HELE-SHAW 流場中可互溶流體運動之研究及KORTEWEG 應力的影響

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摘 要

利用高精密度的數值方法模擬可互溶液滴，於均質的HELE-SHAW 流場中之運動現象。對影響參數，包括黏滯度差異、無因次流量（PECLET NUMBER, PE）和液滴大小以及KORTEWEG 應力，作一系統式 分析，以瞭解各參數之重要性及影響效果。 HELE-SHAW 流場為兩塊透明薄板，夾以極小的間隙接合而成的二維流場。由於其第三維的高度極小於其他兩維的長度，因此可將第 三維的速度加以平均起來，視HELE-SHAW 流場為一非旋轉的勢流場（POTENTIAL FLOW）。計算模擬乃將統御方程式轉換為渦度-流函數之關 係式，深入研究因濃度梯度所造成的速度散度，對流場之影響。當液滴黏滯度較環境流體低時，在下游部分的液滴前沿，指狀化現象 受流場的控制參數影響極大，一旦黏滯度差異愈大，或是PE 值愈高時，指狀化情形將更為劇烈。至於在液滴黏滯度較環境流體高時， 可溶液滴移動較慢且較為穩定，並在液滴後緣處產生一個尾巴外型。在考慮到KORTEWEG 應力的影響時，HU AND JOSEPH 在1992 年曾 利用線性穩定分析結果預測負的Δ? 值，可避免不穩定的發生；而從我們的模擬結果亦顯示這時的液滴，前沿將因KORTEWEG 應力的影 響，呈現穩定的狀態，產生相當類似KOPF-SILL AND HOMSY 實驗觀察到的尾巴形液滴（TAILED-BUBBLES）。這時的液滴外型可類比不可溶液 滴對表面張力分佈的說法來預測之，且這些尾巴形液滴的移動速度均介於實驗所量測的範圍。

關鍵詞 : 可互溶液滴、PECLET NUMBER、KORTEWEG 應力

目錄

參考文獻

1. HILL, S. 1952 CHANNELLING IN PACKED COLUMS. CHEM. ENG. SCI.1:247-53 2. HOMSY, G. 1987 VISCOUS FINGERING IN POROUS MEDIA. ANN. REV. FLUID MECH. 19,271. 3. YORTSOS, Y. 1990 INSTABILITIES IN DISPLACEMENT PROCESSES INPOROUS MEDIA. J. PHYS. CONDENS. MATTER 2, SA443. 4. MCCLOUD, K. V. AND MAHER, J. V. 1995 EXPEROMENTAL PERTURBATIONS TO SAFFMAN-TAYLOR FLOW. PHYSICS REPORTS 260, 139. 5. TANVEER, S. AND SAFFMAN, G. 1987 STABILITY OF BUBBLES IN A HELE-SHAW CELL. PHYS. FLUIDS 30, 2624. 6. TANVEER, S. 1986 THE EFFECT OF SURFACE TENSION ON THE SHAPE OF A HELE-SHAW CELL BUBBLE. PHYS. FLUIDS 29, 3537. 7. TANVEER, S. 1987 NEW SOLUTIONS FOR STEADY BUBBLES IN A HELE-SHAW CELL. PHYS. FLUIDS 30, 651. 8. KOPF-SILL, A. AND HOMSY, G. 1987 BUBBLE MOTION IN A HELE-SHAW CELL. PHYS.FLUIDS 31,18. 9. PARK, C.-W., MARUVADA, S. AND YOON, D.-Y. 1994 THE INFLUENCE OF SURFACTANT ON THE BUBBLE MOTION IN HELE-SHAW CELLS. PHYS. FLUID 6, 3267. 10. MEIBURG, E. 1989 BUBBLES IN A HELE-SHAW CELL: NUMERICAL SIMULATION OF THREE-DIMENSIO -NAL EFFECTS. PHYS. FLUIDS A 1, 938. 11. TAYLOR, G. AND SAFFMAN, Q. 1959, J. MECH. APPL. MATH. 12,265. 12. MCLEAN, J. AND SAFFMAN, P.G. 1981 THE EFFECT OF SURFACE TENSION ON THE SHAPE OF FINGERS IN A HELE-SHAW CELL. J. FLUID MECH.,102, 455. 13. KORTEWEG, D. 1901 SUR LA FORME QUE PRENNENT LES EQUATIONS DU MOUVEMENT DES FLUIDS SI L'ON TIENT COMPTE DES FORCES CAPILLARIES CAUSES PAR DES VARIATIONS DE DENSITE. ARCH. NEEL. SCI. EX. NAT. (II),6. 14. JOSEPH, D. 1990 FLUID DYNAMICS OF TWO MISCIBLE LIQUIDS WITH DIFFUSION AND GRADIENT STRESSES. EUR. J. MECH., B/FLUIDS 9. 15. FREUDLICH, H. 1926 COLLOID AND CAPLLARY CHEMSTRY, LONDON, MATHUEN AND CO. LTD. 16. QUINKE, G, 1902 DIE OBERFLAECHENSPANNUNG AN DER GRENZE VON ALCOHOL MIT WAESSERIGEN SALZLOESUNGEN. ANN. PHY., 1902, 4. 17. SMITH, P.G., VAN DE VEN, T.G.M. AND MASON, S.G. 1981 THE TRANSIENT INTERFACIAL TENSION BETWEEN TWO MISCIBLE FLUIDS. J. COLLOID AND INTERFACE SCIENCE 80, 1, 302. 18. DAVIS, H. 1988 A THEORY OF TENSION AT A MISCIBLE DISPLACEMENT FRONT. IN NUMERICAL SIMULATION IN OIL RECOVERY. IMA VOLUMES IN MATHEMATICS AND ITS APPLICATIONS 11, SPRINGER. 19. JOSEPH, D. AND RENARDY, Y. 1992 FUNDAMENTALS OF TWO-FLUIDDYNAMICS. PART II, SPRINGER. 20. JOSEPH, D. HUANG, A. AND HU, H. 1996 NON-SOLENOIDAL VELOCITY EFFECTS AND KORTEWEG

