TITLE OF THE INVENTION

USE OF SURFACE-TREATED CARBON BLACKS IN AN ELASTOMER TO REDUCE COMPOUND HYSTERESIS AND TIRE ROLLING RESISTANCE AND IMPROVE WET TRACTION

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CROSS-REFERENCE TO RELATED APPLICATIONS

Priority of US Provisional Patent Application Serial No. 61/237,593, filed 27 August 2009, incorporated herein by reference, is hereby claimed.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not applicable

REFERENCE TO A "MICROFICHE APPENDIX"

Not applicable

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a compound composition utilizing surface-treated carbon blacks. More particularly, the present invention relates to surface-treated carbon blacks used in conjunction with a functionalized elastomer,

where the elastomer is functionalized along the polymer chain, giving a higher probability of increased carbon-black-elastomer interaction, providing substantial reductions in rubber vulcanizate hysteresis and is useful for the manufacture of rubber articles, including tires.

2. General Background of the Invention

The reduction of rolling resistance in tire tread compounds is important in raising the fuel economy of vehicles and reducing carbon dioxide emissions. One method of reducing the rolling resistance of tire tread compounds, normally composed of styrene butadiene copolymers and butadiene or natural rubber polymer blends and carbon black, is to alter the filler characteristics such that the filler-filler interaction is reduced and the filler-elastomer interaction is increased. This works because the highest source of heat generation in carbon-black-filled elastomeric compounds typically arises from the carbon black as a result of its propensity to form through-going networks via high filler-filler interaction. Reducing this filler-filler interaction and increasing the filler-elastomer interaction can substantially reduce the degree of filler networking and compound hysteresis, and thus the rolling resistance of the tire tread compound and ultimately the tire itself. Typically, reduced filler-filler interaction or networking is measured by a decrease in the low strain dynamic modulus, which results in a smaller change in the difference between the low strain and high strain dynamic elastic modulus. This phenomenon is called the Payne Effect.

This Payne Effect is demonstrated in **Figure 1** for normal carbon black containing elastomeric compounds, where the compounds with the smaller change (flatter curve) in dynamic modulus as a function of strain, also demonstrate lower tangent delta as a function of strain, where tangent delta is the ratio of the dynamic loss modulus to the dynamic elastic modulus, and is a typical parameter used in dynamic testing as an indicator of heat buildup of elastomeric compounds, with lower tangent delta values representing compounds with lower heat buildup properties.

Methods that can be used to reduce filler-filler and increase filler-elastomer interaction in elastomeric compound compositions include:

-use of broad distribution carbon blacks to increase the average interaggregate spacing and thus reduce the degree of filler-filler networking, *(e.g. see US Patent 7,238,741)*

-use of coupling agents with carbon black to increase the carbon-black-elastomer interaction, where coupling agents work by directly bonding

with both the filler and elastomer; *(e.g. see US Patent 5,494,955)*

-use of coupling agents with silica to facilitate silica dispersion and decrease filler-filler interaction *(e.g. see US Patent 5,227,425)*

-use of functionalized elastomers with compatible functionalized fillers, as has been done with SBR elastomers functionalized at the chain ends, in combination with an oxidized carbon black. *(e.g. see US Patents 5,248,722 and 2006/0178467)*

Several disadvantages of the above approaches are evident.

First the magnitude of the change in vulcanizate hysteresis with the use of broad distribution carbon blacks has been minimal and on the order of 3 to 10%, based upon tangent delta measurements at 60 to 75 °C.

Secondly, the use of coupling agents for carbon black and silica in compound compositions adds additional cost, requires additional mixing steps and special VOC emission handling systems for ethanol emissions that result from activation of the coupling agent used for increasing the filler-elastomer interaction via reactive mixing.

Thirdly, when carbon blacks are used in conjunction with coupling agents, relatively small benefits are also obtained in terms of compound hysteresis reduction.

Lastly, when silica is used with a coupling agent, which does provide significant reduction in vulcanizate hysteresis on the order of 40% or more, penalties are not only again incurred in terms of the cost of the silica and coupling agent, but the silica itself is very abrasive and causes an increase in the wear rate of the rubber mixers used in industrial factories. Silica also requires longer mixing and dispersion times, resulting in higher energy use and cost and lower factory output.

