COMPATIBILITY STUDY OF ETHYLENE ACRYLIC DIPOLYMER / ETHYLENE PROPYLENE DIENE TERPOLYMER RUBBER BLENDS WITH A HOMOGENIZING AGENT

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Abstract

The effects of the homogenizer type and amount on cure characteristics, mechanical properties and thermal stabilities of the AEM (Ethylene acrylic dipolymer)/EPDM(Ethylene propylene diene terpolymer) blends were investigated. To observe the effect of the homogenizer incorporation, mechanical properties of the blends were determined under thermally aged conditions at two different temperatures of 160°C and 180°C. Experimental results showed that, the amount of homogenizer has a major effect on mechanical properties of all blend ratios. Although the addition of 5 phr homogenizer caused an increase in the thermal stabilities of the blends, the addition of 10 phr homogenizer resulted in a decrease in the thermal stabilities of the blends at both temperatures. These findings were further supported by the Differential Scanning Calorimetry (DSC) analysis.

Keywords: *polymer blends, rubbers, compatibility, homogenizer*

1. INTRODUCTION

In last decades several researchers focused on elastomer blends to create most appropriate and economical materials for intended applications. One of the biggest advantages of the blending is that, it is possible to tailor the mechanical properties of the final materials for specified applications. For example, due to its low unsaturated backbone, EPDM has been widely studied in this manner to improve the weathering and ozone resistances of diene containing elastomers.

Although blending is a very useful technique, it is not so easy to find the best ratio and the curing system for the blend mixture since lots of the elastomers are incompatible with each other. The diversity between the elastomers affects their reactivity with curatives and results more heterogeneous networks. This mismatch caused a decrease in the mechanical properties of the resulted blends which is needed to be overcome.

Lowered blend properties may be attributed to the different solubility and curing properties of the mixed elastomers. In order to increase the compatibility and to decrease the heterogeneity of the blend network, lots of modifiers were investigated. They are used to increase the interface adhesion of the polymer chains. For example, Branwal et. al. grafted some accelerators on EPDM to increase the covulcanizaton in NR/EPDM blends. Another example was explored by Chang Y.W. and co-workers. The addition of a low molecular weight material like trans-polyoctylene rubber as a third component to the NR/EPDM blends acted as the interface between the NR/EPDM blend phases. The effects of the mercapto-modified copolymers on mechanical properties of NR/EPDM blends were also investigated. Among these studies, incorporation of maleic-anhydride grafted elastomer into the blends is reported as a good approach to lower the interfacial tension between the polymer chains and to increase the compatibility. The effects of maleic anhydride grafted compatibilizers were also examined in thermoplastic elastomer blends. It has been found that Ma-g-PP (polypropylene) is an efficient compatibilizing system, since it promotes an improved tensile properties and compression set when compared with noncompatibilized blends.

Homogenizing agents are also considered as effective alternatives for this purpose. The main idea of using a homogenizer is to increase the compatibility without decreasing mechanical properties. Basically, they increase the homogeneity of the elastomeric blends and keep the compound more

compact with increase in the mixing efficiency and usually with reduced mixing time. Besides, they decrease the interfacial tension between the polymer chains and increase the attraction between them.

Although there are lots of studies about the effect of the modifiers on different elastomer systems, no attention was paid the effect of the homogenizer on the mechanical properties of the AEM/EPDM blends. In this study, different amounts of Struktol 60NS, which is a hydrocarbon resin, was used as a homogenizer. Within this framework, several elastomer mixtures were prepared and changes in cure characteristics, mechanical properties and heat aging resistances depending on homogenizer addition were investigated.

2. MATERIALS AND METHODS

2.1. Materials

Following materials were used to prepare the AEM /EPDM elastomer blends in this study:

- The Ethylene propylene diene terpolymer rubber (Vistalon 5601) was supplied from Exxon Company, USA.
- Ethylene Acrylic Dipolymer (Vamac® DP) was supplied from DuPont Co., USA.
- Homogenizing agent used was an aliphatic hydrocarbon resin, under code Struktol 60 NS was supplied from Schill and Seilacher, Germany.
- Carbon black (Purex HS 25) was supplied from Orion Company, Italy.
- The cross linking assisting agent MgO was supplied from Premier Magnesia Company, USA.
- The cross linking agent was 1,3(4)-bis(tert-butylperoxyisopropyl) benzene (Luperox F 40) was supplied from Arkema Company, Italy.
- The co-crosslinking coagent, %70 ethylene glycol dimethacrylate-%30 silica (Rhenofit EDMA) was supplied from Rhein Chemie Company, Germany.
- The other compounding ingredients used were, Vulkanox HS/LG from Lanxess Company, Germany; Paraffinic Oil from Petsan Company, Turkey; Naugard 445 from Chemtura Company, USA.

