Preparation And Properties of Non-fluorinated and Non-protein Foam Extinguishing Agent

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Abstract

Take Cocoamidopropylbetaine (LAB), silicone surfactants (SS), alkyl glucoside (APG), fatty amine polyoxyethylene ether (PEAA), twelve (SDS), sodium dodecyl sulfate polyacrylamide gel (PAM), Huang Yuan (XG), sodium carboxymethyl cellulose (CMC) and sodium alginate (SA) as monomers, Mix built up a kind of high-performance, environmental non fluorine non protein foam extinguisher. The foaming property, foam stability, spreading property and the sealing performance of foam on gasoline were tested. The optimum concentration of single-component surfactant was obtained, and then the best performance of mixed liquid was found. Using the best mixture to carry on a fire test, it shows a good result.

Keywords

Non-fluorinated, Non-protein.

1. Introduction

With the development of society and the progress of the times, the occurrence of fires is more and more frequent. The property losses and casualties are increasing. Therefore, a new type of fire extinguishing agent [1], which is environmentally friendly, effective, practical and cheap, is urgently needed. It is necessary to study and prepare a new type of fire extinguishing agent.

Fire extinguishing foam extinguishing agent is very effective for extinguishing class B fires. It can form an isolation belt on the surface of the burning liquid, which plays the role of cooling and suffocating, and ultimately achieves the purpose of extinguishing [2]. There are many types of foam fire extinguishing agents, which are classified into air foam fire extinguishing agents, fluorine protein foam fire extinguishing agents, water-forming foams and anti-soluble foams, etc. [3]

The purpose of this study is to mine on a more superior performance fire extinguishing gel, research content mainly includes the following aspects:

(1) The foaming ratio of single surfactant foam mixture with different concentration was studied

(2) The surfactant dialysis time was determined using a 2152 Roche foam tester (3) Determination of surface tension measurement of mixed liquid with BZY-3 type surface tension meter

(4) Several surfactants were selected for compounding

(5) Determination of mixture after the performance parameters change

(6) Select the best compound results, the preparation of a foam fire extinguishing agent for fire experiments

2. Experimental part

2.1 Reagents and equipment

lauroylamidopropyl betaine (LAB), silicone surfactants (SS), alkyl glucoside (APG), fatty amine polyoxyethylene ether (PEAA), twelve sodium dodecyl sulfate (SDS), polyacrylamide (PAM), xanthan gum (XG), sodium carboxymethylcellulose (CMC) and sodium alginate (SA).

50/100/500ml beaker , 50ml electron tube, 1000g electronic scale, 100/500ml measuring cylinder, plastic dropper, glass rod, stopwatch, surface tension meter, moving mixer

2.2 Experimental steps

2.2.1 Experimental reagents and equipment

A single surfactant or compound system (each raw material is mixed in a certain proportion and stirred evenly) and the water is mixed with the mass ratio of 3:97.

2.2.2 Test foaming ratio

The commonly used method of measuring foaming multiple is 2152 Roche bubble apparatus, 2mL liquid can be taken from the all glass syringe to be put into the instrument, and the temperature should be kept constant in the measurement. In order to reduce the error, the experimental data more accurate.

2.2.3 Test 25% drainage time

The commonly used method is to measure them 25% drainage time by 2151 Roche foam meter.

The tapered tube with foaming multiple is shaken evenly and then the plug is removed. Start the timing from the static, and stop the timing when the bottom liquid is 25% of the liquid. At this time, the time is 25% drainage time. Through the length of the drainage time, we can know the foam stability of the liquid to be tested, the longer the drainage time, the better the foam stability.

2.2.4 Testing surface tension

Using the BZY-3 surface tension meter, we need to measure the liquid to be measured into the watch glass. According to the use of the instrument instructions, we should operate the instrument formally and measure the liquid to be measured, and need to repeat experiments and take the average of multiple measurements.

