Application of instant fluid black gold rubber in tires

Han Hongwei[1], Yu Jiangsheng[1], Zhou Hong[2], Liu Zhiyong[2]

(1. Tianjin Wanda Tire Group Co. LTD., Tianjin 300402, China;
2. Jiangsu Zhonghong Environment Technology Co. LTD., Jiangyin 214437, Jiangsu, China)

Abstract: This study explores the application of instant fluid black gold rubber in tire compounds. As a novel modified eco-friendly material, it reduces waste emissions, conserves raw materials, blends well with traditional rubbers (natural rubber, cis-polybutadiene rubber, styrene-butadiene rubber), and enables vulcanization crosslinking. Technologically, it enhances material dispersion, reduces compound Mooney viscosity, and effectively lowers tire manufacturing costs. Performance-wise, compared to processing oil in formulas, it significantly improves rubber tensile properties, boosting wear resistance, reducing heat build-up, and enhancing wet traction.

Key words: tensile properties; wear resistance; environmentally friendly modification; cost

Classification number: TQ330.7 **Article number:** 1009-797X(2026)03-0039-05

Document code: B **DOI:**10.13520/j.cnki.rpte.2026.03.009

With the rapid development of the automotive industry, tires, as one of the important components of automobiles, face higher requirements for performance and cost. The demand for raw materials is also increasing. The innovation of functional new materials is crucial for improving tire performance, and the application of environmentally friendly modified new materials in tires is also urgent. Reducing carbon emissions and conserving raw material usage are essential to meet the sustainable development of tire manufacturing.

The use of bio-based materials and recycled materials can reduce the demand for petroleum-based materials, lower carbon emissions, and effectively reduce tire manufacturing costs. Instant fluid black gold rubber is an environmentally friendly modified new material made from waste tires after a series of physical and chemical modification treatments. It contains rubber hydrocarbon components, functions as a softener, and can undergo crosslinking reactions with rubber. Compared to operating oil, it does not precipitate out of the formula and has a positive effect on environmental protection. This work studies the application of instant fluid black gold rubber in tires at different proportions as a substitute for traditional operating oil.

1 Experiment

1.1 Main raw materials

Natural rubber, STR20, Thai product; nickel-based butadiene rubber, grade BR9000, Sinopec Daqing Petrochemical Company Limited; emulsion styrene-butadiene rubber, brand SBR1723, produced by Rubber Factory of Sinopec Qilu Petrochemical Company; carbon black, brand N234, produced by Jiangxi Black Cat Carbon Black Co., Ltd.; environmentally friendly aromatic oil, brand V500, produced by Ningbo Hansheng Chemical Co., Ltd.; instant fluid black gold rubber, produced by Shanxi Honghui New Material Technology Co., Ltd.

1.2 Test formula

The test tread formula is shown in table 1, where instant fluid black gold rubber is used to replace 0%, 30%, 50%, and 80% of the amount of environmentally friendly aromatic oil in the formula, respectively.

Biography: Han Hongwei (1984-), male, holds a bachelor's degree and is primarily engaged in research and application of raw materials for tires, design and development of formulations, and management of formulation processes.

Table 1 Test formula (in parts)

Component	Formula number			
	1#	2#	3#	4#
STR20	55	55	55	55
BR9000	15	15	15	15
SBR1502	30	30	30	30
N234	60	60	60	60
V500	12	8.4	6	2.4
Instant fluid black Gold rubber	0	3.6	6	9.6
Others	17.4	17.4	17.4	17.4

1.3 Main equipment and instruments

XM270 (4~40) internal mixer, a product of Dalian Rubber and Plastics Machinery Co., Ltd.; MFR100 automatic rotorless rheometer, Shanghai Nuojia Instrumentation Co., Ltd.; MVS3L Mooney viscometer, Shanghai Nuojia Instrumentation Co., Ltd.; GT-AI-7000S electronic universal testing machine, Gaotie Testing Instrument Co., Ltd.; GT-7012-D DIN abrasion tester, Gaotie Testing Instrument Co., Ltd.; GT-7012-Q rubber dynamic cutting tester, Gaotie Testing Instrument Co., Ltd.; RPA2025 rubber processing analyzer, a product of Shanghai Zimeng Intelligent Robot Co., Ltd.; VR-7130 dynamic mechanical analysis (DMA) instrument, a product of UESHIMA, Japan.

