Study on the Damping of EVM Based Blends

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Received 22 November 2009; accepted 21 August 2010
DOI 10.1002/app.33260
Published online 8 November 2010 in Wiley Online Library (wileyonlinelibrary.com).

ABSTRACT: The mechanical and damping properties of blends of ethylene-vinyl acetate rubber(VA content >40 wt %) (EVM)/nitrile butadiene rubber (NBR) and EVM/ethylene-propylene-diene copolymer (EPDM), both with 1.4 phr BIPB (bis (tert-butyl peroxy isopropyl) benzene) as curing agent, were investigated by DMA. The effect of polyvinyl chloride (PVC), chlorinated polyvinyl chloride (CPVC), and dicumyl peroxide (DCP) on the damping and mechanical properties of both rubber blends were studied. The results showed that in EVM/EPDM/PVC blends, EPDM was immiscible with EVM and could not expand the damping range of EVM at low temperature. PVC was miscible with EVM and dramatically improved the damping property of EVM at high temperature while keeping good mechanical performance. In EVM/NBR/PVC blends, PVC was partially miscible with EVM/NBR blends and remarkably widened the effective damping temperature range from 41.1°C for EVM/NBR to 62.4°C, while CPVC mixed EVM/NBR blends had an expanded effective damping temperature range of 63.5°C with only one damping peak. Curing agents BIPB and DCP had a similar influence on EVM/EPDM blends. DCP, however, dramatically raised the height of tan δ peak of EVM/NBR = 80/20 and expanded its effective damping temperature range to 64.9°C. © 2010 Wiley Periodicals, Inc. J Appl Polym Sci 120: 1121–1125, 2011

Key words: EVM; damping; EPDM; NBR; PVC

INTRODUCTION

Polymers have been widely applied for achieving acoustic and vibration damping due to a unique combination of low modulus and inherent damping.[1] However, homopolymers usually exhibit effective damping (tan $\delta > 0.3$) in a narrow temperature range of 20–30°C around their glass transition temperatures (T_g), during which the polymers have pronounced dissipation of the mechanical energy as heat based on the onset of coordinated chain molecular motion.[2] Thus blending two or more rubbers has been used as an effective way to obtain damping materials with an enlarged temperature range.[3,4]

EVM is the accepted abbreviation for ethylene vinyl acetate copolymers with between 40% and 90% vinyl acetate (VA) and having elastomeric properties. The peak value of the damping factor tan δ of EVM700 with 70% of VA was 0.93 because of abundant ester side groups and its glass transition temperature zone was between −5°C and 30°C, which happens to be the use of temperature of many damping materials. So EVM700 could be a good choice as a damping material.[5]

EPDM and NBR have been used as damping materials due to their high tan δ values.[6,7] So, it is expected that blending EVM with EPDM or NBR could enlarge the damping peak zone and a blended, multi-functional damping material with good oil and ozone resistance, thermostability and flame-retardance would be expected.

In this research, a Haake torque rheometer was employed to blend EVM with EPDM or NBR. The effects of PVC, CPVC, and curing agent DCP on the mechanical and damping properties were examined to provide some reference data for preparation of high damping materials with wider effective damping temperature range.

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EXPERIMENTAL

Main materials

Ethylene vinyl acetate copolymer rubber (EVM700), (Levapren 700, VA = 70 wt %, manufactured by Lanxess Deutschland GmbH, Leverkusen, Germany), EPDM [Nordel 4640 (46 wt % propylene and Mooney Viscosity of 40), manufactured by Dow Chemcial Company, Seadrift, Texas, USA] nitrile-butadiene rubber (NBR), (Perbunan3470 (AN = 34 wt %, manufactured by Lanxess Deutschland GmbH, Leverkusen, Germany), PVC (S-1000, manufactured by Qilu Branch of SINOPEC, Zibo, China), CPVC(67.3 wt % Cl, manufactured by Qingdao Sanyou Chemical Company, China), precipitated silica (manufactured by Shandong Haihua Silica Factory, Qingdao, China), BIPB (bis (tert-butyl peroxy