2.2.5 Determination of the spreading coefficient

The measurement of the spreading coefficient requires an instrument BZY-3 surface tension, which is used to determine the oil－liquid interface Y by a platinum plate method. Determination of oil - liquid interfacial tension of $\gamma_{O/S}$: select a clean medium in a Petri dish sample injected into the mixed solution of appropriate test, the surface tension of γ_S ; a dropper to use medium, slowly adding gasoline, immersion platinum reached a moderate in height (in which platinum plate at the junction from the oil surface and the surface of the liquid, can be completely immersed in gasoline), observe and record the readings, denoted as $F_{浮(O/S)}$; floating junction platinum plate from the oil surface and the surface of the plate, let completely immersed in the platinum gasoline, observe and record the readings, denoted as $F_{浮(O)}$. Calculation of oil liquid interfacial tension: $\gamma_{O/S}=F_{浮(O/S)}-F_{浮(O)}+0.3$. Spreading coefficient $S_{0/S}=\gamma_0-(\gamma_S+\gamma_{O/S})$. The above experiment was repeated, and the mean value was considered as the result of the measurement.

2.2.6 Fire suppression performance test

Take a combustor, diameter 125mm, the most moderate of the deep is 40mm, pour into 50mL water and No.90 gasoline, because the density of gasoline is smaller than water, so gasoline can be spread over the water, the amount of gasoline added is just on the surface of the water. The best surfactant solution we have chosen is placed in a manual sprayer, than, light the gasoline on the surface of the water, the manual sprayer's nozzle is aligned with the fire source, a uniform jet to oil and fire, test many times, record fire extinguishing time, the mean value is taken as the result of measurement.

3. Result analysis.

3.1 Study on the properties of several surfactants

The data in Table 3.1 can be seen, Alkyl Polyglycoside (APG) has the strongest foaming multiple, which is 20 times, but its foam stability is the worst. The 25% precipitation time of Fatty amine polyoxyethylene ether (PEAA) is longer, it shows that the foam stability is good. The surface tension of an organosilicon surfactant (SS) is smallest .So the compound results of these three kinds of surfactants were observed in the compound.

Table 3.1 The performance parameters of concentrated surfactant

Surfactant	Foaming ratio	25% drainage time	Surface tension
LAB	16	11	25.1
SS	17	13	18.6
PEAA	17	15	29.4
APG	20	5	25.2
SDS	13	8	24.4

3.2 Study on the performance of several surfactants compound system

We will use these five surfactants to compound, five surfactants are five factors, each factor is selected three levels, and get the five factors and three levels orthogonal test table.

Table 3.2 Orthogonal experimental factors and level tables

Level	Factor				
	LAB	SS	PEAA	APG	SDS
1	a1	b1	c1	d1	e1
2	a2	b2	c2	d2	e2
3	a3	b3	c3	d3	e3

According to the orthogonal table, design experiments, and get data through experiments. The results are shown in table 3.3. K_1, K_2 and K_3 are the average values of all factors under the same level. R is the difference of the same level of all factors.

Table 3.3 L27(Factor5 Level3)Orthogonal Experimental Table Design Experiment

Sample number	Factor					Evaluating indicator		Surface tension
	LAB	SS	PEAA	APG	SDS	Foami-ng time	25% draina-ge time	
1	a_1	b_1	c_1	d_1	e_1	14	6	25.9
2	a_1	b_1	c_1	d_1	e_2	16	8	25.6
3	a_1	b_1	c_1	d_1	e_3	15	7	25.6
4	a_1	b_2	c_2	d_2	e_1	14	8	27.1
5	a_1	b_2	c_2	d_2	e_2	17	7	27.3
6	a_1	b_2	c_2	d_2	e_3	18	12	27.1
7	a_1	b_3	c_3	d_3	e_1	17	10	27.9
8	a_1	b_3	c_3	d_3	e_2	20	20	27.5
9	a_1	b_3	c_3	d_3	e_3	19	21	27.8
10	a_2	b_1	c_2	d_3	e_1	17	8	25.6
11	a_2	b_1	c_2	d_3	e_2	17	9	25.7

