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Study on a New Formulation of Domestic Metro Synthetic Brake Shoe

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***Abstract*—**In this paper, taking Chinese Nanjing Metro ALSTOM vehicle synthesis brake as an example, the subway with synthetic brake shoe formula components of final product performance, has done a lot of research and performance test, final is drawn with hybrid fiber as reinforcing material, modified phenolic resin as matrix material, and then filling friction modifier performance, by the hot pressing process made a new type of domestic subway brake shoe. The product of the test performance indicators that can replace the similar foreign products.

***Keywords*—**Metro; synthetic brake shoe; component analysis; formula research

I. Introduction

IN recent years, China's development of metro project to blossom the huge investment development is swift and violent. Chinese manufacturing industry transformation and upgrading process requirement of metro train in the introduction of advanced technology at the same time some parts of progressively implementation is homebred change. At present, China most of domestic subway train using the high price of the imported Metro synthetic brake shoe, some units of the existing research has not been able to fully replace the brake shoe and replacement of the entire train with imports of brake shoe.

Subway brake shoe for formulation development is the basis of domestic and foreign railway system and relevant technical documents, as well as the city track transportation departments of the vehicle brake shoe of the physicochemical properties of the relevant provisions, in the import brake performance comprehensive test based on ALSTOM, taking Nanjing metro vehicle synthetic brake shoe for technology development of new synthetic target localization for Subway Brake shoe. According to the physical and chemical performance test and the brake shoe braking friction, abrasion performance test report, confirmed that the Nanjing subway ALSTOM vehicle synthetic brake shoe with rubber, hybrid fiber wet process for production of high friction composite brake shoe.

II. National Railway synthetic brake shoe circumstance brief introduction

In recent years, China has been used in the railway vehicle technology is relatively mature high friction composite brake shoe includes subway instead of common cast iron brake shoes, rubber brake (styrene-butadiene rubber, butadiene rubber), modified phenolic resin matrix semi metal subway synthetic brake shoe.

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They are mainly used at 120km / h below, secondary brake shoe pressure on a railroad train. China in the resin modified technology, heat-resistant reinforcing fiber, filler system research and synthetic brake shoe production technology has been a new breakthrough and improvement. These properties have made great progress, and gradually to replace imported products. But compared with foreign similar products, in the solution of" three hot" problem, such as friction performance stability, especially at high temperature and friction performance stability and wet condition stability of friction coefficient has some deficiency[4].

French TGV, PSE train on the synthetic materials used in brake shoe components are: adhesive for butyraldehyde (butadiene styrene (SBR)) elastic binder or formaldehyde phenolic resin, iron and iron oxide, silicon and silicon dioxide (abrasive), alumina, barium sulfate, zinc and zinc oxide, magnesium oxide and copper[1]. Japan synthetic brake shoe usually adopts non asbestos technology of heat-resistant aramid fiber instead of asbestos fiber, but also has the use of metal fibers[3]. Brake material in addition to the use of fiber, graphite, rubber and other materials are mixed, with phenolic resin molding.

From the French and Japanese synthetic brake shoe components, synthetic brake shoe is generally phenolic material resin or rubber, metal powder and lubricating materials are mixed and heated and pressed into the shoe, compared with cast iron brake shoes, brake shoe is characterized by: high speed high coefficient of friction (0.15 ~ 0.35), and not with the train speed change, and by changing the formula and process adjustment; good wear resistance, braking without sparks and the quality of small (only for cast iron brake shoe 1 / 2 ~ 1/ 3), long life and other characteristics.

A. Subway of new composite brake shoe for matrix resin modification research

Composite adhesive (matrix) is based on phenolic resin based friction material, which accounted for the binder dosage of more than 90%, in spite of phenolic resin with abundant raw materials, low prices, reliable, industrialized production process of high temperature performance advantages, but the phenolic resin hard, brittle, high temperature and low residue hinder it high performance composite materials application, so the research focus is on the phenolic resin modified[2]. Over a very large number of trials, developed GP-7 resin phenol, the resin phenol phenolic resin is to maintain the original advantages, and removal of phenolic resin hard brittle faults, the phenolic resin high temperature degradation residue friction and viscous flow characteristics are enhanced, thereby improving the comprehensive properties of friction materials. GP-7 resin phenol in bisphenol A, a boron containing compound, cashew

nut shell as the main raw material, a melamine as a modifier, using a special process in the reaction kettle disposable synthesis. GP-7 resin phenol structure type as shown in Figure 1, characteristic peak as shown in figure 2.

