

TYRE BALANCING COMPOSITION.

FIELD OF INVENTION.

The present invention relates to chemically inert, low density gel compositions for use in eliminating imbalances in motor vehicle wheel assemblies, a method for preparation of such compositions as well as the use of such compositions.

BACKGROUND OF THE INVENTION.

Imbalance in a truck or car wheel assembly (tyre plus rim) due to imperfect tyres or rims causes vibrations which, apart from the discomfort to the driver and any passengers, dramatically can increase the tyre wear as well as mechanical wear. Traditionally imbalance is remedied by fastening lead weights on the wheel rim. However, this balancing technique, being of a static nature, cannot compensate for changes in load (i.e. deformation of the tyres), uneven wear of the tyres, dirt collection of the rim, and the like. Therefore the balancing by lead weights must be repeated several times during the life time of a tyre.

The present invention is based on the fact that vibrations caused by imbalance in a wheel assembly can induce a motion in a liquid inside the tyre in a direction that will diminish the vibrations and the imbalance. However, to utilize this "vibrational pressure" to achieve balancing of a wheel assembly (that is the gravitational center is in the intersection between the rotational plane and the axis of rotation) is by no means trivial. If a free flowing liquid such as water is introduced into a spinning tyre, any movement of this mass caused by a "vibrational pressure" would immediately be counteracted by the centrifugal force, which frequently exceeds 100xg during normal driving, resulting in an oscillating movement of the liquid with no balancing effect.

SUMMARY OF THE INVENTION

I have now invented certain gels in which the movement caused by the vibrational pressure in an imbalanced wheel assembly is only offset to a certain extent by the centrifugal force, allowing a steady state to be formed in which the gels are not evenly distributed around the inner rim of the tyre (by

even distribution, I refer to distribution around the inner rim of the tyre, due to the centrifugal force in such a way that the surface of the gel is always at the same distance from the rotational axis). The equilibrium distribution is determined by the density and the viscoelastic (rheological) properties of the composition, the vibrational pressure (the amplitude and frequency of the vibrational waves), and the centrifugal force excised on the composition. The vibrational pressure caused by imbalance is determined by the amount (weight) of the imbalance, the weight of the motor vehicle (pressure on the tyres) and the speed of the motor vehicle in a roughly proportional manner, i.e.

Vibrational Pressure =

Constant x (Weight of Imbalance)x(Vehicle weight)x(Vehicle Speed)

It is of importance to notice that this Vibrational Pressure is independent of the properties of the balancing gel and the diameter of the tyre.

The centrifugal force excised on a composition located on the inside rim of a tyre is proportional with the density of the composition and the square of the rotational speed. The stress caused by the centrifugal force in such a composition, if unevenly distributed, can be estimated by the equation:

$$\Delta P = [dxV^2/(12,96xr)]x(r-r_1)$$

where ΔP is the pressure drop (in Pascal) between the parts of the unevenly distributed balancing composition at distances (in meters) r_1 and r respectively from the axis of rotation, d is the density of the balancing composition (kg/m^3), V is a dimensionless number equal to the speed of the vehicle in kilometers per hour (KMH), r is the inner radius of the tyre, and r_1 is the distance from the rotational axis to the "top" layer of the balancing material. The actual stress is determined by the distance between the thinnest and the thickest parts and by the pressure drop (the "slope" of the balancing composition).

The displacement of a balancing gel required to offset a certain imbalance is determined by the weight and the nature of the imbalance as well as by the diameter of the tyre.

Lets consider an extreme case, a standard 22 inch truck tyre with a static imbalance of 300 g in one heavy spot. 300 g is the maximum imbalance encountered in practice. In order for the balancing composition to balance this heavy spot the sloping layer should contain $300 \times \pi^2/4$ g of mass, that is 740 g. The width of the balancing composition layer is of the order 10 cm. Assuming that the specific weight of the balancing composition is 900 kg/m^3 and that the thickness of the film increases linearly to its thickest point opposite the heavy spot, we can calculate that the film is approximately 3.3 mm thicker at the point opposite the heavy spot corresponding to a stress of approximately 14 Pa.

