one of the factors that have encouraged the industry to explore more challenging hydrocarbon targets once considered unreachable and towards harsh environments, such as the marginal fields in an extreme environment (Sharath *et al.*, 2013; Bipin *et al.*, 2013). The oil and gas industry will have to invest massive amounts of capital and venture into even more challenging and costlier production provinces such as the ultra-deep waters, ultra-deep reservoirs, and unconventional resources. However, to drill in such difficult environments and current low global oil prices scenario, an unexpected mud loss to formation can worsen the situation and subsequently increases the oil operator's overall cost (Sharath *et al.*, 2013; Sharath *et al.*, 2014). Hence, preventing and curing lost circulation of drilling fluid is imperative. Therefore, over the past few years numerous papers related to lost circulation have been published (Brandli *et al.*, 2014). Alsaba *et al.* (2014) highlighted that the amount of drilling fluid losses into the formation were estimated to be around 1.8 million barrels per year.

When a lost circulation is detected, commercial lost circulation materials (LCMs) such as mica and calcium carbonate are spotted into the formation. According to Samuel (2014), there are some disadvantages of these lost circulation additives as they are not effective in a cavernous formation and may cause formation damage due to plugging in the production zones. Commercial LCMs often reach their limit of effectiveness and become unsuccessful in deeper holes where formations are structurally weak or naturally fractured and faulted (Wang *et al.*, 2005). For cavernous or vugular formations the typical LCMs applied are fibrous material however they have some limitations in oil-based mud (OBM).

Durian rind is a fibrous material and it may form a network over the fracture to reduce the mud loss. Therefore, in this research work, durian rind was studied as a new lost circulation additive. It is interesting to note that the recent successful solution in curing mud losses in the formation was via the usage of fibrous material (Valsecchi, 2013). Fiber composed of inert material, which is easy to disperse and able to form a 3D network across the loss zone, allowing the solids in the drilling fluid to bridge-off thus curing the losses and regaining circulation (Nicolas *et al.*, 2014). Furthermore, fibers are a bridging material that can form an interlocking net over the pores or fractures and prevent other particles in the fluid from passing through. There are several parameters that affect the performance of a LCM to cure mud losses, namely type, concentration, particle size distribution, and fracture width (Mortadha *et al.*, 2014).

Since drilling time is related to operational cost therefore any solution that can provide drilling engineers a solution to combat losses in a relatively short period and allow further drilling is valuable because it can reduce expenditure (Bipin *et al.,* 2013) especially via the reduction of NPT. Apart from that, the obvious benefits of maintaining circulation, curing or preventing mud losses are important to other drilling objectives such as obtaining a good quality formation evaluation and achieving an effective primary single- or two-stage cement bond on casing (Shamsa *et al.*, 2014). Furthermore, controlling mud losses during a drilling operation can prevent an influx of reservoir gas or fluids into wellbore as kick which may result in blowout under the worst scenario (Shamsa *et al.*, 2014). Apart from that, the potential of using agro-waste materials like durian rind to combat mud losses would result in a great benefit in terms of reducing drilling operational cost.

1.2 Problem Statement

Lost circulation is the loss of drilling fluid to the formation which can significantly increase the operational cost and risks to oil companies and drillers around the world and threaten to pose greater challenges in the future. Lost circulation

may be encountered due to the presence of highly permeable formation, (i.e., high natural permeability in sandstones), or large natural fractures and vugs as found in limestones. This problem is critical as it increases the drilling costs due to NPT, plus the possibility of stuck pipe and even losing the well. Estimates of direct and associated costs run into hundreds of millions of dollars globally including whole mud losses, cost of treatment as well as lost time (or including increase in non-productive time) and tools (Sanders *et al.*, 2010). Furthermore, other detrimental effects due to mud losses are lost of rig time, blowouts, and in some cases the abandonment of expensive wells (Catalin *et al.*, 2003). When lost circulation occurs, it can provoke new requirements of time and mud and add substantially to the overall cost of a well. A routine practice to control lost circulation is by adding lost circulation additive(s) into the drilling fluid system in order to fill the fractures and vugs induced by overbalanced drilling fluids.

If lost circulation issues not were prevented it may affect oil and gas production which would result in failure to secure production tests and samples while the plugging of production zones has led to decreased productivity (Ivan *et al.*, 2003). Minimize or overcome the lost circulation issues is important because it can cut down significant expenditure. Once a driller is able to overcome the lost circulation issues, it can reduce NPT and complication cost.

Generally durian waste causes negative impacts in terms of environmental concern due to high amount of pollutant disposal. Such a waste disposal would increase huge cost related to its waste management. The use of durian rind as a new additive in controlling lost circulation would provide another opportunity to reduce the waste problem. In Malaysia, the rind constitutes in average 45% for each fruit and subsequently the durian rind waste generates about 133,688 to 171,304 metric tons from the year of 2006 to 2013 respectively (Shaiful *et al.*, 2016). Based on an annual report released by the Ministry of Agriculture and Agro based Industry of Malaysia (2016), there was 368,271 metric tons of durian produced in 2015. Hence, a huge amount of durian waste was disposed (i.e., 368,270 metric tons) and this caused an alarming environmental problem to the community. Therefore, the utilization of durian rind as a lost circulation additive would be beneficial in addressing the issue.

