Title: A RUBBER COMPOUND FOR THE PRODUCTION OF MOTORCYCLE TYRE TREADS, PROCESS FOR PRODUCING THE RUBBER COMPOUND AND THE MOTORCYCLE TYRE TREAD PRODUCED

Abstract: A rubber compound for the manufacture of motorcycle tyre treads comprising a rubber component derived from natural rubber based polymers, a dual-filler system consisting of carbon black and silica, a plasticizer derived from epoxidized palm oil containing not more than 2% oxirane oxygen content, a neutralizing agent derived from calcium stearate and a vulcanization agent derived from sulphur. The rubber compound has low rolling resistance, good abrasion and wear resistance and improved wet traction performance. A method for producing the rubber compound above comprising of providing an appropriate amount of natural rubber based polymers into a mixing device, then mixing the rubber compound with the plasticizer and neutralizing agent, while adding a dual-filler system at a suitable time in at least two separate stages. The mixture is then added with the vulcanization agent and heated to vulcanize the compound. A motorcycle tyre tread comprising a body and a tread wherein the tread is manufactured from the rubber compound above.
A RUBBER COMPOUND FOR THE PRODUCTION OF MOTORCYCLE TYRE TREADS,
PROCESS FOR PRODUCING THE RUBBER COMPOUND AND THE MOTORCYCLE
TYRE TREAD PRODUCED

FIELD OF INVENTION

This invention generally relates to rubber compounds for motorcycle tyre treads. More particularly, the invention relates to a rubber compound for the manufacture of motorcycle tyre treads, the method of producing the rubber compound and the motorcycle tyre tread made from the rubber compound.

BACKGROUND ART

A tyre is generally a circular-shaped covering that wraps around the rims of the wheels of a vehicle and provides a flexible surface that acts as a cushion that absorbs shock when the vehicle is in motion. Tyres are usually made of synthetic rubber and/or natural rubber, fabric and wire, along with other compounds and chemical additives. The tyre consists of a tread and a body, with the tread portion providing traction to the surface it is in contact with while the body provides support. The majority of tyres today are inflatable structures where the tyre is filled with compressed air to form an inflatable cushion.

Motorcycle tyres are the only contact between the motorcycle vehicle and the ground. The contact surface of a motorcycle tyre is generally very small compared to a tyre used for larger vehicles such as cars, lorries and trucks. Hence, it is particularly vital for the motorcycle tyre to have good traction performance, good rolling and abrasion resistance and high wear resistance. It is impossible to have all the preceding ideal physical properties in a rubber compound. However, with the right combination of rubber components and suitable amounts of additives, a good compromise between each of the desired physical properties can be achieved.

Conventional motorcycle tyres are generally manufactured from synthetic rubber such as styrene-butadiene rubber (SBR) and polybutadiene rubber (PBR), which are derived from fossil fuels such as crude oil. The rubber compound is usually reinforced with carbon black and further comprises fatty acid additives (cure aid) and vulcanization aids. Synthetic
rubber produced in this manner exhibits high abrasion resistance, good wet grip and low rolling resistance.

A further key component in the manufacture of tyres is the plasticizer or softening oil. Typically, the plasticizer used is an aromatic oil derived from crude oil. Plasticizers that contain high polycyclic aromatic hydrocarbon content have been deemed carcinogenic and are effectively prohibited for use in tyre production in Europe.

To reduce reliance on unsustainable crude oil, alternatives have been proposed to replace synthetic rubber and the crude oil derived plasticizer.

European publication no. 2 340 946 Al teaches a method to produce a rubber compound for tyre components such as beads, apexes and sidewall veneers mainly comprising preferably a blend of at least two diene based elastomers (natural and/or synthetic).

One known drawback of using natural rubber for tyre manufacturing as disclosed in the European publication is lower tensile strength and low elongation at break values of the compound.

The compound of this prior European publication further comprises epoxidized palm oil as a plasticizer to negate the use of fatty acids as a cure aid due to its undesirable effect on tack retention. This is possible due to the natural presence of stearic acid in epoxidized palm oil. However, only a small amount (1 phr) of stearic acid is present in the epoxidized palm oil, and this leads to a prolonged cure time.

The epoxidized palm oil used in this European publication contains between 2.6% to 3.4% oxirane oxygen content, which aids in improving tack retention of the rubber compound. If an epoxidized palm oil with a lowered oxirane oxygen content is used, it may cause an increased acidity in the rubber compound leading to the compound having poor ageing resistance and increased curing time during vulcanization. Use of an epoxidized palm oil with lower oxirane oxygen content than 2.6% to 3.4% is desirable as this will aid in increasing abrasion resistance of the compound. However, doing so with the teachings of this European publication will lead to the undesirable consequences described above.
Hence, there is a need for a rubber compound for producing motorcycle tyre treads having its major components solely derived from natural sustainable resources with the compound exhibiting high tensile strength, good elongation at break values while maintaining desirable properties of a tyre such as low rolling resistance, good processability and abrasion resistance. This invention thus aims to alleviate some or all of the problems of the prior art.

