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RESEARCH ARTICLE

STUDY ON INFLUENCE FACTORS OF COMPOSITE OIL PHASE MATERIAL AND ITS INFLUENCE ON STORAGE STABILITY OF EMULSION EXPLOSIVE

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ABSTRACT

The factors affecting the viscosity of oil phase materials and the effect of viscosity on the storage stability of emulsion explosives were investigated in this paper. The results showed that the emulsifier was the crucial factor in the viscosity of composite oil phase materials, in which the polymeric emulsifier had a significant impact on the viscosity of composite oil phase materials. Whereas within the frequently-used range of emulsifiers for composite oil phase materials, the content change of emulsifier had few significant impact on the viscosity of oil phase materials. The study also found that the influence of composite oil phase materials on the storage stability of emulsion explosives is mainly determined by the formula composition, the storage stability of emulsion explosive matrices had a great difference which was prepared by different formula composition but approximate viscosity of composite oil phase materials.

KEYWORDS

Emulsion explosive, Emulsifier, Composite oil phase material, Storage stability

1. INTRODUCTION

Emulsified explosive is a kind of W/O emulsion. Because of its wide source of raw materials, simple production process, waterproof, safe, environmental protection and good stability, it has been widely used in engineering blasting at home and abroad, but it has the disadvantage of short storage time in application. In China, emulsified explosive is required to have a storage period of more than 3 months and stable detonation. Therefore, the research on improving the explosive performance and storage stability of emulsion explosive has become the focus of research on emulsion explosive (Xuguang, 2008; Jingxian et al., 2022; Feiyang et al., 2017; Mingsheng et al., 2021; Jiangtao et al., 2018).

The appearance state of emulsion explosive is a special viscoelastic body between solid and fluid, and its physical state is rheological property. The rheological property of emulsion explosive affects the production process and application of emulsion explosive, and also has an important impact on storage stability and explosion performance (Sang and Anh, 2020; Ao et al., 2019; Zhan et al., 2018; Guoguang et al., 2017; Masalova et al., 2018; Zhao et al., 2021; Al-Sabagh et al., 2017; Mertuszka et al., 2019; Agrawal and Ishra, 2018). Previous studies have shown that the oil phase material is the main factor affecting the rheological properties of emulsion explosive (Jinquan and Xuguang, 2002). The oil phase material is mainly composed of oil phase and emulsifier in a certain proportion. The viscosity of oil phase material is related to the storage stability of emulsion explosive. However, the influencing factors of viscosity of oil-phase materials have not been studied. In this paper, on the basis of investigating the influence of oil phase material components on the viscosity of the system, the influence of oil phase material system viscosity on the particle size and storage stability of emulsion explosive emulsion was studied.

2. EXPERIMENTAL PART

2.1 Experimental Reagents and Instruments

Reagent: compound wax, Huayue Special Wax Technology Co. LTD; Oil, Beijing Shao Lubricating oil Co. LTD; Vaseline, Huayue Special Wax Technology Co. LTD; span80, Nantong Hantai Chemical Co. LTD;T154, Zhonghe Chemical Co. LTD; Ammonium nitrate, Anhui Huai Chemical Group Co. LTD; Sodium nitrate, Anhui Huai Chemical Group Co. LTD; Distilled water, self-made in laboratory;

Instrument: Nano laser particle size instrument Model: Zetaizer NanoS UK Malvern Instrument LTD; oil bath oven Model: DV-80L Jinhua Huachenghenglei Experimental Instrument Factory; rotary viscosimeter model: DVNXLVCJG Ametek brookfiled

2.2 Preparation method of composite oil phase

The type selection and proportion of composite oil phase materials directly affect the dispersion stability of emulsion matrix and the detonation performance of emulsion explosive. In order to investigate the effects of different emulsifiers on the viscosity of oil phase materials, composite wax, oil, petroleum jelly, span80, T154 and other components of oil phase materials were mixed according to the set ratio to prepare composite oil phase materials. The experiment process is as follows: Composite wax, oil, Vaseline, span80, T154, etc., were used as the composition of the oil phase material. Each component was weighed and heated to 85°C in proportion and stirred until all components melted and then stirred for 30min. The mixing system was poured into the mold and cooled to room temperature to obtain the composite oil phase material.