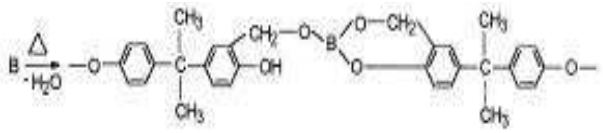

Fig. 1 Infrared spectrum display

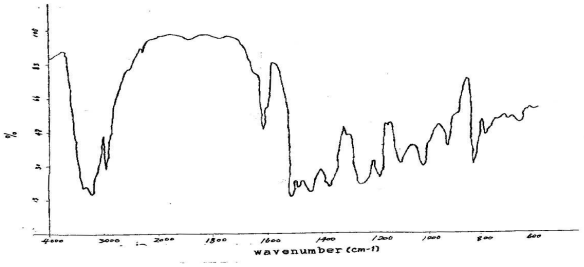

Fig. 2 Feature peak

Look from the exterior, GP-7 resin is a brown powder (180), the free phenol < 5%, softening point 90-105 C, gel time in 60-90 sec / 150 C, infrared spectral analysis are shown in table I.

As a result of cashew nut oil grafted polymer backbone, more supple, ensure the resin products and toughness and the abutted surface bonding strength, improves the impact resistance performance; at the same time, in GP-7 resin by infrared spectroscopy, can be seen at 1440 cm-1 and 1385cm-1 has two peaks, visible boron has entered into the structure of the resin, and the formation of the chelate structure (as shown in Figure 3), which makes boron element in addition to three normal valence bond, also formed another valence bond, so that the boron atoms with coordination number saturation, which makes boron oxygen bonds to water price stability is greatly improved. High temperature resin residue percentages are shown in table 2.

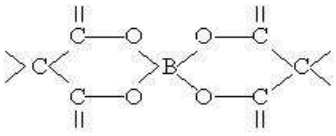

Fig. 3 Chelating structure

Melamine and boron ions into the resin heat temperature increased significantly (B - O bond can amount to 185000 cal / mol), and boron ions in braking because of high temperature in the joint surface formation of boron carbide transfer membrane, can not only ensure the braking safety, stable, and avoid the heat conduction into the internal matrix materials, which can effectively prevent the train braking of high temperature failure risk.

Resin decomposition temperature and residues on the friction properties of material at high temperature and surface features are crucial, decomposition temperature directly determines the material using a limit temperature, while the high temperature

TABLE I
INFRARED SPECTRUM ANALYSIS

—OH Association	3380cm-1
	3210 cm-1
Benzene—C=C—	1616 cm-1
	1510 cm-1
Outside C—O—B	1440 cm-1
C—O→B	1365 cm-1
	1385 cm-1
1, 2, 4, three substituted phenyl ring	1180 cm-1
	1110 cm-1
	830 cm-1

TABLE II
HIGH TEMPERATURE RESIN RESIDUE PERCENTAGE

Project Resin	400℃residual percentage (%)	600℃residual percentage (%)	800℃residual percentage (%)
GP-7 resin	77.2	49.9	37.8
2123 phenolic resin	70.5	41.8	28.7

residues is a reflection of the temperature has been decomposed by the amount of resin. Since the resin decomposition products containing extracts of tar and other viscous substance, thus affecting the friction surface self-cleaning, will wear mechanism from mainly abrasion into adhesive wear, the more easy to produce metal inlay. Unmodified resin decomposition temperature of 397.7 DEG C, decomposition rate of the temperature of 420 degrees C, 725 degrees C decomposition residues is only 3.02%. After modified GP-7 resin decomposition temperature of 420 degrees C, decomposition rate of the temperature of 465 degrees C, 800 degrees C decomposition residues reached 37.87%.

III. New Chinese Subway Synthetic Brake Shoe Formula Research

Bonded to the substrate will directly affect the friction material of the structure strength and modulus of elasticity. Material from the view of performance to price, choose the traditional heat resistance is better, to fill strong adhesive power, relatively cheap price of phenolic resin and rubber technology; selection of fiber has excellent mechanical properties including high toughness, high wear resistance, excellent thermal conductivity and heat resistance; filler as friction friction coefficient of friction modifiers and adhesion agent, strengthening agent, in its respective material plays a different role.

A. Phenolic resin and rubber composition

Figure 4, figure 5 is a rubber and phenolic resin toughening mechanics performance and the relationship between the content of each. As can be seen from the graph, the addition of rubber content, increase of impact strength, compression

strength. According to the technical requirements for the synthetic brake shoe, the stable and mature technology molding method, this research used in the plastic is improved, so the four resin and rubber were studied, table 3 different resin and rubber ratio of compressive strength and modulus of elasticity in compression.