SUMMARY OF THE INVENTION

In an aspect of the invention, there is provided a rubber compound for the manufacture of motorcycle tyre treads comprising a rubber component derived from natural rubber based polymers, a dual-filler system consisting of carbon black and silica, a plasticizer derived from epoxidized palm oil containing not more than 2% oxirane oxygen content, a neutralizing agent derived from calcium stearate and a vulcanization agent derived from sulphur. The tyre tread manufactured from the rubber compound of this invention exhibits low rolling resistance, good abrasion and wear resistance and improved wet traction performance.

It was surprisingly found that the use of an epoxidized palm oil with an oxirane oxygen content of not more than 2% advantageously improves the abrasion resistance of the rubber compound without compromising tack retention.

Use of calcium stearate as a base addition aids in lowering the acidity of the rubber compound and this leads to better scorch safety and increase in the ageing performance of the rubber compound.

In another embodiment, the rubber may comprise about 40 parts by weight of epoxidized natural rubber and about 60 parts by weight of natural rubber, about 20 to about 80 parts by weight carbon black, about 20 to about 80 parts by weight silica, about 5 to about 30 parts by weight of epoxidized palm oil containing not more than 2% oxirane oxygen content, about 1 to about 5 parts by weight of calcium stearate and about 1.8 parts by weight of sulphur.
In a further embodiment, the rubber compound may comprise about 10 to about 90 parts by weight of epoxidized natural rubber and about 10 to about 90 parts by weight of natural rubber.

In another embodiment of the present invention, the rubber compound may comprise about 100 parts by weight of epoxidized natural rubber, about 20 to about 80 parts by weight carbon black, about 20 to about 80 parts by weight silica, about 5 to about 30 parts by weight of epoxidized palm oil containing not more than 2% oxirane oxygen content, about 1 to about 5 parts by weight of calcium stearate and about 1.8 parts by weight of sulphur vulcanization agent.

In another embodiment of the present invention, the epoxidized natural rubber (ENR) used may be ENR with 25 mole% epoxide content.

In a further embodiment, the carbon black may be of a type selected from a group comprising super abrasion furnace (SAF), intermediate SAF (ISAF), high abrasion furnace (HAF) and/or easy processing channel (EPC).

In another embodiment, the silica may be fumed silica or hydrated amorphous silica.

In another embodiment of the present invention, the plasticizer used may be epoxidized palm oil containing from about 1.8 to about 2.0% oxirane oxygen content.

In another embodiment of the present invention, the plasticizer used may be epoxidized palm oil containing less than 1% oxirane oxygen content.

In a further embodiment, the compound may further comprise zinc oxide and/or stearic acid as vulcanization activators.

The zinc oxide may be present in an amount ranging from about 1 to about 5 parts by weight.
In another embodiment, the compound may further comprise vulcanization accelerators such as guanidine, sulphonamide, thiazole, and/or thiuram. The compound may contain about 1.5 to about 2.5 parts by weight of vulcanization accelerator.

In a further embodiment of the present invention, the compound may further comprise an anti-ageing agent in an amount from about 1 to about 3 parts by weight. The anti-ageing agent may be N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine.

In another embodiment, the compound may further comprise anti-degradant agents in an amount from about 1 to about 3 parts by weight. The anti-degradant agent may be 2,2,4-trimethyl-1,2-dihydroquinoline.

In a second aspect of the present invention, there is provided a method for producing the rubber compound of the present invention. The method comprises the following steps:

i) providing an appropriate amount of natural rubber based polymers into a mixing device;

ii) mixing the rubber polymers with the plasticizer, the neutralizing agent; and adding at a suitable time the dual-filler system in at least two separate stages;

iii) adding the vulcanization agent to the mixture of step (ii);

iv) heating the resultant mixture of step (iii) to vulcanize the compound.

Adding the dual-filler system in at least two separate stages facilitates in dispersing and distributing the silica and carbon black efficiently into the rubber component by reducing the interaction of silica particles with other silica particles while maximizing the interaction of silica particles with the rubber elastomers resulting in better reinforcement properties.

In an embodiment, the mixing device used in the above method may be an internal mixer and/or a two-roll mill.

In an embodiment, addition of the dual-filler system may be carried out before the non-productive mixing stage of step (ii).

In a further embodiment, the addition of the dual-filler system may be carried during
In a further embodiment of the present invention, the dual-filler system of step (ii) may comprise 0.5:0.5 by weight ratio of carbon black and silica which may be added in two separate stages.