STRESSES IN SIMPLE MIXTURE OF INCOMPRESSIBLE LIQUIDS. PHYSICA D 97. 21. CHEN, C.-Y. AND MEIBURG, E. 1996 MISCIBLE DISPLACEMENTS IN CAPILLARY TUBES. PART 2: NUMERICAL SIMULATIONS. J. FLUID MECH. 326,57. 22. GALDI, G. JOSEPH, D., PREZISI, L. AND RIONERO, S. 1991 MATHEMATICAL PROBLEMS FOR MISCIBLE, INCOMPRESSIBLE FLUIDS WITH KORTEWEG STRESSES. EUR. J. MECH., B/FLUIDS 10. 253. 23. CHEN, C.-Y. AND MEIBURG, E. 2000 THE DYNAMICS OF MISCIBLE INTERFACES AND THE EFFECTS OF KORTEWEG STRESSES. PROC. OF THE 7TH (ROC) NATIONAL COMPUTATIONAL FLUID DYNAMICS CONFERENCE. 24. HU, H. AND JOSEPH, D. 1992 MISCIBLE DISPLACEMENT IN A HELE-SHAW CELL. Z ANGEW MATH PHYS 43, 626. 25. PETITJEANS, P., CHEN, C.-Y., MEIBURG, E., AND MAXWORTHY, T. 1999 MISCIBLE QUARTER FIVE-SPOT DISPLACEMENTS IN A HELE-SHAW CELL AND THE ROLE OF FLOW-INDUCED DISPERSION. PHYS. FLUIDS 7, 1705. 26. RUITH, M. AND MEIBURG, E. 2000 MISCIBLE RECTILINEAR DISPLACEMENTS WITH GRAVITY OVERRIDE. PART 1: HOMOGENEOUS POROUS MEDIUM. J. FLUID MECH. 420, 225. 27. TAN, C.T. AND HOMSY, G.M. 1987 STABILITY OF MISCIBLE DISPLACEMENTS IN POROUS MEDIA: RADIAL SOURCE FLOW. PHYS. FLUIDS 30, 1239. 28. CHEN, C.-Y. AND MEIBURG, E. 1998 MISCIBLE POROUS MEDIA DISPLACEMENTS IN THE QUARTER FIVE-SPOT CONFIGURATION. PART 1: THE HOMOGENEOUS CASE. J. FLUID MECH. 371, 233. 29. CHEN, C.-Y. AND MEIBURG, E. 1998 MISCIBLE POROUS MEDIA DISPLACEMENTS IN THE QUARTER FIVE-SPOT CONFIGURATION. PART 2: EFFECT OF HETEROGENEITIES. J. FLUID MECH. 371, 269. 30. WARY, A. 1991 MINIMAL STORAGE TIME-ADVANCEMENT SCHEMES FOR SPECTRAL METHODS. PREPRINT. 31. CANUTO, C., HUSSAINI, M.Y.,QUARTERONI, A. AND ZANG, T.A. 1988 SPECTRAL METHODS IN FLUID MECHANICS, SPRINGER. 32. LELE, S. 1992 COMPACT FINITE DIFFERENCE SCHEMES WITH SPECTRALLIKE RESOLUTION. J. COMPUT. PHYS. 103, 16. 33. MEIBURG, E. AND CHEN, C.-Y. 2000 HIGH-ACCURACY IMPLICIT FINITE DIFFERENCE SIMULATIONS OF HOMOGENEOUS AND HETEROGENEOUS MISCIBLE POROUS MEDIA FLOWS. SPE J. JUNE 5, 2. 34. ROGERSON, A. AND MEIBURG, E. 1993A SHEAR STABILITY OF MISCIBLE DISPLACEMENT PROCESS IN POROUS MEDIA. PHYS. FLUIDS A5, 1344. 35. MAXWORTHY, T. 1986 BUBBLE FORMATION, AND INTERACTION IN A HELE-SHAW CELL J. FLUID MECH. 173, 95. 36. DACCORD, G., NITTMANN, J., STANLEY, H. E. 1986. RADIAL VISCOUS FINGERS AND DIFFUSIONLIMITED AGGREGATION : FRACTAL DIMENSION AND GROWTH SITES. PHYS. REV. LETT. 56 : 336-39