A similar calculation for a standard 11 inch car tyre with a static imbalance of 90 g in one heavy spot (90 g is the maximum imbalance encountered in practice), assuming that the width of the balancing composition layer is of the order 7 cm, indicates that the film is approximately 2.3 mm thicker at the point opposite the heavy spot corresponding to a stress of approximately 19 Pa.

Using the estimates and the formula above I reach the estimates shown in Table 1 for pressure drops and stress induced by the centrifugal force on the balancing composition.

Table 1

Stress induced in unevenly distributed balancing gel by centrifugal force in rolling tyres of varying diameter.

d kg/m ³	V km/h	TRUCK			PASSENGER CAR			TRUCK ΔP Pa	CAR ΔP Pa	TRUCK Stress Pa	CAR Stress Pa
		r m	η m	Imbalance g	r m	η m	Imbalance g				
900	120	0.5	0.501	92	0.3	0.301	38	2000	3333	1	4
900	120	0.5	0.502	183	0.3	0.302	77	4000	6667	5	14
900	120	0.5	0.503	275	0.3	0.303	116	6000	10000	11	32
900	120	0.5	0.504	367	0.3	0.304	154	8000	13333	20	57
900	120	0.5	0.505	459	0.3	0.305	193	10000	16667	32	88
900	120	0.5	0.506	550	0.3	0.306	231	12000	20000	46	127
1100	120	0.5	0.501	112	0.3	0.301	47	2444	4074	2	4
1100	120	0.5	0.502	224	0.3	0.302	95	4889	8148	6	17
1100	120	0.5	0.503	336	0.3	0.303	141	7333	12222	14	39
1100	120	0.5	0.504	448	0.3	0.304	188	9778	16296	25	69
1100	120	0.5	0.505	561	0.3	0.305	235	12222	20370	39	108
1100	120	0.5	0.506	673	0.3	0.306	283	14667	24444	56	156

By careful tuning of the density and the viscoelastic properties of the gel composition a perfect, self adjusting balancing of a tyre assembly can be achieved by just introducing such a composition into the tyre (tube tyres or tubeless). The Gel is either introduced through the valve stem of the tyre or spread evenly around the inner rim with a spatula before mounting the tyre. After driving 2-10 km all vibrations due to imbalance cease.

The most important rheological properties of the balancing composition are its Storage Modulus, G' , and its Loss Modulus, G'' . G' is a measure of the strength of the gel, that is the strength and the number of bonds between the molecules of the gel former. I have found that in order to achieve satisfactory balancing properties the value of G' should be in the range 3000 to 15000 Pa. A strain sweep of a functional balancing gel is shown in Fig. 1. A very satisfactory balancing composition has a value of G' around 9000 Pa. A typical shear stress/viscosity-shear rate curve for a well working balancing composition is shown in Fig. 2. The lower limit of G' for a well functioning balancing composition has been determined experimentally to be 3000 Pa. According to the theoretical reasoning above, the density of the balancing gel should be irrelevant. However, to my surprise I have discovered that the density of the balancing gel is indeed of great importance. In practical tests low density gels ($d < 900 \text{ kg/m}^3$) based on various hydrocarbon oils consistently performed much better than high density gels ($d > 1000 \text{ kg/m}^3$) based on various thickened glycols. This was particularly true for passenger cars and buses, where high density compositions failed irrespective of viscoelastic properties.

Of equal importance as the density and the viscoelastic properties is the long term stability in service of the balancing gel, the performance at various temperatures of the gel, and the chemical inertness of the gel.

An acceptable tyre balancing gel must remain functional during the life time of the tyre and under the various driving conditions, in particular it must remain functional within the normal driving speed interval, 0 to approximate 160 KMH, and within the normal temperature range, -30°C to $+90^\circ\text{C}$, experienced in service. Furthermore, the tyre balancing gel must not have any harmful effect on the tyre, in particular it should not affect the inner lining of the tyre or cause any damage to the cord or other tyre parts if it accidentally reaches such parts (i.e. by puncture of the tyre).

