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TECHNICAL BULLETIN

EPDM Engine Mounts

Abstract

Increasingly hostile under-the-hood environments have led to an examination of EPDM as a replacement for natural rubber in automotive engine mounts. Thermal carbon black (N990) is widely used in natural rubber anti-vibration applications due to its ability to provide superior dynamic properties, compared to other types of carbon black. It is also used in many applications to provide better heat resistance. This report is intended as a reference for mount manufacturers in evaluating various types and loadings of carbon black in new-generation EPDM engine mount compounds. The thermal black compounds were shown to have good physical properties and in particular, superior rubber-to-metal adhesion. The formulations and data provided will serve as a reference for further compound development.

Background

Smaller engine compartment sizes and stricter emission control specifications are increasing the environmental temperatures of many automotive engine mounts. In many cases, the temperatures are above what is recommended for natural rubber.

Natural rubber is widely used in vibration applications such as automotive engine mounts because of its excellent strength, fatigue resistance, high resilience and low level of strain sensitivity. It is the elastomer of choice for the majority of applications involving high stress and cyclic flexing. However, natural rubber is characterized by poor resistance to oxygen, ozone, hydrocarbon solvents and heat. NR is not suitable for many applications that require long-term resistance to continuous temperatures in excess of 100°C or exposure to oils and solvents.

Ethylene propylene diene monomer (EPDM), in contrast, has excellent resistance to heat, oxidation and ozone, as well as to oils and chemicals, including ethylene glycol. The use of proper curatives and fillers can provide good compression set properties, but EPDM does not possess the resilience and dynamic fatigue resistance of natural rubber.

Nonetheless, EPDM is the leading candidate for replacement of natural rubber in automotive engine mount applications. Rising under-the-hood temperatures and the use of hydraulic engine mounts (for which resistance to ethylene glycol is required property) are driving the consideration of EPDM worldwide. EPDM manufacturers have given the subject substantial review. High molecular weight grades of oil-extended EPDM are now commercialized for this application.

However, there are still questions remaining on the dynamic capability of EPDM and compound design, including the filler system. The use of a peroxide cure system has been recommended due to the high temperature stability provided, but this has been at the expense of resilience and results in a higher compound cost over a sulphur system. As EPDM has no polar groups or groups with high electron density, it is difficult to bond to metals. Using a high oil content EPDM would also have an adverse effect on bonding. Thus several questions remain on the inherent deficiencies of EPDM.

Thermax® medium thermal carbon black (N990) is well known for its use in anti-vibration applications such as engine mounts because of its positive effect on dynamic properties. A non-reinforcing black, it is characterized by a large particle size and low particle agglomeration. It is widely accepted for applications requiring high rebound, low hysteresis and low tan delta. With a mean particle diameter of 250 nm, N990 has the largest particle size black of all carbon blacks. Combined with low particle structure (typical DBP: 38 ml/100g), thermal black allows rubber to maintain its inherent elastomeric properties, even at high loadings.

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Experimental

The base formulation was a reference compound (#1) provided by DSM Co-Polymer. With a calculated target hardness of Shore A 50, the following filler systems were evaluated:

1. N990/N550 blends a various loadings
2. N990 compound
3. N990/N358 blend (N358 is high structure, super processing furnace black)
4. N990/N326 blend (N326 is a low structure, high abrasion furnace black)

Compound preparation, mixing and analysis were performed at the BFGoodrich Laboratory in Brecksville, Ohio. Dynamic testing was performed at Experimental Services Inc. in Akron, Ohio. Adhesion testing was performed at Lord Corporation.

Filler loadings were considered with the basic requirements for engine mounts and other anti-vibration products in mind, as follows:

1. Low dynamic to static spring ratio, low tan delta
2. Target Hardness Shore A 50
3. Acceptable high temperature and aging properties
4. Good compound processing
5. Acceptable compound cost

The DSM grade DE304, an ultra fast curing oil-extended EPDM developed for engine mount applications, was used for this evaluation. Similar grades recommended by other polymer manufacturers for this application include Buna T 5459, JSR EP 98, Royalene 645, Vistalon 3666 and Nordel 1470 (Note: Manufacturers should be consulted for proper grade selection). A peroxide cure system was selected for optimum high temperature properties, with Perkadox 14/40, a' bis(t-butylperoxy) diisopropyl benzene at 40% active (Akzo Nobel). The small amount of sulphur utilized is known to improve fatigue resistance.