In another embodiment, the dual-filler system of step (ii) may be added in three separate stages with 0.5:0.5 by weight ratio of carbon black and silica added during the first stage; 0.125:0.125 by weight ratio added during the second stage; and 0.375:0.375 by weight ratio added during the third stage.

In an embodiment, step (i) to step (ii) may be conducted at a temperature ranging from about 30 °C to about 180 °C.

In a further embodiment, step (iv) may be conducted at a temperature ranging from about 100 °C to about 190 °C.

In another embodiment, a vulcanization activator such as zinc oxide and/or stearic acid may be further added in step (iii).

In a further embodiment, an anti-ageing agent may be further added in step (ii).

In another embodiment of the present invention, an anti-degradant agent may be further added in step (ii).

In a third aspect of the present invention, there is provided a motorcycle tyre comprising a body and a tread wherein the tread is produced from the rubber compound of the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

The present invention is directed to a rubber compound for the manufacture of motorcycle tyre treads, the method of producing the rubber compound and the motorcycle tyre tread made from the rubber compound.
Rubber Compound

The rubber compound mainly comprises a rubber component derived from natural rubber based polymers, a dual-filler system consisting of carbon black and silica, a plasticizer derived from epoxidized palm oil containing not more than 2% oxirane oxygen content, a neutralizing agent derived from calcium stearate and a vulcanization agent derived from sulphur.

The rubber component of the present invention comprises of at least one natural rubber based polymers. The rubber based polymers may be solely epoxidized natural rubber (ENR) or a mixture of ENR and natural rubber in a suitable ratio. For example, the rubber component may comprise an amount of 40 parts by weight of ENR and 60 parts by weight of natural rubber or 10 parts by weight of ENR and 90 parts by weight of natural rubber. Alternatively, the rubber component may comprise 100 parts by weight of ENR.

Natural rubber is more elastomeric in nature compared to synthetic rubbers and promotes higher tensile properties in the resultant rubber compound. This in turn aids in improving tackiness of the compound without the need for addition of a tackifying resin. The natural rubber used may be of any suitable grade such as Standard Malaysian Rubber (SMR).

ENR is less elastomeric in nature in comparison to natural rubber due to the presence of epoxide groups and this leads to better compatibility when mixed with silica, thus reducing the need for a coupling agent and providing better hysteresis performance. The ENR used may be of any suitable grade and preferably of about 25 mole% epoxide content such as EKOPRENA™25.

It is known that silica and carbon black may be used as a reinforcing agent for rubber compounds. However, when silica is used alone and in high amounts for a rubber compound, it will lead to poor reinforcement characteristics compared to using carbon black alone. This is due to the nature of silica having stronger interaction with other silica particles rather than rubber particles. Rubber compounds reinforced with silica alone also exhibit poor processability and low abrasion resistance.

Hence, a dual-filler system consisting of carbon black and silica that increases the abrasion...
Any suitable type of carbon black may be used. Preferably the carbon black used for tyre production has a specific area for nitrogen adsorption of 30 ml/100g to 200 ml/100g and an adsorption amount of compressed dibutyl phthalate (DBP) of 30 ml/100g to 150 ml/100g. Examples of suitable carbon black are Super Abrasion Furnace (SAF), Intermediate SAF (ISAF), High Abrasion Furnace (HAF) and Easy Processing Channel (EPC). The amount of carbon black added to the rubber component may be 20 to 80 parts by weight, preferably 20 to 40 parts by weight.

Carbon black improves reinforcement of the rubber compound and also the abrasion resistance of the tyre produced from the rubber compound.

Any suitable type of silica may be used in the present invention. Silica grades such as fumed silica or hydrated amorphous silica may be used and are known and commercially available. Preferably, the silica used in the present invention is Zeosil® 1165MP. The amount of silica added together with the carbon black to the rubber component may be 20 to 80 parts by weight, preferably 20 to 40 parts by weight.

Silica improves reinforcement of the rubber compound and traction and rolling resistance of the tyre produced.

Common processing oils used in industry include aromatic, paraffinic, naphthenic, bio-based oils (other than castor oil), and low Polycyclic Aromatic (PCA) oils such as Mild Extract Solvate (MES), Treated Distillate Aromatic Extract (TDAE), Residual Aromatic Extract (RAE) and heavy naphthenic oils. Suitable low PCA oils include those having a polycyclic aromatic content of less than 3 percent by weight as determined by IP346 test method. However, all of these processing oils derived from crude oil are deemed carcinogenic. The plasticizer consisting of epoxidized palm oil is used as processing oil of the rubber compound of the present invention.