Thus, the object of this invention is to provide a novel rubber compound composition based on surface-treated carbon blacks and a functionalized polymer, that does not require the use of expensive coupling agents, and does not result in premature wear of factory rubber mixers, but yet provides significant reductions in compound hysteresis and maintains or improves compound wet traction more similar to silica, provides good abrasion resistance and provides easy dispersion for shorter mixing cycles, lower energy costs and higher factory throughput versus silica-based compound compositions. Additionally, this unique performance benefit is obtained with the combination of surface-treated carbon blacks and a functionalized solution-SBR, which has its functionalization along the polymer chain that provides a much higher probability of increasing the filler-elastomer interaction as opposed to elastomers with terminal, chain-end functionalization. Prior art, especially for

solution SBR, teaches the use of polymer functionalization at the chain ends.

BRIEF SUMMARY OF THE INVENTION

Scientists employed by Columbian Chemicals Company and Lanxess jointly developed the invention disclosed herein. In summarizing the invention, surface-treated carbon blacks have been used in conjunction with a functionalized elastomer, where the elastomer is functionalized along the chain, giving a higher probability of increased carbon-black-elastomer interaction, providing surprising and substantial reductions in hysteresis and benefits in wet traction relative to conventional carbon-black containing compounds, with said reductions in compound hysteresis and increases in wet traction more closely approaching silica-containing compounds, while also maintaining the excellent abrasion resistance of a carbon black compound.

BRIEF DESCRIPTION OF THE DRAWINGS

For a further understanding of the nature, objects, and advantages of the present invention, reference should be had to the following detailed description, read in conjunction with the following drawings, wherein like reference numerals denote like elements and wherein:

Figure 1 illustrates Payne Effect and Corresponding Affects on Tangent Delta for a Wide Range of Carbon Blacks in a Normal (non-functionalized) Elastomer System;

Figure 2 illustrates Payne Effect Reduction for Peroxide and Ozone Treated (for Varying Times) N234 in functionalized (along the chain) BUNA VSL VP PBR-4003 vs a non-treated N234 Control and Silica in Normal BUNA VSL 5025-2 (compounds with 0.2 phr DPG);

Figure 3 illustrates Payne Effect Reduction for Peroxide, Ozone and Amine Treated N234 in functionalized (along the chain) BUNA VSL VP PBR-4003 vs a non-treated N234 Control and Silica in Normal BUNA VSL 5025-2 (compounds with 0.2 phr DPG);

Figure 4 illustrates Tangent Delta as a Function of Dynamic Strain for Peroxide and Ozone Treated (for Varying Times) N234 in functionalized (along the chain) BUNA VSL VP PBR-4003 vs a non-treated N234 Control and Silica in Normal BUNA VSL 5025-2 (compounds with 0.2 phr DPG);

Figure 5 illustrates Tangent Delta as a Function of Dynamic Strain for Peroxide, Ozone and Amine Treated N234 in functionalized (along the chain) BUNA

VSL VP PBR-4003 vs a non-treated N234 Control and Silica in Normal BUNA VSL 5025-2 (compounds with 0.2 phr DPG);

Figure 6 illustrates Tangent Delta as a Function of Temperature for Peroxide and Ozone Treated (for Varying Times) N234 in functionalized (along the chain) BUNA VSL VP PBR-4003 vs a non-treated N234 Control and Silica in Normal BUNA VSL 5025-2 (compounds with 0.2 phr DPG);

Figure 7 illustrates Tangent Delta as a Function of Temperature for Peroxide, Ozone and Amine Treated N234 in functionalized (along the chain) BUNA VSL VP PBR-4003 vs a non-treated N234 Control and Silica in Normal BUNA VSL 5025-2 (compounds with 0.2 phr DPG);

Figure 8 illustrates Payne Effect Reduction for Ozone Treated (5.5 hrs) N234 and Higher Surface Area Carbon Blacks (N115, N134, CD2115) in functionalized (along the chain) BUNA VSL VP PBR-4003 vs a non-treated N234 Control and Silica in Normal BUNA VSL 5025-2 (compounds with 2.0 phr DPG);

Figure 9 illustrates Tangent Delta Reduction for Ozone Treated (5,5 hrs) N234 and Higher Surface Area Carbon Blacks (N115, N134, CD2115) in functionalized (along the chain) BUNA VSL VP PBR-4003 vs anon-treated N234 Control and Silica in Normal BUNA VSL 5025-2 (compounds with 2.0 phr DPG);

Figure 10 illustrates Tangent Delta as a Function of Temperature for Ozone Treated N234 and Higher Surface Area Carbon Blacks in functionalized (along the chain) BUNA VSL VP PBR-4003 vs a non-treated N234 Control and Silica in Normal BUNA VSL 5025-2 (compounds with 2.0 phr DPG); and

Figure 11 illustrates the changes in tangent delta at 0°C and 60°C predicting wet traction and rolling resistance for Inventive Compound 8, BUNA VSL VP PBR 4003/BR with N234 oxidized, to be equal to better than the Silica Reference Compound 10, shown in **Tables 11-13**.