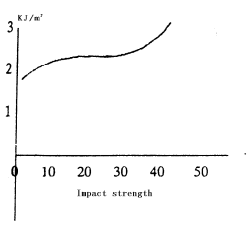

Fig. 4 Impact strength curves

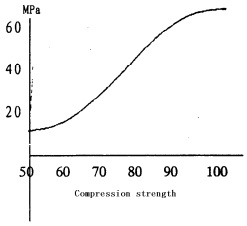

Fig. 5 Compression strength curve

From table 3 data can be seen, the measured performance all reached the technical requirements, but considering the actual use of the thermal damage degree, the project selected compression elastic modulus lower resin and rubber composition.

TABLE III
DIFFERENT RESIN AND RUBBER RATIO OF COMPRESSIVE STRENGTH AND MODULUS OF ELASTICITY IN COMPRESSION

The proportion of resin and rubber	Compression strength MPa	Elastic compression strength GPa
4: 1	46.7	2.2
3: 1	39.9	1.8
2: 1	33.6	1.1
1: 1	31.1	0.8

B. Phenolic resin choice

Determination of the phenolic resin and rubber proportion, the project according to the present domestic and foreign phenolic resin production levels, optimize the three domestic and overseas production plant phenolic resin mechanical properties and friction performance. Table 4 the physical and mechanical properties of test results. From the test results, the difference is not big, this is mainly because the formula is completely consistent, and tests are under a mild condition, the difference is not significant.

TABLE IV
PHENOLIC RESIN WITH DIFFERENT PHYSICAL AND MECHANICAL PROPERTIES

Manufacturer	Compression strength MPa	Elastic strength GPa	Impact strength KJ/m^2
A	33.0	1.2	2.9
B	31.0	1.0	3.2
C	31.0	1.1	3.1

Three types of resin for brake performance testing, test results show that the three braking distance is relatively close, the average friction coefficient are also in line with the standard requirements, but tends to limit, but from the data reproducibility, a data reproducibility is better, with a phenolic resin with good performance, comparative concentration curve.

C. Heat resistant reinforcing fibers

At present, can be used as a friction material used in fiber are mainly the following: asbestos fiber, high strength fiber and metal fiber, its main properties as listed in table 5.

TABLE V
SEVERAL MAIN PERFORMANCE

Fiber	Specific gravity	Tensile strength	Tensile modulus
Chrysotile asbestos	2.4 ~ 2.6	19750 ~ 30300	163
Blue asbestos	3.2 ~ 3.3	33000 ~ 42600	191
Glass fiber (E)	2.54	35000	73.5
Carbon fiber	1.75	22000 ~ 30000	220 ~ 270
Boron fiber	2.63	32200	420
Silicon carbide filaments	3.15	35000	490
Alumina filaments	3.9	~ 70000	700 ~ 2450
Organic fiber (K-49)	1.47	14000 ~ 28000	140
Alloy steel	8	26500	
A_3 steel	7.85	12800	
Aluminium alloy	2.8	4000	
Cast iron	7.4	4200	

From table 5 of the tensile strength and tensile modulus size can be seen, asbestos fibers (highly hydrated magnesium silicate) compared with other material performance comparison is excellent, it as a friction material heat-resistant reinforcing fibers, due to its low price and almost occupy the entire market, but international on asbestos use controversial, some countries have in some areas with its alternatives, so the study is not used; for high strength fiber, because its price is higher, and the stability of the product the reason such as difference, also failed to adopt; combined with the application of more successful experience, considering the cost, this project adopts metal fibre.

D. Filler system

The filler is the role of the friction coefficient in all cases remained stable, in particular to maintain temperature curve, coefficient of friction coefficient of friction velocity curve is smooth, can not simply rely on adhesive and reinforced fiber of two element, is usually joined by packing all kinds of solutions, comprehensive analysis of domestic and foreign material, according to the material stability and the hardness parameter, optimal selection of several raw materials. Such as the use of graphite as solid lubricant, lead where the soil and reduced iron powder as friction modifier performance, taking into account the synthetic brake shoe machinery performance and reduce the cost, also took part in other powder filler.

IV. Conclusion

China synthetic brake shoe is a hybrid fiber as reinforcing material, modified phenolic resin as matrix material, and then filling friction modifier performance, by the hot pressing process. The shoe components and weight percent content as follows: steel fiber 5 ~ 25%, 0.5 ~ 5% aryl acrylic pulp, modified phenolic resin 5 ~ 20%, 1 ~ 10% NBR powder, zinc oxide 1 ~ 10%, 0.1 ~ 1% of corundum, clay, 10 ~ 40%, 5 ~ 20%, the graphite, barite powder 20. 40%. The hole is a through hole, hole at the rate of 5 ~ 20%, 1 ~ 2 m diameter. Its feature is the

formulation of the brake shoe with high PV value, friction performance is very stable, low hardness, in use can well protect the wheel tread, does not produce metal inlay and thermal cracking, noise is low, the product of the physical and chemical properties of not less than similar imported products, is a performance excellent new shoe.

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