1.4 Sample preparation

The rubber compound is processed using a 3-stage mixing process, all conducted in an XM270 internal mixer.

The first-stage mixing process is as follows: add various raw rubbers, other masterbatch additives, and carbon black → press the rammer for 30 seconds at a speed of 55r/min → raise the rammer in place, clean, and maintain a temperature of 115℃ → add oil → press the rammer for 25 seconds → raise the rammer in place, clean → press the rammer until the temperature reaches 160℃ to discharge the rubber;

The second-stage mixing process is as follows: add a portion of masterbatch → press the rammer for 40 seconds at a speed of 45 r/min → lift the rammer in place and clean → press the rammer for 30 seconds at a speed of 30 r/min → lift the rammer in place and clean → press the rammer until the temperature reaches 160℃ to discharge the rubber.

The three-stage mixing process is as follows: add the second-stage masterbatch and final rubber compound small materials → press the rammer for 40 seconds at a speed of 25 r/min → lift the rammer in place and clean → press the rammer until the temperature reaches 100℃ to discharge the rubber.

1.5 Performance analysis

(1) Processing performance. The loss factor tanδ of the rubber compound was tested using RPA under the following conditions: temperature of 100℃, frequency of 0.1 Hz, and strain sweep ranging from 0.7% to 1256%.

(2) Dynamic mechanical properties. Testing was conducted using a DMA instrument under the following conditions: frequency of 10 Hz, dynamic strain of 0.25%, and temperature scanning from −60~ 80 ℃.

(3) Dynamic cutting performance: Test the cutting quality loss rate using a rubber dynamic cutting tester.

(4) Environmental performance: Testing H-bay protons using a nuclear magnetic resonance (NMR) instrument.

(5) Low-temperature performance: Test the Shore A hardness after different parking durations using a low-temperature chamber.

(6) Other performance indicators are tested in accordance with corresponding national standards or enterprise standards.

2 Results and Discussion

2.1 Vulcanization characteristics

The vulcanization characteristics of the rubber compound are shown in table 2.

Table 2 Vulcanization characteristics of rubber compound

Project	Formula Number			
	1#	2#	3#	4#
Mooney viscosity [M_L(1+4) at 100℃]	61	61	61	62
Mooney scorch time t_5 (125℃)/min	34.13	34	33.9	33.78
Cure meter data (160℃)				
M_L/(dN·m)	1.98	1.97	1.99	2.1
M_H/(dN·m)	13.54	13.61	13.8	14.22
T_{C10}/min	2.86	2.78	2.7	2.61
T_{C30}/min	4.04	4	3.95	3.85
T_{C90}/min	8.04	8.02	7.96	7.90
T_{R97}/min	-	-	-	-

As can be seen from table 2, after substituting instant black gold rubber for different proportions of environmentally friendly aromatic oil, there is almost no effect on Mooney viscosity and scorch time, and the vulcanization rate remains at the same level. As the substitution ratio increases, the rheometer's maximum torque (MH) increases, which is related to the rubber hydrocarbon component contained in the instant fluid black gold rubber material. During the vulcanization process, it can blend with rubber and undergo a crosslinking reaction, forming a network-like spatial structure.

2.2 Physical properties

The physical properties of the rubber compound are shown in table 3.

Table 3 Physical properties of rubber compound

Project	Formula Number			
	1#	2#	3#	4#
Density / (g·cm⁻³)	1.141	1.141	1.142	1.142
Shore A hardness/degree	65	65	65	66
300% modulus/MPa	10.8	11.1	11.5	12.1
Tensile strength/Mpa	18.5	18.9	19.3	19.2
Elongation at break, %	480	480	475	460
Tear strength / kN.m^{-1}	66	70	75	76
DIN abrasion index /%	105	109	115	120
Akron abrasion index /%	110	118	120	124
After aging at 100℃ for 24 hours				
Shore A hardness/degree	70	71	70	72
300% modulus/MPa	13.5	13.8	13.6	14.5
Tensile strength / Mpa	14.1	14.8	15.1	15.1
Elongation at break, %	390	380	380	365

From table 3, it can be seen that the addition of instant fluid black gold rubber maintains the hardness and enhances the tensile strength and modulus of the rubber compound. As the dosage increases, the elongation at break tends to decrease. In practical applications, appropriate substitution ratios can be formulated according to performance requirements. It can effectively improve the wear resistance of the tread and enhance the tear resistance. The tensile properties remain good after aging.