2.2. Preparation of Elastomer Blends

Formulations used for preparation of the blends were listed in the Table 1. The modified blends were prepared by adding 5 phr and 10 phr of homogenizer for all blend ratios. The mixing process was carried out in a laboratory size Banbury type internal mixer (5,5 L volume, Farrel Company, USA). The mixing conditions were set as flows: fill factor = 0.7, initial chamber temperature = 80 °C, rotor speed = 40 rpm. Elastomers and homogenizing agent were initially masticated in the mixer for 1 min and then paraffinic oil and carbon black was added. After mixing for 3 min, MgO, Vulkanox HS/LG and Naugard 445 were charged and mixed for 1 min. Thereafter, EDMA/S and Luperox F40 were added, and the mixing process was continued for 45 sec. The mixtures were finally discharged and sheeted out on a two-roll mill.

2.3. Determination of Cure Characteristics

The cure characteristics of the mixtures were determined using Dynamic Mechanical Rheological Tester, RPA 2000 supplied by Alpha Technologies, USA, according to ASTM D 2084-11 method for 30 min at 170 °C. The Mooney viscosity (ML1+4, 100 °C) was determined by using a Mooney viscometer (MV 2000 Mooney Viscometer, Alpha Technologies, USA). The testing procedure was conducted according to the method described in ASTM 1646.

Table 1. Formulations used for the preparation of the blends.

	Ingredient (phr[a])										
Blend Codes	Type of mixture[b]	EPDM	VAMAC D	Struktol 60NS	Purex HS25	Paraffinic Oil	MgO	Vulkanox S/LG	EDMA/S	Luperox F40	Naugard 445
DE2080	N	80	20	-	92	40	4	0.8	2.0	6.6	0.2
	H5	80	20	5	92	40	4	0.8	2.0	6.6	0.2
	H10	80	20	10	92	40	4	0.8	2.0	6.6	0.2
DE4060	N	60	40	-	84	30	3	0.6	2.25	6.2	0.4
	H5	60	40	5	84	30	3	0.6	2.25	6.2	0.4
	H10	60	40	10	84	30	3	0.6	2.25	6.2	0.4
DE6040	N	40	60	-	76	20	2	0.4	2.50	5.8	0.6
	H5	40	60	5	76	20	2	0.4	2.50	5.8	0.6
	H10	40	60	10	76	20	2	0.4	2.50	5.8	0.6
DE8020	N	20	80	-	68	10	1	0.2	2.75	5.4	0.8
	H5	20	80	5	68	10	1	0.2	2.75	5.4	0.8
	H10	20	80	10	68	10	1	0.2	2.75	5.4	0.8

[a] phr: parts per hundred of rubber

[b] N: neutral, H5: 5 phr Struktol 60NS, H10: 10 phr Struktol 60NS

2.4. Vulcanization Process

All compounds were molded at 170 °C and compressed under a pressure of 21 MPa using a hydraulic hot press according to their respective optimum curing time (tc_{90}), determined with a Dynamic Mechanical Rheological Tester. Blends were conditioned for 24 h before testing.

2.5. Determination of Mechanical Properties

Bareiss Digital Tester were used to measure the hardness values of the samples in terms of Shore A according to the DIN 53505. In sample preparation, three of the test samples were cut into size 25mm x 25mm x 2mm for the measurements and placed on top of each other. Tensile properties of all samples were investigated using Mechanical Zwick Tensometer Z010/TN2S. Tensile strength and elongation at break tests were conducted according to the DIN53504 with sample S3A. In order to evaluate the temperature resistances of the blends, samples were aged at 160 °C and 180 °C for 94 hours. All measurements were performed after taking out the samples from the oven 30 minutes after according to DIN 53508.