MINIMUM CRITERIA FOR A FUNCTIONAL BALANCING GEL

Rheology: $3000 \text{ Pa} < \text{Storage Modulus (G')} < 15000 \text{ Pa}$.

Loss Modulus (G'') $\leq$ G'. Critical yield Stress $> 25 \text{ Pa}$.

Specific gravity $< 1000 \text{ kg/m}^3$

Volatility: Less than 6% (by weight) evaporation loss after 10 hours at 99°C

Pour point of base liquid: $< -15^\circ\text{C}$ (ASTM D97)

Solubility: Insoluble in water, hydrophobic

Separation stability: Less than 1% separation (by weight) of the base oil after 24 hours at $125 \times g$ and 100°C .

Chemical reactivity: No effect on rubber or other polymers, non-corrosive to metals.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 Shows a plot of the logarithm of the Storage Modulus, G' (in Pa) versus the strain (in m) for the composition described in Example 1.

Fig. 2 Shows a plot of the logarithm of the shear stress (in Pa) versus the shear rate (in s^{-1}) for the composition described in Example 1. The left hand end point of the plot curve corresponds to the critical yield stress (174 Pa), i.e. the stress at which break down of the gel network sets in resulting in a drop in the viscosity of the composition.

Fig. 3 Shows the results of an oscillation test of the composition described in Example 1.

DETAILED DESCRIPTION OF THE INVENTION

Based on the criteria mentioned above and extensive experiments and field evaluations a number of functional balancing gels have been invented.

The inventive compositions comprise three major components, namely, an oil, a gel former, and a viscosity index improving agent.

Among the oils useful in the practice of the invention are paraffinic or naphthenic oils having a maximum specific gravity of 880 kg/m^3 at 25°C and a maximum pour point (ASTM D 97) of -15°C ; polybutene oils having a maximum specific gravity of 900 kg/m^3 at 25°C and a maximum pour point (ASTM D 97) of -15°C ; synthetic or naturally occurring polyol esters, such as pentaerythritol esters of fatty acids, castor oil and jojoba oil; and alkyl

ethers of polyols or polyglycols, such as alkyl polypropylene glycol ethers. Other oils which are expected to be useful in the practice of the invention other synthetic hydrocarbon oils such as polypropylene oils and poly-alpha-olefins.

Specific examples of oils useful in the practice of the invention are 1) a polybutene oil having kinematic viscosity as per ASTM D445 of about 50 cSt at 99 °C, pour point per ASTM D 97 of -26 °C, specific gravity 868 kg/m³, and average molecular weight 610, available from Amoco Chemical Company, Chicago, Illinois, U.S.A., under the trade designation H-25; 2) No. 1 Castor oil which is a mixture of the glyceryl triesters of ricinoleic acid (approximately 89.5%), linoleic acid (approximately 4.2%), oleic acid (approximately 3.0%), palmitic acid (approximately 1.0%), stearic acid (approximately 1.0%), dihydroxystearic acid (approximately 0.7%), linolenic acid (approximately 0.3%), and eicosanoic acid (approximately 0.3%); and 3) an alkyl polypropylene glycol ether having kinematic viscosity as per ASTM D445 of about 36.9 cSt at 100 °C, pour point per ASTM D 97 of -29 °C, specific gravity 985 kg/m³, and average molecular weight 2080, available from Union Carbide Corporation, Danbury, Connecticut, U.S.A., under the trade designation UCON LB 1145.

Gel formers useful in the practice of the invention are fumed silica (hydrophobic or hydrophilic), asbestos fibers, bentonite clay and metal soaps.

Specific examples of gel formers useful in the practice of the invention are a polydimethylsiloxane-coated fumed silica having a BET surface area of 90 +/-20 m²/g containing approximately 5% chemically bonded carbon, available from Degussa under the trade designation Aerosil® R202, and a fumed silica having a BET surface area of 200 +/-20 m²/g, available from Cabot Corporation under the trade designation Cab-O-Sil M-5.

Among the viscosity index improving agents useful in the practice of the invention are poly-alkyl-methacrylates (PAMA), styrene-ethylene-butylene-styrene block copolymers (SEBS), styrene-ethylene-propylene block copolymers (SEP), polyisobutylenes, ethylene-propylene copolymers, hydrogenated butadiene-styrene-copolymers, polymers of fumaric acid esters and maleic acid esters, and various polyhydroxycarboxylic acid amides.