TABLE I
Effect of PVC on the Mechanical Properties of EVM/EPDM Blends

	1#	2#	3#	4#
Tensile strength (MPa)	16.7	18.9	21.5	16.0
Elongation at break (%)	476	328	244	382
Modulus at 100% (MPa)	2.2	4.3	9.5	3.1
Compression set (%)	15.0	16.3	16.9	12.4
Hardness/shore A	76	83	90	80

1#, EVM/EPDM4640 = 80/20; 2#, EVM/EPDM4640/PVC = 70/20/10; 3#, EVM/EPDM4640/PVC = 60/20/20; 4#, EVM/EPDM4640 = 60/40.

isopropyl) benzene), and DCP (dicumyl peroxide) (both manufactured by Rhein Chemie Qingdao, China) were used.

Sample preparation

EVM and EPDM or NBR were first mixed in a HAAKE Rheomix30000S mixer for about 2–3 min at 80°C (blended with PVC or CPVC at 160°C) at a rotor speed of 50 rpm. Then silica was added and mixed for about 7–8 min. Finally BIPB or DCP were put in and mixed until the torque became constant. The blends were taken out of the mixer and processed on an SK-160B two-roll mill (compounding with PVC or CPVC at 80°C) manufactured by Shanghai Plastics & Rubber Machinery Factory, China, and then molded into sheets in a VC-150T-FTMO-3RT vacuum press manufactured by Jiaxin Electric Company, China, at 180°C for 8 min.

Measurements

Hardness was tested using a shore A Hardness tester, manufactured by Shanghai Liuling Instrument Factory, according to ISO 7619 : 1986.

Compression set was tested according to ASTMD395-2003.

Tensile testing was carried out using an AI-7000S Universal Material Tester, manufactured by Taiwan

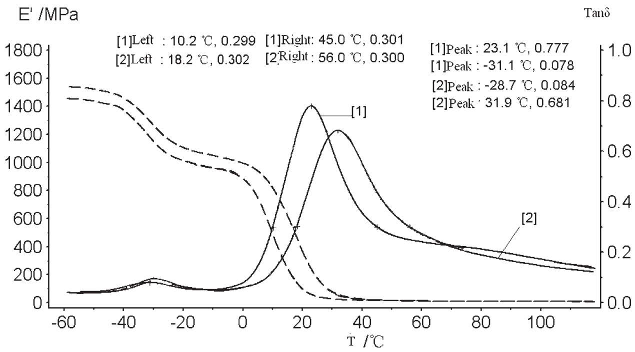

Figure 2 Effect of PVC content on the damping of EVM/EPDM blends. (1) EVM/EPDM4640/PVC = 70/20/10 and (2) EVM/EPDM4640/PVC = 60/20/20.

Gaotie Company, at a tensile speed of 500 mm/min according to ISO 37 : 1994.

The dynamic mechanical analysis was carried out on a NETZSCH DMA 242 Dynamic Mechanical Analyzer, manufactured by Netzsch Company, Germany, from −80°C to 100°C at a heating rate of 3 K/min and a fixed frequency of 10 Hz in a mode of double cantilever deformation. Curves of tan δ and E' as a function of temperature were examined.

RESULTS AND DISCUSSION

Effect of PVC on the mechanical and damping properties of EVM based blends

PVC has a polar side atom and a T_g of 87°C. Adding PVC to the blends might be expected to expand the effective damping temperature range (shorted as EDTR) in the higher temperature area.

Table I shows the mechanical properties of EVM/EPDM/PVC blends. Comparing 1# with 2# and 3# with 4# (shown in Table I), the tensile strength, modulus at 100%, compression set and hardness increased as the content of PVC increased while the elongation at break declined. This is fully in accordance with the trend of rubber blended with added plastics.