Epoxidized palm oil is produced by the epoxidation of palm oil, where typically, a fraction of the double bond in the palm oil is epoxidized, converting the palm oil fatty acids to epoxide functional groups such as oxirane.
Any epoxidized palm oil containing not more than 2% oxirane oxygen content may be used in this invention, for example, epoxidized palm oil containing between 1.8 to 2% oxirane oxygen content and more preferably less than 1% oxirane oxygen content. 5 to 30 parts by weight of epoxidized palm oil may be added to the rubber component. Commercially available epoxidized palm oil such as Rovpro® 5300 and 5301 from Rovski Industries Sdn. Bhd. may be used. It was surprisingly found that epoxidized palm oil with not more than 2% oxirane oxygen content provides the rubber compound with high abrasion resistance without compromising tack retention. An increased acidity of the compound causes a bloom experience which reduces the tack of the rubber component. A bloom experience is when sulphur rises to the surface of the rubber instead of dispersing within the rubber compound affecting the tack retention of the rubber compound's surface.

The higher the oxirane oxygen content of the epoxidized palm oil used, the more effective it is in reducing the build up acidity in the rubber compound which aids in reducing the curing time during vulcanization. However, this affects the abrasion resistance of the compound.

A neutralizing agent that acts as a base addition is listed in this invention. The neutralizing agent used is calcium stearate which may be added in an amount of 1 to 5 parts by weight. The neutralizing agent acts as a scorch safety agent during the vulcanization process. The acidity of the rubber compound causes the ring-opening of the epoxy group of ENR during the coagulation of the rubber. This causes the rubber compound to lose its ageing resistance. When the acidity of the rubber compound is neutralized, the rubber is able to coagulate efficiently and form stronger bonds and increasing ageing resistance.

The vulcanization agent used for vulcanization of the rubber compound of this invention is sulphur. The sulphur is added at an amount of 1.8 parts by weight to the mixture. Heat is applied to the mixture by any known technique to activate the vulcanization process.

Any suitable vulcanization activators may be used. The vulcanization activators used may be zinc oxide and/or stearic acid which may be used independently or in any combination thereof. The activators may be added in an amount of 1 to 5 parts by weight and preferably, 3 to 5 parts by weight of zinc oxide and 1 to 3 parts by weight of stearic acid may be added.
Any suitable vulcanization accelerators may be used. The vulcanization accelerators used may be selected from a group consisting of guanidine, sulphonamide, thiazole and thiuram and the like, which may be used independently or in any combination thereof. These accelerators may be added in an amount of 1.5 to 2.5 parts by weight.

The vulcanization activators are preferably added to the compound before the vulcanization process. The vulcanization agent and vulcanization accelerators are added later to avoid any premature vulcanization of the rubber compound which may cause hardening and result in reduced processability of the compound.

The compound may also be selectively mixed with further components such as anti-ageing agents and anti-degradant agents.

Any suitable anti-ageing agent may be used. The anti-ageing agent used may comprise N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine added in 1 to 3 parts by weight to the compound.

Any suitable anti-degradant agent may be used. The anti-degradant agent used may comprise 2,2,4-trimethyl-1,2-dihydroquinoline added in 1 to 3 parts by weight to the compound of the present invention.

Method of Producing Motorcycle Tyre Tread

The method for producing the rubber compound of the present invention mainly comprises the following steps:

i) providing an appropriate amount of natural rubber based polymers into a mixing device;

ii) mixing the rubber polymers with said plasticizer, said neutralizing agent; and adding at a suitable time said dual-filler system in at least two separate stages;

iii) adding said vulcanization agent to the mixture of step (ii);

iv) heating the resultant mixture of step (iii) to vulcanize the compound.

Any suitable mixing device may be used. Two types of mixing devices are used in the method for producing the rubber compound of this invention. The first mixing device used
Anti-ageing agents and anti-degradant agents may be selectively added in step (ii).

The dual-filler system may be added in at least two separate stages before or during the non-productive mixing stage of step (ii). The dual-filler system may be added into the mixing device at any ratio that incorporates, disperses and distributes the silica and carbon black efficiently into the rubber component.

The dual-filler system of step (ii) may be added in two separate stages comprising 0.5:0.5 by weight ratio of carbon black and silica each stage.

The dual-filler system of step (ii) may be added in three separate stages with 0.5:0.5 by weight ratio of carbon black and silica added during the first stage; 0.125:0.125 by weight ratio added during the second stage; and 0.375:0.375 by weight ratio added during the third stage.

Adding the dual-filler system in stages will reduce the interaction of silica particles with other silica particles while maximizing the interaction of silica particles with the rubber elastomers. This will result in better reinforcement properties between the silica particles and rubber elastomers and removing the need for a tackifying resin.

The vulcanization agent is added in step (iii) to the resultant rubber mixture of step (ii).

