Research status of styrene acrylic damping coatings

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Abstract: Styrene acrylic emulsion as an important functional intermediate has been widely studied in chemical industry, but its modification research on damping property is still less. At present, the main modification methods are blending, grafting and interpenetrating.

1. Introduction

With the development of social economy, noise pollution has gradually attracted people's attention. It has been listed as one of the three major pollution in the world, along with air pollution and water pollution. As a commonly used vehicle for modern people, the production, sales and ownership of cars are growing steadily, and people pay more and more attention to the noise control inside the car. The control level of interior noise and environmental protection has gradually become one of the important signs to measure the quality of automobile safety and comfort. There are many kinds of vibration sources on the automobile. The long-term vibration and noise will cause serious harm, such as causing damage to the mechanism, affecting the normal operation of instruments and instruments, affecting the comfort of drivers and passengers, and easy to cause driver fatigue. Therefore, in order to reduce the noise caused by vibration in the process of driving, improve the comfort of the car and meet the needs of heat insulation of air conditioning, and make the noise of car meet the requirements of regulations below 78 dB, it is necessary to use sound-proof, shock-proof and sound-absorbing materials inside the car body [1].

At present, there are three main methods for reducing vibration and noise: (1) in the structural design of automobile body, in order to weaken the contribution of body resonance to the interior noise, the natural frequency of the whole body structure mode should avoid the excitation frequency generated by the outside; (2) the sealing technology is used to improve the sealing performance of the whole body, so as to avoid the external noise directly transmitted to the driver through the gap Indoor; (3) use some sound insulation and sound absorption damping materials inside and outside the car to reduce noise. This paper focuses on the third vehicle damping and noise reduction technology [2].

There are many kinds of damping materials on the market, mainly vulcanized rubber damping materials, asphalt damping materials, solvent damping coatings, water-based damping coatings. At present, most of the automobile industry uses asphalt damping plate, which is low cost and easy to use, but its environmental performance is poor. The water-based damping coating uses water as the dispersion medium, in which VOC content is very low, which is safe and environmental protection; moreover, the water-based damping coating has excellent damping performance. With the requirements of automobile industry policy and the enhancement of people's awareness of environmental protection, water-based damping coating [3-8] will be adopted by more enterprises.
2. Comparison between traditional damping material and water-based damping material
Road roughness and body response caused by powertrain seriously affect people's requirements for comfort and safety. Therefore, it is the basis of vehicle modal analysis and dynamic analysis. Some scholars use the finite element method to analyze the natural frequencies and modes of vehicle components and carry out structural optimization [2-8].

(1) Characteristics of traditional damping materials:
a. It has advantages in material cost and process manufacturing cost.
b. In terms of manufacturing technology, it can realize automatic feeding, high-speed dispersion, double pass magnetization of permanent magnet roller, automatic control of calendering, anti sticking of isolating agent and automatic sorting of film.

(2) Characteristics of water based damping materials
a. It has a wide range of formulation systems, three sets of high, medium and low formulation systems are suitable for different performance and cost requirements.
b. For example, the dry film density of LASD is 0.97 g/cm³, while the average density of asphalt damping plate is 1.8 g/cm³, which can reduce weight by 45% under the same construction area.
c. It can provide a variety of spraying construction schemes, such as manual, automatic, manual self integration, etc.

3. Modification of styrene acrylic emulsion
Styrene acrylic emulsion in waterborne damping coatings has good viscoelastic properties. In recent years, some scholars have studied and modified their damping properties. The main modification methods are three kinds of blending modification, graft modification and interpenetrating modification.

3.1. Blending modification
The surface effect of nanoparticles is prominent, which can form weak adhesion and interface friction with polymer, so it can improve damping performance. The emergence of nanomaterials has become a hot topic in the research of modification of damping materials by nanoparticles. The problem of improving the dispersion stability of nanoparticles in emulsion is also a problem to be solved at present. Hu et al. Used nano montmorillonite to modify the styrene acrylic emulsion of the traditional IPN structure, so that the damping capacity and the damping range were extended [9]. Li Chong and so on studied the influence of the different mass ratio of mica powder on the damping capacity of styrene acrylic emulsion, and determined the best proportion of each component [10]; Zhang Yalian and so on studied the micromorphology and damping of the talcum powder and glass fiber on the emulsion. It is found that the performance is the best when the mass percentage of filler is 1% [11].