DETAILED DESCRIPTION OF THE INVENTION

In a preferred embodiment of the present invention, the results of this work in a model tire tread compound have shown significant reduction of tangent delta (main parameter used to evaluate potential of a rubber compound to reduce heat build-up in a dynamic application). In fact, these results have been unexpected in terms of the magnitude of the decrease in tangent delta and the corresponding improvement in predicted wet traction (tangent delta in the range of 0 to -10°C). This type of behavior, lower tangent delta at 60°C to 75°C (lower rolling resistance prediction) and a higher

tangent delta at 0°C (higher wet traction prediction), was surprising for carbon black.

Normally, compound hysteresis reduction is relatively small for carbon black, either used as manufactured or even surface treated, when combined with common and normal SBR, BR, NR or EPDM compounds, and normally one or the other parameters (rolling resistance or wet reaction) might be improved, but not both simultaneously, and not to a significant degree. In the present invention, the combination of the surface-treated carbon black and the functionalized elastomer, with functionalization along the polymer chain, provides a compound composition with significant tangent delta reduction and maintains and improves the potential wet traction response.

What is provided is a compound composition comprised of a surface-treated carbon black, treated via oxidation, oxidation followed by treatment with a base, or chlorination followed by treatment with a base, which provides a carbon black with surface functional groups composed of oxygen, basic or a combination of oxygen and basic functional groups, and a functionalized polymer with functionalization along the polymer chain, with the polymer representing a solution SBR, and the functionalization representing a carboxylic acid (-COOH) or hydroxide (-OH) functionality.

Additionally, there is provided a compound that is reactively mixed to facilitate chemical interaction between the functionalized carbon black and the functionalized elastomer, where reactive mixing is accomplished in a rubber mixer such that the compound is held at an elevated temperature in the range of 145°C to 160°C for a time period of 2 to 8 minutes.

The present invention utilizes a typical tire tread compound composition as represented in **Table 1**, where the compound is composed entirely of the Lanxess functionalized solution SBR, BUNA VSL VP PBR 4003 (hereafter referred to as PBR 4003), but might also be represented by SBR/BR blends of ratios of 60/40 SBR/BR to 100/0 SBR/BR, as shown in **Table 2**. Additionally, surface-treated N234 carbon black and/or mixtures of surface-treated and as-manufactured carbon black or silica in ratios ranging from 50/50 to 100/0 can be used, in amounts ranging from 40 to 120 phr, along with typical processing oils, ranging from 2 to 50 phr, being representative of a typical tire tread formulation as might be used for tires.

The present invention also utilizes a typical mixing scheme as represented in **Table 3**, where the order of ingredient addition shown is typical of rubber mixing schemes, but, in addition, normal mixing times and temperatures are used and

compared to reactive mixing times and temperatures, which are longer and higher temperature, respectively versus normal mixing schemes. The reactive mixing schemes are required to facilitate the increased carbon black-elastomer interaction of the surface-treated carbon blacks and functionalized polymer with functionalization along the polymer chain to realize the compound advantages of low hysteresis and good wet traction and abrasion resistance as described above.

A preferred embodiment of this invention provides compound compositions prepared with several different carbon black surface treatment schemes with different chemistries, to synergistically interact with the functionalized polymer with functionalization along the polymer chain, and in this case with carboxylic acid functionalization along the polymer chain, to increase filler-elastomer interaction and decrease the filler-filler interaction, as evidenced by reduction of the low strain elastic modulus, per the Payne Effect, and significantly reduce compound hysteresis and maintain and improve compound wet traction and abrasion resistance.

Besides compound compositions including N234, carbon blacks as defined and listed in **Table 4** include carbon blacks with nitrogen surface areas in the range of 60 to 300 m^2/g (NSA, see ASTM D6556), and structure levels or oil adsorption (OAN, see ASTM D2414) levels in the range of 50 to 180 cc/100g, as might be produced via the furnace, impingement on lampblack process.

There is provided a compound composition of functionalized polymer with functionalization along the polymer chain and a carbon black surface treatment with oxidation of the carbon black surface via peroxide *(e.g. see US Patent 6,120,594)* or ozone *(e.g. see US Patent 6,471,933)* to provide a polar-polar and/or intermolecular-hydrogen-bonding mechanism between the oxygen-based functional groups on the carbon black surface and the carboxylic acid functionality along the polymer chain of the functionalized polymer, with the functionalization along the polymer chain resulting in increased filler-elastomer interaction, reduced filler-filler interaction and reduced Payne Effect.

