ACTION MICROMECHANISM BETWEEN GEMINI SURFACTANT DNGS AND CORE POROUS WALL

Chunyuan Gu[a)], Qinfeng Di ,Xinliang Wang Yichong Cheng, Weipeng Ding,Wei Gong,Renliang Zhang
Shanghai Institute of Applied Mathematics and Mechanics,Shanghai Key Laboratory of Mechanics in Energy and Environment Engineering ,Shanghai University,Shanghai, 200072, China

Summary The distribution features of a Gemini surfactant DNGS were studied by LSDA. Calculation models for the micro action forces between DNGS and core porous wall were established and the calculating results were given. The microstructure and the wettability of CPW were investigated by SEM and OCAMD. The forces of DNGS and CPW were far larger than these of water molecular and CPW and DNGS can replace water molecular and adsorb on CPW surface, all these were testified by calculation models and experiments.

INTRUDUCTION

Surfactant flooding is one important process to enhance oil recovery(EOR)[1]. Gemini surfactant(GS) is one of the most potential new types of Surfactant for EOR and has many better properties than conventional surfactant[2]. In recent years, more attention is paid to GS, Because this GS has not only greater in oil displacement efficiency but also better drag reduction property. The interaction characteristics and micromechanism between GS DNGS and CPW are very important and introduced in this paper.

MICRO DISTRIBUTION CHARACTERISTICS OF GS DNGS

The size distribution and Zeta potential distribution of a GS DNGS were studied in water solution by Laser size distribution apparatus and Zeta sizer， which concentration is 1.0 g/L under the normal temperature. The average size of the GS DNGS is about 151 nm and far larger than a GS DNGS molecular size of about 3.5 nm, it show the surfactant is existing in micelle state at this concentration. The zeta potential is about positive 96.1 mV. The tested sizes of the GS DNGS at the concentration of 0.3g/L and 0.5g/L are about 50 nm and 85nm respectively. The results indicates micelle size increase with the increase of concentration, and the micelle state is relatively dynamic steady. Some surfactant moleculars adsorb and desorb continuously on micelle surface, So the micelle and molecular coexist in solution.

CALCULATION MODELS FOR THE MICRO ACTION FORCES

Calculation models of interaction forces between GS and CPW

Base on the analysis of action between gemini surfactant DNGS and core porous wall(CPW)in detail. The interaction force $F_{\mathrm{p-f}}$ of GS and CPW include static electricity force F_{k} and Van Der Waals force F_{v}.

The formulae of action force is following as

$$F_{\mathrm{p-f}} = F_{\mathrm{k}} + F_{\mathrm{v}} \tag{1}$$

In accordance with two exsiting states of surfactant DNGS, two calculation models for the micro action force between the two action objects were established which represent the interactions between a molecule and a plane and between a particle and a plane respectively. the force formulae were deduced according to interaction Energy of a molecule -plane and a particle-plane[3,4].

If the surfactant are existing in molecularly state，the force fomulae of the molecular model were given as following

$$F_{\mathrm{k}} = \frac{\varphi_{\mathrm{c}} z e}{L} \tag{2}$$

$$F_{\mathrm{v}} = -\frac{H}{2\pi N_{\mathrm{m}} L^4} \tag{3}$$

If the surfactant are existing in micelle state，the force fomulae of the micelle model were given as following

$$F_{\mathrm{k}} = \text{-a}R_{\mathrm{p}}\left(\frac{\kappa\exp(-\kappa L)}{1-\exp(-\kappa L)} - \mathrm{b}\frac{\kappa\exp(-\kappa L)+\kappa\exp(-\kappa L)(1+\exp(-\kappa L))/(1-\exp(-\kappa L))}{1+\exp(-\kappa L)}\right) \tag{4}$$

$$F_{\mathrm{v}} = \frac{H}{6}\left[\frac{4R_{\mathrm{p}} + 2(L+R_{\mathrm{p}})\mathrm{Ln}\frac{L}{L+2R_{\mathrm{p}}}}{L\,(L+2R_{\mathrm{p}})} - \frac{2\,R_{\mathrm{p}}\,(L+R_{\mathrm{p}}) + L\,(L+2R_{\mathrm{p}})\,\mathrm{Ln}\frac{L}{L+2R_{\mathrm{p}}}}{L\,(L+2R_{\mathrm{p}})^2} - \frac{2\,R_{\mathrm{p}}(L+R_{\mathrm{p}}) + L\,(L+2R_{\mathrm{p}})\mathrm{Ln}\frac{L}{L+2R_{\mathrm{p}}}}{L^2\,(L+2R_{\mathrm{p}})}\right] \tag{5}$$

Here $a = \pi\varepsilon_0\varepsilon_r\left(\varphi_{\mathrm{c}}^2 + \varphi_{\mathrm{m}}^2\right)$, $b = 2\varphi_{\mathrm{c}}\varphi_{\mathrm{m}} / (\varphi_{\mathrm{c}}^2 + \varphi_{\mathrm{m}}^2)$.

