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A Study on Nano Powdered Rubber as an Friction Materials

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Abstract—Styrene butadiene nano powdered rubber and nitrile-butadiene nano powdered rubber were used for manufacturing clutch facings, disc brake pads and brake linings to replace conventional styrene butadiene rubber and nitrile-butadiene rubber. The results of constant speed friction test and dynamometer test showed that nano powdered rubber can substantially improve properties of friction materials. The friction coefficient of friction materials modified with nano powdered rubber varies steadily with the change of temperature, and the wearing rate of friction materials is relatively low by using nano powdered rubber. These results indicate that nano powdered rubber has ideal application effect in various friction materials and is a kind of novel rubber modifier for friction materials.

Keywords— Friction materials, Nano powdered rubber, Phenolic resin, Brake, Brake Lining Material

I. INTRODUCTION

All Automotive friction materials have been formulated for about 100 years. In the early 1920s, asbestos fiber was chosen as a friction material for use in all kinds of vehicles. Nowadays however non-asbestos (NAO) formula becomes main stream to overcome the negative effect of asbestos on human respiratory system. A typical brake lining formula includes phenolic resin mixed with metal powder, inorganic fillers and fibers. Friction materials made of pure phenolic resin are poor in toughness due to the resin's hard and brittle nature, resulting in easy formation of craze cracking on final product surface and unpleasant braking noise in use. Therefore, the use of phenolic resin compound with rubber prevails over the rare use of pure phenolic resin. The most commonly used rubbers in friction materials are SBR and NBR. Rubbers can be applied in two forms, i.e. rubber block and rubber powder. Generally speaking, application of rubber block in friction material production is complicated and less efficient, involving processes of mastication, phenolic resin compounding, compound pulverizing, and etc. By contrast, application of rubber powder is much simpler, where most of the industry use direct mixing process, the simplest one among resin/rubber compounding processes. In direct mixing process, all raw materials including powdered rubber, resin, fiber, filler, and etc. are directly mixed in a mixer and compounded into compounding material. Properties of rubber component can be better retained, and will have direct influence on the properties of cured phenolic resin binder and hence the properties of final products. While the industry has put substantial investment in new friction materials to improve the performance of brake pads, researches on the optimization of commercial disc brake pads for better performance are also reported. In this paper, a novel powdered rubber product with nano-scale particle size is introduced for the first time in friction material application. Since its industrialization, the novel rubber product has been already successfully applied to areas such as thermoplastics and thermosets toughening, thermoplastic vulcanizates preparation, and so on.

II. NANO POWDERED RUBBER TECHNOLOGY

Nano powdered rubber technology was developed by SINOPEC Beijing Research Institute of Chemical Industry and Peking University. More than 30 patents with regard to this technology have been filed, and among them 15 have been issued in China and 1 has been issued in the US

(USP6,423,760). In this technology, rubber latex was used as raw material and subject to irradiation cross linking and drying to obtain full-vulcanized powdered rubber with basically same particle size as particles in rubber latex. As illustrated in Fig. 1, the macromolecules in latex particles will change from linear or slightly cross-linked to highly cross-linked structure after irradiation. The latex particles in most chosen rubber latexes are less than 100 nm in size, therefore this full-vulcanized powdered rubber is called nano powdered rubber or elastomeric nano particle (ENP).In addition, some other rubber latex particles are 100–200 nm in size, so we totally call all the full-vulcanized powdered rubbers with size much less than micron scale as ultrafine full-vulcanized powdered rubber (UFPR). It can be inferred from above manufacturing process that the surface part of ENP or UFPR has higher cross linking degree than the interior due to a higher concentration of cross linking agent near the surface part as well as more reactions with excited molecules and ions in water produced by the irradiation. Therefore, the ENP not only has good rubber properties, but also can be easily dispersed in plastics at nano-scale when blended with plastics. Eight series of UFPR products have been developed up to now, as listed in Table 1. These products were solely produced by Beijing BHY Chemical Industry New Technology Company, a subsidiary company of SINOPEC Beijing Research Institute of Chemical Industry. A pilot production unit with a capacity of 500 t per year was put into production in September 2001, the capacity of which has been increased to 1000 t per year at present. The trademark of these products is Narpow®, an acronym of nano rubber powder. Among the eight series of nano powdered rubber products, polarities of various rubbers are different from each other. According to the resin to be modified, the rubbers with good compatibility or having chemical reaction on interface with the modified resins can be chosen to achieve good modification effect. As for friction materials, VP-101, VP-201, VP-401 and VP-501 series can all be employed.

