INFLUENCE OF PARAFIN CONCENTRATION ON THE SEDIMENTATION OF DISPERSED PARTICLES IN THE PETROLEUM MEDIA

Phan Dinh Tuan, Ta Dang Khoa
University of Technology, VNU-HCM
(Manuscript Received on January26th, 2006, Manuscript Revised August 29th, 2007)

ABSTRACT: *The sedimentation of solid phase in continuous media depends on the media's viscosity, physical properties, forms, surface roughness, concentration of particles [1]. Besides, surface tension also has effect to the sedimentation. To include all these factors in the Stockes' equation, experiments on the sedimentation of sand particles in paraffin-dissolved petroleum have been done. Viscosity has been adjusted to required values by changing temperature. Paraffin amount, which changes the surface tension of the media, was included as an adjustment in Richardson & Zaki's correlation [2]. Calculated results have been shown to be quite appropriate with the experiments.*

Keywords: *Sedimentation, paraphin, surface tention.*

1. INTRODUCTION

According to the investigation results before [1], adjusting the Stokes's equation by coefficients in Richardson and Zaki's correlation leads to a rather good adequateness with the experiments. However, experiments on the sediment of sand-particles in petroleum containing parafin with different amount at constant viscosity pointed out a disagreement in sedimentation speed. Besides the base factors, surface tention also has effect to the sedimentation because of the interaction between continuous media and particles. This investigation complements the referred factors into the Richardson and Zaki's correlation.

2. INVESTIGATION RESULTS

2.1. Methods

Methods, the equipments and standard tests are the same to the study in [1].

The study is carried out with the experimental sedimentation column. Sedimentation speed is determined also by measuring sand concentration along the column after periods of time. The continuous phase is the crude oil of the White Tiger Well, adjusted by different amounts of parafin and applied with different temparatures, so as to keep set-constant viscosities. To stabilize temperature, outter hot water jacket has been used. Sediment concentration is determined by ASTM D-473-69 standard, other parameters of the continuous phase and parafin – by UOP-46 and viscosity – by ASTM D445 [1]

Experimental results will be then compared with theoretical values which are found by applying Stockes' equation for particles of the same diameters and the same continuous phase. The deviations will be adjusted by a function describing influence of the surface tension which affects the existance and amounts of parafin. Coefficients in the function will be found with the help of the least square method.

2.2. Study on the sedimentation of particles in petroleum containing parafin

The experiment results of the sedimentation of particles in petroleum containing parafin are described in the tables 1 to 6. Table 1 is for the sedimentation in petroleum media of viscosity μ=0,0043 Pa.s, Table 2 - the sedimentation in petroleum media of viscosities in the range of μ = 0,0017 - 0,0069 Pa.s. Tables 3 and 4 are for the ratio coefficient K between the measurred and theoretical speed calculated to Stokes's equation. Tables 5 and 6 are for the same ratio coefficient K in tables 3 and 4, but the Stokes equation is replaced by the Richardson & Zaki's correlation.

2.3. Influence of parafin concentration on the sedimentation of dispersed particles in the petroleum media

Methods of calculating the influence of parafin concentration to the sedimentation of particles are same to the one were shown in [1]. The coefficient of the parafin amount in the Richardson & Zaki equation is determined by planned experiments with the calculations as follows:

The definition of the ratio coefficient K:

$$K = \frac{U'_{Pa}}{U_{LT}} = C'(1-\omega)^{\alpha} d^{\beta} P^{\gamma}$$

(C': hằng số tỷ lệ)

Logarithmization the above equation leads to the following correlation:

$$\ln K = \ln C' + \alpha \ln(1-\omega) + \beta \ln d + \gamma \ln P$$

The real variables are coded by the correlations:

$$X_1 = \frac{2[\ln(1-\omega) - \ln(1-\omega)_{max}]}{\ln(1-\omega)_{max} - \ln(1-\omega)_{min}} + 1 \quad X_2 = \frac{2(\ln d - \ln d_{max})}{\ln d_{max} - \ln d_{min}} + 1$$