The non-productive mixing stage of step (i) and step (ii) is subjected to a thermomechanical mixing step conducted at a temperature ranging from 30 °C to 180 °C. The thermomechanical mixing step comprises a period of suitable mixing time in a mixing device to produce a rubber compound with Mooney viscosity ranges of 55 Mooney Unit to 70 Mooney Unit (at 100 °C).

The productive mixing stage of steps (iii) is typically conducted at a temperature lower than the mixing temperature of the preceding productive mixing stages.

The vulcanization process may be conducted at a temperature ranging from 100 °C to 190 °C with cura time of about 5 to 20 minutes depending on the type of rubber compound.
steam or hot air. The vulcanization curing time for the present invention is about 15 minutes at an operating temperature of 150 °C.

Motorcycle Tyre

The motorcycle tyre manufactured using the rubber compound of the present invention does not contain any synthetic rubbers or any crude oil based plasticizers. Motorcycle tyres manufactured from the compound of this invention comprising natural rubber derived polymers exhibit low rolling resistance, good abrasion and wear resistance and improved wet traction performance as will be shown in the following examples.

The rubber compound of the present invention is advantageous for the manufacture of motorcycle tyres due to its low rolling resistance, good abrasion and wear resistance, and improved wet traction properties. This is especially useful when the motorcycle tyre is used on off-road surfaces, poorly maintained roads or laterite roads which are not optimal surfaces for a normal tyre to operate.

The rubber compound of the present invention has a wet traction index of 177 to 263 which aids in reducing the occurrence of aquaplaning. This usually occurs on wet roads with improper drainage design where excess amounts of water forms a layer between the tyre and the road which affects the traction performance of the tyres.

The rubber compound of this invention exhibits high tensile strengths of 23.1 to 27.4 MPa and elongation of 510 to 577%. Since motorcycle tyre treads are generally much thinner than normal tyres used in larger vehicles, the rubber compound must withstand higher physical forces applied onto the surface of the tread especially during off-road use without puncturing.

The rubber compound must generally resist wear and tear for at least a sufficient period of time before needing a change of tyre. The rubber compound of this invention has a crescent tear value of 107 to 120 N/mm. Being generally thinner than normal tyres, the rubber compound of a motorcycle tyre would wear off quickly if the abrasion resistance of the rubber compound is low and the rolling resistance is high. The rubber compound of the present invention provides high abrasion resistance index of 80 to 95 and low rolling resistance.
resistance index of 86 to 115 which is particularly suitable for the manufacture of motorcycle tyre treads.

Low rolling resistance will result in better fuel economy while the good abrasion and wear resistance properties as well as the improved wet traction performance will aid in better tyre performance compared to normal rubber tyres.

Also, the motorcycle tyre manufactured using the rubber compound of the present invention comprises major raw material components derived solely from sustainable sources. Reliance on crude oil and fossil fuels is reduced and impact to the environment is greatly lowered.
The following Examples illustrate the various aspects, methods and steps of this invention. These Examples do not limit the invention, the scope of which is set out in the appended claims.

Example 1

Preparation of natural rubber based elastomeric compositions reinforced with a dual-filler system and compounded with epoxidized palm oil

The elastomeric compositions for motorcycle tyre tread using natural rubber based elastomeric composition reinforced with a dual-filler system and mixed with epoxidized palm oil are shown in Table 1.

Table 1: Formulations of Natural Rubber Derived Polymers

<table>
<thead>
<tr>
<th>Blend</th>
<th>1&quot;</th>
<th>2&quot;</th>
<th>3&quot;</th>
<th>4&quot;</th>
<th>5&quot;</th>
<th>6</th>
<th>7</th>
</tr>
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<tr>
<td>1st Stage</td>
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<tr>
<td>SBR¹</td>
<td>80</td>
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</tr>
<tr>
<td>BR²</td>
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<tr>
<td>SMR 20³</td>
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<td>100</td>
<td>100</td>
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<td>60</td>
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<td></td>
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<tr>
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<td>2</td>
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<td>2</td>
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<td>2</td>
</tr>
</tbody>
</table>

2nd Stage

| | | | | | | | |
| Sulphur | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 |
| TBBΣ¹² | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| DPG¹³ | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |

* Control elastomeric composition
⁴ Comparative elastomeric composition

¹ SBR: Styrene Butadiene Rubber (Nipol® 1502 - Zeon);
² BR: Polybutadiene (Buna CB 25 - LANXESS);
³ SMR 20: Standard Malaysian Rubber 20 (Technical Specified Polyisoprene - Malaysian Rubber Board);
⁴ ENR 25: Epoxidised Natural Rubber with 25% mole epoxidation (EKOPRENA™ - Malaysian Rubber Board);
EPO: Epoxidised Palm Oil with less than 1% oxirane oxygen content (ROVPRO® 5301 - Rovski Industries Sdn Bhd);
EPO: Epoxidised Palm Oil with 1.8 - 2.0% oxirane oxygen content (ROVPRO® 5300 - Rovski Industries Sdn Bhd);