2.6. Determination of Swelling Properties

In order to determine the swelling properties of the samples an experiment was conducted in toluene at room temperature for 24h and following at 60 °C for 24h. Measurements were performed before and after aging using Densi Tech II (TechPro) and results were calculated according to the following equation where Q is the swelling ratio, W_{a1}, W_{a2}, W_{w1}, W_{w2} are the weights in the air and water, before and after immersion, respectively (Equation (1));

$$Q = \frac{(W_{a2} - W_{w2}) - (W_{a1} - W_{w1})}{(W_{a1} - W_{w1})} \times 100 \quad (1)$$

Crosslink densities of the samples were calculated according to the Flory-Rehner Equation (2) by neglecting the filler effect as described in the literature.

$$N_c = \frac{1}{2} \frac{\ln(1 - V_R) + V_R + X V_R^2}{V_S(V_R^{\frac{1}{3}} - \frac{V_R}{2})} \quad (2)$$

where N_c is the overall crosslink density, X is the polymer-solvent interaction parameter,

V_R is the volume fraction of the rubber in the swollen sample, and calculated from the Equation (3);

$$V_R = \frac{\frac{\text{Wt. dry polymer}}{\rho \text{ polymer}}}{\frac{\text{Wt. dry polymer}}{\rho \text{ polymer}} + \frac{\text{Wt. solvent}}{\rho \text{ solvent}}} \quad (3)$$

V_S is the volume fraction of 1 mole of solvent and calculated from the Equation (4).

$$V_S = \frac{MW_{solvent}}{\rho \text{ solvent} \times N_A} \quad (4)$$

2.7. Differential Scanning Calorimetry (DSC) Analysis

DSC analyses of the sealed samples in an aluminum pan were performed by Metler Toledo DSC822E. Glass transition temperatures (T_g) of the AEM/EPDM blends were determined by cooling the samples from room temperature to -80 °C with a cooling rate -5 °C/min and then heating to -25 °C with a heating rate of 10 °C/min in nitrogen atmosphere.

3. RESULTS AND DISCUSSION

3.1. Effects of homogenizer on the Cure Characteristics of the Blends

The effects of homogenizer on Mooney Viscosity values of the blends were investigated and the results are given in Figure 1. It was observed that the Mooney viscosity values decreased with addition of homogenizer.

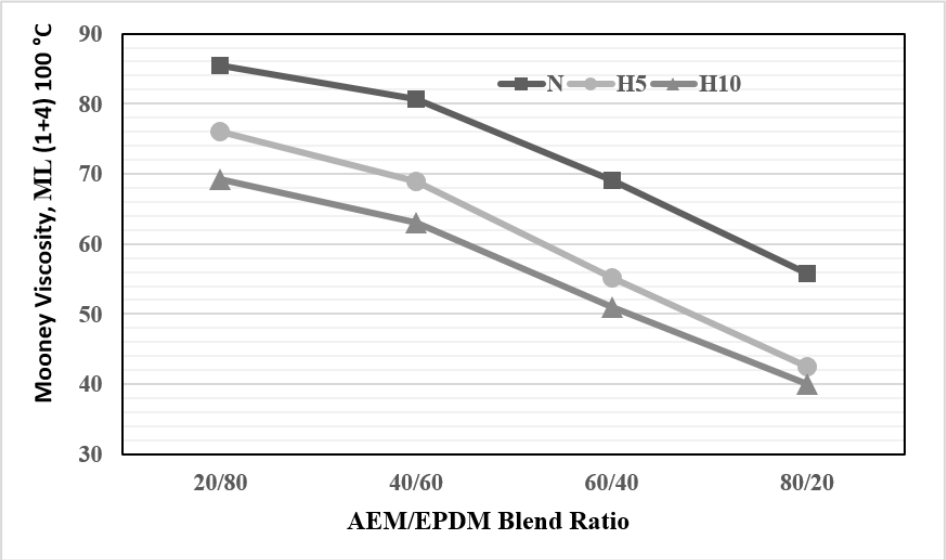


Figure 1. Effects of modifiers on Mooney viscosity values of the neutral and modified AEM/EPDM blends.

Mooney viscosity is a significant parameter which gives an idea about the effects of the homogenizers on curing characteristics of the blends as well as the compatibilities of the different polymers. This parameter is also important for manufacturing which effects the energy consumption and consequently the cost of production.

According to the Mooney viscosity results, it was concluded that, homogenizer acted as a lubricant and decreased the Mooney viscosity values. This may be due to the increased slippage of the polymer chains one above the other. Increasing the amount of homogenizer in the blend also caused a decrease in the Mooney viscosity values, especially for EPDM rich blends. This result can be attributed to the non-polar nature of the homogenizer and therefore should be more compatible with EPDM than AEM.