$$X_3 = \frac{2(\ln P - \ln P_{max})}{\ln P_{max} - \ln P_{min}} + 1$$

The regresion equation will be found in the form

$$Y = bo + b1X1 + b2X2 + b3X3$$

in which, the coefficients will be calculated from experiments as

$$b_o = \frac{\sum_{i=1}^{8}(X_{oi}Y_i)}{8} = -0,615 \quad b_1 = \frac{\sum_{i=1}^{8}(X_{1i}Y_i)}{8} = 0,076$$

$$b_2 = \frac{\sum_{i=1}^{8}(X_{2i}Y_i)}{8} = 0,134 \quad b_3 = \frac{\sum_{i=1}^{8}(X_{3i}Y_i)}{8} = -0,114$$

$$\ln Khq = -0,615 + 0,076X1 + 0,134X2 - 0,114X3$$

$$K = 0,408(1-\omega)35,7d0,387P-0,208$$

$$U'_{Pa} = KU_{LT} = 85,69\frac{(1-\omega)^{35,7} d^{2,387} P^{-0,208}(\rho_p - \rho_f)g}{18\mu}$$

In the above correlations, UPa and ULT denote the measured and the Stokes' theoretical sedimentation speeds. The calculated results are shown in table 7 and 8. From the calculations, K, ratio between the measurred and Stokes' theoretical speed is a function of the form:

$$K = 0,403\varepsilon 32,41d0,392P-0,208$$

And the sedimentation speed of particles in petroleum dissolving parafin:

$v = Kv_{LT} = 90,64\dfrac{\varepsilon^{32,41}d^{0,392}P^{-0,208}\left(\rho_p - \rho_f\right)g}{18\mu}$ (d by metre). Comparison the calculated and experiment results are shown in table 9, which show the more adequate correlation with the measurred results.

3. CONCLUSION

1) In petroleum containing parafin, beside viscosity and the properties of particles, surface tension also has effect to the sedimentation.

2) To the set of particles, the sedimentation is affected by particle concentration, parafin amount and their form. The influences could be evaluated by the function of the form:

K = 0,403ε32,41d0,392P–0,208

and the sedimentation speed of the particle set in petroleum containing parafin could be calculated by the following correlation:

$v = Kv_{LT} = 90,64\dfrac{\varepsilon^{32,41}d^{2,392}P^{-0,208}\left(\rho_p - \rho_f\right)g}{18\mu}$ in which v and vLT denote the measured and the Richarson & Zaki's theoretical sedimentation speeds. The calculated results show a good adequateness to experiments.

3) This calculated method could be helpful to the estimation of sedimentation of the particle in petroleum containing parafin, which is typical to the crude oil of the White Tiger Well. However it is also necessary to study further on the sedimentation of multi- dispersed particles. The application of the proposed method to other sources of crude oil need further investigations.

Table 1: Sedimentation speed of a particle in a liquid medium of viscosity 0,0043 Pa.s

Particle size (μm)		5	10	15	20	25	30
Theoretical speed v_{LT}, mm/s		0,0038	0,0152	0,0343	0,0609	0,0952	0,1371
Experimental speed, mm/s							
Parafin amount (%KL)	5	0,0026	0,0121	0,0301	0,0556	0,0877	0,1250
	10	0,0019	0,0100	0,0266	0,0500	0,0800	0,1130
	15	0,0016	0,0091	0,0240	0,0455	0,0735	0,1036
	20	0,0014	0,0078	0,0224	0,0424	0,0685	0,0971
	25	0,0014	0,0077	0,0211	0,0400	0,0658	0,0926
	30	0,0014	0,0077	0,0205	0,0391	0,0639	0,0901
	35	0,0014	0,0070	0,0200	0,0387	0,0625	0,0881

Table 2: Sedimentation speed of a particle depends on dimensions, viscosity and parafin amount

Viscosity, (Pa.s)	0,0017			0,0043			0,0069		
Particle size (μm)	10	15	20	10	15	20	10	15	20
Theoretical speed (mm/s)	0,0386	0,0866	0,1539	0,0152	0,0343	0,0609	0,0095	0,0214	0,0380
Experimental speed (mm/s)									

