

# Application of environmentally friendly longlasting antioxidant 3100G in rubber shock absorber products

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**Abstract:** This work focuses on optimizing the rubber compound used in shock-absorbing products by adjusting the main rubber material and vulcanization system. By incorporating an appropriate amount of the environmentally friendly and long-lasting anti-aging agent 3100G, which exhibits excellent performance, the compound's properties, as well as the product's aging and fatigue resistance, are enhanced. This approach further elevates the product's quality and extends its fatigue life.

**Key words:** main material; auxiliary vulcanization system; product stiffness change rate; product fatigue deformation

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## 1 Experiment

### 1.1 Main raw materials

Natural rubber (NR), RSS3, Thailand product; butadiene rubber (BR), grade 9000, product of Beijing Yanshan Petrochemical Rubber and Plastics Chemical Co., Ltd.; butadiene-isoprene rubber TFBI68, rare earth butadiene rubber NdBR910, Zhejiang Chuanhua Synthetic Materials Co., Ltd.; carbon black N550, N774, N234, product of Shanghai Cabot Chemical Co., Ltd.; homogenizer 50P, anti-fatigue agent Zincolet – 40P, provided by Shanghai Shenmao Rubber and Plastics Technology Co., Ltd.; anti-sulfurization reducing agent TDB680, 3100G environmentally friendly long-acting rubber antioxidant, product of Anhui Fuyang Lipu Chemical Co., Ltd.; Rhine microcrystalline wax 500, provided by Qingdao Tangle Chemical Co., Ltd. The remaining raw materials are commercially available products in the rubber industry.

### 1.2 Main instruments

XK-450 open mill, a product of Guangdong Zhanjiang Machinery Factory; GT-7104 electric heating flat vulcanizing press and AI-7000S electronic tensile machine, products of Taiwan, China High-Speed Rail Testing Instrument Co., Ltd.; UR-2010SD rubber vulcanization tester and UA-2079 high

and low temperature test chamber, products of Taiwan Youken Technology Co., Ltd.; vulcanized rubber creep tester, product of Jiangsu Mingzhu Testing Machinery Co., Ltd.; MTS322.31 fatigue testing machine, product of MTS Industrial Systems, Inc.

### 1.3 Performance testing standards

The tensile property test of rubber compound is conducted according to the standard GB/T528-2009 "Determination of Tensile Stress-Strain of Vulcanized Rubber or Thermoplastic Rubber"; the tear property test of rubber compound is conducted according to the standard GB/T529-2008 "Determination of Tear Strength of Vulcanized Rubber or Thermoplastic Rubber (Trouser, Right-Angle, and Crescent Test Pieces)"; the aging property test of rubber compound is conducted according to the standard GB/T3512-2014 "Accelerated Aging and Heat Resistance Tests of Vulcanized Rubber or Thermoplastic Rubber in Hot Air"; the compression set property test of rubber compound is conducted according

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to the standard GB/T7759.1-2015 "Degree of Compression Set of Vulcanized Rubber or Thermoplastic Rubber - Part 1: Under Normal and Elevated Temperature Conditions"; the creep test of compound is conducted according to the standard GB/T19242 "Determination of Creep of Vulcanized Rubber in Compression or Shear"; the ozone aging resistance property is tested according to the test method GB/T7762; and the dynamic fatigue test of product is conducted according to the product fatigue standard test.

### 1.4 Original rubber compound formula

Rubber, 100; sulfur and accelerator, 3.5; activator, 7; antioxidant, 4.5; carbon black and reinforcing agent, 70; coumarone, 3; flow aid, 2.5; plasticizer, 5; others, 5; total: 200.5.

## 2 Results and discussion

The forms of fatigue failure in shock-absorbing rubber products are generally fatigue aging deformation and cracking. Cracking is generally caused by ozone aging. Adding a certain amount of protective wax and rubber antioxidant can improve the cracking phenomenon that occurs during product use. Fatigue deformation of the product is a direct factor leading to a reduction in the service life of rubber shock-absorbing products. To improve fatigue deformation of the product, it is necessary to improve the rubber compound formula of the product, enhance the fatigue aging resistance of the rubber compound, and reduce the fatigue aging deformation performance of the product. By optimizing the main material of the product compound and adding vulcanization aids, and selecting to increase environmentally friendly long-acting antioxidants, the fatigue and aging resistance of the compound can be improved, reducing the occurrence of cracking and fatigue deformation of the product, and enhancing the fatigue performance of the product.

### 2.1 Optimization of the main material of rubber compound

The main material of shock-absorbing products is rubber, typically natural rubber or cis-polybutadiene rubber. To enhance the fatigue performance of the product, high Mooney number rare earth cis-polybutadiene rubber NdBR9106 is used instead of ordinary BR9000 to improve the elasticity of the rubber compound. To balance the tear resistance and fatigue

performance, butadiene-isoprene rubber is appropriately added. The test results of rubber compound and product performance before and after optimizing the main material of the shock-absorbing product rubber compound are shown in Table 1.