There is provided a compound composition of functionalized polymer with functionalization along the polymer chain and a carbon black surface treatment with oxidation of the carbon black followed by treatment with amine-based compounds (e.g. see US Patent 5,708,055), preferably diamine compounds, that provide an acid-base interaction with the basic amine functional groups on the carbon black and the carboxylic acid groups along the polymer chain of the functionalized polymer,

with the functionalization along the polymer chain resulting in increased filler-elastomer interaction, reduced filler-filler interaction and reduced Payne Effect.

There is provided a compound composition of functionalized polymer with functionalization along the polymer chain and a carbon black surface treatment with oxidation of the carbon black followed by treatment with amine-based compounds, preferably amine compounds with hydroxide or other polar, oxygen containing functional groups, that provides an acid-base interaction and/or acid-base and polar-polar interaction with the functional groups on the carbon black and the carboxylic groups along the polymer chain of the functionalized polymer, with the functionalization along the polymer chain resulting in increased filler-elastomer interaction, reduced filler-filler interaction and reduced Payne Effect.

There is provided a compound composition of functionalized polymer with functionalization along the polymer chain and a carbon black surface treatment with oxidation of the carbon black followed by treatment with hydroxy-based compounds, that provides a polar-polar interaction and/or intermolecular-hydrogen-bonding with the functional groups on the carbon black and the carboxylic groups along the polymer chain of the functionalized polymer, with the functionalization along the polymer chain resulting in increased filler-elastomer interaction, reduced filler-filler interaction and reduced Payne Effect.

There is provided a compound composition of functionalized polymer with functionalization along the polymer chain and a carbon black surface treatment with chlorination of the carbon black followed by treatment with ammonia, that provides an acid-base interaction between the functional groups on the carbon black and the carboxylic groups along the polymer chain of the functionalized polymer, with functionalization along the polymer chain resulting in increased filler-elastomer interaction, reduced filler-filler interaction and reduced Payne Effect.

A compound composition comprised of a surface-treated carbon black and a functionalized polymer with carboxylic-acid functionalization along the polymer chain, with the polymer representing a solution SBR, to reduce compound hysteresis and rolling resistance and improve wet traction in tires, while maintaining good abrasion resistance including passenger, truck and racing tires.

The present invention further provides the use of the inventive compound composition for the production of vulcanizates, which in turn serve for the production of highly reinforced mouldings, in particular for the production of tires.

The present invention further provides the use of the inventive compound composition for the production of rubber mixtures.

EXPERIMENTAL: POLYMERS AND CARBON BLACK PREPARATION

The polymers and as manufactured and surface-treated carbon blacks used in this present compound composition invention are listed in **Table 5** and analytical results showing the affects of surface treatment are shown in **Table 6.**

Ozonated samples of carbon black included Sturdivant-milled beaded-carbon-black treated in a rotating drum for various lengths of time, ranging from 1.5 to 5.5 hours, with an air flow containing approximately 2% ozone concentration followed by wet beading and then drying the samples in an oven at 125°C for six hours.

Hydrogen peroxide samples included powder carbon black wet beaded with a 50/50 weight percent of 35% to 50% hydrogen peroxide in a pin beader following Columbian Internal Batch Lab Procedure LS0-1. The resulting wet beads were then dried in a fluid bed drier at 125°C for two hours.

Amine samples of carbon black were prepared by treating fifty grams of ozonated N234 powder added to 2.5 liters of water and 25 ml of acetone in a 6 liter Lab Max reaction vessel. Ethylene diamine, diluted to a 1 % solution in distilled water, was slowly added to the Lab Max with constant stirring until the target pH was reached. The carbon black was separated from the water by pressure filtration and soxhlet extracted with distilled water for 16 hours. The carbon black sample was then coffee milled, wet beaded, and dried in an oven for six hours at 125°C.

Typical examples of the affects of the surface treatments are shown in **Table 6**, where Volatile Content (Columbian Internal Procedure LS2-700) and pH (ASTM D1512) and Thermometric Titration (Columbian Internal Procedure LS2-702) values are shown, which reflect changes in the surface properties as a result of the surface treatments. As can be seen, the ozone oxidized carbon black shows an absolute 4.7% increase in volatile content, with a dramatic drop in pH and increase in thermometric titration (measure of heat of reaction between carbon black surface moieties and the base, butyl amine, that is used as the titrant), as well as an increase in moisture uptake (more polar groups), indicating the oxidation treatment was successful as the results show the typical increase in surface acidity normally observed for oxidized carbon blacks.

The amine treated carbon black shows a large increase in pH (oxidized CB used as feedstock, so acid groups neutralized) with a corresponding large drop in the

thermometric titration value.