12		a_2	b_1	c_2	d_3	e_3	15	14	25.7
13		a_2	b_2	c_3	d_1	e_1	20	18	25.4
14		a_2	b_2	c_3	d_1	e_2	18	21	25.6
15		a_2	b_2	c_3	d_1	e_3	20	29	25.7
16		a_2	b_3	c_1	d_2	e_1	17	16	25.3
17		a_2	b_3	c_1	d_2	e_2	18	12	25.6
18		a_2	b_3	c_1	d_2	e_3	20	11	25.5
19		a_3	b_1	c_3	d_2	e_1	15	16	25.3
20		a_3	b_1	c_3	d_2	e_2	16	11	25.6
21		a_3	b_1	c_3	d_2	e_3	18	13	25.5
22		a_3	b_2	c_1	d_3	e_1	18	21	25.3
23		a_3	b_2	c_1	d_3	e_2	20	23	25.1
24		a_3	b_2	c_1	d_3	e_3	20	31	25.1
25		a_3	b_3	c_2	d_1	e_1	19	18	24.5
26		a_3	b_3	c_2	d_1	e_2	22	24	24.6
27		a_3	b_3	c_2	d_1	e_3	21	29	24.9
Foam ratio	K1	16.66	15.78	17.39	18.28	16.67	-	-	-
	K2	17.78	18.17	17.83	16.78	18.22	-	-	-
	K3	18.83	19.28	18.00	18.17	18.33	-	-	-
	R	2.17	3.50	0.61	1.50	1.66	-	-	-
Drain- -age time	K1	10.67	10.11	19.89	17.67	13.39	-	-	-
	K2	15.17	18.78	19.11	11.56	19.78	-	-	-
	K3	20.61	17.56	17.50	17.22	18.33	-	-	-
	R	9.94	8.67	2.39	6.11	6.39	-	-	-

Through the 3.3, it can be seen that the best group of foaming times is a3b3c3d1e3, through the range R, it can be seen that the size of each factor is b>a>e>d>c, and the water-soluble silicone surfactant (SS) has the greatest influence on the foaming performance of the compound foaming system. The lowest time of liquid analysis is a3b2c3d1e3, indicating that the foam stability is best after their combination. From the range R, it can be seen that the degree of the influence of various factors on foam stability is a>b>d>e>c. Therefore, lauramide propyl betaine (LAB) has the greatest influence on the foam stability of the mixed liquid after the compound. By combining the surface tension of Table 3 and table 1, it is known that in several surfactants, the surface tension is affected by water soluble organosilicon (SS). According to the results of orthogonal experiment, a lot of conclusions can be drawn. In Table 4, a3b3c3d1e3 is the best group of foaming times. The best foaming performance, 25% liquid analysis time and surface tension are tested according to the experimental method.

Table 3.4 Best compound foam system (a3b3c3d1e3) performance parameters

Sample number	LAB	SS	PEAA	APG	SDS	Foaming time	25% drainage time	Surface tension
28	3	3	3	1	3	24	19	25.1

3.3 Effect of foam stabilizer on the performance of compound foaming system

The optimum solution mass ratio of the compound foam stabilizer and foaming system is 3: 7, so we mixed the solution of the compound foam stabilizer and the compound foaming system No.28 into 600mL solution by mass ratio of 3: 7, and we measured the foaming ratio and 25% drainage time of the mixed surfactant solutions, the results are shown in Table 3.5. In the table, K1 indicates the average value of the evaluation index at the first level, and, K2 and K3 represent the average value of the evaluation index at the second and third levels, and R is the range of K at the corresponding level of each factor.

According to the evaluation index of foaming ratio in Table 3.5, we can find an optimal compound combination --a1b1c1d1; According to the size of R, we can see that the effect of a, b, c, d in this compound combination is a> d> b> c. It can be seen that polyacrylamide (cationic) (PAM) and SA have great influence on the foaming property of the compound system. According to the data of "foaming ratio" in the table, it can be seen that the foaming ratio of different compounding systems after adding the foam stabilizer is 18-22,and the foaming ratio of the foaming compound system without the foam stabilizer is 24, which indicates that the foaming ability of the compound system with foam stabilizer decreases slightly.

According to the data of "25% drainage time " in 3.5,the best compound combination of foam stability is a3b3c2d3.The range R of the average 25% drainage time at the corresponding level shows that the order of influence of each factor on the mixed solution of compound system is c>b>d>a. According to the data, we can conclude that carboxymethyl (CMC) has the greatest influence on the foam stability of the mixed surfactant solution. In addition, the compound system is added to the foam stabilizer, the different 25% drainage time of compound system foam is within the range of 29-49s.After compounding, the 25% drainage time of solution is far greater than 19s before without foam stabilizer , which fully shows that the addition of foam stabilizer has played a very good foam stabilization on the solution of the compound system.