As can be seen from Table 1, after optimizing the main materials of the formulated rubber compound, the physical properties of the rubber compound and the product performance are generally good.

### 2.2 Optimization of vulcanization system

The original rubber compound vulcanization system used CZ and DM vulcanization systems, resulting in general fatigue performance of the rubber compound. Since the rubber compound was mainly composed of natural rubber, in order to reduce the vulcanization reduction performance of natural rubber compounds and improve product service life, an appropriate amount of anti-vulcanization reducing agent TDB680 and dispersant 50p were added as auxiliary vulcanization systems for the rubber compound, thereby enhancing the vulcanization degree of the rubber compound and improving the performance of shock-absorbing products. After optimizing the rubber compound vulcanization system, the test results of the rubber compound and product performance are shown in Table 2 below.

As can be seen from Table 2, after optimizing the vulcanization system using the formulated rubber compound, the physical properties have been improved, and the fatigue performance of the product has been enhanced.

### 2.3 Optimizing the protective system of rubber compound for shock-absorbing products

3100G environmentally friendly long-acting rubber antioxidant is compounded from amines with different antioxidant activities and high molecular weight phenolic antioxidants. It is non-toxic and serves as an environmentally friendly long-acting antioxidant in natural rubber and synthetic rubbers such as chloroprene, nitrile, styrene-butadiene, and butadiene. It exhibits excellent long-term protective properties against heat, oxygen, ozone, climate, and flexing.

Compared to traditional antioxidants, antioxidant 3100G has the following advantages:

- (1) The anti-aging effect is similar to that of 4020,

**Table 1 Test results of rubber compound and product performance before and after optimizing the main material**

Project	Technical standard	Original rubber compound main material	Optimized rubber compound main material
Rubber compound vulcanization performance (145 °C×15 min)			
$M_L/dN\cdot m$		0.12	0.13
$M_H/dN\cdot m$		1.07	1.23
$T_{10}/min$		5:20	5:24
$T_{90}/min$		10:12	10:34
Rubber compound performance (145 °C×12 min)			
Hardness	65±5	22.7	21.8
Tensile strength / MPa	≥15.0	386	399
Elongation at break, %	≥350	56	68
Unnotched right-angle tear strength (kN·m <sup>-1</sup> )			
Compression set			
35 °C×24 h(25%)	≤10	10.8	8.9
70 °C×24 h(25%)	≤20	18.9	16.3
110 °C×3 h(25%)	≤25	20.3	16.8
Tensile strength change rate/%			
70 °C×96 h	≥-15	-2.9	-2.9
110 °C×3 h	≥-10	-5.1	-6.0
Product performance			
Product (vulcanized at 145 °C for 50 minutes)			
Stiffness change rate of the product at high temperature (50°C)	≤10 %	8.90%	8.80%
Stiffness change rate of the product at low temperature (-40°C)	≤20 %	20%	13.80%
Product fatigue performance			
The surface of the product appears in the longitudinal fatigue test			
Number of cracks (W times)	≥100W	89.6W	100W
Rate of stiffness change after product fatigue, as a percentage	≤20 %	18.80%	13.80%
Product deformation after fatigue/mm	≤4	3.8	2.6

**Table 2 Test results of rubber compound and product performance after optimizing the vulcanization system of rubber compound**

Project	Technical standard	Original rubber compound main material	Optimized rubber compound and product performance
Rubber compound vulcanization performance (145 °C×15 min)			
ML/dN·m		0.13	0.16
MH/dN·m		1.07	1.23
T10/min		5:24	5:56
T90/min		10:34	10:04
Rubber compound performance (145 °C×12 min)			
Creep increment (70 °C for 24 hours)			
Shore A hardness	65±5	65.00	66.00
Tensile strength/MPa	≥15.0	21.80	23.80
Elongation at break, %	≥350	399.00	412.00
Unnotched right-angle tear strength (kN·m <sup>-1</sup> )			
Compression set			
35 °C×24 h(25%)	≤10	8.90	6.80
70 °C×24 h(25%)	≤20	16.30	14.60
110 °C×3 h(25%)	≤25	16.80	10.80
Change rate of tensile strength, %			
70 °C×96 h	≥-15	-2.90	-2.90
110 °C×3 h	≥-10	-6.00	-2.90
Product performance			
Product (vulcanized at 145 °C for 50 minutes)			
Stiffness change rate of the product at high temperature (50°C)	≤10 %	8.80%	6.70%
Stiffness change rate of the product at low temperature (-40°C)	≤20 %	16.80%	10.50%
Product fatigue performance			
The surface of the product appears after longitudinal fatigue testing			
Number of cracks (W times)	≥100	100	106
Rate of stiffness change after product fatigue, as a percentage	≤20 %	13.80%	9.80%
Product deformation after fatigue / mm	≤4	2.6	2.0

with good protective properties against heat, oxygen, ozone, climate, and flexing. It has high solubility in rubber compound, is easily dispersible, and will not bloom even when used in amounts up to 5 parts of rubber compound. It is particularly suitable for rubber products with high anti-aging performance requirements and large amounts of anti-aging agents.