Amine treatment appears successful, but some acid sites possibly remain as evidenced by the pH value being <7 and possibly indicates that a carbon black with dual-surface-functionality has been obtained (basic amine and polar, and / or oxygen-based acid sites are both present).

The results of the surface treatment for these three carbon blacks shown in **Table 6** represent typical values and represent the carbon black types primarily used for the in-rubber evaluations.

The polymers used in this present compound composition invention listed in **Table 5** include Lanxess Buna VSL-5025-2, solution SBR with 50% vinyl and 25% styrene content, 37.5 phr of TDAE oil, and Mooney viscosity ML (1+4) @ 100°C of 47 MU; and Lanxess PBR 4003, a functionalized polymer containing carboxylic functionalization along the polymer chain, and composed of

Vinyl content of 45% +/-7% per weight of SBR portion

Styrol-content of 25% +/-5% per weight

Oil-content (TDAE) of 27% +/- 1.5% per weight

Mooney Viscosity ML (1+4) @ 100°C of 55MU +/- 10 MU

Content of functional COOH-groups of 35 mmol +/-10 mmol per kg oil-extended rubber.

EXPERIMENTAL TESTING

The compound variables used in this evaluation are described in **Table 7**, and compound performance of the compound compositions of the present invention were compared against normal SBR polymer (Lanxess Buna VSL-5025-2), with fillers including regular, ozonated, peroxide or amine treated carbon blacks and silica, with and without silane, and with and without reactive mixing. The in-rubber compound performance properties are listed in **Tables 8 through 13**. The reactive mixing procedure recommended by Lanxess for use with Si69 includes mixing up to and maintaining a temperature of 150-160°C for 3 minutes, each for two passes, followed by addition of the curatives on a mill. The all SBR compounds (**Table 1** and **Tables 8 through 10**) were mixed on a Brabender Plasticorder Mini-Mixer, while the SBR/BR compounds (**Table 2 and Tables 11-13**) were mixed on a GK 1,5 litre intermeshing mixer. Dynamic Properties for the SBR/BR compounds shown in **Table 2**, were determined using an MTS servo-hydraulic machine for the strain amplitude sweeps and a Gabo Explexor machine was used for determining the temperature sweeps. Amplitude

sweeps were conducted under the following conditions: Double shear test piece, 1 Hz frequency and amplitude range from 0.2 to 80% DSA at 60°C. The Temperature Sweeps were conducted under the following conditions: 1 % mean strain, 10 Hz frequency, 0,1 % amplitude from -120°C to 100°C. The cure accelerator, DPG (N,N-diphenylguanidine) was varied from 0.2 to 2.0 phr to improve and optimize cure rates due to effects on this property from the varied surface chemistry of the carbon blacks. Improved cure rates and in-rubber properties were obtained with the higher amount (2.0 phr) of the DPG.

COMPOUND TESTING RESULTS

In-rubber properties evaluated included the following: MDR (ASTM D5289), Shore A Hardness (ASTM D2240), Rebound (ASTM D1054) and Stress-Strain (ASTM D412). Dynamic properties for the all SBR compounds in **Table 1** were determined using a TA Instruments Advanced Rheometric Expansion System (ARES) Model LS/M DMA, and were conducted in shear. Amplitude sweeps were conducted under the following conditions: 0% Mean Strain, 10Hz Frequency, and amplitude range from 0.2-125% ptp at 75°C. The Temperature sweeps were conducted under the following conditions; 0% Mean Strain, 10Hz Frequency, amplitudes of 8% (40°C and lower) and 15% ptp (50°C and higher), and temperature range from -5°C to 60°C.

Table 8 shows the performance advantages of the Inventive Compound compositions versus normal or Reference Compound compositions typically employed, and Figures 2, 4 and 6 show these results graphically for this data for the dynamic elastic modulus, G´ as a function of strain, tangent delta maximum at 75°C as a function of strain, and for tangent delta as a function of temperature for rolling resistance and wet traction prediction, respectively. Compound 1 in **Table 8** shows normal N234 in the normal Buna VSL 5025-2 as the Reference Compound 1. Compound 2 shows the normal N234 in the chemically modified PBR-4003 and only a slight 10% reduction in the tangent delta at 75°C as well as a 17% reduction in the Payne Effect is realized. However, for the Inventive Compounds 3,4,5 and 6, significant and surprising decreases in tangent delta ranging from 19 to 39% are realized, with increasing levels of ozonation (oxidation) resulting in larger decreases in tangent delta. The all-Silica Compound 7, which can be considered a rolling resistance standard, showed tangent delta decrease relative to Compound 1 of 79%. The Payne Effect also shows significant decreases in the range of 33 to 42% for the

Inventive Compounds 3, 4, 5 and 6, respectively, relative to the Reference Compounds 1 and 2. This feature appears to result in directionally better wet traction prediction at -5°C, as shown by the higher tangent delta for Compounds 3, 4, 5 and 6 at -5°C versus the Reference Compounds 1 and 2. Note the higher ozonation time (higher level of oxidation) results in the most improvement in lowering tangent delta at 75°C (predicting lower rolling resistance) and increasing tangent delta at -5°C (predicting increased wet traction), indicating the higher the level of surface oxidation, the better the performance of the compound composition in terms of lower predicted rolling resistance and improved predicted wet traction.

