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Article / Book Information

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（博士課程）
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論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	機械 エネルギー	系 コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of	(Engineering)
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

In recent years, due to the urgent demand of reducing CO_2 emission, requirements of establishing reliable risk assessment and long-term monitoring systems in CCS are rising. As one of the determinant factors for the prediction of CO_2 migration, accurate models of dispersion are expected to be derived from laboratory experiments that mimic real geological formations.

In single-phase flow, shear flow can be generated due to natural convection caused by density difference, the influence of which remains unknown. Designing and generating shear flow in porous media is exceedingly difficult. The objective of this work is to create varied velocity gradient in a single-phase flow condition, and quantitively study the impact of shear actions on dispersion.

In Chapter 2, a state-of-the-art apparatus is designed, which enables generation of shear flow in porous media for the first time in laboratory experiments. Dispersion behaviors of a NaI tracer cloud are investigated under different shear rates ranging from 0.001 to 0.04 s^{-1} and *Pe* ranging from 10 to 200 using an innovative experimental apparatus via an X-ray technique in 2D. In the power-law regime, the dispersion behaviors in the transverse and longitudinal directions are strengthened by shear action, with a larger dependence of the power law on the shear rates and *Pe* compared with that in the uniform flow.

In two-phase flow, the oil viscosity and system wettability have significant impacts on oil trapping and two-phase flow conditions. Trapped oil ganglia create complicated velocity fields even in a steady state, which affects dispersion. It is necessary to create different two-phase flow conditions and simulate natural reservoirs to study dispersion. We want to study the impact factors of dispersion in different two-phase flow within a porous structure through 3D reconstruction experiments and derive a general model to describe dispersion in two-phase flow. To achieve the objective, innovative column-scale (macroscale) tracer experiments are combined with pore-scale two-phase flow experiments using micro-focused X-ray computer topographies (CTs) to investigate the behaviors of dispersion and related two-phase topologies. Dispersion and mixing are studied in a steady oil-water co-flow generated using a co-injection method to mimic two-phase flow in real geological conditions. Following co-injection, a non-wetting phase is trapped by capillarity with few migrations of

the phase volume (Na et al., 2011). Instability at the interface between the two phases is increased, promoting the mixing of a solute plume (Al-Murayri et al., 2016).

In Chapter 3, the impact of oil viscosity on dispersion in a co-flow is investigated over a large range of fluid viscosity ratios. The results indicate that highly heterogeneous flow fields are generated by a wide distribution of oil clusters with varied volumes. Variation in the velocity distribution enhances the deformation and spreading of a tracer plume, resulting in large dispersion scales and accelerates spreading rates. The dispersion coefficients vary with time and exhibit a non-Fickian dispersion in co-flow. Consequently, anomalous mixing behaviors can be observed when the viscosity ratio exceeds 10. The mixing strength, characterized by SDR, is first enhanced by distortion on the surface of the solute. Therefore, diffusion contributes to mixing, resulting in a faster decrease in the mixing strength in the late time regime. These results can be attributed to the fact that the non-wetting fluid becomes disconnected, and the size of each cluster decreases as the oil viscosity increases. The formation of an oil film narrows pore spaces, and a lubrication effect of the oil film may contribute to the enhanced dispersion and mixing state, even with the low relative permeability of the wetting phase.

In Chapter 4, the impact of wettability on aqueous dispersion in two-phase flow is studied. We use physical and chemical methods to alternate the surface wettability of silica sand. By synchrotron-based X-ray computed tomography, the macro-scale mixing process and the pore-scale's two-phase transport process are visualized and studied. We find that wettability greatly affects the pore-scale flow regimes in an immiscible oil-water co-flow. In a neutral-wet system, pore spaces are intermittently filled with oil and brine. This process alone suppresses mixing by limiting the extension of surface area compared with a single-phase dispersion. In a strong-water-wet system, in which mixing is slightly strengthened, oil and water only flow through their preferential paths. In water-wet and oil-wet systems, mixing is strongly enhanced in the flow regime, in which both preferential paths and intermittency contribute to the heterogeneity of velocity fields. In this flow regime, preferential paths create local heterogeneity while unstable intermittency disturbs the morphologies of preferential paths and causes more vigorous velocity fluctuation.

Finally, some conclusions and prospects for future research are presented in Chapter 5.