Calculation results of interaction force of GS and CPW

The relevant forces were calculated on the base of the calculation micelle models, including formulae(1),(4)and(5), the forces between water molecular and CPW were given in accordance with these formulae in the paper[5]. The composition force of GS DNGS micelle and CPW was about 2.1×10^{-18}N at the distance of 1.0nm from CPW，and the

a) Corresponding author. Email: wein1989@163.com.

composition force of water molecular and CPW was about 5.3×10^{-31}N in Tab.1, so the former was far larger than the latter. This results indicate that the GS DNGS micelles can take the place of water molecular and adsorb on CPW surface.

Tab.1 The force of GS DNGS micelle and CPW

The distance between two objects /nm	L	100.00	10.00	5.00	1.00	0.40
The forces between water molecular and CPW /N	F_{v-p}	−5.33E−35	−5.33E−33	−2.13E−32	−5.33E−31	−3.96E−29
The forces between water molecular and CPW /N	F_v	−2.87E−24	−6.97E−22	−2.97E−21	−7.81E−20	−4.92E−19
	F_k	−1.05E−29	−6.50E−20	−2.71E−19	−2.11E−18	−5.57E−18
	$F_{p\text{-}f}$	−2.87E−24	−6.57E−20	−2.74E−19	−2.19E−18	−6.06E−18

EXPERIMENTS AND RESULTS

The microscopic feature of CPW surface treated by GS DNGS

The microscopic feature of CPW surface were investigated by means of core adsorption experiments and Scanning Electron Microscopy (SEM) . Some core slices were immersed in GS solution with concentration 1g/L for some time, and then were taken out and detected by SEM. Fig.1(a) and (b) are SEM photos of two slices which were immersed for 12h and 24h respectively. The microstructure show some very small particles were adsorbed on core surface which size is more than teens of nanometers in Fig.1(a). Many particles were adsorbed on core surface, the particles size are about several dozens of nanometers in Fig.1(b) and adsorbtion thickness is more than the one in Fig.1(a). Because of the differences of the mineral composition and micro structure on CPW surface, adsorption thickness and distribution state were very different. Adsorption layer is thick on rough surface and clay minerals surface, and surfactant micelles size is larger than the size which surface is smooth and the minerals are Quartz or feldspar.

The wettability of CPW surface treated by GS DNGS

The wettability of CPW surface were studied by Optical Contact Angle Measuring Device. The contact angle of the surface were measured using OCA30, Fig.2 show the shape of water drop on the surface after the cores were immersed in GS solution for 12h (a) and 24h (b) respectively. The contact angles were 143.9° for 12h in Fig.2(a) and 146.7° for 24 h in Fig.2(b), the surfaces were changed from very hydrophilic to strong hydrophobic. The results follow the same track with hydrophobic nanomaterial SiO_2 with synergism of Surface Rough and hydrophobicity, so the surface must have the drag-reducing characteristics.

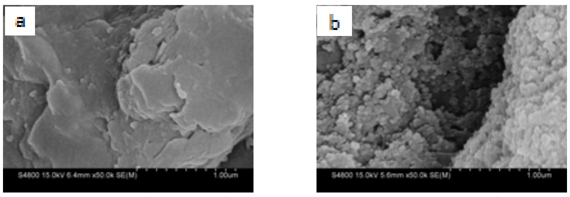

Fig.1 SEM photoes of core surface immersed in DNGS solution for(a)12h and(b)24h

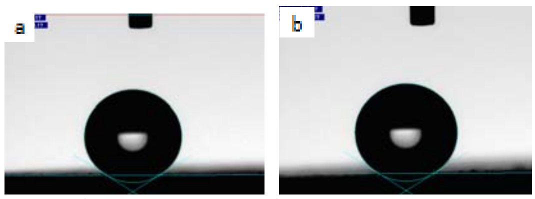

Fig.2 Shape of water drop on core surface immerse in DNGS solution

CONCLUSIONS

The calculation models were established and the composition force of DNGS and CPW was far larger than one of water molecular and CPW by the models, The results indicate DNGS can take the place of water molecular and adsorb on CPW surface. The experimental results testified the DNGS adsorbed core surface and formed surfactant layer with strong hydrophobicity instead of water molecule film, and are concordant with the calculated results.

References

[1] Ge J.J, Zhang G.C, Jiang P, Sun M.Q. Development of Surfactants as Chemicals for EOR [J].Oilfield Chemistry.2009,16(5):110-112.

[2] Fan Z.Z,Du Q.Q.Synthesis and Evaluation of a New Type of Cationi Gemini Surfactant[J].Science Technology and Engineering,2011,11(27):6713-6718

[3] Gao L, Sun J, Liu Y. Q. : Dispertion and Surface Modification of Nano-Powder[M]. Chemical Industry Press, Beijing, 2003.

[4] Ren J, Shen J, Lu C. H. : Particles Dispertion Science and Technology[M]. Chemical Industry Press, Beijing, 2005.

[5] Gu C.Y, Di Q.F., Shen C, Wang Z.H., Shi L.Y, Wang X.L. Adsorption of hydrophobic nanoparticles in reservoir microchannels[J]. Petroleum Exploration and Development, 2011,38(1):84-88

Appenddixes

φ_c or φ_m : surface potential of core porous wall or GS micelle,V; N_m :molecular number density of GS,m^{-3}; R_p : radius of micelle, m; L : the distance from CPW,m; κ : reciprocal of Debye length,1/m; z: valences of ionic; ε_0 :vacuum dielectric constant,8.84E-12 F/m; ε_r :relative permittivity of water.