

**TURBULENT DRAG REDUCTION OF POLYACRYLAMIDE AND
70% HYDROLYZED POLYACRYLAMIDE SOLUTIONS**

Ms. Wunpen Chonkeaw

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for the Degree of Master of Science
The Petroleum and Petrochemical College, Chulalongkorn University
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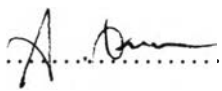
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By : Ms. Wunpen Chonkeaw
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Assoc. Prof. Anuvat Sirivat

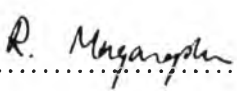
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.......... College Director
(Prof. Somchai Osuwan)

Thesis Committee :

..........
(Prof. Alexander M. Jamieson)

..........
(Assoc. Prof. Anuvat Sirivat)

..........
(Dr. Rathanawan Magaraphan)

ABSTRACT

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It is well known that the energy loss due to skin friction in a turbulent flow is substantially lowered when a small amount of polymer is added to the flowing solvent. In this work, the effects of polymer concentration, salt concentration and molecular weight on the turbulent drag reduction were investigated in PAM and 70% HPAM solutions. They were tested for turbulent drag reduction using our homemade Couette apparatus. Polymer hydrodynamic radius and solution viscosity were measured using dynamic light scattering technique and Ubbelohde viscometer for both sterile water and saline solutions. The amount of turbulent drag reduction was found to correlate well with polymer hydrodynamic radius. The Kolmogorov microscale scales with both hydrodynamic radius, degree of polymerization and concentration, but the scaling exponents differ from those predicted by Lumley's and de Gennes's theories. Our viscoelastic theory with the new truncation length scale is proposed to explain drag reduction mechanism. The theory suggests two opposing roles for elasticity. The correlation between our viscoelastic length scale, l_{ve} and N, c_p was shown. The approximate agreements with experimental data was obtained if we take 'a' to lie between 0.2-0.3, depending whether we want to match concentration or degree of polymerization dependences more closely.

บทคัดย่อ

นางสาววันเพ็ญ ช้อนแก้ว : ชื่อหัวข้อวิทยานิพนธ์ (ภาษาไทย) การลดแรงเสียดทานที่ผนังในการไหลแบบปั่นป่วนโดยสารละลายพอลิอะคริลาไมด์และ70%ไฮโดรไลซ์พอลิอะคริลาไมด์ (ภาษาอังกฤษ) (Turbulent Drag Reduction of Polyacrylamide and 70 % Hydrolyzed Polyacrylamide solutions) อ. ที่ปรึกษา : ศ. ดร. อะเล็กซานเดอร์ เอ็ม เจมิตันและ รศ. ดร. อนุวัฒน์ ศิริวัฒน์ 101 หน้า ISBN 974-331-943-3

เป็นที่ทราบกันดีว่าการสูญเสียพลังงานเนื่องจากความเสียดทานที่ผิวในการไหลแบบปั่นป่วนจะลดลงเมื่อเติมสารละลายเจือจางพอลิเมอร์ลงไป การวิจัยนี้ทำการศึกษาอิทธิพลของความเข้มข้นของสารละลายพอลิเมอร์ ความเข้มข้นของเกลือ และน้ำหนักโมเลกุลของพอลิเมอร์ที่มีต่อการลดแรงเสียดทานที่ผนังในการไหลแบบปั่นป่วนโดยทดสอบกับสารละลายพอลิอะคริลาไมด์และ70%ไฮโดรไลซ์พอลิอะคริลาไมด์ สารละลายของพอลิเมอร์ทั้งสองชนิดนี้ถูกทดสอบการลดแรงเสียดทานที่ผนังโดยใช้เครื่องมือวัดคุณสมบัติทางการไหลแบบทรงกระบอกซึ่งได้รับการออกแบบเป็นพิเศษ เทคนิคการวัดการกระจายแสงและการวัดความหนืดได้ถูกนำมาใช้ในการวัดรัศมีไฮโดรไดนามิกและความหนืดของสารละลายทั้งในน้ำสเดอไรต์และสารละลายเกลือ เราพบว่าปริมาณการลดลงของแรงเสียดทานที่ผนังมีความสัมพันธ์ยิ่งยวดกับรัศมีไฮโดรไดนามิก และโคลโมโกรอฟไมโครสเกลสามารถสเกลกับรัศมีไฮโดรไดนามิกและความเข้มข้นของสารละลายพอลิเมอร์ แต่ค่าเลขกำลังที่คำนวณได้จากการทดลองแตกต่างจากค่าที่ได้จากการทำนายโดยทฤษฎีของลัมเบย์และดี เจนเนส นอกจากนี้ทฤษฎีวิสโคอิลาสติกได้ถูกเสนอขึ้นเพื่อที่จะอธิบายกลไกการลดลงของแรงเสียดทานที่ผนังโดยทฤษฎีนี้ได้เสนอสองบทบาทที่ขัดแย้งกันของแรงอิลาสติกและยังได้แสดงความสัมพันธ์ระหว่างสเกลความยาววิสโคอิลาสติกกับความเข้มข้นและค่าแสดงความยาวของการเกิดปฏิกิริยาซึ่งพบผลที่ได้จากการทดลองจะสามารถอธิบายได้โดยทฤษฎีนี้เมื่อเรากำหนดค่าเลขกำลังที่ไม่ทราบค่า 'a' ให้อยู่ในช่วงระหว่าง 0.2 ถึง 0.3 ซึ่งจะเป็นค่าใดนั้นขึ้นอยู่กับว่าเราต้องการให้ความสำคัญกับค่าความสัมพันธ์ของความเข้มข้นหรือความสัมพันธ์ของค่าแสดงความยาวของการเกิดปฏิกิริยากับความยาววิสโคอิลาสติกมากกว่ากัน

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LIST OF SYMBOLS

R_h = hydrodynamic radius (nm)

R_g = radius of gyration (nm)

T_1 = molecular relaxation time (s)

N = degree of polymerization

N_A = Avogadro's number

M_a = molecular weight of repeating unit

u_* = friction velocity of drag reduction $(\tau_w / \rho)^{1/2}$ (cm/s)

c_p = polymer concentration (g/l)

C_p^* = overlap concentration (g/l)

Greek Letters

$[\eta]$ = intrinsic viscosity (l/g)

Π = reduced slope increment

κ = slope modulus

ν = kinematic viscosity of solution (cm²/s)

ν_s = kinematic viscosity of solvent (cm²/s)

ν_{turb} = kinematic viscosity of solution due to unraveling chains (equation 1.3)

ζ_{turb} = effective kinematic viscosity enhancement

ρ = density (g/cm³)

τ_* = wall shear stress at onset of drag reduction

τ_w = wall shear stress

Ω = onset length scale constant

δ = slope increment