Rubber process analyzer is used as a tool to optimize the amounts of the additives in an elastomer mixture and also to examine the curing behaviors of the elastomers. In order to examine the effect of the homogenizer addition on curing behaviors, rheological curves were obtained for all blends. Rheological results obtained for AEM/EPDM blend were summarized in Table 2.

Table 2. Rheological results of the AEM/EPDM blends.

Blend Codes	Cure Characteristics					
	$S'_{(ML)}$ (lb-in)	$S'_{(MH)}$ (lb-in)	$\Delta S'_{(MH-ML)}$ (lb-in)	ts_2 (min.)	tc_{90} (min.)	CRI[a] ($min.^{-1}$)
DE2080N	2.09	17.71	15.62	0.99	8.02	14.22
DE2080H5	2.32	18.69	16.57	0.95	7.91	14.37
DE2080H10	2.01	17.53	15.52	1.01	8.10	14.10
DE4060N	2.02	16.88	14.85	1.10	8.38	13.74
DE4060H5	2.29	19.36	17.02	0.99	8.26	13.76
DE4060H10	1.88	16.66	14.78	1.14	9.46	12.02
DE6040N	1.57	15.60	14.04	1.27	9.21	12.59
DE6040H5	1.68	17.44	15.76	1.26	9.17	12.64
DE6040H10	1.54	14.00	12.46	1.50	9.77	12.09
DE8020N	1.17	14.26	12.98	1.98	10.31	12.00
DE8020H5	1.12	13.94	12.82	1.89	10.33	11.85
DE8020H10	1.00	11.21	10.20	2.42	11.33	11.22

[a] CRI: Cure rate index; $CRI = 100 / (tc_{90}-ts_2)$

The results given in Table 2 clearly showed that addition of homogenizer caused significant changes on the curing parameters of the AEM/EPDM blends. Addition of the 5 phr homogenizer cause a decrease in the scorch time (ts_2) and optimum curing time (tc_{90}) values in the EPDM rich blends (DE2080 and DE4060). Addition of the homogenizer, which has a non-polar nature like EPDM chains, helped to their curing times. However, when the amount of the homogenizer in the blend increased from 5phr to 10 phr, its effect on the ts_2 and tc_{90} turned into a negative way. An increase in the ts_2 and tc_{90} values was observed for all blends. Due to the lubricating action of Struktol 60NS in the elastomer blends decreased the physical interactions between the polymeric natures was observed.

The minimum elastic torque S'(M_L) and the maximum elastic torque S'(M_H) values obtained for DE2080, DE4060 and DE6040 were increased with the addition of 5phr homogenizer and 10 phr compatibilizer but decreased with the addition of 10 phr homogenizer. Increment in the torque value indicates that adhesion between the polymer chains is promoted. On the other hand, for the blend DE8020, which has the highest AEM content, both min and max elastic torque values decrease with addition of homogenizer. Since the non-polar homogenizer is behaved as a lubricant only in polar elastomer rich media the min and max elastic torque values were decreased.

3.2. Effects of Homogenizer on the Mechanical Properties of the Blends

The results represented in Figure 2 clearly show that the addition of the homogenizer into the polymer blends had changed the mechanical properties of the related mixtures.

Hardness value of the elastomers is quite important not only in their application area but also in the production process of the elastomers. Harder elastomers are much more resistant to applied external force i.e. extrusion. However, softer elastomers show better seal properties on rough surfaces and stretches easier.

Addition of the homogenizer into the polymer network caused a decrease in the hardness values for all blend ratios. The effect of the incorporation of the 5 phr homogenizer into the blend, which contains 80 phr EPDM, is the most obvious among all other blends. The lubricating effect of the homogenizer is getting higher when increasing its ratio from 5 phr (H5) to 10 phr (H10). The difference in between the hardness values of the samples containing 5 phr homogenizer and the neutral blends are -5.1 and the -1.5 Shore A for the blend ratios DE2080 and DE8020, respectively. These results showed that with the increasing AEM ratio in the blend the decrease in the hardness is getting smaller. This is probably because of the non-polar nature of the homogenizer is more compatible with the EPDM chains.

The decrease in the cross-linking densities of the blends affected the tensile strength values of all blends in a negative way. However, the addition of homogenizer resulted in an increase in % elongation at break values (Figure 2). Changing of the elongation values match up with the hardness values of the mixtures. As it is mentioned before, the soft elastomer blends stretches more than the harder ones.