Table 9 shows the performance advantages of the Inventive Compound compositions versus normal or Reference Compound compositions typically employed, and Figures 3, 5 and 7 show these results graphically for this data for G´ as a function of strain, tangent delta at 75°C as a function of strain, and for tangent delta as a function of temperature for rolling resistance and wet traction prediction, respectively. Compound 1 in **Table 9** shows normal N234 in the normal Buna VSL 5025-2 as the Reference Compound. Compound 2 shows the normal N234 in the chemically modified PBR-4003. **Table 9** compares the Inventive Compounds 5 and 6 containing amine-treated carbon blacks to the Reference Compounds, Compounds 1, 2 and 7 and the Inventive Compounds 3 and 4 that contain oxidized carbon blacks. Note that the Compounds 5 and 6 that contain amine-treated carbon blacks also show large reductions in tangent delta at 75°C on the order of 34 and 39%, respectively versus the standard Compound 1. These tangent delta reductions for the Inventive Compounds 5 and 6 are very similar to the Inventive Compound 5 in **Table 8** (also shown as Compound 4 in **Table 9**), which has the lowest tangent delta response of all Inventive Compounds containing oxidized carbon blacks. One additional advantage of the Inventive Compounds 5 and 6 containing amine-treated carbon blacks is that the cure rate, or time to 90% cure, (t_{90}) is also reduced due to a basic surface chemistry present on the amine-treated carbon blacks, which is a desirable feature. The Payne Effect also shows significant decreases in the range of 57 to 62% for the Inventive Compounds 5 and 6, respectively, which is a larger decrease than for the Inventive Compounds containing the ozonated only carbon-blacks. This feature appears to result in directionally better wet traction prediction at -5°C, as shown by the higher tangent delta for Compounds 5 and 6 versus the Reference Compound 1 and the ozonated Inventive Compound 5 in **Table 8** (and shown as Compound 4 in

Table 8). Thus utilization of amine-treated carbon blacks versus ozonated only carbon blacks in the Inventive Compound Compositions, appears to result in better curing characteristics and improved wet traction prediction with similar low rolling resistance properties.

Table 10 compares the Inventive Compounds containing ozonated carbon blacks of higher surface area than N234, which includes N115, N134 and CD2115 and Figures 8, 9 and 10 show these results graphically for this data for G´ as a function of strain, tangent delta at 75°C as a function of strain, and for tangent delta as a function of temperature for rolling resistance and wet traction prediction, respectively. Reference Compounds 1 and 2 in **Table 10** show results for normal N234 and N134, respectively in the normal Buna VSL 5025-2. Compounds 3, 4, 5 and 6 show the results for the Inventive Compounds containing ozonated N234, N134, N115 and CD2115, respectively in the Lanxess PBR-4003, and for this data set, the amount of DPG was increased to 2.0 phr, which is more typical of formulations used in the rubber industry for silica compounds that require secondary accelerators due to their surface chemistry. The results show an overall better balance of cure, stress-strain and dynamic properties for all compounds. In this data set, the Inventive Compound 3 (ozonated N234, 5.5 hours) shows a more significant and surprising drop in tangent delta of 50% relative to the Reference Compound 1, and in this case, now more closely matches the all-Silica Reference Compound 7, which has a 60% drop in tangent delta relative to the Reference Compound 1. Surprisingly, the higher surface area carbon blacks, N115, N134 and CD2115 also show large reductions in tangent delta maximum at 75°C on the order of 40% relative to the Reference Compound 1 containing N234. Normally higher surface area carbon blacks give higher heat buildup and tangent delta values due to their higher propensity to form through-going networks, and the Reference Compound 2 in **Table 10** that contains normal N134 in normal Buna VSL 5025-2, demonstrates this phenomenon (15% higher tangent delta relative to the Reference Compound 1 containing N234). Relative to Reference Compound 2 containing N134, the Inventive Compound with ozonated N134 shows a 64% drop in tangent delta, which is a significant and surprising result. The same can be said for the N115 and especially the CD2115, which is a significantly finer or higher surface area carbon black. The Payne Effect also shows significant decreases in the range of 40 to 75% for the Inventive Compounds 3, 4, 5 and 6, which again is a large change and surprising result. Note