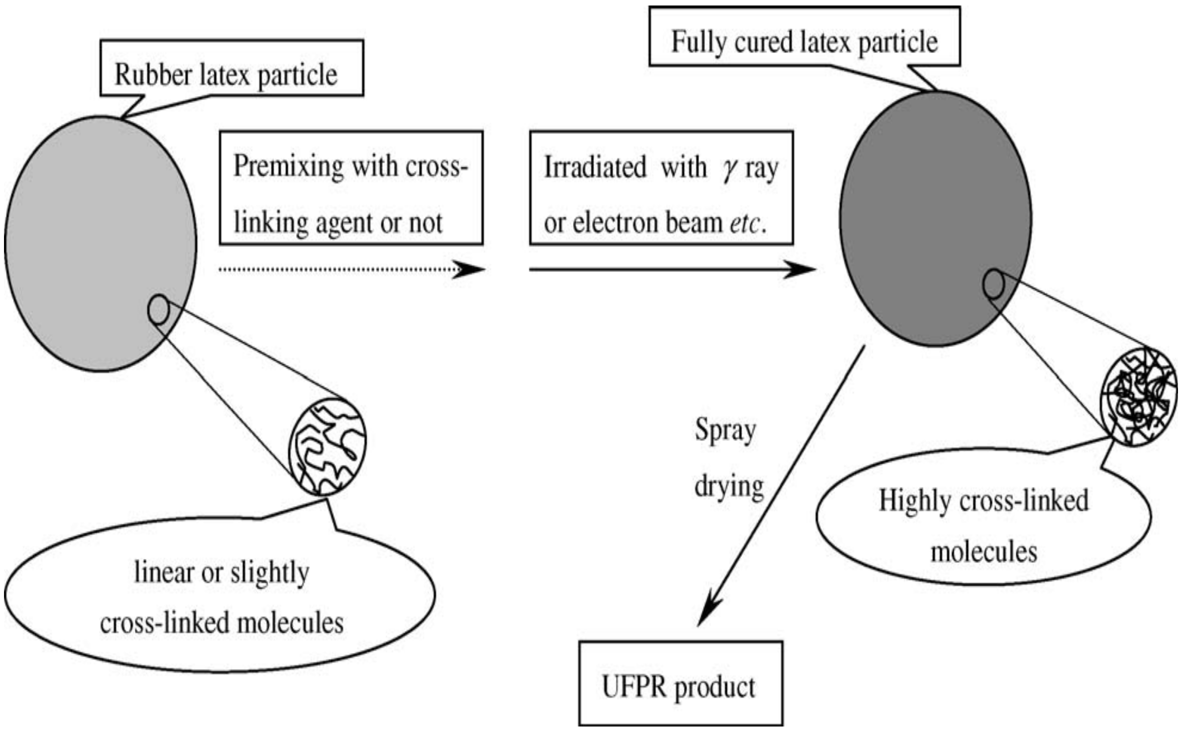


Figure 1. Schematic diagram of the preparation of UFPR

Table 1. Brands and application of nano powdered rubber

Brand	Name	Particle size	Application
VP-101, 108, 121	Narpow® Styrene-Butadiene UFPR	Ca. 100 nm	Toughening agent for non-polar thermoplastic resins such as PP,PS, PE, etc. and using for preparing corresponding TPV; modifying friction materials
VP-201	Narpow® Carboxylic Styrene-ButadieneUFPR	100–150 nm	Toughening polar thermoplastic resins such as nylon, and preparing corresponding TPV; modifying friction materials
VP-301	Narpow® Acrylic UFPR	100–150 nm	Toughening polyester, POM, nylon, AS, PVC, PMMA, etc. and preparing various oil-proof TPV
VP-401, 402, 412	Narpow® Nitrile-Butadiene UFPR	Ca. 100 nm	Toughening thermoset resin such as epoxy resin and thermoplastic resin such as PVC, nylon, etc.
VP-701	Narpow® Butadiene styrene vinyl-pyridineUFPR	Ca. 100 nm	Toughening polar resins such as nylon, polyester, and preparing TPE

III. TESTING RESULTS OF INDUSTRIAL SCALE IN FRICTION MATERIALS

3.1 Testing results in disc brake pads

Nitrile-butadiene UFPR VP-402 was used in NAO (nonasbestos) formula and the prepared disc brake pads for cars (model “Hongqi” CA7220) were tested on a JF132 dynamometer. The composition of all components in the formula are: phenolic resin–12 wt.%, VP-402 rubber powder–5 wt.%, mineral fibers–15 wt.%, steel wool–8 wt.%, other fibers–5 wt.%, friction modifiers and fillers –55 wt.%. As shown in Fig. 2, the friction coefficients of brake pads were measured on a dynamometer by changing pressure, speed, braking times and temperature. This dynamometer test is carried out on a JF132 friction material tester (manufactured by Jilin University, China), which is equipped with inertia flying wheel and can perform both Krauss test and inertia test. Its control software can be edited