CORROSION RATE PREDICTION OF OIL FLOWING IN PIPELINES BY COMPUTATIONAL FLUID DYNAMICS

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DEDICATION

This thesis is dedicated to my father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

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In The Name Of Creator of Existence

The Most Merciful and the Most Gracious

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ABSTRACT

The transportation of crude oil by pipelines has been reported as the most important process in petroleum industry. The pipe line corrosion problem is a very complex phenomena arising from the concurrent activation of several chemical reactions, one of the most popular instant of corrosion in the two phase flow oil water containing CO_2 dissolved in water in pipe lines. The pipe line internal corrosion is under a synergistic effect of electrochemical reactions, mass transfer and wall shear stress exerted by fluid flow and the effect of flow velocity. In this work, computational fluid dynamics (CFD) simulations were performed to determine wall shear stress in oil-water two phase fluid flow in pipelines for two types of crude oils (different viscosities) at flow velocities of 0.2, 0.3, 0.5 and 1 m/s. The CFD based empirical model is able to predict corrosion rate of pipelines, with the modelling results validated by actual measurements. The input parameters to ANSYS Fluent are (viscosity, density and fluid flowing velocity), and the output of computer simulation is the wall shear stress. From the computer simulation results, the maximum value of wall shear stress occurs at the maximum value of velocity. From that the corrosion rate in the pipeline was determined by applying the corrosion rate equation at two different values of CO_2 partial pressure. From the results, the wall shear stresses for the two crude oils were in different values depending on the properties of the crude. The result showed that corrosion rates for both crudes increased with increase in flow velocity and CO_2 partial pressure. This study concluded that the ANSYS capability to predict the corrosion rate of the pipeline for two types of crude oil after determining the wall shear stress with different values of velocities.

Key words: corrosion rate, shear stress, CFD, Carbon dioxide, pipeline

ABSTRAK

Pengangkutan minyak mentah oleh saluran paip telah dilaporkan sebagai proses yang paling penting dalam industri petroleum. Masalah hakisan karat dalam saluran paip adalah fenomena yang sangat rumit yang timbul daripada pengaktifan beberapa tindak balas kimia yang berlaku serentak, salah satu tindak balas pantas penghasilan hakisan karat yang paling popular ialah dua aliran fasa minyak yang mengandungi CO_2 yang larut dalam air yang mengalir melalui saluran paip. Penghasilan karat dalaman saluran paip adalah di bawah kesan tindak balas sinergistik elektrokimia, pemindahan jisim dan tekanan geseran dinding yang disebabkan oleh pengaliran cecair dan kesan halaju aliran cecair. Dalam kertas kerja ini, simulasi dinamik bendalir dinamik (CFD) dilakukan untuk menentukan tekanan ricih dinding dalam aliran air dua fasa aliran minyak dalam saluran paip untuk dua jenis minyak mentah (kelikatan yang berlainan) pada halaju aliran 0.2, 0.3, 0.5 dan 1 m /s. Model empirikal berasaskan CFD mampu meramalkan kadar hakisan karat saluran paip, dengan hasil pemodelan melalui pengukuran sebenar. Parameter yang digunakan dalam ANSYS Fluent adalah (kelikatan, ketumpatan dan halaju aliran bendalir), dan keputusan simulasi komputer adalah tekanan geseran dinding. Daripada keputusan simulasi komputer, nilai maksimum geseran dinding adalah pada nilai maksimum halaju.Oleh itu kadar hakisan karat ditentukan dengan menggunakan persamaan kadar hakisan karat pada dua nilai tekanan separa CO2 yang berbeza. Keputusan yang diperolehi, tegasan geseran dinding untuk kedua-dua minyak mentah berada dalam nilai yang berbeza bergantung pada sifat-sifat minyak mentah. Hasilnya menunjukkan bahawa kadar hakisan karat bagi kedua-dua minyak mentah meningkat dengan peningkatan halaju aliran dan tekanan separa CO2. Kajian ini menyimpulkan bahawa ANSYS berupaya untuk meramalkan kadar hakisan karat saluran paip untuk dua jenis minyak mentah selepas menentukan tekanan geseran dinding dengan nilai halaju yang berlainan.

Kata kunci: kadar hakisan karat, tegasan ricih, CFD, Karbon dioksida, saluran paip

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LIST OF SYMBOLS

K_{sp}	-	The solubility
$\frac{A}{V}$	-	Surface area to volume ratio
G*	-	Complex modulus
G′	-	Modulus of elasticity
G″	-	Loss modulus
°C	-	Degree Celsius
%	-	Percentage
KR_{NOR}	-	Norsok model corrosion rate
K_t	-	Temperature dependent constant
f_{CO2}	-	Fugacity of CO_2
τ_w	-	Wall shear stress
$f(pH)_t$	-	Complex function of pH
i_{Fe}	-	Anodic corrosion current density
$-D\nabla c$	-	Concentration gradient
$\overrightarrow{\vartheta} c$	-	Moving fluid
S_h	-	Sherwood number
Re	-	Reynolds number
Sc	-	Schmidt number
P_{CO2}	-	Carbon dioxide partial pressure
S	-	Saturates
A	-	Aromatics
R	-	Resins
U	-	Velocity
P	-	Density
μ	-	Viscosity
D	-	Rate of deformation tensor
up	-	Mean velocity
yp	-	Distance from point p to the wall
kp	-	Turbulent kinetic energy
k	-	Von karman constant
E	-	Empirical constant
m	-	Meter
s	-	Second

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CHAPTER 1

INTRODUCTION

1.1 Background

The transportation of Crude oil by pipelines has been reported as the most important process in petroleum industry. The variation of physical and chemical properties of crude oil usually affected by different environmental conditions (Saniere *et al.,* 2004). Alot of researchs conducted to estmate the rheological properties of un-similar kinds of crude oils (Jian Zhang *et al.*, 2012). Generally, specific gravity, density and sulfur content are the essntial factors that define crude oil.