Parafin amount (%KL)	5	0,0305	0,0761	0,1409	0,0121	0,0301	0,0556	0,0075	0,0187	0,0346
	10	0,0253	0,0673	0,1266	0,0100	0,0266	0,0500	0,0062	0,0166	0,0312
	15	0,0230	0,0608	0,1143	0,0091	0,0240	0,0455	0,0057	0,0150	0,0283
	20	0,0198	0,0567	0,1070	0,0078	0,0224	0,0424	0,0049	0,0140	0,0264
	25	0,0195	0,0533	0,1010	0,0077	0,0211	0,0400	0,0048	0,0132	0,0249
	30	0,0194	0,0518	0,0990	0,0077	0,0205	0,0391	0,0048	0,0128	0,0243
	35	0,0177	0,0506	0,0980	0,0070	0,0200	0,0387	0,0044	0,0125	0,0241

Table 3: Ratio v/v_{LT} of a set of a particle in a liquid medium of viscosity 0,0043 Pa.s

Parafin amount (%KL)	Particle size (μm)					
	5	10	15	20	25	30
5	0,684	0,796	0,878	0,913	0,921	0,912
10	0,500	0,658	0,776	0,821	0,840	0,824
15	0,421	0,599	0,700	0,747	0,772	0,756
20	0,368	0,513	0,653	0,696	0,720	0,708
25	0,368	0,507	0,615	0,657	0,691	0,675
30	0,368	0,507	0,598	0,642	0,671	0,657
35	0,368	0,461	0,583	0,635	0,657	0,643

Table 4: Ratio v/v_{LT} of a set of a particle depends on dimensions, viscosity and parafin amount

Viscosity, (Pa.s)		0,0017			0,0043			0,0069		
Particle size (μm)		10	15	20	10	15	20	10	15	20
Parafin amount (%KL)	5	0,790	0,879	0,916	0,796	0,878	0,913	0,789	0,874	0,911
	10	0,655	0,777	0,823	0,658	0,776	0,821	0,653	0,776	0,821
	15	0,596	0,702	0,743	0,599	0,700	0,747	0,600	0,701	0,745
	20	0,513	0,655	0,695	0,513	0,653	0,696	0,516	0,654	0,695
	25	0,505	0,615	0,656	0,507	0,615	0,657	0,505	0,617	0,655
	30	0,503	0,598	0,643	0,507	0,598	0,642	0,505	0,598	0,639
	35	0,459	0,584	0,637	0,461	0,583	0,635	0,463	0,584	0,634

Table 5: Sedimentation speed of the mono – dispersed particles

Volumetric part (ε)		0,99790			0,99579			0,99366		
Particle size (μm)		10	15	20	10	15	20	10	15	20
Theoretical speed (mm/s)		0,0151	0,0340	0,0604	0,0150	0,0338	0,0600	0,0149	0,0335	0,0595
Experimental speed (mm/s)										
Parafin amount (%KL)	10	0,0089	0,0237	0,0450	0,0083	0,0222	0,0417	0,0076	0,0200	0,0379
	20	0,0075	0,0209	0,0392	0,0065	0,0187	0,0354	0,0064	0,0176	0,0333
	30	0,0068	0,0195	0,0365	0,0064	0,0171	0,0326	0,0058	0,0167	0,0323

Table 6: Ratio v/v_{LT} of a set of the mono – dispersed particles

Volumetric part (ε)		0,99790			0,99579			0,99366		
Particle size (μm)		10	15	20	10	15	20	10	15	20
Theoretical speed (mm/s)		0,0151	0,0340	0,0604	0,0150	0,0338	0,0600	0,0149	0,0335	0,0595
Experimental speed (mm/s)										
Parafin amount (%KL)	10	0,589	0,697	0,745	0,553	0,657	0,695	0,510	0,597	0,637
	20	0,497	0,615	0,649	0,433	0,553	0,590	0,430	0,525	0,560
	30	0,450	0,574	0,604	0,427	0,506	0,543	0,389	0,499	0,543

Table 7: Factors influence on the value of K

Factors	Coded variables	Factor's values and corresponding coded values		
		Uper level, +1	Center level , 0	Lower level, –1
Volumetric part (ε)	X1	0,99790	0,99579	0,99366
Particle size, d, μm	X2	20	15	10
Parafin amount, P, %KL	X3	30	20	10