and perform European, US, Japanese and Chinese test standards, such asVWPV-3212,VWTL-110, SAE J212, JB 3980, and etc. The Volkswagen standard VW TL110 was applied in the test, the procedure of which can simulate the real working condition of disc brake pads and reflect the performance of disc brake pads as used in vehicles. The test is a cycle test, as shown from (a) to (e), and (f) is the start of next cycle as (a). During the test, two disc pads were measured at the same time. The test was firstly run for 10 cycles (the data collected here are designated as group A), and then the two disc pads were unloaded from the tester and checked if there were any cracks on their surfaces. If no cracks, the two disc pads will be tested for another five cycles (designated as group B). The straight lines in each diagram represent the limits of the design criteria, and any test data which falls between these two lines are considered ideal. The control sample, modified with ordinary nitrile-butadiene rubber powder, was plotted together for comparison. The test curves shown in Fig. 2 indicate that the disc brake pad sample modified with nano powdered rubber can substantially meet the design criteria while the data of the control sample mostly fall beyond the design limits. In addition, the friction coefficient of sample modified with nano powdered rubber is stable, especially at high temperature zone. The test data of group A and group B are close to each other in the whole test. The wear of group A is 2.25 g, group B 2.2 g, while the value for the control sample are 3.45 g (control A), and 3.35 g (control B), respectively. Therefore, the test data prove that nano powdered rubber has a good performance in the preparation of disc brake pads. The ordinary powdered rubber can be replaced by nano powdered rubber to get better friction properties at low wear.