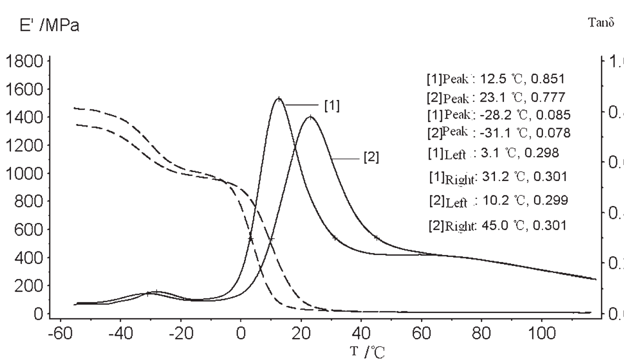

Figure 1 Effect of PVC content on the damping of EVM/EPDM4640 blends. (1) EVM/EPDM4640 = 80/20 and (2) EVM/EPDM4640/PVC = 70/20/10.

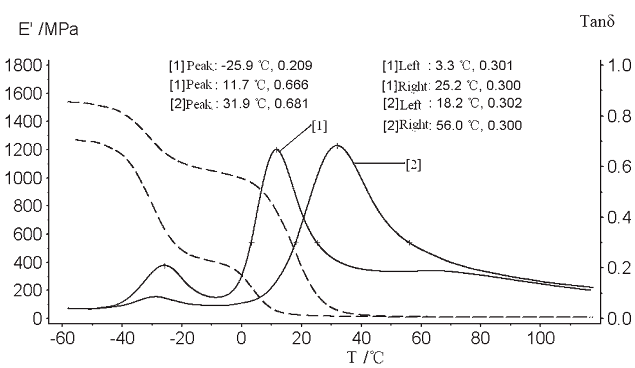

Figure 3 Effect of PVC on the damping of (1) EVM/EPDM4640 = 60/40 and (2) EVM/EPDM4640/PVC = 60/20/20.

TABLE II
Effect of PVC and CPVC on the Mechanical Properties of EVM/NBR Blends

	Tensile strength (MPa)	Elongation at break (%)	Modulus at 100% (MPa)	Compression set (%)	Hardness/ shore A
EVM/NBR = 80/20	18.5	303	4.7	31.9	87
EVM/NBR/PVC = 70/20/10	16.5	212	6.2	22.9	89
EVM/NBR/CPVC = 70/20/10	12.8	144	8.6	18.9	77

The effect of PVC on the damping of EVM/EPDM is shown in Figure 1. The peak value of tan δ of EVM/EPDM4640 = 80/20 was 0.851 with corresponding T_g of 12.5°C and an effective damping temperature range (EDTR) (tan δ > 0.3) of 28.1°C. After PVC was added (curve [2] in Fig. 1), a new tan δ peak for the PVC at about 87°C was not found (T_g of PVC = 87°C). However, the blend's T_g moved from 12.5°C to the higher temperature of 23.1°C, the EDTR was widened from 28.1°C to 34.8°C and the low temperature tan δ peak of EPDM, which was too low to contribute to the EDTR, even moved to lower temperature. This indicated that PVC was fully miscible with EVM700 and immiscible with EPDM, widening the EDTR of EVM/EPDM in the high temperature area.

More about the damping of EVM/EPDM/PVC is shown in Figure 2. Comparing curves [1] with [2], the tan δ peak of PVC did not appear as its content increased and the tan δ peak of the blend moved to higher temperature with a further widened EDTR of 37.8°C.

The damping properties of EVM/EPDM4640 = 60/40 and EVM/EPDM4640/PVC = 60/20/20 are shown in Figure 3. The low temperature tan δ peak of EPDM became larger, but still less than 0.3. Only the tan δ of EVM at high temperature contributed to the useful damping of the blend. After 20 phr PVC was added for EVM/EPDM4640/PVC = 60/20/20 blend, the EDTR was widened from 21.9 to 37.8.

Through the above analysis, we conclude that PVC and EVM700 are completely miscible. Increasing the content of PVC expanded the EDTR of the blends at the cost of a decrease in height of tan δ.

It is concluded that EVM and EPDM are not miscible and EPDM could not improve the effective damping temperature range of EVM at low temperature. PVC is completely miscible with EVM700 and consequently expanded the effective damping temperature range of EVM at high temperature.

