

**DISSOLUTION OF WAX USING FUSED CHEMICAL REACTION
WITH ENCAPSULATION**

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for the Degree of Master of Science
The Petroleum and Petrochemical College, Chulalongkorn University
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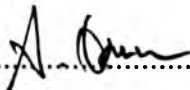
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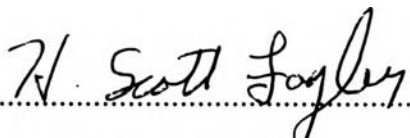
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ABSTRACT

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Wax deposition in pipelines, which causes losses of millions of dollars to the petroleum industry annually, is a persistent and challenging problem. A substantial number of alternative solutions have been suggested but none has succeeded in achieving both technical and economical efficiency. The primary challenge is how to supply heat to regions further down the pipelines that are more susceptible to wax deposition.

This research seeks to prove that the encapsulation technique is promising in delaying the release of heat from an exothermic reaction; the heat, combined with solvents, can then totally melt and redissolve the deposited wax. The rate of polymer dissolution as a function of the regime of the flow, the thickness of the coating, temperature and pH of the solution, and the number of capsules in a unit volume of the solution was determined and used together with the reaction kinetics to simulate the temperature profiles in a batch reactor. The good agreement between the simulation results and the experimental results clearly verifies the kinetics found as well as the model proposed for simulation. Moreover, the experimental results showed that encapsulation technique could delay the release of heat as long as 30 hours, which, as normal operating conditions, is approximately equivalent to a length of 100 kilometers in a pipeline. This important finding was further confirmed by simulation for a pipeline at steady state.

บทคัดย่อ

เหงียน อัน ตีก: การละลายแว็กซ์โดยใช้ปฏิกิริยาการแตกสลายทางเคมีของสารภายในแคปซูล (Dissolution of Wax Deposit Using Fused Chemical with Encapsulation) อ.ที่ปรึกษา : ศ. เอช สกอดด์ ฟอกเลอร์ และ รศ. สุเมธ ชวเดช 55 หน้า ISBN 974-331-901-8

ในแต่ละปี อุตสาหกรรมปิโตรเลียม สูญเสียรายได้ไปหลายล้านเหรียญดอลลาร์ เนื่องจากปัญหาการสะสมตัวของแว็กซ์ที่ผนังท่อในขั้นตอนการขุดเจาะน้ำมันดิบ ซึ่งเป็นปัญหาที่แก้ไขได้ยาก และท้าทายสำหรับนักวิจัยในปัจจุบัน มีวิธีการหลายวิธีในการแก้ไขปัญหานี้แต่ไม่มีวิธีการใดที่มีประสิทธิภาพทั้งทางด้านเทคนิคและเศรษฐศาสตร์ แนวทางการวิจัยหนึ่งที่มีความน่าสนใจสำหรับการแก้ไขปัญหานี้คือ การใช้ความร้อนในการละลายแว็กซ์ที่เกาะตัวอยู่ตามผนังท่อที่ระยะห่างออกไป วัตถุประสงค์ของงานวิจัยนี้เพื่อสาธิตการใช้เทคนิคการบรรจุสารในแคปซูลเพื่อช่วยประหยัดเวลาในการปล่อยความร้อนจากปฏิกิริยาคายความร้อน ความร้อนร่วมกับสารทำลายทำให้แว็กซ์หลอมและละลาย โดยได้ทำการศึกษาปัจจัยที่มีผลต่ออัตราการละลายสารพอลิเมอร์ได้แก่ อัตราการไหล ความหนาของสารที่เคลือบ อุณหภูมิ และค่าความเป็นกรด-เบสของสารละลาย และจำนวนแคปซูลในหนึ่งหน่วยปริมาตรของสารละลาย และอัตราการละลายของสารโอลิเมอร์ถูกใช้คู่กับจลนศาสตร์ของปฏิกิริยาในการสร้างแบบจำลองของอุณหภูมิที่จุดต่างๆ ในปฏิกรณ์แบบกะ จากผลการศึกษาพบว่า ผลของแบบจำลองที่สร้างขึ้นมีความสอดคล้องกับข้อมูลทางจลนศาสตร์ที่ได้จากการทดลอง ผลการทดลองแสดงเทคนิคการบรรจุสารในแคปซูลสามารถประหยัดเวลาในการปล่อยความร้อนได้กว่า 30 ชั่วโมง ซึ่งเทียบเท่ากับความยาวของท่อในการใช้งานจริงประมาณ 100 กิโลเมตร ซึ่งการค้นพบที่สำคัญนี้ได้ถูกพิสูจน์โดยการจำลองในเส้นท่อที่สภาวะคงที่

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LIST OF SYMBOLS

ν_i	stoichiometric coefficient of species i.
α, β	exothermic reaction order
ΔH_{rx}	heat of reaction at temperature T_0
ΔC_p	overall change in the heat capacity
q	polymer dissolution reaction order with respect to $[H^+]$
r	polymer dissolution reaction order with respect to $[P]$
a	heat exchange area per unit volume
A	heat transfer area of the reactor
C_A	concentration of reactant A in the solution
C_{A0}	initial concentration of the limiting reactant in the solution
C_B	concentration of reactant B in the solution
C_i	concentration of species i.
Cl_i	concentration of each ion
C_{p_i}	heat capacity of species i.
C_{ps}	heat capacity of the solution with respect to the limiting reactant
E_0	activation energy of the medium pH region
E_1	activation energy of the low pH region
E_2	activation energy of the high pH region
E_p	activation energy for the polymer dissolution
F_i	molar flowrate of species i.
f_i	salt effect on H^+ or OH^-
I	ionic strength
k_p	rate constant of the polymer dissolution
k_{00}	rate constant of the medium pH region
k_{01}	rate constant of the low pH region
k_{02}	rate constant of the high pH regions
k_{p0}	frequency factor for the polymer dissolution

l	length in the pipeline.
l	thickness of the polymeric coat
m, n	proton concentration orders
n_c	charge of acidic ion
N_0	number of moles of catalyst encapsulated in one capsule
N_{A0}	initial number of mole of the limiting reactant in the solution
n_c	number of capsules introduced into the reactive solution
pH	pH of the solution at the given condition
pK'_a	equilibrium constant with salt effects
pK_a	equilibrium constant without salt effects
r	radius of the pipeline.
r_A	rate of appearance of the limiting reactant
Re	Renold number
Sc	Scmidth number
Sh	Sherwood number
T	temperature of the solution
t	time
t_l	lag time
t_r	release time
U	overall heat transfer coefficient of the reactor
V	total volume of the solution
V	volume in the pipeline
X	conversion of the limiting reactant
z_i	charge of each ion
$[OH^-]$	concentration of OH^- in the solution
$[H^+]$	concentration of proton in the solution
$[A_i^{a_i+}]$	concentration of cation i having a charge of $a_i +$
$[B_i^{b_i-}]$	concentration of anion i having a charge of $b_i -$