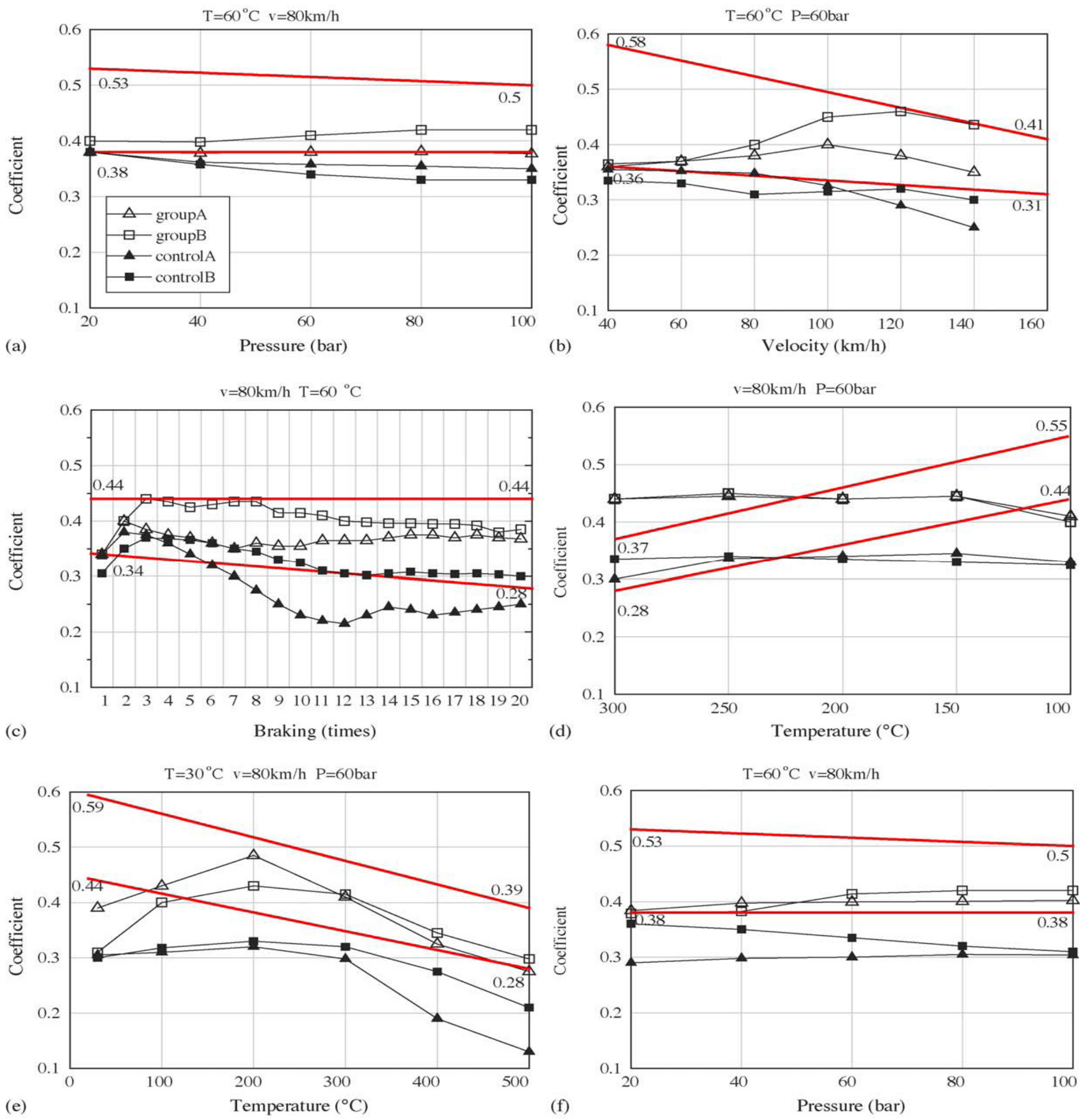


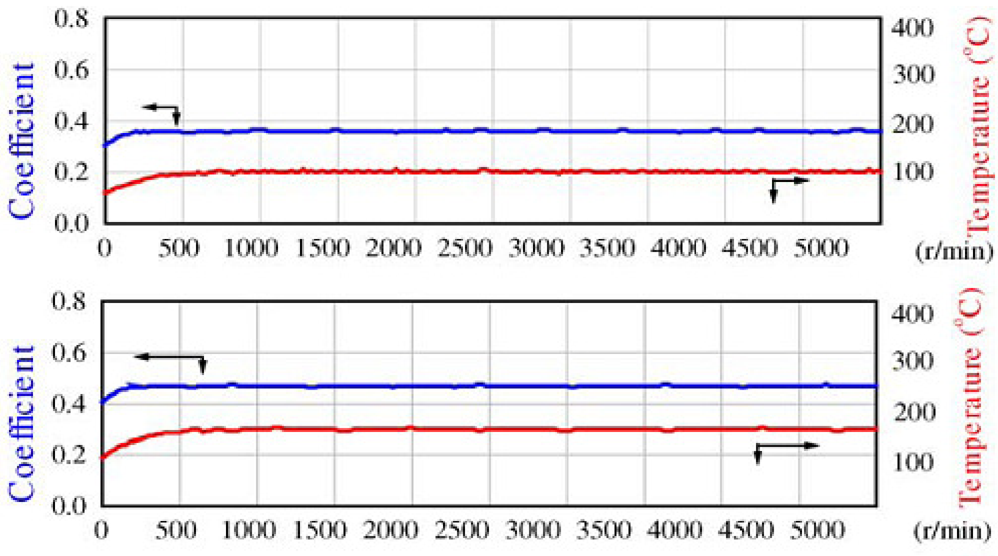
Fig. 2. Dynamometer test results of disc brake pads modified with nano powdered rubber, VP-402.