6PPD (anti-ageing agent): N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine (Santoflex® - Flexsys);
TMQ (anti-degradant agent): 2,2,4-Trimethyl-l,2-dihydroquinoline (Flectol® - Flexsys);
TBBS (accelerator): N-tert-butyl-2-benzothiazolesulphenamide (Santocure® - Flexsys);
DPG (accelerator): N,N'-Diphenylguanidine (Perkacit® - Flexsys);

The mixing was carried out in two different stages. All the ingredients were mixed at the first stage except for sulphur, TBBS and DPG, using a Banbury internal mixer (1.6 L) for about 5 minutes (1st Stage). The elastomeric composition was dumped between 145 °C to 155 °C.

The sulphur, TBBS and DPG were mixed in a two-roll mill during the second stage (2nd Stage).

The elastomeric composition was vulcanized at 150 °C for 15 minutes.

Blend 1 is a control rubber composition. Blends 2, 3, 4 and 5 are comparative rubber compositions.

Blends 2 to 5 are epoxidized natural rubber compositions reinforced with a dual-filler system and naphthenic type process oil with polycyclic aromatic hydrocarbon content of less than 10 ppm.

Blends 6 and 7 is epoxidized natural rubber and natural rubber blend elastomeric composition reinforced with a dual-filler system and mixed with epoxidized palm oil that has no polycyclic aromatic hydrocarbon content.

Example 2

Measurement of physical properties of natural rubber based polymers

The following physical properties were quantified for each blend crosslinked at 150 °C for 5 minutes.
Wet Traction and Rolling Resistance Performance

As the motorcycle tyre rotates, it experiences repeated cycles of deformation and recovery of the rubber compound. Tangent delta (\(\tan \delta\)) is expressed by the ratio of the energy lost as heat (loss modulus - \(G''\)) versus the energy stored (storage modulus - \(G'\)). This ratio represents the mechanical loss angle. The mechanical loss angle is expressed as \(G''/G'\).

Specifically, good wet traction or wet grip is predicted by a high value for \(\tan \delta\) at 0°C. Low rolling resistance is predicted by low \(\tan \delta\) value at temperatures of 60°C or higher. Good (high) wet traction and low rolling resistance will require a compromise between the two physical properties.

Tan \(\delta\) was measured under conditions of temperatures ranging from 0°C and 60°C with initial strain of 10%, a dynamic strain of ± 0.1% and a frequency of 10 Hz by employing a Rheometric Scientific Dynamic Mechanical Thermal Analyser (DMTA) IV. The results were expressed as index values determined by the following equation when the \(\tan \delta\) of Example 1 was regarded as 100. The larger index, the better the performance.

The index was calculated using the following formulas:

\[
\text{(Wet traction performance index)} = \frac{\text{\(\tan \delta\) of Example 1 at 0°C}}{\text{\(\tan \delta\) of each composition at 0°C}} \times 100
\]

\[
\text{(Rolling resistance performance index)} = \frac{\text{\(\tan \delta\) of each composition at 60°C}}{\text{\(\tan \delta\) of Example 1 at 60°C}} \times 100
\]

Abrasion Resistance Performance

A Hampden Abrasion instrument was used to measure according to the DIN standard 53516. The amount of abrasion was measured under a predetermined condition with temperatures of 20°C.

The results were shown as indexes using the value of Blend 1 of Example 1 as 100.
The index was calculated using the following formula:

\[
\text{(Abrasion resistance index)} = \frac{\text{Abrasion resistance of each composition}}{\text{Abrasion resistance of Example 1}} \times 100
\]

The following conditions were applied during measurement:

i) Tensile mechanical properties at 23°C according to ISO standard 37.

ii) Hardness in IRHD degree at 23°C according to ISO standard 48.

iii) Crescent tear at 23°C according to standard ISO 34.

The results obtained are shown in Table 2 below.

Table 2: Physical Properties Natural Rubber Derived Polymers

<table>
<thead>
<tr>
<th>Manufactured According to Example 1</th>
<th>Blend</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1*</td>
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<tr>
<td>IRHD Hardness</td>
<td>67</td>
</tr>
<tr>
<td>Tensile Strength (MPa)</td>
<td>14.0</td>
</tr>
<tr>
<td>Elongation at Break (%)</td>
<td>483</td>
</tr>
<tr>
<td>M100 (MPa)</td>
<td>1.98</td>
</tr>
<tr>
<td>M300 (MPa)</td>
<td>6.39</td>
</tr>
<tr>
<td>M500 (MPa)</td>
<td>14.5</td>
</tr>
<tr>
<td>Crescent Tear (N/mm)</td>
<td>40.0</td>
</tr>
<tr>
<td>DIN Abrasion Index</td>
<td>100</td>
</tr>
<tr>
<td>Wet Traction Index</td>
<td>100</td>
</tr>
<tr>
<td>Rolling Resistance Index</td>
<td>100</td>
</tr>
</tbody>
</table>

* Control elastomeric composition
# Comparative elastomeric composition

As can be seen, blends 2, 3, 4, 5, 6 and 7 have high tensile strength and good elongation at break. However, only blends 2, 6 and 7 exhibit moderate hardness value which are preferable for motorcycle tyre tread applications.