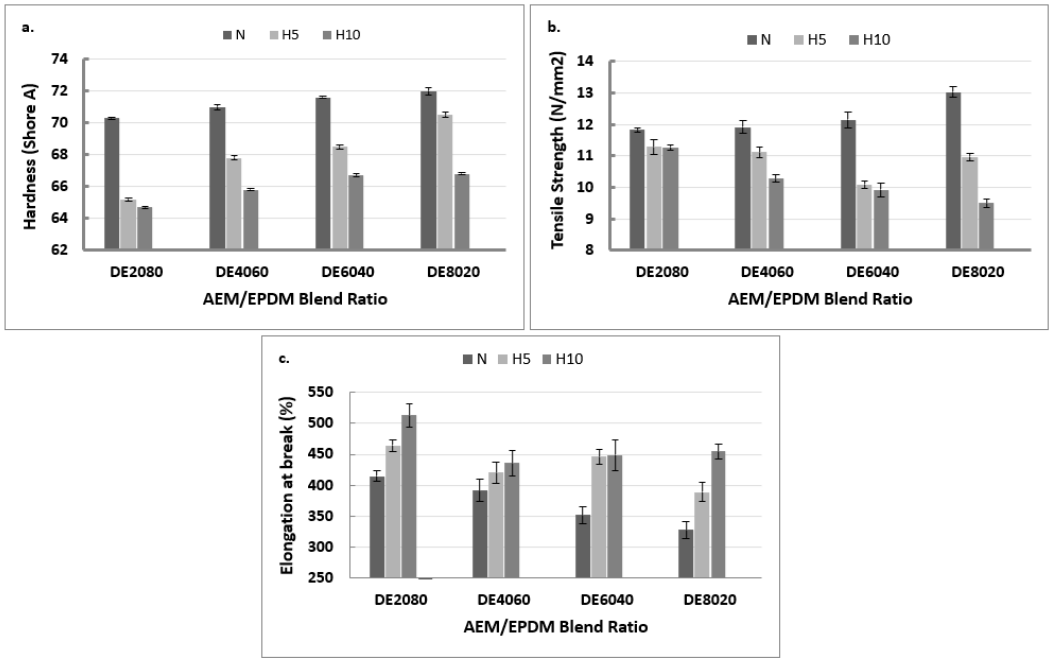


Figure 2. Variations in mechanical properties of the neutral and modified AEM/EPDM blends; a. Hardness values in Shore A, b. Tensile strength values in N/mm^2, c. % Elongation at break values.

3.3. Effect of Thermal Aging on the Mechanical Properties of Neutral and Modifier Added Blends

On account of the differences in the mechanical properties of the neutral and homogenizer added blends, it is also worth to examine these changes in the thermally aged samples. Elastomer blend samples were waited in oven at two different temperatures which are 160 °C and 180 °C for 94 hours and changes in the mechanical properties were determined (Figure 3).