3.2 Testing results in drum brake linings

Styrene butadiene nano powdered rubber, VP-108, has been vastly applied in drum brake linings of trucks and buses. The physical properties, friction properties of modified brake linings as well as the adaptability for production, storage properties of nano powdered rubber were all objectively evaluated by the manufacturers of friction materials. The physical properties of brake linings modified with VP-108 are listed in Table 2. The nonasbestos formula consist of the following components: phenolic resin–16 wt.%, VP-108 rubber powder–5 wt.%, mineral fibers –31 wt.%, steelwool–15 wt.%, aluminum oxide–1 wt.%, iron powder –3 wt.%, friction modifiers and fillers –29 wt.%. Friction data are listed in Table 3. This friction test was carried out on a DSM-150 constant speed friction tester according to GB 5763/98 standard (size of friction surface of specimen, 25mm×25 mm; the friction disc will rotate for 5000 revolution at each testing temperature such as 100 ◦C and the average friction force during rotation was used for calculating friction coefficient). The friction coefficients at different temperatures were measured while heating and cooling the test samples. The wear data was also obtained after the whole test. Compared to the data range of standard, the friction coefficient and wear rate of drum brake lining modified with VP-108 are all within the required limits. This indicates that styrene butadiene UFPR, the nano powdered rubber with lower cost, can be applied in drum brake lining and ensure the products with good friction properties. The straight lines in each diagram represent the limits of the design criteria, and any test data that falls between these two lines are considered ideal. The numbers inside each diagram are the end point values of the design criteria. The solid symbols represent the control sample.

3.3 Testing results in clutch facings

Clutch facing is expected to have stable friction coefficient at different speed and different temperature. However, the friction coefficient of Clutch facing is usually unstable at higher speed, especially at higher temperature. When nitrile butadiene UFPR VP-401 was used in clutch facings' formula, stable friction coefficient could be achieved at different speed and different temperature. The results obtained from constant speed friction tester DMS-150 were shown in Fig. 3. The curves in Fig. 3 show that friction coefficient of clutch facing modified with VP- 401 varies steadily in the temperature range of 100–300 ◦C, especially the friction coefficient at high temperature is ideal. One may wonder why Narpow® with nano-scale particle size could perform differently from conventional rubber powder in friction material. As the adhesive material, phenolic resin is the matrix in all friction materials; therefore, the heat resistance and friction properties of the friction material substantially depend on the properties of phenolic. Narpow® with nano-scale particle size can be dispersed well in phenolic as mentioned above, therefore there are larger interface and more chemical reaction on the interface between rubber particle and phenolic. It has been found by the authors that phenolic modified with Narpow® has much higher impact strength and heat resistance than pure phenolic and phenolic with conventional rubber powder, which will be published in other papers of the authors.