For blends 2, 3, 4, 5, 6 and 7, the crosslinked manufactured product obtained from the rubber composition shows significant improvement in wet traction except for blends 4, 5, 6 and 7 with slight reduction on rolling resistance. Lower rolling resistance indicates less drag force which equates to lower energy consumption and enhanced fuel economy.
Factors taken into consideration to improve the fuel economy of a particular tyre include tyre design and inflation pressure of the tyre during operation. Other factors such as vehicle weight, vehicle aerodynamic design and alignment of vehicle's tandem and steer axles will affect the fuel economy performance as well.

Also, blends 6 and 7 exhibit significant improvement on tensile properties, elongation at break and tear strength that indicates better cut resistance compared to blend 1.

Blends 6 and 7 show better performance for wet traction and cut resistance performance compared to synthetic rubber elastomeric composition as indicated by blend 1.

Generally, blends 6 and 7 comprising natural rubber based polymers reinforced with a dual-filler system and mixed with epoxidized palm oil indicate excellent wet traction and cut resistance performance while exhibiting low rolling resistance and good abrasion resistance properties.

Blend 7 shows the best physical properties for a motorcycle tyre tread although it has a slightly lower abrasion and wet traction index. Other physical properties are significantly better than that of blend 6 and hence, it is surmised that a rubber compound with blend 7 would be able to perform as well, if not better than the tyre tread from the rubber compound of blend 6.

As will be readily apparent to those skilled in the art, the present invention may easily be produced in other specific forms without departing from its scope.
CLAIMS

1. A rubber compound for the manufacture of motorcycle tyre treads comprising:
   a rubber component derived from natural rubber based polymers;
   a dual-filler system consisting of carbon black and silica;
   a plasticizer derived from epoxidized palm oil containing not more than 2% oxirane oxygen content;
   a neutralizing agent derived from calcium stearate; and
   a vulcanization agent derived from sulphur;

   wherein the tyre tread manufactured from said rubber compound exhibits low rolling resistance, good abrasion and wear resistance and improved wet traction performance.

2. A rubber compound according to claim 1, wherein said compound comprises:
   about 40 parts by weight of epoxidized natural rubber and about 60 parts by weight of natural rubber;
   about 20 to about 80 parts by weight carbon black;
   about 20 to about 80 parts by weight silica;
   about 5 to about 30 parts by weight of epoxidized palm oil containing not more than 2% oxirane oxygen content;
   about 1 to about 5 parts by weight of calcium stearate; and
   about 1.8 parts by weight of sulphur.

3. A rubber compound according to any one of the preceding claims, wherein said rubber component comprises about 10 to about 90 parts by weight of epoxidized natural rubber and about 10 to about 90 parts by weight of natural rubber.

4. A rubber compound according to claim 1, wherein said compound comprises:
   about 100 parts by weight of epoxidized natural rubber;
   about 20 to about 80 parts by weight carbon black;
   about 20 to about 80 parts by weight silica;
   about 5 to about 30 parts by weight of epoxidized palm oil containing not more than 2% oxirane oxygen content;
   about 1 to about 5 parts by weight of calcium stearate; and
   about 1.8 parts by weight of sulphur vulcanization agent.
5. A rubber compound according to any one of claims 2 to 4, wherein said epoxidized natural rubber (ENR) used is ENR with 25 mole% epoxide content.

6. A rubber compound according to any one of the preceding claims, wherein said carbon black is of a type selected from a group comprising super abrasion furnace (SAF), intermediate SAF (ISAF), high abrasion furnace (HAF) and/or easy processing channel (EPC).

7. A rubber compound according to any one of the preceding claims, wherein said silica is fumed silica or hydrated amorphous silica.

8. A rubber compound according to any one of the preceding claims, wherein said plasticizer used is epoxidized palm oil containing from about 1.8 to about 2.0% oxirane oxygen content.

9. A rubber compound according to any one of the preceding claims, wherein said plasticizer used is epoxidized palm oil containing from less than 1% oxirane oxygen content.

10. A rubber compound according to any one of the preceding claims, wherein said compound further comprises zinc oxide and/or stearic acid as vulcanization activators.

11. A rubber compound according to claim 10, wherein said zinc oxide is present in an amount ranging from about 1 to about 5 parts by weight.