Durian rind is an agricultural waste fiber mainly constituted of cellulose that is glucose polymer with relative high modulus (Charoenvai, 2014). Natural fiber has drawn increased attention due to the distinctive performance its features, such as relatively high stiffness, low density, renewability, low cost, and environment friendliness. The presence of high percentages of cellulose and lignin in durian rind was the main reason for getting chosen as the potential LCM to be investigated further. High percentages of cellulose and lignin might make the durian rind tougher.

From a study done by Ismail *et al*. (2015), the performance of durian rind was said to have been affected by the presence of pectin. Pectin is able to form gel. Sundari (2015) stated that gel formation is caused by hydrogen bonding between free carboxyl groups of the pectin molecules and also between the hydroxyl groups of neighbouring molecules (Chan *et al*., 2017). The presence of pectin in durian rind increased the viscosity of the drilling fluid. Increase of viscosity causes friction which impedes the circulation of the mud causing excessive pump pressure, hampers the solids removal equipment, and decreases the drilling rate. Durian rind without pectin might produce a better performance as LCM where its pectin could be removed using a solvent. Therefore this research work covered the experimental investigation of the performance of durian rind with and without pectin in water-based mud.

1.3 Objectives of Study

The overall of objective of this study is to develop a new lost circulation material based on durian rind as additives.

The objectives of this research work are as follow:

(1) To determine the rheological properties of untreated durian rind (with natural pectin) and treated durian rind (without natural pectin) as LCM
(2) To investigate the effect of pectin on mechanical and thermal properties on untreated durian rind and treated durian rind

(3) To investigate the performance of untreated durian rind and treated durian rind as a lost circulation material in a water-based mud system

1.4 Scope

To successfully cure the mud losses during drilling operations, the lost circulation additives are added into the drilling mud. There are several parameters influence the performance of loss control additives such as type of drilling fluid, type of additive, type of formation and fractures, particle size distribution, and concentration of additive added. However, this research work only focused on the effectiveness of durian rind as a lost circulation additive in water-based mud. Besides that, the commercial additive – Fibro seal – provided by Scomi Energy was used as the commercial lost circulation control additive when evaluating the performance of durian rind with and without pectin.

The scope of this research composed of:

(1) Laboratory experiments were conducted using three types of materials i.e., untreated durian rind, treated durian rind, and fibro seal
(2) Laboratory experiments were conducted on four different sizes of particles i.e., fine (44 to 74 microns), medium (74 to 250 microns), intermediate (250 to 2000 microns), and coarse (greater than 2000) size in a water-based mud system.
(3) Laboratory experiments were conducted on six different concentrations of particles (i.e., 5, 10, 15, 20, 25, and 30 lb/bbl) in a water-based mud system.
(4) Laboratory experiments were conducted to determine the category of losses: fracture formation (slot discs of 1, 2, and 3 mm) and unconsolidated formation (marble bed)
(5) Rheological properties tests were conducted before and after hot rolling at temperature 250 ^{o}F.

1.5 Significance of Study

The high demand for oil requires petroleum engineers to explore more complex and challenging deeper tertiary formations. Hence, lost circulation study becomes prevalent and thus the significance of this research work became apparent. This statement was well supported by many research findings in open literature (Li *et al.*, 2009; Brandi *et al.*, 2014). The positive findings from this research work would contribute directly to well drilling practices in reducing significant expenditure in drilling operations. By understanding the properties of drilling fluid and the lost circulation material's behaviour in drilling fluid allows the operators to make accurate decisions in combating mud losses. Pumping lost circulation additives into drilling mud to arrest drilling fluid losses in formation only can be effective via an engineered approach — understand the loss zone's characteristics and also the selection of mud loss additive.

Solutions for dealing with conventional lost circulation materials are numerous and well reported by Saadeep *et al.* (2012). Conventional lost circulation materials contribute several disadvantages such as not effective in cavernous formation and may cause plugging which subsequently will damage the production zones (Samuel *et al.*, 2014). Hence, durian rind – a fibrous material – was evaluated for its performance as LCM in this research work. If durian rind was proven to be a good loss circulation control material for tertiary formation, it would be able to mitigate durian rind waste problem, if not avoided, and at the same time can improve further farmers' quality life and oil companies' profitability.

Having lost circulation material onsite is insufficient to counter effectively lost circulation incidences. For that reason, a comprehensive knowledge related to physical and chemical properties of the additives would be an added advantage. FTIR analyses were conducted to identify the absence of pectin after chemical treatment. Besides that, this research study also emphasized the degradation of durian rinds in terms of size reduction during circulation processes.

1.6 Chapter Summary

This chapter briefly describes lost circulation events, its definition and detrimental effects to drilling operations. It is complemented with the difficulties in controlling drilling fluid losses to formation during a drilling phase. This chapter also highlights the importance of combating and curing lost circulation. Four scope have been outlined to realise the objectives of this research work. The scope were physical and chemical tests of durian rind, measurement of rheological properties of drilling fluids, shear degradation test, loss circulation test, and mud rheological model test. Last but not least, this chapter highlights the significance of this study which includes the possibility of mitigating loss circulation in a more effective manner and improving profit for durian farmers and oil operators.

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