The data indicates that in this collaborative experiment, using instant fluid black gold rubber to replace the existing operating oil in the formula at different proportions, with a replacement ratio of 30%~50% being optimal.

2.3 Dynamic performance

The dynamic properties of the rubber compound are shown in table 4:

Table 4 Tg and tanδ of rubber compound

Project	Formula Number			
	1#	2#	3#	4#
T_g/℃	−44.7	−44.3	−44.1	−43.8
tanδ(0℃)	0.209	0.215	0.221	0.224
tanδ(60℃)	0.158	0.155	0.149	0.147

The tanδ−temperature relationship curve of vulcanized rubber is shown in figure 1.

From table 4 and figure 1, it can be observed that after adding the environmentally friendly aromatic oil used in the instant fluid black gold rubber replacement formula to the formulation, the glass transition temperature remains essentially unchanged, the tanδ at 0℃ increases, and the tanδ at 60℃ slightly decreases, which is beneficial for reducing the hysteresis loss of the rubber. DMA data indicates that the substitution of instant fluid black gold rubber for operating oil in the formulation does not significantly affect the glass transition temperature and positively contributes to improving the wet grip performance and reducing heat build-up of the rubber compound.

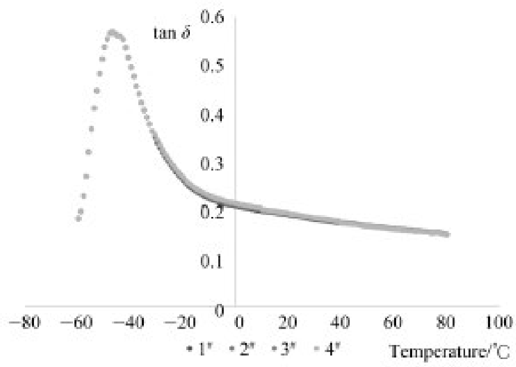

Figure 1 tanδ-temperature relationship curve of vulcanized rubber

2.4 Low temperature performance

The hardness increase of vulcanized rubber at low temperatures is shown in table 5.

Table 5 Shore A hardness of vulcanizate during low-temperature storage

Temperature	Formula Number			
	1#	2#	3#	4#
25	65	65	65	66
0	68	68	68	69
−10	71	71	71	72
−20	73	73	73	73
−30	75	76	76	76

Place the vulcanizate test pieces at constant temperatures of 25℃, 0℃, −10℃, −20℃, and −30℃, respectively, and measure the hardness after the same duration of storage to study the changes in hardness under various temperature conditions after substitution at different proportions. As can be seen from table 5, after substituting the environmentally friendly aromatic oil in the instant fluid black gold rubber formula, the Shore A hardness of the vulcanizate increases almost uniformly at low temperatures, without affecting the low-temperature performance of the rubber compound. This is related to the chemical modification treatment of this material.

2.5 Dynamic cutting resistance

The dynamic cutting mass loss rate of vulcanized rubber is presented in table 6.

Table 6 Dynamic cutting mass loss rate of vulcanized rubber

Project	Formula number			
	1#	2#	3#	4#
Cutting quality loss rate /%	0.45	0.42	0.39	0.35

It can be seen from table 6 that as the addition and dosage of instant fluid black gold rubber increase, the properties of the vulcanized rubber

The dynamic cutting quality loss rate is reduced, which can improve the cutting resistance of the rubber compound and positively contribute to enhancing the cutting resistance of tread rubber used on unpaved roads.

2.6 Processing performance

The loss factor tanδ-strain curve of unvulcanized rubber is shown in figure 2.