Specific examples of viscosity index improvers useful in the practice of the invention are, a PAMA of average molecular weight 480.000 available from Röhm GMBH Chemische Fabrik, Darmstadt, Germany under the trade designation Viscoplex® 2-500, a SEP having a styrene/rubber ratio of 37/63, specific gravity 0.92, and tensile strength, psi of 300, available from Shell Chemical Company, Houston, Texas, U.S.A., under the trade name Kraton® G-1701X, and a proprietary polyhydroxycarboxylic acid amide mixture available from BYK-Chemie U.S.A., Connecticut, U.S.A., under the trade name BYK-405.

A composition according to the invention typically comprises between about 80 and about 95 % by weight of the oil, between about 4 and about 15 % by weight of the gel former, and between about 1 and about 5 % by weight of the viscosity index improving agent.

Optionally, the composition may also comprise minor amounts of corrosion inhibitors and anti-oxidants.

The gelling effect of the gel formers on the oils is accomplished by the formation of a network of the molecules of the gel former through hydrogen bonding via hydroxy groups or via van der Waals attraction between segments molecules of of the gel former. The number and the strength of these bonds determines the gel strength, and the ability of the gel to support a load (critical yield stress). In Figures 1-3 is given a complete rheological characterization of a functional tyre balancing gel (Example 1). At loads above the critical yields stress (strong vibrational pressure caused by imbalance) the network breaks down and the composition assumes liquid like character.

An extensive series of compositions satisfying the rheological criteria mentioned above have been prepared using the types of oils and gel formers given above. However none of them satisfies the endurance criteria. All the gel formers have a higher density than the oil, and under the influence of the centrifugal force in a rolling tyre, separation invariably occurs after a while. This separation is further aggravated by the increase in temperature (up to 70 °C in normal use) due to friction against the road surface, which decreases the viscosity of the oil. Due to the requirement for low temperature functionality and the effect on the elasticity (becomes too high) of the balancing composition base oils of higher viscosity cannot be

used. In the present invention I have discovered that this problem can be solved by the addition of viscosity index improving agents.

Exemplary compositions that were studied are shown in Table II.

TABLE II

Ex. No.	L-100*	H-25	No.1 Castor oil	Ucon LB1145	Kraton® 1701X	BYK® -405	Viscoplex® 2-500	Aerosil® R202	Cab-O-Sil M-5	Functional test
	%Wt	%Wt	%Wt	%Wt	%Wt	%Wt	%Wt	%Wt	%Wt	
1		88,5			1,5			9,0		Pass
2		91,5			1,5			7,0		Pass
3	88,5				2,0			9,5		Pass
4	90,5				2,0			7,5		Pass
5		87,0					4,0	9,0		Pass
6		89,0					4,0	7,0		Pass
7		91,0						9,0		Fail#
8	91,0							9,0		Fail#
9			90,0				2,0	8,0		Pass
10			92,8			1,2			6,0	Pass
11			90,8			1,6		8,0		Pass
12			94,0						6,0	Fail#

*Polybutene oil from Amoco, having kinematic viscosity as per ASTM D445 of about 220 cSt at 38 °C, pour point per ASTM D 97 of -35 °C, specific gravity 850 kg/m³, and average molecular weight 460.

These compositions failed in the separation test, although the rheological criteria were satisfied.

The compositions were prepared by known methods.

The resulting compositions were evaluated by rheometry with a computerized Bohlin VOR Rheometer System (from Bohlin Rheology, Lund, Sweden) and in field test using passenger cars, trucks and buses. The car tyres were supplied with 500 g of the balancing gels, either by applying the gel to the inner perimeter of the tyre before mounting or by introduction through the valve stem. The bus or truck tyres were supplied with 1 kg of the gels in the same manner as for the passenger cars. Both tubeless and tube tyres were included in the tests, and no difference in balancing capability between the two kinds of tyres was observed.