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2.3 Preparation Method of Latex Matrix

A certain amount of ammonium nitrate and sodium nitrate were dissolved in 90~100℃ water and kept at constant temperature for use. The composite oil phase material was added to the emulsion tank and heated to 95℃ to melt the oil phase material completely. At the stirring speed of 750 RPM, the aqueous solution was slowly added into the oil phase material. After the addition of the water, the stirring speed was adjusted to 1000 RPM and kept stirring for 5 min to form the latex matrix. The formulation of the latex matrix is shown in Table 2.

Table 1: Formula of latex matrix (%)

Ammonium nitrate	sodium nitrate	water	composite oil phase material
76.0	8.0	10.0	6.0

2.4 Measurement of Viscosity of Composite Oil Phase Materials

DVNXLVCJG rotary viscometer was used to measure the viscosity of composite oil phase material with sample size of 2 g. The test temperature was 85 ℃, CP-41 rotor was selected, the speed was 20 RPM, and the test time was 2 min. The average value of the two test results of each sample was taken.

2.5 Determination of Latex Particle Size

Take about 0.1g of latex matrix sample and put it in a test tube, dissolve in 2 mL petroleum ether, gently shake the test tube sample evenly distributed, and transfer the sample into the sample dish to test the particle size of the sample.

2.6 Storage Stability Test of Latex Matrix

The storage stability of latex matrix was tested by high and low temperature cycle method. After cooling to room temperature, the latex matrix samples were stored at -15℃ for 16 h, and then placed in a constant temperature control box at 50℃ for 8 h, as a high and low temperature cycle, a total of 15 cycles.

3. Results and Discussion

3.1 Analysis of Factors Affecting Viscosity of Composite Oil-phase Material System

The results are shown in Table 2.

Table 2: Formula specific viscosity of composite oil phase materials (mPa·s)

number	Compound wax	Engine oil	Vaseline	span80	T154	Mean viscosity
1	1	1	/	/	/	15.88
2	2	1	/	/	/	15.25
3	3	1	/	/	/	15.2
4	4	1	/	/	/	14.65
5	2	1	0.25	/	/	15.34
6	2	1	0.5	/	/	14.28
7	2	1	0.75	/	/	14.13
8	2	1	1	/	/	14.04
9	5	2.5	/	1.68	/	17.87
10	5	2.5	/	1.8	/	18.04
11	5	2.5	/	2.0	/	18.24
12	5	2.5	/	3.0	/	19.45
13	5	2.5	/	1.8	0.35	18.96
14	5	2.5	/	1.9	0.3	19.25
15	5	2.5	/	1.2	0.5	19.57
16	5	2.5	/	1.8	0.4	19.80
17	5	2.5	/	1.8	0.5	20.11
18	5	2.5	/	1.8	0.7	21.36
19	1	/	/	/	/	13.18
20	/	1	/	/	/	23.05
21	/	/	/	1	/	92.56
22	/	/	/	/	1	212.4

The effects of different emulsifier contents on the viscosity of composite oil phase are shown in Figure 1-Figure 4.