3.2. Graft modification
In theory, the crystallinity of the main chain can be destroyed by introducing or increasing the volume of the side group in the main chain, which can obviously improve the damping performance. In addition, the introduction of ionic bond in macromolecular chain can not only broaden the damping temperature range, but also increase the damping factor. Side groups and ionic bonds can be introduced by grafting and block copolymerization. For two kinds of copolymers, there are usually three situations: completely incompatible, completely compatible and partially compatible. Effective damping materials need to have a wide damping temperature range. Both completely compatible and completely incompatible systems do not meet the requirements. Only partially compatible copolymers can meet the actual requirements. Zhang Dingjun and other silane coupling agents were used as modifier to improve the mechanical properties and effective damping temperature range of the film, providing a reference for further synthesis of high performance damping coatings [12]. The application of waterborne polyurethane in the graft modification of Xiong Meng can expand the effective damping temperature domain of the original emulsion, and when PU/PBS=0.25 has the best damping effect, Li have studied
the effects of different crosslinking agents on the milk [13]. At the same time, it is found that the products with sequential monomer feeding method tend to provide good tensile damping properties [14].

3.3. Interpenetrating modification
The TG range (damping temperature range) of homopolymer is very narrow, which is difficult to meet the needs of wide damping temperature range in practical application. Although blending, block copolymerization and graft copolymerization with plasticizers or fillers can broaden the TG range of polymers to a certain extent, the effect is still not ideal. Due to the mutual penetration and entanglement between the crosslinked networks, the IPN materials have the characteristics of macroscopic phase separation and microscopic phase separation, which creates conditions for the preparation of wide temperature (broadband) damping materials. Wang et al. Direct polymerization of hindered phenol / polymer composite emulsion is applied in waterborne damping coatings, so that the effective damping temperature domain is extended to 112°C, and the maximum loss factor can reach 2.7 [15]. Li Heng prepared multilayer shell core emulsion, and found that the effective damping temperature range moved to the low temperature region, and the three layer core shell structure temperature range was the largest [16].

4. Determination and characterization of main results

4.1. Emulsion particle size test
The size and distribution of emulsion particles directly affect the appearance, viscosity and gloss of the styrene acrylic emulsion. The larger the particle size, the better the viscosity, and the worse the gloss of the film.

4.2. Solid content test of emulsion
High solid content emulsion has a significant effect on the drying time of emulsion, but if the solid content is too high, it is easy to coagulate, precipitate and stratification [17].

4.3. FT-IR test
FTIR spectra can infer the structure of compounds, and the IR spectra obtained from material analysis reflect the kinds of functional groups contained in the emulsion and the chemical environment in which they are located.

4.4. Determination of water absorption of adhesive film
By measuring the water absorption of the film, the effect of high humidity on its damping performance was studied.

4.5. Test on damping property of adhesive film
The dynamic thermo mechanical analysis of the adhesive film is carried out by DMA, thus the damping performance of the adhesive film can be directly displayed in a certain temperature range [18].

5. Conclusion
With the rapid development of automobile industry, people put forward higher requirements for vibration reduction, noise reduction and environmental protection of automobiles, and the requirements for damping properties and other properties of damping materials are also higher. Therefore, it is necessary for the majority of damping coating researchers to continuously explore and innovate, and develop a new water-based damping material with good damping and sound insulation performance, long-term stability and reliability of physical and mechanical properties, stable storage performance, convenient construction, safety and environmental protection [19].
References

[1] Zhang J P, Gao Z X, Li J W and Li X X 2019 Appearance control and damping performance of baking water-based damping coatings Adhesion 40(01) 33-35.