(2) It is not easily extracted by water, has high thermal stability, long-lasting effectiveness, does not change color, does not pollute, and is non-toxic. It belongs to the category of environmentally friendly long-lasting rubber antioxidants.

(3) With low volatility, resistance to migration, and resistance to extraction, it effectively prevents thermal oxidative degradation of rubber during long-term aging.

(4) Especially effective for products such as tire treads and sidewalls that are resistant to hot water, detergent extraction, and high temperatures and heat, preventing sidewall discoloration and long-term thermal-oxidative aging cracking.

To enhance the aging and fatigue resistance of the product

rubber compound, reduce heat generation and deformation during use, stabilize the product's rigidity, and prolong the service life of the rubber elastic shock absorber, we chose to add an appropriate amount of rubber antioxidant 3100G for testing. The test results of the product rubber compound are presented in Table 3 below.

From Table 3 above, it can be seen that by adding an appropriate amount of environmentally friendly long-acting antioxidant 3100G to the product rubber compound, both the product rubber compound and the product performance have been improved significantly.

### 2.4 Optimization of product rubber compound formula

The rubber compound formula is as follows: rubber, 100; sulfur and accelerator, 3.50; TDB680, 50P 1.50; activator, 8; antioxidant, 6.0; carbon black and reinforcing agent, 70.0; anti-fatigue agent 40P, 2.0; Rhine protective wax 500, 1.5; others, 10; total: 202.5.

**Table 3 Test results of rubber compound and product performance after adding 3100G environmentally friendly long-acting rubber antioxidant**

Project	Before optimization	Optimized
Rubber compound vulcanization performance (145 °C×15 min)		
$M_c/dN\cdot m$	0.15	0.1
$M_{10}/dN\cdot m$	1.23	0.96
$T_{10}/min$	5:56	6:04
$T_{90}/min$	11:12	12:14
Rubber compound performance (145 °C×12 min)		
Creep increment (70 °C for 24 hours)	0.0203	0.0186
Shore A hardness	66.00	65.00
Tensile strength/MPa	23.80	24.20
Elongation at break, %	412.00	431.00
Uncut right-angle tear strength (kN/m)	72.00	78.00
Rubber compound aging performance		
70 °C×24 h		
Shore A hardness change	+1	0.00
Change rate of tensile strength, %	-1.70%	-1.80%
Rate of change of elongation at break, %	-5.10%	-3.5%
70 °C×96 h		
Shore A hardness change	+6	+3
Change rate of tensile strength, %	-6.30%	-3.70%
Rate of change of elongation at break, %	-17.60%	-12.3%
110 °C×24 h		
Shore A hardness change	+6	+3
Change rate of tensile strength, %	-16.80%	-11.40%
Rate of change of breaking elongation, %	-36.70%	-32.0%
Ozone aging		
(40°C, 168h, ozone concentration $50\times 10^{-8}$ volume fraction, relative humidity $\leq 65\%$ , pre-elongation 20%)	cracked	crack-free
UV aging (UV exposure for 336 hours) Change in rubber compound hardness	+6	+3
Tensile strength change rate %	-12.40%	-8.10%
Change rate of elongation at break (%)	-19.50%	-10.40%
Product performance test (142 °C for 55 minutes)		
Product aging (70 °C for 336 hours)		
Product stiffness change rate %	10.90%	4.70%

**Table continued**

Product aging under high and low temperatures		
Stiffness change rate of the product at -40 °C (%)	19.80%	9.80%
Stiffness change rate of the product at +50 °C (%)	10.80%	5.90%
Ozone aging performance		
The surface of the product appears in the longitudinal fatigue test		
(40 °C, 336 h, ozone concentration of $50 \times 10^{-8}$ volume fraction, relative humidity $\leq 65\%$ ) Product stiffness change rate (%)	9.40%	3.80%
Ultraviolet aging (UV exposure for 336 hours) Product stiffness change rate (%)	9.80%	4.90%
Product fatigue performance		
Product fatigue 300 W		
Stiffness change rate (%)	9.80%	6.70%
Product deformation (mm)	2.60	1.25

## 2.5 Optimization of product rubber compound mixing and product vulcanization process

To ensure the performance of the rubber compound and the product, it should be supported by a better production process. To fully reflect the improved performance of the rubber compound and the product after the above optimization measures, improvements have been made to the rubber compound mixing and vulcanization processes. The adoption of a multi-stage mixing process has enhanced the dispersibility and stability of the rubber compound; the use of a low-temperature long-duration vulcanization process has improved the bonding performance and pass rate of the product, while

also enhancing its fatigue resistance.

## 3 Conclusion

This work aims to enhance the aging and fatigue resistance of the rubber compound used in shock-absorbing products, as well as the overall aging and fatigue performance of the products, by optimizing the main materials and vulcanization system of the rubber compound, selecting an environmentally friendly and long-lasting anti-aging agent 3100G with excellent performance, and improving the production process of shock-absorbing rubber products, thereby further extending the product's service life.