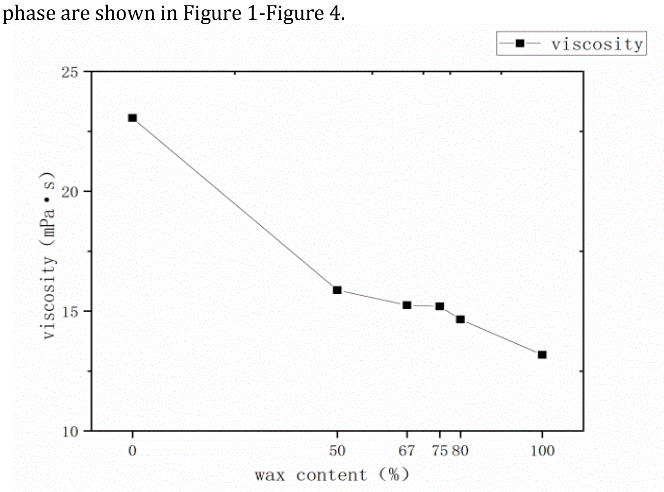

Figure 1: Effect of wax content on the viscosity of wax-oil composite oil phase

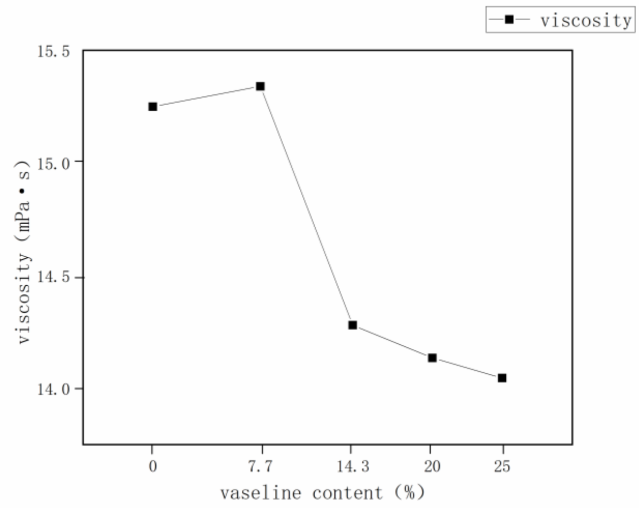

Figure 2: Effect of vaseline content on the phase viscosity of wax-oil-vaseline composite oil

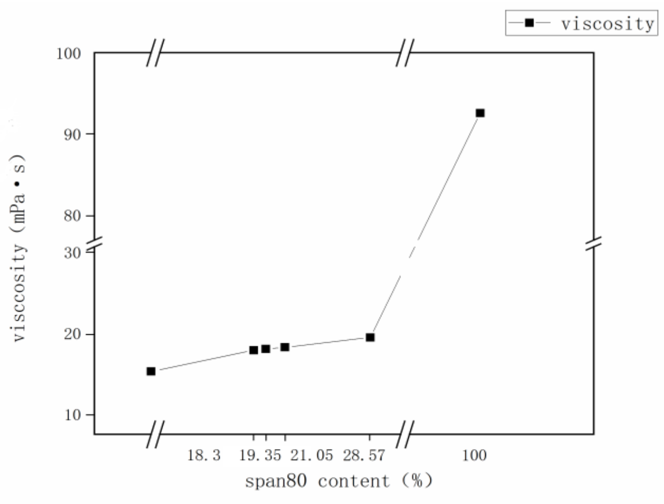

Figure 3: Effect of span80 content on the phase viscosity of wax-oil-Span80 composite oil

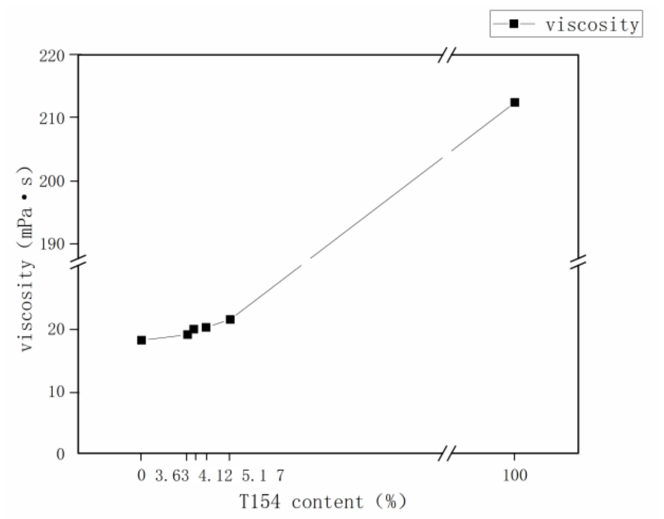

Figure 4: Effect of T154 content on the viscosity of wax-oil-Span80-T154 composite oil

As can be seen from Figure 1, with the wax content increasing by 30%, that is, from 50% to 80%, the average viscosity of composite oil phase material decreases by 7.74% from 15.88 mPa·s to 14.65 mPa·s, indicating that the change of wax and oil ratio has little effect on the overall viscosity of composite oil phase material. This is because wax and oil are aliphatic hydrocarbons, which are similar in structure. The difference mainly lies in molecular weight size and molecular regularity. When the temperature rises to 85℃, wax and oil become liquid at high temperature, and the structural similarity shows similar viscosity. Therefore, the change of wax-oil ratio at high temperature has little effect on viscosity.

It has been reported that the addition of petroleum jelly to the oil phase material can improve the toughness and firmness of the oil film of emulsifier explosive (Xuguang, 2008). In this paper, the effect of petroleum jelly on the viscosity of composite oil phase material was investigated. As can be seen from Figure 2, when petroleum jelly content increases by 17.3%, that is, from 7.7% to 25%, the average viscosity of composite oil phase material decreases by 8.44% from 15.34mPa •s to 14.045mPa •s, and the increase of petroleum jelly content on the surface has little effect on the overall viscosity of composite oil phase material. This is also because petroleum jelly, like wax oil, is an aliphatic hydrocarbon, which has structural similarities.