Compound Properties/Results

Rheometer data indicates similar processing properties, with slightly longer cure times for the compounds that were highly extended with carbon black (3, 4, 5 & 9). Mooney viscosity and scorch data were influenced by the low surface area/chemically inactive thermal black. This is particularly evident in compound #5, with 147 parts of N990 and compound #8, with 55 parts N990 and 40 parts low structure N326, having the lowest viscosity. The results are typical of thermal black compounds, i.e. low viscosity and longer scorch time, due to the inactive surface chemistry, low surface area and low structure of the carbon particles.

The stress-strain results reflect the properties of the individual carbon blacks and their respective loadings. Hardness results ranged from 47.9 for the 21/40 blend of N990/N358, to 51.9 for the compound with 147 parts of N990. Lower tensile strength was evident in the compound with the low structure N326/N990 blend. Tear resistance, in both original and aged tests, was low in the compounds with the higher structure N358 and with the lower levels of the reinforcing blacks. Of note, the compound with 147 parts of N990 had the highest tear resistance.

To evaluate high temperature resistance the samples were aged for 28 days @ 120°C. Compounds #5 and #8 had the least amount of change in 100% Modulus, and for Compound #5 with 147 parts of N990, there was no change in tensile strength. The increase in hardness ranged from 3% – 8% above the original, reflecting the good high temperature resistance of EPDM.

Compression set ranged from 5.5% in the compound with 52 parts of N990 and 32 parts of N358, to 8.5% in Compound #9, with 100 parts of N990 and 16 parts of N358. Rebound properties were similar at roughly 66% for all compounds.

Dynamic Properties

Dynamic testing was performed on an MTS Model 831, at 23°C, 100°C and 125°C. At all three temperatures, tan delta (K"/K') values and the dynamic stiffness ratio were essentially equal. No loss in dynamic properties was seen in the highly loaded compounds nor in the compounds with the high structure N358. None of the compound changes gave any significant change in rebound, loss tangent or spring rate ratios. Higher temperatures gave a large decrease in loss tangent values and a slight decrease in spring rate ratio (Kd/Ks). However, all of the compounds exhibited the same trends.

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Adhesion Testing

Adhesion testing was performed at Lord Corporation according to ASTM D 429B. Three different systems were selected (Chemlok 207/259 and Chemlok 205/252X solvent adhesive systems and Chemlok 8007/8560 aqueous adhesive system). It is noteworthy that increased levels of N990 tended to give higher adhesion pull values. Compound #5, for example, had the highest pull values with all three of the adhesive systems evaluated. Compounds #9 & #10, with 100 parts and 84 parts respectively, also had high pull values. This effect is typical of N990 and may be attributed to the inactive surface chemistry.

Conclusion

Compounds with high loadings of thermal black provide low viscosity, scorch safety and had enhanced aging properties. Thermal black loaded compounds provide good compression set, good rebound and dynamic properties. High loadings of thermal black were also shown to give substantial improvement in metal adhesion.

Thermal black is an excellent choice of filler to be incorporated into EPDM engine mount formulations.