that the all-Silica Compound 7, shows a 64% decrease in the Payne Effect relative to Reference Compound 1. The results in **Table 10** also show directionally better wet traction prediction at -5°C for Inventive Compounds 3 and 4, as shown by the higher tangent delta for the Inventive Compounds 3 and 4 versus the Reference Compound 1. Thus surface modification of higher surface area carbon blacks (higher surface area than N234) used in compound compositions containing PBR4003, can result in compounds with significantly lower heat buildup and predicted rolling resistance with directionally better to equal predicted wet traction versus normal Reference Compounds containing N234 or their respective counterparts.

Tables 11-13 show the performance advantages of the compositions of the Inventive Compounds versus normal or Reference Compound Compositions typically employed, but in this case SBR/BR blends as described in **Table 2**, more typical of an actual tire tread compound, are shown. **Table 11** shows the basic stress-strain properties indicating a very good balance of modulus, tensile strength and elongation for the Inventive Compounds 4, 6 and 8 versus the normal Reference Carbon Black Compound Compositions 1,9 and Silica Compound Compositions 10, 11. **Table 12** shows the Amplitude Sweep dynamic properties at 60°C, and shows that all Inventive Compounds 4, 6 and 8 give reduced tangent delta in the range of 9% to 21%, relative to the Reference Compound 1 and 9 for N234. The ozonation and amine treatments for Inventive Compounds 4 and 6 had higher tangent delta maximum than Inventive Compound 8, which has an optimal amount of surface oxygen groups or volatile content greater than the 5% level. Consequently, as shown in **Table 9**, the tangent delta response for Innovative Compound 8, most closely matched the tangent delta response for Silica Compounds 10 and 11. **Table 12** also shows the Temperature Sweep data for the SBR/BR Reference and Inventive Compounds, and as can be seen, the Inventive Compounds 4, 6 and 8 have tangent delta values at 0°C similar to or greater than the Silica Reference Compound 10, indicating equal to greater predicted wet traction response for the Inventive Compounds 4, 6 and 8. The improved predicted rolling resistance and wet traction of Inventive Compound 8 versus the Normal Reference N234 Compound 1 and the Silica Reference Compound 10, is shown graphically in Figure 11. **Table 13** shows the DIN Abrasion, Shore A Hardness and Rebound for the SRB/BR Reference and Inventive Compounds. The DIN Abrasion for the Inventive Compounds 4, 6 and 8 is similar to the Reference Compounds 1 and 9, and both are approximately 18% lower in DIN Abrasion than the

Silica Reference Compound 10. For DIN Abrasion testing, a lower number indicates better resistance to abrasion, and hence, better or higher predicted treadwear. This result indicates that the Inventive Compounds 4, 6 and 8 have an overall improved compound performance versus the Silica Reference Compound 10, meaning the Inventive Compound 8 has equal to better predicted rolling resistance, wet traction and treadwear than the corresponding Silica Reference Compound 10.

These results indicate the Inventive Compounds have overcome the challenging hurdle of significantly and simultaneously improving rolling resistance, wet traction, treadwear and mixing and compound costs at the same time in a rubber compound.

The foregoing embodiments are presented by way of example only; the scope of the present invention is to be limited only by the following claims.

CLAIMS

1. A compound composition comprised of a surface-treated-carbon-black and a functionalized polymer with functionalization along the polymer chain, with the polymer representing a solution SBR including, but not limited to blends of the SBR with BR, NR and EPDM, and the SBR polymer functionalization composed of polar, oxygen-containing functional groups resulting in a compound with very low hysteresis and rolling resistance, improved wet traction, excellent abrasion resistance and excellent mixing and compound costs as would be used in passenger, truck and racing tires.

2. The composition in claim 1 wherein the surface-treated carbon blacks' surface area and structure range from 60 to 300 m^2/g and 50 to 180 cc/100g, respectively, and as might be produced from the furnace, impingement over lampblack process.

3. The composition in claim 1 wherein the compound is reactively mixed to facilitate chemical interaction between a surface-treated-carbon black and a functionalized-elastomer, where reactive mixing is accomplished in a rubber mixer such that the compound is held at an elevated temperature for a certain time period.

4. The compound composition in claim 1, wherein the components are mixed in such a manner such that the carbon-black-elastomer interaction is increased through the interaction between the elastomer functional groups along the polymer chain and the surface-treated carbon black.