Span80 is a commonly used emulsifier for composite oil phase materials in China, with a general content of 20% to 35%. In this paper, the influence of span80 on the viscosity of the composite oil-phase material system was investigated, and the results are shown in Figure 3. It can be seen that when 18.3% span80 was added into the wax oil mixture, the viscosity of the system after span 80 increased significantly, from 15.25 mPa·s to 17.875 mPa·s, an increase of 17.21%. However, when span80 content continued to increase by 10.27%, that is, from 18.3% to 28.57%, the average viscosity of composite oil-phase materials increased by 8.12% from 17.875 mPa·s to 19.455 mPa·s, indicating that within the range of commonly used emulsifiers, the viscosity of the composite oil phase material system increases slightly with the increase of span80 content, but it is not obvious.

Polyisobutylene succinimide is a polymer emulsifier commonly used in emulsified explosive oil phase materials in China. The additive amount is generally less than 10%. In this paper, T154 was used to study the influence of polymer emulsifier on the viscosity of composite oil phase materials, and the results are shown in Figure 4. It can be seen that the viscosity of the system increases significantly when 3.63% T154 is added into the wax oil mixture, from 18.045mPa•s to 18.965 mPa•s, an increase of 5.09%. When T154 content continues to increase by 3.37%, that is, from 3.63% to 7.00%, the average viscosity of composite oil phase material increases by 12.62% from 18.965 mPa•s to 21.36 mPa•s, indicating that the addition of T154 can significantly improve the viscosity of composite oil phase material. And the viscosity change is more obvious than span80, indicating that the polymer emulsifier is the main factor affecting the viscosity of the composite oil phase system.

3.2 Influence of Viscosity of Composite Oil-phase Material System on Emulsion Particle Size

Emulsified explosive is a kind of multi-disperse system. The size and distribution of dispersed phase particles are the basic characteristic data of emulsified explosive, which is one of the important indicators of the quality of emulsified explosive and is closely related to the storage stability of emulsified explosive. Generally speaking, the smaller the droplets in the emulsion matrix, the better the storage stability of the emulsion body. Liao Zhijun et al. showed that within a certain range, the greater the viscosity of the oil phase material, the better the storage stability of the latex matrix (Zhijun et al., 2015). In this paper, the particle sizes of latex samples prepared from oil phase materials with similar viscosity and different formulations were investigated. The results are shown in Table 3.

Table 3: Particle size table of emulsions prepared by different oil phase materials with similar viscosity

Sample number	Formula composition（%）				Oil phase viscosity（85℃）	Size of latex（nm）	Number of high and low temperature cycles
	Compound wax	Engine oil	T154	Span 80			
1	47.6	23.8	/	28.6	19.59	5637	15
2	51.5	25.8	4.1	18.6	19.50	1866	15
3	54.3	27.2	5.4	12.4	19.51	9864	15

As can be seen from the Table 3, although the viscosity of the three samples is similar, the particle size of the prepared latex matrix is quite different. The particle size of the latex matrix prepared by composite oily material without T154 is about 5μm, and the particle size can be reduced to 1.2μm after adding T154, but when the content of T154 increases to 5%, The particle size of the emulsion matrix increases to 9.8μm, indicating that the particle size of the emulsion is closely related to the composition of the composite oil phase material, but has no obvious relationship with the viscosity. Only when span80 and polymeric emulsifier exist at the same time and the ratio of them is appropriate, the size of latex particles is minimum. The size of the latex particles is larger and the distribution is wider when the ratios of the two exist separately or simultaneously. Particle size consistency is poor.

3.3 Influence of Viscosity of Composite Oil-phase Material System on the Storage Stability of Latex Matrix

The high and low temperature cycle experiment was carried out on the three kinds of composite oil-phase materials with different formulations in Table 3 to test the storage stability. The composite oil-phase materials with formula 2 did not have demulsification after 15 high and low temperature cycles, while demulsification occurred in both formula 1 and formula 2. According to the theory of emulsion, the size of the emulsion particles, the strength of the interfacial film, the tension of the oil-water interface, the charge of the emulsion particles and the viscosity of the external phase are the key factors affecting the storage stability of the emulsion explosive. As can be seen from Table 4, the viscosity of the three oil-phase materials is similar, but the colloidal particle size and storage stability of the prepared latex matrix are different. The smaller the latex particle size, the better the storage stability of the latex matrix. It shows that the storage stability of latex matrix is closely related to the size of latex particles. The influence of viscosity on storage stability is mainly realized by the size of the latex particles formed. Generally speaking, the smaller the particle size of dispersed phase, the more uniform the distribution of W/O structure, and the better the storage stability of latex matrix. At the same time, W/O structure is an unstable thermodynamic system, which is easy to demulsification during long-term storage and affects its performance.