The efficacy and durability of a composition was evaluated by measuring vibrations from the wheel assemblies during a period of 50.000 km driving. Composition that balanced perfectly (no discernible vibrations) in this test,

and that showed less than 2% separation of the oil after inspection by the end of the test, were deemed functional.



What is claimed is:

1. A tyre balancing gel contained within the air cavity of a motor vehicle tyre, CHARACTERIZED IN THAT the gel comprises

(a) 80 to 95% by weight of oil, or mixture of oils, selected from the class consisting of

- (i) polybutene oil of maximum specific gravity of about 900 kg/m^3 and a pour point (ASTM D97) of less than $+2^\circ\text{C}$,
- (ii) paraffinic or naphthenic oils having a maximum specific gravity of about 900 kg/m^3 and a pour point (ASTM D97) of less than $+2^\circ\text{C}$,
- (iii) Castor oil and other polyol esters having a pour point (ASTM D97) of less than $+2^\circ\text{C}$,
- (iv) Polypropyleneglycol alkyl ethers having a pour point (ASTM D97) of less than $+2^\circ\text{C}$,
- (v) polypropylene oil having a pour point (ASTM D97) of less than $+2^\circ\text{C}$,

(b) 4 to 15 % by weight a gel former selected from the class consisting of

- (i) fumed silica having a BET surface in the range from about 50 to about $400 \text{ m}^2/\text{g}$
- (ii) metal soaps
- (iii) clay

(c) up to 5% of a viscosity index improving agent selected from the class consisting of

- (i) Poly-alkyl-methacrylates with a molecular weight of about 100,000 to about 900,000
- (ii) styrene-ethylene-butylene-styrene block copolymers and styrene-ethylene-propylene block copolymers having a styrene rubber ratio between about 13/87 and about 37/63
- (iii) polyisobutylenes.
- (iv) polyhydroxycarboxylic acid esters or amides

the balancing gel having a Storage Modulus (G') between 3000 Pa and 15000 Pa at 22°C , a Loss Modulus (G'') smaller than the Storage Modulus, a Critical Yield Stress exceeding 15 Pa at 22°C , a Specific Gravity less than 1000 kg/m^3 at 22°C , an evaporation loss of less than 6% (by weight) after 10 hours at 99°C , and an oil separation of less than 1% after 24 hours at $125 \times g$ and 100°C .



2. A composition as claimed in claim 1 in which the Storage Modulus at 22°C is about 9500 Pa.
3. A composition as claimed in claim 2 in which the base oil is a polybutene oil having kinematic viscosity as per ASTM D445 between 1005 and 8910 SUS at 38 °C, a pour point per ASTM D 97 between -35 and -15 °C, a specific gravity between 850 and 890 kg/m³, and an average molecular weight between 460 and 750, the gel former is a hydrophobic fumed silica having a BET surface area of between 70 and 400 m²/g, and the viscosity index improver is a styrene-ethylene-propylene block copolymer having a styrene/rubber ratio of 37/63.
4. A composition as claimed in claim 2 in which the base oil is castor oil having kinematic viscosity of 25 cSt at 25 °C and a specific gravity of 950 kg/m³, the gel former is a hydrophilic or hydrophobic fumed silica having a BET surface area of between 70 and 400 m²/g, and the viscosity index improver is a polyhydroxycarboxylic acid amide.
5. A composition as claimed in claim 2 in which the base oil is an alkyl polypropylene glycol ether having kinematic viscosity as per ASTM D445 of about 36.9 cSt at 100 °C, pour point per ASTM D 97 of -29 °C, specific gravity 985 kg/m³, and average molecular weight 2080, the gel former is a hydrophilic or hydrophobic fumed silica having a BET surface area of between 70 and 400 m²/g, and the viscosity index improver is a polyhydroxycarboxylic acid amide.
6. A method for balancing a motor vehicle wheel assembly comprising applying to the inner surface of the tyre, either directly or indirectly through the valve stem of the tyre, a gel balancing composition according to any of the claims 1 - 5, mounting the wheel assembly on a motor vehicle, and driving the vehicle for a distance sufficient to allow the balancing composition to balance the wheel assembly.