Table 8: Planned matrix

STT	X_o	X_1	X_2	X_3	$Y = \ln K$	$Y_{hq} = \ln K_{hq}$	$(\ln K_i - \ln K_{hqi})^2$
1	+	+	+	+	–0,504	–0,510	$3,6*10^{-5}$
2	+	–	–	+	–0,944	–0,920	$57,6*10^{-5}$
3	+	+	–	+	–0,799	–0,782	$28,9*10^{-5}$
4	+	–	+	+	–0,611	–0,648	$136,9*10^{-5}$
5	+	+	+	–	–0,294	–0,282	$14,4*10^{-5}$
6	+	–	–	–	–0,673	–0,692	$36,1*10^{-5}$
7	+	+	–	–	–0,529	–0,554	$62,5*10^{-5}$
8	+	–	+	–	–0,451	–0,420	$96,1*10^{-5}$

Table 9: Comparison the calculated and experimental speed of the mono – dispersed particles

Volumetric part (ε)		0,99790			0,99579			0,99366		
Particle size (μm)		10	15	20	10	15	20	10	15	20
Theoretical speed (mm/s)		0,0151	0,0340	0,0604	0,0150	0,0338	0,0600	0,0149	0,0335	0,0595
Experimental speed (mm/s)										
Parafin amount (% weight)	10	0,0089	0,0237	0,0450	0,0083	0,0222	0,0417	0,0076	0,0200	0,0379
	20	0,0075	0,0209	0,0392	0,0065	0,0187	0,0354	0,0064	0,0176	0,0333
	30	0,0068	0,0195	0,0365	0,0064	0,0171	0,0326	0,0058	0,0167	0,0323
Calculated speed (mm/s)										
Parafin amount (% weight)	10	0,0088	0,0231	0,0459	0,0082	0,0216	0,0429	0,0076	0,0201	0,0401
	20	0,0076	0,0200	0,0398	0,0070	0,0187	0,0372	0,0066	0,0174	0,0347
	30	0,0069	0,0184	0,0366	0,0065	0,0172	0,0342	0,0061	0,0160	0,0319

ẢNH HƯỞNG CỦA HÀM LƯỢNG PARAPHIN ĐẾN SỰ LẮNG CỦA CÁC HẠT RẮN PHÂN TÁN TRONG MÔI TRƯỜNG DẦU THÔ

Phan Đình Tuấn, Tạ Đăng Khoa
Trường Đại học Bách khoa, ĐHQG-HCM

TÓM TẮT: *Quá trình lắng của hạt rắn trong môi trường liên tục phụ thuộc độ nhớt môi trường, tính chất vật lý, hình dạng, độ nhám bề mặt và mật độ hạt [1]. Ngoài ra, sức căng bề mặt cũng ảnh hưởng đến quá trình lắng. Để đưa tất cả các yếu tố này vào phương trình Stock, bài báo trình bày các kết quả nghiên cứu thực nghiệm nghiên cứu quá trình lắng của các hạt cát trong môi trường dầu thô có paraphin hoá tan. Độ nhớt của môi trường được điều chỉnh bằng cách thay đổi nhiệt độ. Hàm lượng paraphin. Sức căng bề mặt của môi trường được đưa vào phương trình Richardson & Zaki [2] như một yếu tố hiệu chỉnh dưới dạng hàm lượng paraphin. Kết quả tính toán nhờ các hiệu chỉnh đã nêu cho thấy một sự phù hợp hoàn toàn với các kết quả thực nghiệm.*

REFERENCES

[1]. Phan Dinh Tuan, Ta Dang Khoa, *Modeling of the settlement of dispersed particles in the petroleum media with different viscosity*, Proceeding of the Asian RSCE, Hanoi (2005) (to be presented and published).

[2]. Martin Rhodes, *Introduction to Particle Technology*, (1998).

[3]. Wu Chen and Keith J.Scott, *Handbook of powder science.*

[4]. Willkinson W.L., N*on Newtonian fluids – Fluid mechanics, mixing and heat transfer*, Pergamon Press, (1960).

[5]. V.V. Kafarov, *Methods of cybernetics in chemistry and chemical technology,* Khimia Pulisher, Moscow, (1975) (in Russian)

[6]. Truong Dinh Hoi, *Characteristics of Vietnamese Petroleum, its potention and product quality,* J. of Oil & Gas, (1995) (in Vietnemese).

[7]. Laurier L. Schramm, Suspensions, F*undamentals and Application in the Petroleum Industry*, (1977).