Table 3.5 L9(Factor4 Level3)Analysis of orthogonal test results

Number		Factor				Evaluating Indicator	
		PAM	XG	CMC	SA	Foaming time	25% drainage time
29		a_1	b_1	c_1	d_1	22	29
30		a_1	b_2	c_2	d_2	19	38
31		a_1	b_3	c_3	d_3	21	42
32		a_2	b_1	c_2	d_3	19	44
33		a_2	b_2	c_3	d_1	19	39
34		a_2	b_3	c_1	d_2	18	29
35		a_3	b_1	c_3	d_2	20	29
36		a_3	b_2	c_1	d_3	21	38
37		a_3	b_3	c_2	d_1	22	49
Foam ratio	K_1	20.83	20.50	20.33	21.00	-	-
	K_2	19.07	19.33	20.17	19.33	-	-
	K_3	20.67	20.33	20.17	20.33	-	-
	R	1.76	1.17	0.16	1.67	-	-
Drainage time	K_1	36.33	35.09	38.83	39.17	-	-
	K_2	39.17	38.17	43.17	35.50	-	-
	K_3	40.17	41.67	38.67	41.00	-	-
	R	3.84	5.83	9.33	5.50	-	-

Note: K is the average of the performance parameters of each level,and the R is the range.

3.4 Fire extinguishing performance

In order to test the extinguishing effect of mixed liquid after remixing, we selected compound sample No. 37 as the experimental object, because its foaming ratio and foam stability were excellent. We found that the sample water mixed with 3:97 as a foam extinguishing agent has a good effect on the extinguishing of gasoline fires. So the sample ratio was set to 3: 97 in the experiment, and then the appropriate amount sample of extinguishing agent was put into the foam fire extinguisher, and punched to 1.2MPa with the punching equipment to extinguish the gasoline fire in the experiment. When the gasoline is ignited, the fire is very strong, and then the fire extinguisher at a fire source spray fire extinguishing agent. After spraying for five seconds, the fire has been effectively controlled, the flame becomes smaller after 10 seconds, and the gasoline fire is extinguished at 20 seconds, this time the oil basin was covered with a thick layer of foam extinguishing agent. It can be seen that the formula has good performance of extinguishing gasoline in oil basin.

4. Conclusion

(1)By contrast, it is found that the foaming performance of the mixed solution system and single component surfactant is slightly improved after compounding, but the stability of foam is obviously enhanced than that of the single component surfactant.

(2)Although the addition of foam stabilizer failed to increase the foaming ratio of the compound solution, it could improve the foam stability of the compound solution.The sealing effect of the compound solution on gasoline shows a good sealing performance in the experiment.

(3)The new foam extinguishing agent prepared in this experiment can only spread a foam isolating layer on the gasoline surface, and cannot form a liquid film, so it is not a water film foam extinguishing agent.

(4)By contrast, it is found that the experimental preparation of the foam extinguishing agent on the fire extinguishing effect of gasoline is very good, and has a further development prospect in extinguishing class B fire.

References

[1] Chen Jing, Wang Linling, Zhuhu, etc. Spatial distribution of perfluorooctanoic acid and perfluorooctane sulfonate in the surface water of East Lake [J] . Environmental Science, 2012,33 (8): 2586-2591.

[2] Chen Rongzhe. Perfluorooctane sulfonic acid restrictions on the sale and use of [J] Dyeing auxiliaries, 2012, (4): 44-46.

[3] Yu Wei, Wang Pengxiang, Tian Liang etc. Progress of PFOS Controlled Conventions and the Use of PFOS in Chinese Fire Protection Industry [J]. Fire Science and Technology, 2010,29 (6): 513-515.

[4] Hou Li, Jin Manxi,Cheng Lin. Properties and Fire Extinguishing Principles of Several New Extinguishing Agents [J]. Shanxi Architecture, 2008,34 (22): 176-177

[5] Bao Zhiming, Fu Xuecheng, Li Mei, etc . China PFS foam fire extinguishing agent substitutes research and production status [C] // persistent organic pollutants forum 2011 sixth persistent postal pollutants National Symposium on Papers Set, 2011: 235-236.

[6]Yu Xuexing, Tan Longmei, Wu Jingfeng, et al. Synthesis of new fluorocarbon surfactants and their application in fire extinguishing agents. [J] .Modern chemical industry, 2008,28(4):51-53

[7]Xu Yunhuan, Zheng Cheng, Lin can, et al. Progress in the synthesis and application of fluorine-containing quaternary ammonium surfactants. [J] .Progress in Chemical Engineering, 2013,32(7):1641-1960.

[8]Xiao Jinxin,Bao Yanxia,Shou Jianhong, et al.Carbon-fluorine-hydrocarbon surfactant mixed aqueous solution spread on oil surface. [J] .Chemical research and application, 2002, 14(2): 137-140.