5. The compound composition in claim 1, wherein the components are mixed in such a manner that the carbon-black-elastomer interaction is increased through polar interaction between the polymer-carboxylic-acid-functional groups and the surface-treated-carbon-black, where the surface treatment is accomplished with oxidizing agents.

6. The compound composition in claim 1, wherein the components are mixed in such a manner such that the carbon-black-elastomer interaction is increased through acid-base interaction between the polymer-carboxylic-acid-functional groups and the surface-treated-carbon-black, where the surface treatment is accomplished with oxidizing agents followed by treatment with amine-based compounds.

7. The compound composition in claim 1, wherein the components are mixed in such a manner such that the carbon-black-elastomer interaction is increased

through acid-base interaction between the polymer-carboxylic-acid-functional groups and the surface-treated-carbon-black, where the surface treatment is accomplished with chlorination of the surface followed by treatment with ammonia.

8. The compound composition in claim 1, such that increased carbon-black- elastomer interaction and reactive mixing reduces the filler-filler interaction and increases filler-elastomer interaction and results in a carbon-black-containing solution-SBR-based compound with low hysteresis and low rolling resistance, comparable to all-Silica-based compounds.

9. The compound composition in claim 1, such that increased carbon-black- elastomer interaction and reactive mixing reduces the filler-filler interaction and increases the filler-elastomer interaction and results in a carbon-black-containing solution-SBR-based compound with improved wet traction, comparable to all-Silica-based compounds.

10. The compound composition in Claim 1, such that increased carbon-black-elastomer interaction and reactive mixing reduces the filler-filler interaction and increases the filler-elastomer interaction and results in a carbon-black containing solution-SBR-based compound with excellent DIN abrasion resistance, significantly better than all-Silica-based compounds.

11. The compound composition in claim 1, wherein the composition results in both significantly lower hysteresis and improved wet traction comparable to all-Silica-based compounds, but with improved DIN Abrasion and treadwear.

12. A surface-treated-carbon-black used in conjunction with a functionalized elastomer, where the elastomer is functionalized along the polymer chain, giving a higher probability of increased carbon-black-elastomer interaction, providing substantial reductions in hysteresis as measured by dynamic testing and the decreased tangent delta factor at 60 to 75°C, and improved wet traction as measured by dynamic testing and the increased tangent delta factor at 0 to -10°C.

13. A compound composition comprising a surface-treated-carbon-black, preferably treated with peroxide or ozone, resulting in oxidation of the surface with polar, oxygen-containing functionalities, and a functionalized polymer with functionalization along the polymer chain, with the polymer representing a solution SBR, and the functionalization representing a polar, carboxylic-acid functionality.

14. A compound composition comprising a surface-treated-carbon-black, preferably treated with an oxidizing agent followed by treatment with a

diamine-based compound, resulting in amine functionalization, and a functionalized polymer with functionalization along the polymer chain, with the polymer representing a solution SBR, and the functionalization representing a polar, carboxylic-acid functionality.

15. A compound composition comprising a surface-treated-carbon-black, preferably treated with a chlorinating agent followed by treatment with ammonia, resulting in amine functionalization, and a functionalized polymer with functionalization along the polymer chain, with the polymer representing a solution SBR, and the functionalization representing a polar, carboxylic-acid functionality.

16. A compound composition comprising the components from claims 1 or 2 and mixed in such a manner such that the carbon-black-elastomer interaction is increased through polar-polar or intermolecular hydrogen bonding between the carboxylic-acid functional groups along the polymer chain and the oxygen-containing functional groups on the surface-treated, oxidized carbon black.

17. A compound composition comprising the components from claims 1 or 2 and mixed in such a manner such that the carbon-black-elastomer interaction is increased through acid-base interactions between the carboxylic-acid functional groups along the polymer chain and the amine-containing functional groups on the surface-treated oxidized/chlorinated and amine/ammonia-treated carbon-black surface.

18. A compound composition comprising the components from claims 1 or 2 and mixed in such a manner such that the carbon-black-elastomer interaction is increased simultaneously through both polar-polar or intermolecular hydrogen bonding and acid-base interactions between the carboxylic acid functional groups along the polymer chain and the oxygen containing functional groups, and the amine containing functional groups on the oxidized/chlorinated and amine/ammonia-treated carbon-black surface.

19. A compound composition comprising an oxidized/chlorinated and amine/ammonia- treated carbon-black surface with oxygen containing functional groups and/or amine-containing functional groups, and a functionalized polymer with carboxylic-acid functionalization along the polymer chain, with the polymer representing a solution SBR including, but not limited to blends of the SBR (PBR4003) with BR, NR and EPDM, with reduced compound hysteresis and rolling

resistance, improved wet traction and excellent treadwear as would be used in passenger, truck and racing tires.

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