
REVISTA
INCLUSIONES
HOMENAJE A NATALIA MILANESIO
Revista de Humanidades y Ciencias Sociales
Volumen 7 . Número 4
Octubre / Diciembre
2020
ISSN 0719-4706

REVISTA INCLUSIONES M.R.
REVISTA DE HUMANIDADES Y CIENCIAS SOCIALES

CUADERNOS DE SOFÍA EDITORIAL

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CUADERNOS DE SOFÍA EDITORIAL

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Revista Inclusiones, se encuentra indizada en:

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REVISTA INCLUSIONES M.R.
REVISTA DE HUMANIDADES Y CIENCIAS SOCIALES

CUADERNOS DE SOFÍA EDITORIAL

ISSN 0719-4706 - Volumen 7 / Número 4 / Octubre – Diciembre 2020 pp. 646-658

NEW APPROACHES TO STABILIZE AQUEOUS SOOT SUSPENSIONS IN THE FIELD OF ULTRASOUND

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Fecha de Recepción: 11 de junio de 2020 – **Fecha Revisión**: 27 de junio de 2020

Fecha de Aceptación: 23 de septiembre 2020 – **Fecha de Publicación**: 01 de octubre de 2020

Abstract

In this work, we investigated the possibility of stabilization of aqueous low- and highly concentrated dispersed soot systems by diphilic high-molecular compounds. Based on the results, it can be concluded that the presence of hydrophobic fragments in the macromolecule chain plays a very significant role and positively affects the results of stabilization of aqueous soot dispersions. Studies have shown that the use of a stabilizer in combination with ultrasonic treatment of dispersed systems makes it possible to obtain stable homogeneous finely dispersed pastes. It was noted that a strong increase in the time and intensity of ultrasound processing of the system does not lead to a significant improvement in the results.

Keywords

Soot – Stability – Particles – Copolymers – Ultrasound

Para Citar este Artículo:

Aleksandrova, Yulia P.; Bdanova, Natalia S.; Zharova, Nelli P.; Okorokova, Nadezhda S.; Ustvuzhaninova, Galina N.; Farmakovskaya, Ariadna A. y Kohlert, Victoria. New approaches to stabilize aqueous soot suspensions in the field of ultrasound. Revista Inclusiones Vol: 7 num 4 (2020): 646-658.

Introduction

Soot (carbon black) is very widely used in the rubber and synthetic rubber industries[1]. The range of fields of its application is very wide: from use as a pigment for coloring various products to filling rubber products[2]. While making soot-filled rubbers, 10-25% aqueous suspension of soot is preliminarily prepared[3] Dispersion is carried out in an apparatus with a stirrer[4]. However, soot has a hydrophobic surface and is not wetted by water [5]. Therefore, it is interesting to investigate the possibility of modifying the surface of it in order to obtain aqueous dispersions and pastes with high aggregative and sedimentation stability[6].

In this work, we investigated the possibility of stabilization of aqueous low- and highly concentrated dispersed soot systems by diphilic high-molecular compounds[7]. The reason for choosing such substances as a surfactant is the need to create a diphilic adsorption layer on the surface of soot particles that impedes the processes of aggregation and coagulation of particles due to the adsorption-solvate and structural-mechanical stability factor of colloidal systems[8]. However, in a number of studies, as well as in the course of preliminary experiments, it was shown that a high-intensity mechanical effect on a dispersed system, in particular, processing the system in an ultrasound field, is an effective method of activating surfactant adsorption on the surface of pigments[9].

The dispersing effect of the ultrasonic field on colloidal systems is well known[10]. It is based on the phenomenon of cavitation, which occurs in a liquid as a result of a local

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decrease in pressure during the passage of an acoustic wave of high intensity[11]. The cavitation bubbles formed, moving to a region with a higher pressure, collapse, emitting a shock wave[12]. However, in order to prevent subsequent coagulation of particles, the effect of ultrasound should be fixed by the creation of protective layers of the stabilizer[13].

Stabilization of aqueous soot suspensions using water-soluble copolymers

In order to select optimal surfactants for stabilization of aqueous soot suspensions, colloidal stability studies of 0.1% and 12% aqueous soot suspensions in the presence of high molecular weight surfactants were carried out[14]. As a result, optimal stabilizers for soot – water systems were selected, and the concentrations of these stabilizers were determined[15].

As surfactants, industrially produced ionogenic (1-4) and nonionic (5) water-soluble stabilizers were used:

1) copolymer of polyacrylic ester and sodium polyacrylate (commercial name is Tegodispers 750 W);

2) copolymer of polyacrylic ester and ammonium polyacrylate (commercial name is Coatex P 90);

3) copolymer of polyacrylic acid and sodium polyacrylate (commercial name is Dispex N 40);

4) copolymer of polyacrylic acid and ammonium polyacrylate (commercial name is Dispex A 40);

5) ethylhydroxyethyl cellulose (nonionic, water soluble and environmentally friendly polymer).

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If there is no polymeric surfactants, soot particles are not wetted by water and float on its surface[16]. The introduction of polymer stabilizers without machining the dispersion practically does not allow obtaining stable dispersed systems[17]. The use of mechanical mixing or ultrasonic treatment in the absence of polymers also does not lead to the formation of homogeneous dispersed systems[18]. However, in the presence of polymers, the image changes qualitatively. With the combined effects of polymer stabilizers and ultrasonic treatment, it is possible to obtain highly stable dispersed systems[19].

The stability of disperse systems was studied by sedimentation[20]. As a criterion for assessing colloidal stability, the semi-sedimentation time of the solid phase was chosen[21]. Table 1 presents data on the effect of polymers on the colloidal stability of pigment suspensions[22].