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Compound No.:	1	2	3	4	5	6	7	8	9	10
EPDM DE 304	175	175	175	175	175	175	175	175	175	175
N550	62	50	40	20	-	-	-	-	-	-
Thermax® N990	-	28	52	100	147	52	21	55	100	84
N358	-	-	-	-	-	32	40	-	16	20
N326	-	-	-	-	-	-	-	40	-	-
Sunpar 2280	5	5	5	5	5	5	5	5	5	5
Stearic Acid	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
TEA	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
ZnO	5	5	5	5	5	5	5	5	5	5
S-80	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Perkadox 14/40	9	9	9	9	9	9	9	9	9	9
Total	**258.4**	**274.4**	**288.4**	**316.4**	**343.4**	**280.4**	**257.4**	**291.4**	**312.4**	**300.4**
Rheometer (ASTM D 2084 – 91), 1° arc, 175°C (340°F)										
Min. Torque, dNm	12.3	12.8	12.4	12.7	12.5	12.4	12.1	11.9	12.1	11.8
Max. Torque dNm	30.5	31	31.3	32.5	33.3	31.9	30.3	30.6	32.3	31.6
Ts2, minutes	1.46	1.46	1.39	1.3	1.27	1.41	1.52	1.32	1.34	1.42
Tc50, minutes	3.05	3.11	3.13	3.08	3.08	3.1	3.16	2.92	3.07	3.1
Tc95, minutes	14.04	14.41	15.09	15.37	15.43	14.27	14.27	13.97	14.74	14.43
CRI	10.81	10.47	10.15	9.43	9.48	10.54	10.63	11.1	10.15	10.31
Mooney Viscosity/Scorch, 140°C (275°F)										
Min. Torque, M. units	69.92	70.36	69.38	67.43	67.32	69.22	69.06	67.76	67.65	66.73
S5, minutes	6.92	7.5	6	5.75	4.17	7.92	7.75	6.75	6.5	7.17
S35, minutes	13.17	14.17	13.33	13.58	15.08	15.25	14.42	16.83	14.67	15.25
S35 – S5, minutes	6.25	6.67	7.33	7.83	9.41	7.33	6.67	10.08	8.17	8.08
Mooney Viscosity/Scorch, 100°C (212°F)										
Torque @ 4 minutes	84.28	82.6	80.54	77.07	75.72	80.92	82.16	75.34	77.51	77.51
Stress-Strain (ASTM D 412 - 92)										
100% Modulus, MPa	1.2	1.3	1.3	1.4	1.6	1.3	1.1	1.3	1.4	1.3
300% Modulus, MPa	6.8	7	6.9	6.4	6	7.2	6.3	6	6.7	6.5
Tensile, MPa	12.6	11.6	13	11.6	11.5	11.2	10.4	7.8	11	11.3
Elongation (%)	424	404	446	463	510	392	404	363	419	431
Shore A Hardness	48.5	48.9	48.9	50.1	51.9	49.2	47.9	48	50.2	50.4
Stress-Strain (ASTM D 412 - 92), aged 28 days @ 120°C										
100% Modulus, MPa	1.45	1.47	1.61	1.69	1.77	1.51	1.32	1.42	1.55	1.67
(% retained)	(121)	(113)	(124)	(121)	(110)	(116)	(120)	(109)	(111)	(128)
300% Modulus, MPa	7.25	7.05	7.35	7.23	6.75	7.53	6.62	6.02	6.81	7.25
(% retained)	(107)	(101)	(107)	(113)	(113)	(105)	(105)	(100)	(102)	(112)
Tensile, MPa	14.1	12.32	13.13	12.33	11.5	12.59	11.98	8.83	11.63	11.87
(% retained)	(112)	(106)	(101)	(106)	(100)	(112)	(115)	(113)	(107)	(105)
Elongation (%)	434	419	435	441	458	410	422	384	442	424
(% retained)	(102)	(104)	(98)	(95)	(90)	(105)	(104)	(106)	(105)	(98)
Shore A Hardness	51.6	51.9	51.7	53.7	55.6	52.4	50.8	52	53.2	52.3
(% retained)	(106)	(106)	(105)	(107)	(107)	(106)	(106)	(108)	(105)	(103)