4. Conclusion

This paper studies the influence factors of composite oil phase material viscosity size, types and content of different emulsifiers to the composite oil phase material viscosity has carried on the experimental study on the influence of size, the results show that factors affecting the nature of the oil phase material viscosity is emulsifier, oil phase material viscosity polymer emulsifier span80 in case of influence is most obvious,The change of the proportion of wax and oil has little effect on the viscosity of the oil phase material, but the change of the viscosity of the oil phase material with the content of the emulsifier is not obvious in the range of the emulsifier added to the oil phase material.

In this paper, the storage stability of oil-phase materials with different formulations with similar viscosity was studied, and the results were contrary to previous studies. The viscosity of the oil phase material has nothing to do with the storage stability of emulsion explosive, but is closely related to the formula of the oil phase material. The size of the emulsion matrix prepared by different formula of the oil phase material with similar viscosity is very different.

The experimental results show that the storage stability of latex matrix is mainly determined by the size of latex particles. The smaller the particles are, the more stable the latex matrix is. The influence of viscosity of oil phase material on the storage stability of latex matrix is mainly realized by the size of latex particles formed.

References

Agrawal, H., ishra, A.K., 2018. Study on influence of density and viscosity of emulsion explosive on its detonation velocity. Model Meas Contral C, 78 (03), Pp. 316-336.

Al-Sabagh, A.M., Hussien, M.A., Mishrif, M.R., 2017. Preparation and investigation of emulsion explosive matrix based on gas oil for mining process. Journal of Molecular liquids, Pp. 198-207.

Ao, C., Zhiwei, H., Yang, W., 2019. Effect of Oil Phase Material on Storage Stability of Emulsion Matrix. Initiators & Pyrotechnics, (2) 4.

Feiyang, X., Hongbo, W., Manman, X., 2017. Effect of oil phase material and emulsifier on detonation performance of emulsified explosive. Initiators & Pyrotechnics, 12 (06).

Guoguang, Y., Guohui, Y., Jun, L., 2017. Research on the influence of different emulsifying agent materials to the stability of emulsion matrix. Coal Mine Blasting, (3), Pp. 13-15.

Jiangtao, C., Hongbo, W., Keke, Z., 2018. Effect of oil phase material on storage stability of emulsion explosive. Coal Mine Blasting, (05).

Jingxian, Y., WenChao, Y., XuePing, X., 2022. Experimental study on the effect of oil phase material on storage performance of emulsion explosive. Yunnan Chemical Technology, 49 (03).

Jinquan, S., Xuguang, W., 2002. Discussion on the storage stability of emulsion explosive. Chinese Journal of Explosives & Propellants, (01).

Masalova, I., Kapiamba, F., Tshilumbu, N., 2018. Shear stability of highly concentrated emulsions. Colloid Journal, 80 (1), Pp. 54-58.

Mertuszka, P., Fulawka, K., Pytlik, M., 2019. The influence of temperature on the detonation velocity of selected emulsion explosives. Journal of Energetic Materials, Pp. 1-12.

Mingsheng, Z., Li, Z., Jian, W., 2021. Study on the effect of aqueous component on the properties of mixed emulsion explosive. Engineering Blasting, 27 (05).

Sang, D.Q., Anh, N.T., 2020. Several explosion behaviours of the emulsion explosives sensitized by cenospheres. Vietnam Journal of Chemistry, 58 (3), Pp. 380-385.

Xuguang, W., 2008. Emulsion Explosive. BeiJing: Metallurgical Industry Press.

Zhan, L., Hongwei, L., Lei., D., 2018. Effect of Compound Emulsifier on the Stability and Detonation Rate of HANFO. Initiators & Pyrotechnics, (5), Pp. 44-47.

Zhao, H.R., Wu, J.X., in-Xiao, 2021. Advances in the Rheology of Emulsion Explosive. Journal of Molecular Liquids, Pp. 336.

Zhijun, L., Hongbo, W., Shilong, Y., 2015. Experimental study on the influence of viscosity on the storage stability of latex matrix. Journal of Anhui University of Science and Technology (Natural Science), 35(04).