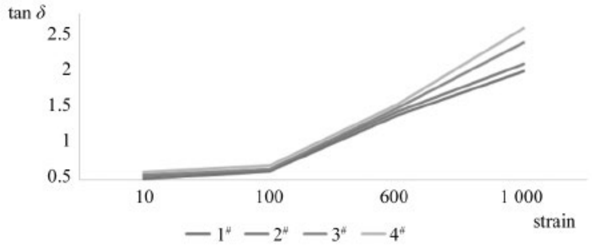

Figure 2 Tanδ-strain relationship curve of unvulcanized rubber

As can be seen from Figure 2, the data measured using RPA indicate that as the proportion of instant fluid black gold rubber increases, tanδ increases, which has a positive effect on reducing the expansion rate of the tread extrusion die. This should be attributed to the increased mixing shear force due to the use of instant fluid black gold rubber, thereby improving the dispersion of the rubber compound and resulting in better uniformity of the mixed rubber.

2.7 Environmental performance

The environmental indicators for the vulcanized rubber, namely SVHC and H-bay content, are presented in tables 7 and 8.

Table 7 H-bay test of instant fluid rubber

Testing items	EU regulations	actual
H-bay/%	⩽ 0.35	0.33

Table 8 SVHC and H-bay of vulcanized rubber

project	Formula Number			
	1#	2#	3#	4#
SVHC/%	Comply with regulations	Comply with regulations	Comply with regulations	Comply with regulations
H-bay/%	0.21	0.21	0.20	0.20

from tables 7 and 8, it can be seen that instant fluid black gold rubber, as a kind of environmentally friendly modified new material, meets the EU regulatory standards for various environmental indicators; after replacing different proportions of environmentally friendly aromatic oil, both SVHC and Hbay meet environmental requirements. As the proportion of instant fluid black gold rubber increases, there is basically no change in environmental indicators. In formulations with high usage of traditional aromatic operating oil, the use of this material as a substitute for operating oil will result in more pronounced environmental performance advantages, which are related to the raw materials used in the preparation of instant fluid black gold rubber and the environmentally friendly processing technology.

2.8 Appearance impact

Appearance is one of the indicators of customer satisfaction with tire quality, especially the discoloration of the tread and sidewall, which has always been a problem plaguing tire appearance. The operating oil, carbon black, and other components in the formula are all related to appearance discoloration, with operating oil having a significant impact. To verify the effect of instant fluid black gold rubber on improving appearance, rubber compounds with formula numbers 1# and 4# were used to confirm the appearance of vulcanized rubber sheets: the appearance of the vulcanized test sheets was observed after being stored for 7 days.

Figure 3 Appearance of vulcanized test piece of rubber compound No. 1#

The appearance of the vulcanized test piece using formula number $1^{\#}$ rubber compound is shown in figure 3, and the appearance of the vulcanized test piece using formula number $4^{\#}$ rubber compound is shown in figure 4.

Figure 4 Appearance of vulcanized test piece of rubber compound No. 4

From the appearance comparison between figure 3 and figure 4, figure 3 appears reddish and dull in color, while figure 4 appears blackish and glossy in color. The use of instant fluid black gold rubber has a positive impact on improving the appearance discoloration of tires. Theoretically, as the amount of alternative operating oil increases, the appearance improvement effect will be better. This is related to the reduction of operating oil in the formula, which reduces the precipitation of small molecular substances in the rubber compound. In addition, some components of the instant fluid black gold rubber participate in chemical reactions during the vulcanization process, which also reduces the precipitation of small molecular substances. The above two points play a positive role in improving the appearance discoloration problem.

3 Conclusion

The substitution of instant fluid black gold rubber for traditional operating oil in tread formulations can improve the physical properties of the rubber compound, positively impacting both processing performance and dynamic mechanical properties. It can enhance wear resistance and wet grip performance, while reducing rolling resistance. From the perspective of verifying the effect on appearance improvement, using this material as a substitute for traditional operating oil can be considered as a measure to address appearance discoloration issues.

Instant fluid black gold rubber replaces operating oil. Due to its rubber hydrocarbon component participating in chemical reactions, it solves the drawbacks of operating oil precipitation, thereby reducing environmental pollution. It is an environmentally friendly raw material, aligning with the currently advocated green environmental protection concept.

Instant fluid black gold rubber is produced using waste tires as the primary raw material, reusing discarded tires. Compared to traditional operating oils, it offers cost advantages and possesses environmental protection properties, which can enhance socio-economic benefits and promote the sustainability of economic development.