The effect of PVC and CPVC on the mechanical properties of EVM/NBR blends is shown in Table II. When 10 phr PVC replacing 10 phr EVM were added in the blend, the tensile strength, elongation at break, and compression set decreased while the modulus at 100% and hardness increased. When 10 phr CPVC replaced 10 phr PVC in EVM/NBR, the tensile strength, elongation at break, compression set, and hardness decreased with increased modulus at 100%. PVC and CPVC might disturb the effective curing of EVM by peroxide.

The effect of PVC on the damping of EVM/NBR blends is shown in Figure 4. T_gs of EVM and NBR were known as 14.3°C and 6.5°C from our previous research. Thus the two tan δ peaks in the EVM/NBR blend would overlap with only one peak being visible in curve [1] with T_g of 11.8°C and EDTR of 41.1°C. After 10 phr PVC was added, two tan δ peaks were present in the EVM/NBR/PVC blend, curve [2]. One T_g is 14.3°C, and the other is 44.1°C. These peaks should be attributed to the T_g of EVM/NBR (11.8 °C) and that of PVC (87°C) moving toward each other. The most dramatic change was

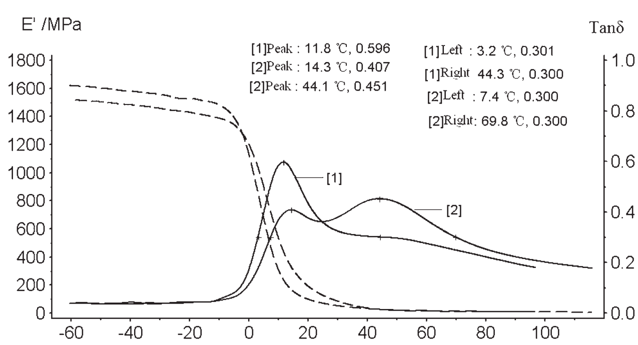

Figure 4 Effect of PVC on the damping of (1) EVM/NBR = 80/20 and (2) EVM/NBR/PVC = 70/20/10.

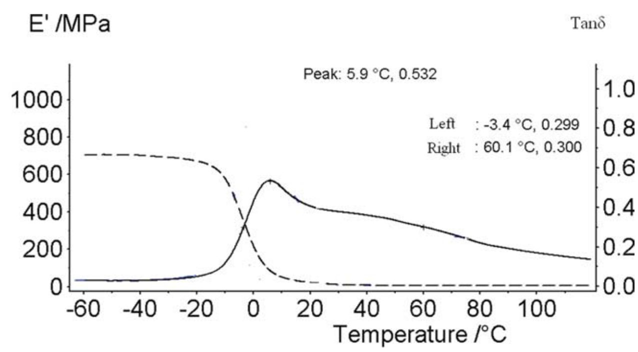

Figure 5 Effect of CPVC on the damping of EVM/NBR/CPVC = 70/20/10.

TABLE III
Effect of DCP on Mechanical Properties of EVM/EPDM = 80/20

Curing agent	Tensile strength (MPa)	Elongation at break (%)	Modulus at 100% (MPa)	Com-pression set (%)	Hardness/shore A
DCP	18.1	533	2.2	17.1	78
BIPB	19.2	242	2.3	16.2	78

TABLE IV
Effect of DCP on Mechanical Properties of EVM/NBR = 80/20

Curing agent	Tensile strength (MPa)	Elongation at break (%)	Modulus at 100% (MPa)	Com-pression set (%)	Hardness/shore A
DCP	13.5	410	2.9	17.9	84
BIPB	19.1	382	4.5	17.8	86

that the EDTR was widened from 41.1°C to 62.4°C. Therefore, PVC was partially miscible with EVM/NBR, which dramatically expanded the effective damping temperature range of EVM/NBR blends.

The effect of CPVC on the damping of EVM/NBR blends is shown in Figure 5. The pure CPVC's T_g is about 89°C. But there were not two obvious damping peaks like PVC mixed blend in Figure 3 although the EDTR was also expanded to 63.5°C.