Stabilizer	Half-life of the solid phase, days
Tegodispers 750 W	90
Coatex P 90	10
Dispex N 40	1
Dispex A 40	0.5
Ethylhydroxyethyl cellulose	3

Table 1
Colloidal stability of aqueous soot dispersions stabilized
by high molecular weight surfactants

As we can see from the Table 1, the colloidal stability of the obtained dispersed systems substantially depends on the nature of the polymer[23]. The strongest effect was obtained when using Tegodispers 750 W as a stabilizer[24].

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The dispersed system does not stratify for 3 months or more[25]. The particle size of soot is about 1 μm. Polymers Dispex N 40 and Dispex A 40 show significantly worse results, nonionic polymer ethylhydroxyethyl cellulose and Coatex P 90 are in the middle of this interval[26].

These results are in good agreement with the data on the values of the contact angles obtained for soot samples treated with these high molecular weight surfactants (Table 2)[27].

Stabilizer	Wetting angle, deg.
Without polymer	124
Tegodispers 750 W	0
Coatex P 90	110
Dispex N 40	116
Dispex A 40	119
Ethylhydroxyethyl cellulose	106

Table 2
Values of water contact wetting angles of soot surfaces treated with high molecular weight surfactants

The table shows that in the absence of polymers deposited on the soot surface, the value of the contact angle is quite large and clearly indicates the hydrophobicity of the pigment surface[28]. The difference in the wetting angle of the clean soot surface from the values obtained in the presence of polymers indicates the formation of surface layers during ultrasonic treatment[29]. It also follows from the table that only Tegodispers 750 W, adsorbing on the surface of soot particles, can effectively wet it with water[30].

Analyzing the Tables 1 and 2, we can conclude that only polymer Tegodispers 750 W (copolymer of polyacrylic ester and sodium polyacrylate) shows good results[31]. This can

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be explained by the presence of hydrophobic fragments of esters of acrylic acid in it, which have an affinity for hydrophobic surfaces and are well adsorbed on the soot surface, as well as a strongly dissociated carboxyl group, which actively interacts with the aqueous phase[32].

Comparing the effect of Tegodispers 750 W and Coatex P 90, which have the same structure and differ only in the nature of the positive ion (Na^+ and NH_4^+), it can be concluded that the nature of the positively charged ion affects the effectiveness of the stabilizing effect of surfactants[33]. The difference in the values of the contact angles of wetting also indicates a significant role of the counterion in the modification of the surface of organic pigments[34].

The presence of carboxyl groups in the H-form in the macromolecule structure negatively affects the stabilization of the system by Dispex N 40 and Dispex A 40 polymers[35]. The nonionic stabilizer ethylhydroxyethyl cellulose is in the intermediate position[36]. Based on the above results, it can be concluded that the presence of hydrophobic fragments in the macromolecule chain plays a very significant role and positively affects the results of stabilization of aqueous soot dispersions[37]. Next, we conducted studies stabilize 12% of aqueous dispersed soot systems (pastes), which can be used to fill various products[38]. The experiments showed that the high molecular weight stabilizers used in the previous stage, even when using ultrasonic treatment as a mechanical effect, do not give a positive effect[39]. The exception is only Tegodispers 750 W, when using which it was possible to obtain relatively stable dispersed systems, but its concentration in this case turned out to be quite high and reached 10%[40]. In this regard,

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the industrially produced anionic stabilizer NF was studied. The use of this stabilizer in combination with ultrasonic treatment of dispersed systems allows obtaining stable homogeneous finely dispersed pastes[41]. The colloidal stability of the obtained disperse systems was studied by the sedimentation method; in addition, the average particle size of soot was evaluated as one of the main criteria for assessing the quality of a disperse system[42].

Three formulations were chosen for the preparation of the studied pastes: using NF stabilizer, using Tegodispers 750 W polymer stabilizer and using them together. The results of the study of colloidal stability and analysis of particle sizes of soot dispersions are shown in the Table 3.

Stabilizer	Half-life of the solid phase, days	Average particle size, µm
Tegodispers 750 W (10%)	10	5 – 6
NF (5% mass)	30	1 – 2
NF (3% mass) + Tegodispers 750 W (5%)	30	1 – 2

Table 3
Colloidal stability and average particle size of aqueous soot dispersions stabilized by various surfactants

From the data presented in the table, it follows that the use of NF stabilizer and mixed formulation allows obtaining sufficiently stable finely dispersed pastes. It was noted that an increase in the time and intensity of ultrasound processing of the system does not lead to a significant improvement in the results.

It was also interesting to find out how the concentration of NF stabilizer affects the stability and particle size of soot pastes and whether it is possible to establish a certain optimal concentration that will provide satisfactory values of these parameters. Therefore, experiments were conducted with different concentrations of NF. The results are presented in the Table 4.

Concentration of NF stabilizer, %	Half-life of the solid phase, days	Average particle size, µm
1	2	6 – 8
2	10	5 – 6
3	20	3 – 4
5	30	1 – 2
10	35	1 – 1.5

Table 4
Colloidal stability and average particle size of aqueous soot dispersions, depending on the concentration of NF stabilizer

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The table shows that the average particle size of the dispersions and their stability depend on the concentration of the stabilizer, therefore, in each case, the required concentration can be determined depending on the requirements for the resulting dispersed system.

Conclusions

Thus, as a result of the studies, the high efficiency of the proposed method for modifying the surface of a hydrophobic organic pigment, carbon black, consisting in the combined action of polymer or low molecular weight surfactants and mechanical activation of the soot surface in the ultrasound field is shown. A number of industrially produced polymer surfactants have been selected, which have an optimal structure and composition, provide high stability for low concentrated aqueous dispersed soot systems, and also show the possibility of stabilizing concentrated suspensions with a low molecular weight anionic stabilizer NF.

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