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Compound No.:	1	2	3	4	5	6	7	8	9	10
Die "C" Tear (ASTM D624-91)										
Tear resistance, kN/m	24.3	24.3	22.4	22.7	25.9	20.7	21.7	21.7	21.4	22.4
Die "C" Tear (ASTM D624-91), aged 28 days @ 120°C										
Tear resistance, kN/m	21.3	23.4	21.7	21.6	22.4	19.1	17.8	19.7	18.8	18.4
(% retained)	(88)	(96)	(97)	(95)	(86)	(92)	(82)	(91)	(88)	(82)
Compression Set (ASTM D 385 – 89), Method B, 24 hours @ 120°C										
(% Set)	6	6.6	6.4	6	6.1	5.5	6.6	6.6	8.5	7.9
Zwick Rebound										
(% Rebound)	66.3	64.4	66.4	65.5	65.7	66.4	67.1	66.2	67.4	66.9
Dynamic Properties, 23°C										
Static Rate (N/mm)	194.6	208.1	215.8	226.3	246	222.4	204.8	202.7	231.5	221.5
K*(100 Hz), (N/mm)	348.1	375.5	381.5	403.4	433	388.2	358.2	350.5	401.4	384.3
Loss Tan (100 Hz)	0.1315	0.1309	0.129	0.1276	0.1285	0.1272	0.1248	0.121	0.1241	0.1224
Kd/Ks	1.79	1.8	1.77	1.79	1.76	1.75	1.75	1.73	1.74	1.74
Dynamic Properties, 100°C										
Static Rate (N/mm)	213.8	230.7	232.5	249.4	275.7	244.5	227.2	220.9	262.8	247.5
K*(100 Hz) (N/mm)	329.9	359.5	370.7	391.1	419.8	372.2	346.9	338.2	393.3	374.2
Loss Tan (100 Hz)	0.0765	0.078	0.079	0.0807	0.0819	0.0735	0.0714	0.0703	0.0742	0.0725
Kd/Ks	1.55	1.56	1.6	1.57	1.53	1.53	1.53	1.54	1.5	1.52
Dynamic Properties, 125°C										
Static Rate (N/mm)	230	237.8	240.7	248	272.5	243.6	230.6	228.2	271	255.2
K*(100 Hz) (N/mm)	356.2	370.8	382.2	407.2	433.2	388	361.2	351.9	410.2	387.6
Loss Tan (100 Hz)	0.0635	0.067	0.0664	0.0692	0.071	0.0642	0.0619	0.0618	0.0654	0.064
Kd/Ks	1.55	1.56	1.59	1.64	1.59	1.6	1.57	1.55	1.52	1.52
Adhesion (to zinc phosphatized steel), ASTM D429B, 45° angle pull @ room temp.										
CH207/CH259 (N/mm)	10.2	14.2	13.7	15.2	16.4	10.6	9.6	11.8	13.6	11.5
	95R	100RC	100RC	100RC	100RC	100RC	100RC	100RC	100RC	100RC
	5RC									
CH205/CH252X (N/mm)	11.2	13.2	14.1	13.5	15.6	10.5	9.9	12.3	12.4	14.2
	100RC	100RC	100RC	100RC	100RC	100RC	95R	100RC	100RC	100RC
							5RC			
CH8007/CH8560 (N/mm)	9.3	12	11	12.9	14.4	9.7	8.4	12.7	10.8	10.3
	70R	65R	25R	95R	100RC	100RC	90R	80R	90R	100RC
	30RC	35RC	75RC	5RC			10RC	20RC	10RC	
ADHESION (to zinc phosphatized steel), ASTM D 429B, 45° angle pull, 120°C										
CH207/CH259 (N/mm)	1.9	1.9	2	2.4	2	1.8	1.5	1.9	1.8	1.7
	100RC	100RC	100RC	100RC	100RC	100RC	100RC	100RC	100RC	100RC
CH205/CH252X (N/mm)	2	1.8	1.8	1.8	2.1	1.8	1.8	1.8	1.8	1.9
	100RC	100RC	100RC	100RC	100RC	100RC	100RC	100RC	100RC	100RC
CH8007/CH8560 (N/mm)	1.9	1.5	1.6	1.7	2.2	1.7	1.4	1.5	1.7	1.8
	100RC	100RC	100RC	100RC	100RC	100RC	100RC	100RC	100RC	100RC