Effect of DCP on the mechanical and damping properties of EVM based blends

For the previous samples, BIPB was used as the curing agent for all ratios of the blends. In this section, DCP was used instead as a curing agent to be compared with BIPB. Table III shows the mechanical properties comparison for EVM/EPDM = 80/20 with 1.4 phr BIPB or DCP as the curing agent. The EVM/EPDM = 80/20 blend with BIPB as the curing agent had a little higher tensile strength and lower elongation at break than those of the blend with DCP. The modulus at 100%, compression set and hardness were similar.

Figure 6 shows the effects of BIPB and DCP on the damping properties of EVM/EPDM = 80/20 blend. The two tan δ curves are nearly identical. This indicated that BIPB and DCP had a similar influence on the damping of EVM/EPDM blends.

The mechanical properties of EVM/NBR = 80/20 with 1.4 phr BIPB or DCP as the curing agent are shown in Table IV. The EVM/NBR = 80/20 with BIPB had a higher tensile strength and modulus and a lower elongation at break, but the compression set and hardness were similar.

The effect of BIPB and DCP on the damping properties of EVM/NBR = 80/20 is shown in Figure 7. EVM/NBR with BIPB had T_g of 11.8°C, tan δ peak data of 0.596 and EDTR of 40.8°C. When DCP was used, the T_g changed to 9.5°C, tan δ peak data was raised to 0.671 and EDTR was expanded to 64.9°C. This indicated that DCP was a better curing agent than BIPB for improving the damping of EVM/NBR blends.

CONCLUSIONS

1. In EVM/EPDM/PVC blends, EPDM was immiscible with EVM and could not improve the damping property of EVM at low temperature. PVC was miscible with EVM and dramatically improved the damping property of EVM at high temperature while keeping good mechanical performance.
2. In EVM/NBR/PVC blends, PVC was partially miscible with EVM/NBR blends and remarkably widened the effective damping temperature range of EVM/NBR from 41. 1 to 62.4°C.
3. In EVM/NBR/CPVC blends, there were no two obvious damping peaks although the effective temperature range of EVM/NBR was expanded to 63.5°C.
4. Curing agents BIPB and DCP had the similar influence on the mechanical and damping

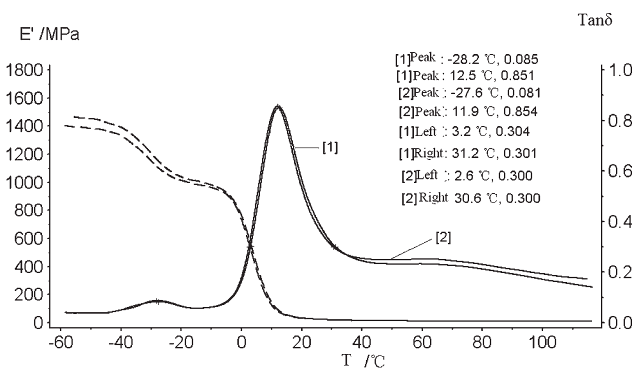

Figure 6 Effect of curing agents on the damping of EVM/EPDM4640 = 80/20; (1) BIBP and (2) DCP.

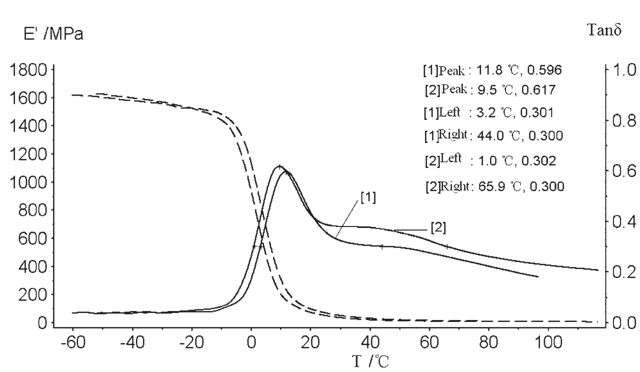

Figure 7 Effect of curing agents on the damping of EVM/NBR = 80/20; (1) BIBP and (2) DCP.

properties of EVM/EPDM blends. DCP, however, dramatically raised the tan δ peak of EVM/NBR = 80/20 and expanded the effective damping temperature range from 40.8 to 64.9°C.

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