[2] Eren B and Solmaz Y 2020 Preparation and properties of negatively charged styrene acrylic latex particles cross-linked with divinylbenzene J. Therm. Anal. Calorim. 141(4) 1331-9.

[3] Yan X X, Cai Y T, Guo W J, Yang R O, Qian X Y, Pan P and Xu W 2019 Preparation of urea-formaldehyde@epoxy resin microcapsule and its effect on waterborne wood coatings J. Forest. Eng. 4(01) 160-4.

[4] Gao M, Dong S L, Xia D L, Wang Y, Wang R Q and Zhou J P 2013 Discussion on application technology of waterborne coatings for railway passenger car Paint. Coat. Ind. 43(11) 53-58.

[5] Zhang M H, Sun Q L, Feng Y Z, Xu J M and Tang X D 2020 Nano SiO2 preparation and hydrophobicity of modified styrene acrylic emulsion Synthetic Resin Plast. (01) 21-24 and 32.

[6] Li M, Qiang X, Zhang H, Liu Z and Yan Z 2014 Synthesis and characterization of cationic waterborne polyurethane with high solid content Gaofenzi Cailiao Kexue Yu Gongcheng/Polymeric Mater. Sci. Eng. 30(8) 37-42 and 47.

[7] Su G H, Tang Y and Cai W 2018 Preparation and performance of waterborne sand-containing multicolor coatings Paint. Coat. Ind. 48(01) 22-27 and 36.

[8] Qiao Y L, Su J B and Shen L 2013 Preparation of polyurethane-acrylate(pua) resins for high performance waterborne wood coating and its film properties Paint. Coat. Ind. 43(04) 30-6.

[9] Hu B, Zhang Z P, Liu X M and Zhang J C 2011 Preparation and damping property study of styrene-acrylic ipn/mt nano-composite material Adv. Mater. Res. 284-286 382-6.

[10] Li C, Zhang W J, Zhang J P, Gao X Z and Li X S 2016 Development of waterborne damping coating Adhesion 37(12) 51-4.

[11] Zhang Y L and Chen R 2016 Preparation and performance research of self-crosslinking acrylic ester emulsion for waterborne wood coatings China Coatings 31(07)19-22 and 26.

[12] Zhang D J, Li Y T, Zhang X T, Feng Z X, Gan M Y, Ma Y X and Chen Z B 2017 Preparation and properties study of high viscosity styrene-acrylic emulsion Appl. Chem. Ind. 46(02)245-8.

[13] Xiong M, Huang Z X, Lv X S, Luo W and Meng P 2016 Preparation and damping properties of polyurethane-modified styrene-acrylic emulsion Coat. Tech. Abstracts 37(4) 36-40.

[14] Li Y W, Zhang Y G, Yang Z, Xue X, He Z Y, Wang H Q, Wang C, Qu J, Feng Y, Zhang W D and Xu L J 2020 Waterborne coatings with sub-ambient cooling under direct sunlight—part I: Optical properties and cooling effect measurements Sol. Energ. Mater. Sol. C. 217 110672.

[15] Wang F, Guo L, Qiu T, Ye J, He L and Li X 2019 A direct polymerization approach toward hindered phenol/polymer composite latex and its application for waterborne damping coating Prog. Org. Coat. 130 1-7.

[16] Li H, Shi Y, Zhang Y, Lin R X and Zhou C 2018 Synthesis and properties of fluorinated acrylate modified waterborne polyurethane Polyurethane Ind. (04) 30-33.

[17] Jiang W and Si Q B 2014 Preparation and performance testing of waterborne damping coating Chem. World 55(04) 208-210 and 214.

[18] Rao Q Q, Chen K L and Wang C X 2016 Preparation and properties of waterborne superhydrophobic coatings based on fas-loaded microcapsules Paint. Coat. Ind. 46(10)1-5.

[19] Zhou X D 2018 Application of waterborne damping material in vehicle body Modern Paint Finish. 21(11) 48-50 and 53.