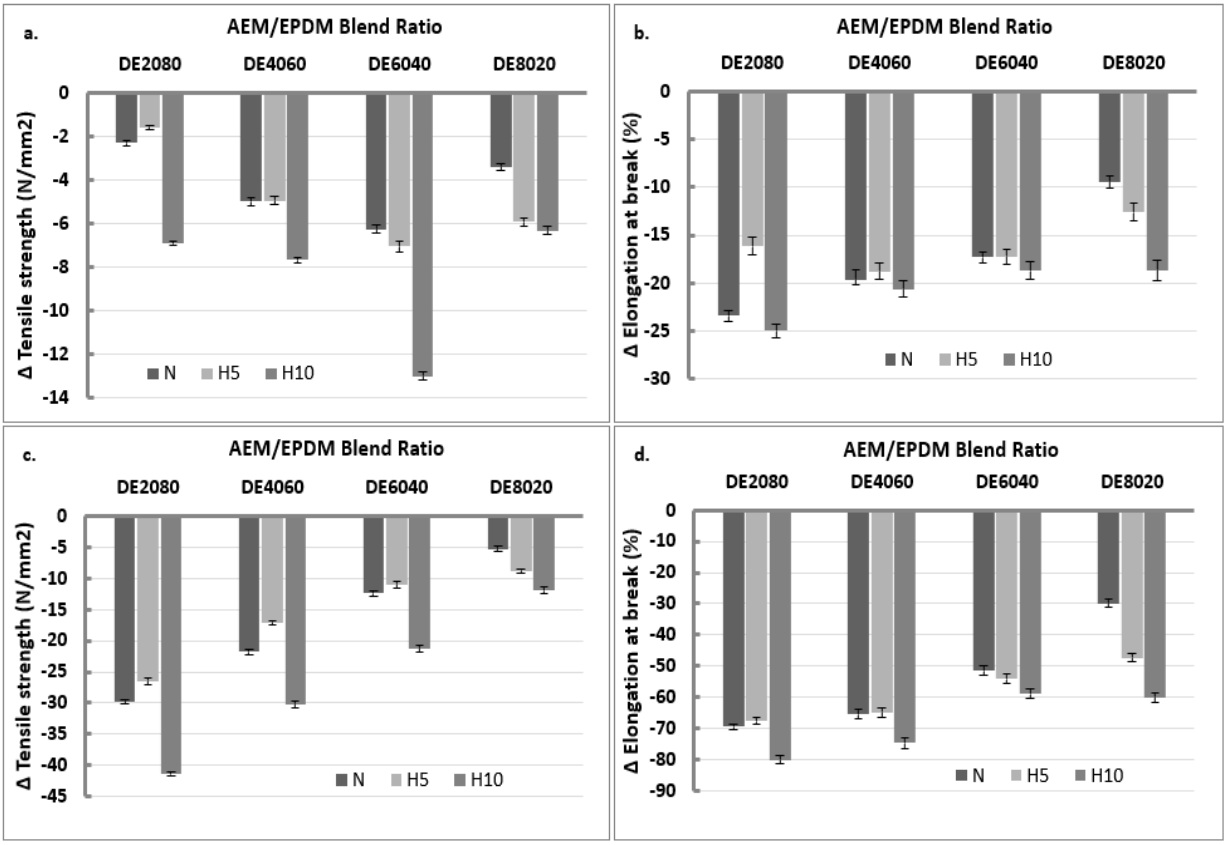


Figure 3. Changes in tensile properties of the neutral and modified AEM/EPDM blends, after thermal aging; a. Δ Tensile strength values at 160°C-94h, b. Δ Elongation at break values at 160°C-94h, c. Δ Tensile strength values at 180°C-94h, d. Δ Elongation at break values at 180°C-94h.

The results given Figure 3 showed that, an increase in the stability against thermal aging with addition of 5 phr homogenizer was only seen in the EPDM rich blends (DE2080 and DE4060) at 160°C. With increasing AEM content of the blend (DE6040 and DE8020), homogenizer caused a negative effect on mechanical properties. Almost the same behavior of was observed for the thermally aged samples at 180 °C. Addition of 5 phr homogenizer into the blend cause a decrease in the Δ tensile strength values of the blends DE2080, DE4060 and DE6040 and an increase of the blend DE8020. When the homogenizer amount in the mixture is doubled from 5 phr to 10 phr, further decrease in resistances was observed for all blend ratios. Addition of 10 phr homogenizer causes a decrease in cross-link density which makes blends difficult to maintain the thermal stability at high temperatures.

3.4. Evaluation of the Swelling and Cross-linking Characteristics of Blends

In order to have a better understanding about the modifiers effect on interfacial interaction between the AEM and EPDM, swelling studies were performed and the crosslink densities were calculated.

According to the data obtained before and after the immersion of the samples into toluene, % swelling ratio were calculated and illustrated in Figure 4. It is well known that, the lower the % swelling ratio the higher the cross-linking densities of the elastomers. According to the results given in Figure 4, the

addition of the 5 phr homogenizer decreased the cross-linking densities where increased the % swellings of the blends. Increase the amount of homogenizer (10 phr) in the blends resulted in a further decrease of the cross-linking densities.