12. A rubber compound according to claim 10, wherein said stearic acid is present in an amount ranging from about 1 to about 5 parts by weight.

13. A rubber compound according to any one of the preceding claims, wherein said compound further comprises vulcanization accelerators such as guanidine, sulphonamide, thiazole, and/or thiuram.

14. A rubber compound according to claim 13, wherein said compound contains about 1.5 to about 2.5 parts by weight of vulcanization accelerator.
15. A rubber compound according to any one of the preceding claims, wherein said compound further comprises an anti-ageing agent in an amount from about 1 to about 3 parts by weight.

16. A rubber compound according to claim 15, wherein said anti-ageing agent is N-((1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine.

17. A rubber compound according to any one of the preceding claims, wherein said compound further comprises anti-degradant agents in an amount from about 1 to about 3 parts by weight.

18. A rubber compound according to claim 17, wherein said anti-degradant agent is 2,2,4-trimethyl-1,2-dihydroquinoline.

19. A method for producing the rubber compound of claim 1 comprising the steps of:
   i) providing an appropriate amount of natural rubber based polymers into a mixing device;
   ii) mixing the rubber polymers with said plasticizer, said neutralizing agent; and adding at a suitable time said dual-filler system in at least two separate stages;
   iii) adding said vulcanization agent to the mixture of step (ii);
   iv) heating the resultant mixture of step (iii) to vulcanize the compound.

20. A method according to claim 19, wherein the mixing device used is an internal mixer or a two-roll mill.

21. A method according to any of claims 19 to 20, wherein addition of the dual-filler system is carried out before the non-productive mixing stage of step (ii).

22. A method according to any of claims 19 to 20, wherein addition of the dual-filler system is carried out during the non-productive mixing stage of step (ii).

23. A method according to any one of claims 19 to 22, wherein the dual-filler system of step (ii) comprising 0.5:0.5 by weight ratio of carbon black and silica is added in two separate stages.
24. A method according to any one of claims 19 to 22, wherein the dual-filler system of step (ii) is added in three separate stages with 0.5:0.5 by weight ratio of carbon black and silica added during the first stage; 0.125:0.125 by weight ratio added during the second stage; and 0.375:0.375 by weight ratio added during the third stage.

25. A method according to any one of claims 19 to 24, wherein step (i) to step (ii) is conducted at a temperature ranging from about 145 °C to about 155 °C.

26. A method according to any one of claims 19 to 25, wherein said step (iv) is conducted at a temperature ranging from about 100 °C to about 190 °C.

27. A method according to any one of claims 19 to 26, wherein a vulcanization activator such as zinc oxide and/or stearic acid is further added in step (iii).

28. A method according to any one of claims 19 to 27, wherein an anti-ageing agent is further added in step (ii).

29. A method according to any one of claims 19 to 28, wherein an anti-degradant agent such is further added in step (ii).

30. A motorcycle tyre comprising
   a body; and
   a tread, said tread produced from the rubber compound according to any one of claims 1 to 29.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

C08L 7/00 (2006.01)  C08L 15/00 (2006.01)  C08K 5/04 (2006.01)  B60C 1/00 (2006.01)

According to International Patent Classification (IPC) or both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPPODOC; WPI, CAPLUS, Google Scholar: Natural Rubber, polyisoprene, epoxidised, oxirane, plasticiser, Tire, tread, compound, composition, Palm Oil and similar

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
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<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<td>X</td>
<td>Further documents are listed in the continuation of Box C</td>
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  "A" document defining the general state of the art which is not considered to be of particular relevance
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  "&" document member of the same patent family

Date of the actual completion of the international search
5 August 2013

Date of mailing of the international search report
05 August 2013

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FormPCT/ISA/210 (fifth sheet) (July 2009)
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<td>KR 10201 10072260 A (HANKOOK TIRE CO LTD) 29 June 2011 Abstract; Para 0040, Table 1</td>
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<td>X</td>
<td>JP 2007-099892 A (THE YOKOHAMA RUBBER CO LTD) 19 April 2007 Abstract; Para 001 1-0012</td>
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<td>A</td>
<td>WAN, N.Y. et al., 'Comparison of epoxidised natural rubber (em) 37.5 and em 25/ em 50 physical blend: specialty polymer for 'green tyre'application', IOP Publishing, IOP Conf. Series: Materials Science and Engineering 11 (2010) 012004, doi: 10.1088/1757-899X/11/1/012004 Page 1, last Paragraph; Page 2, Table 1</td>
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<td>A</td>
<td>KR 10200901 16171 A (KUMHO TIRE CO INC) 11 November 2009 Abstract</td>
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This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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<td>29 Jun 2011</td>
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<td>KR 1020090116171 A</td>
<td>11 Nov 2009</td>
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End of Annex