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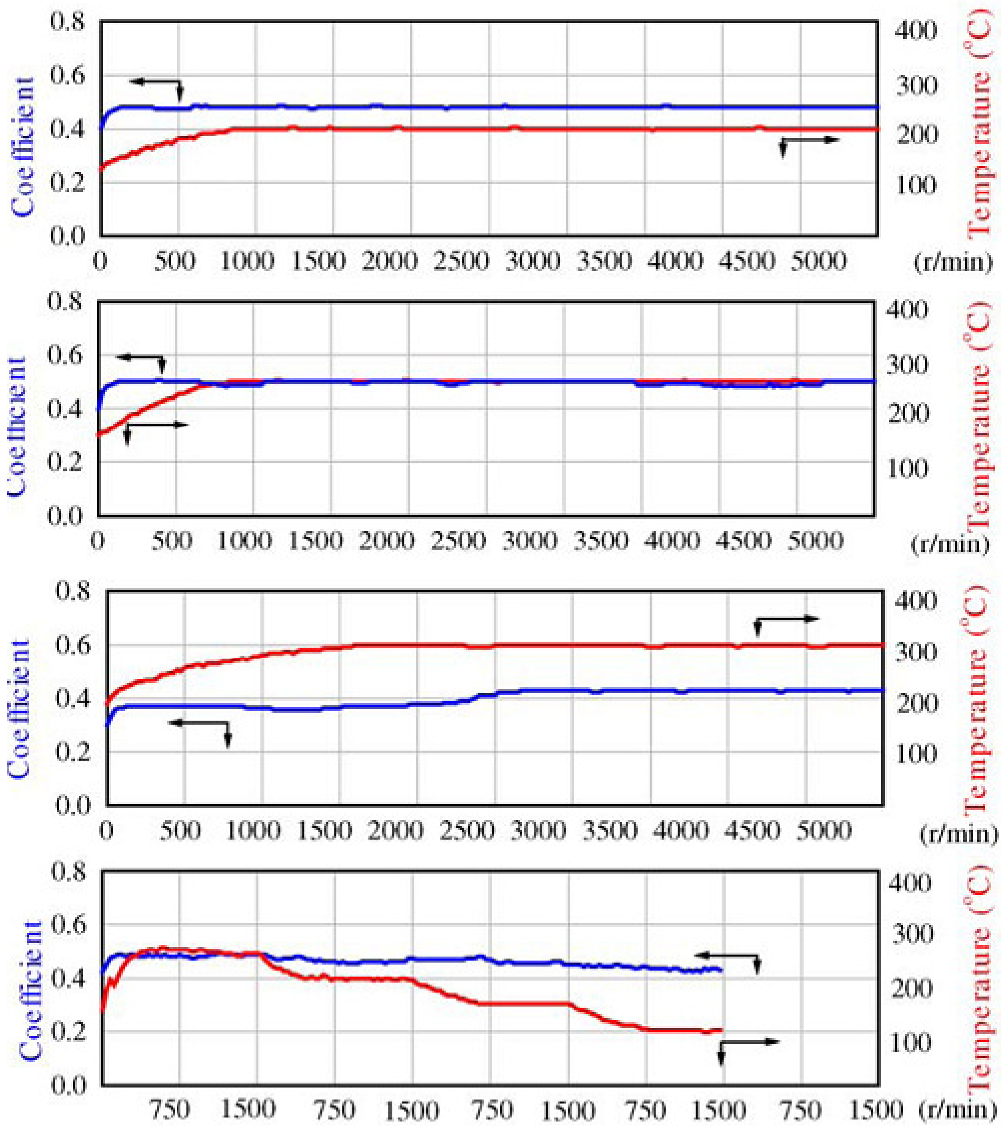

Figure 3. Friction test result of clutch facings modified with nano powdered rubber VP-401 according to GB 5764/98 standard.

IV. CONCLUSION

The results of constant speed friction test and dynamometer test showed that nano powdered rubber can substantially improve properties of friction materials. The friction coefficient of friction materials modified with nano powdered rubber varies steadily with the change of temperature, and the wearing rate of friction materials is relatively low by using nano powdered rubber. These results indicate that nano powdered rubber has ideal application effect in various friction materials and is a kind of novel and ideal rubber modifier for friction materials.

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