Petroleum encompasses a complecated chemical environment with tangled mixture of hydrocarbons and little amounts of heteroatom compounds. To anticipate behavior of any rock oil product, it is therfore necessary to grasp the chemical composition. Corrosion, density, emulsion stability, surface tension and viscosity are all very necessary physiochemical properties that have impact on how that crude oil acts and how crudes ought to be handled. In the process of understanding the physical and chemical behavior of this crude oils it has been found that the Polar substance is the foremost necessary factor. Most far-famed polar compounds are carboxylic and phenolic acids, organic bases and metal. Naphthenic acid is utilized as a word in relevance to all of the organic acids (Borgund *et al.*, 2007; Clemente and Fedorak, 2005; Speight, 2006). The emulsion viscosity is considerably influenced via shear rate. Resultant shear rate toward consistence is attributed via a disperse phase mass. The outcome behavior is reaction for droplets state of affairs / viscosity of the structural.

The dispersed phase water percentage also had a necessary influence toward the emulsion viscous which is up raise when there is an increase with the fractions of

water volume. The number of hydrogen bonds can mainly influence the water fraction as well as the hydrodynamic forces.

1.2 Problem Statement

The analysis of the influence of viscosity of crude oil emulsions is considered very necessary within the field of rheology to seek out the way for the development and transportation of oil (Langevin, 2004; Martínez-Palou, 2011). Often, crudes is found in mixed state during which the concentration of water is consistent. Due to the complexed behavior of the crude oil, it is subjected to numerous difficulties during various processes such as production, separation, transportation, and purification. Infact, the transport of heavy oil feed stock through the pipelines is influnced negativly by the high concentrations of sulfur and acids within it.

Furthermore, Corrosion issues happen in each side of oil and gas trade, from production and transportations to storage and purifiction job . One in all the foremost standard instants corrosion is that of internal corrosion interior transportation pipeline. The inner corrosion in oil and gas wells and pipelines that made of steel is plagued by alot of factors together with water chemistry, temperature, flow velocity, CO_2 and H_2S contents, phase wetting (water wetting or oil wetting) and the composition and surface condition of the carbon steel itself (Kvarekval *el al.*, 2003; Nesic *el al.*, 2003).

This lead to loss of materials, reduction in thickness, and now and then final failure. Some extent are going to be reached wherever the parts could fully break down and also the assembly can have to be replaced whereas production is stopped and thus led to a worldwide issues of the intense consequences of that corrosion method as reported by hill (2000).

In this work, computational fluid dynamics (CFD) simulations was used to calculate the wall shear stress for oil flow in pipelines. As well as an empirical

model was developed to predict the corrosion rate of pipelines crude oil by integration the CFD simulation. In the fluid of two types of oil the model was conducted and the outcomes were validated by truly measured wall shear. Moreover, the reserach explained the method of determining wall shear stress. How the corrosion rate for crude oil through steel pipe could be determined?, Does simulation create a verification of the experimental results?, Does and how velocity has a controll on shear stress along pipe? and Have density and viscosity impact on corrosion rate?.

1.3 Objectives

The main objectives of this study are:

1. To calculate shear stress of two crude oils with different properties at the following velocities (0.2,0.3,0.5 and 1 m/s)
2. To predict corrosion rate of the crude oils at the following velocities (0.2,0.3,0.5 and 1 m/s) and two Carbon dioxide partial pressure.

1.4 Scope of Study

The present research will cover the following scopes:

1. Specific crude oil has been nominated to the analysis by the current study. ANSYS software was chosen to predict the shear rate and for the following velocities (0.2, 0.3, 0.5 and 1 m/s).
2. Investigate corrosion rate for the crude oil by using ANSYS software. The calculations of corrosion rate are depending on shear stress and the velocity of fluid by using the formula of $CR = Kp^c \tau^b$ where CR is corrosion rate (mm/year), k is the coefficient of the corrosion rate with a

value of 15.5, p is the partial pressure (MPa), and c is the exponent with a value of 0.8370, b is the exponent of shear stress with value of 0.1.

1.5 Significant of Research

The results from this project can enable a reappraisal of the competitive theories of corrosion. This issue is one of the foremost vital topics, not solely within the fossil oil only, however globally, as documanted by quantity of papers, books and international conferences on this subject that have taken place over the last few years. The question of what is the way to develop a technique to attenuate the corrosion in industrial, machines and pipes perpetually repeated. Therefore it is anticipated that this project would generate an excellent deal of interest, not solely among researchers however additionally among the overall public.

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