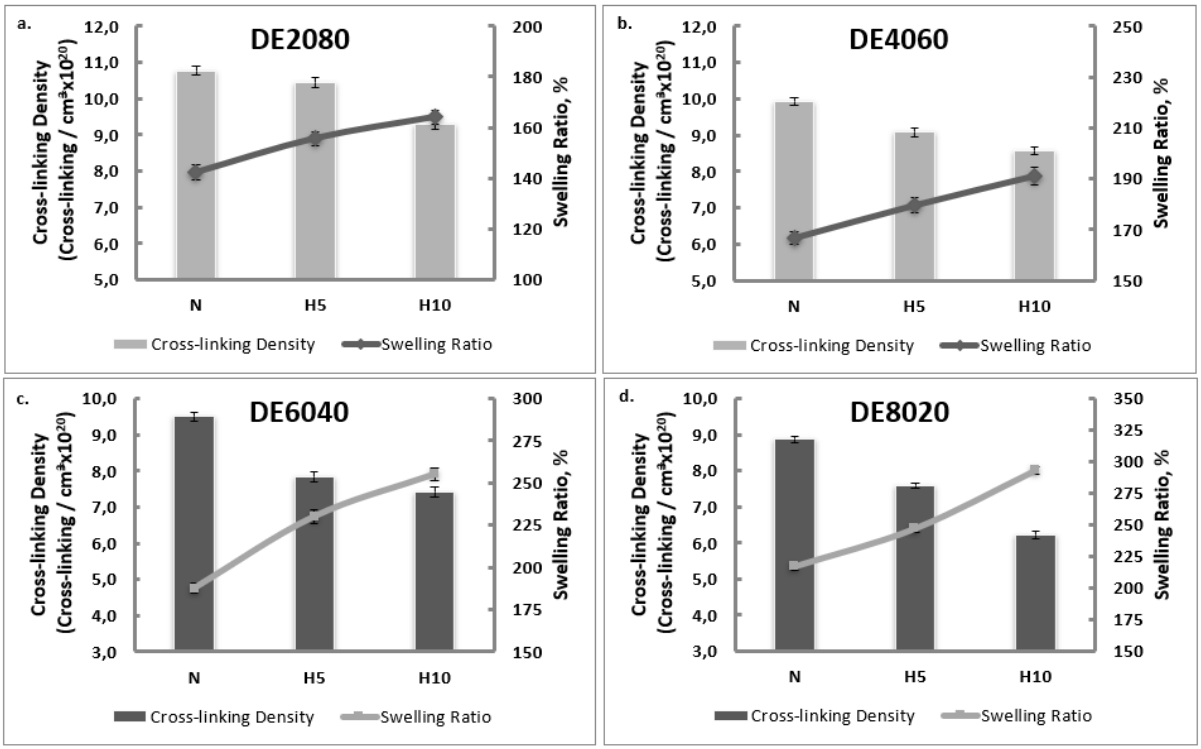


Figure 4. Swelling ratios (%) and cross-linking densities (cross-linking/cm^3*10^{20}) of the neutral and modified AEM/EPDM blends.

3.5. Evaluation of the DSC Results of the Blends

DSC analyses are used to predict the miscibility of polymer systems. The glass transition temperature (T_g) of the polymer depends on the structure and co-operative mobility of the segments. This behavior is reflected in the occurrence of a single glass transition temperature in miscible blends. In the case of partially miscible blends, the glass transition temperature gets shifted.

The T_g values obtained from the experimental DSC curves were given in Table 3. T_{g1} and T_{g2} values of the blends correspond to the EPDM and AEM nature of the blends. According to these results, the blends containing 80 phr AEM (DE8020N) have only one T_g value. This proves that a completely miscible blend was obtained with this ratio. Other blends have two different T_g values. The glass transition temperatures of the blend containing 5 phr -homogenizer were shifted towards each other that indicate improved compatibility. From Table 3, it can be seen that as the amount of homogenizer added into blends increases, the T_g value of each component in the blend shows a temperature shift. It is known that a T_g value outside the two component T_g values strongly indicates a plasticizing effect of the added component. From this it can be concluded that 10 phr homogenizer additions reduces networking degree of blends which is caused by the plasticizing effect.

Table 3. Glass transition temperatures of the AEM/EPDM blends.

Blend Codes	T_{g1} (°C)	T_{g2} (°C)
DE2080N	-52.11	-23.01
DE2080H5	-49.58	-23.45
DE2080H10	-48.06	-21.80
DE4060N	-52.54	-26.01
DE4060H5	-51.59	-27.77
DE4060H10	-50.70	-25.91
DE6040N	-56.15	-26.61
DE6040H5	-53.59	-28.07
DE6040H10	-53.16	-26.50
DE8020N	-27.25	
DE8020H5	-27.26	
DE8020H10	-27.15	

CONCLUSION

AEM (Ethylene Acrylic Dipolymer) / EPDM elastomer blends were successfully formulated with different blend ratios. The addition of the 5phr homogenizer into the blends caused a decrease in the ts_2 and tc_{90} values, however, an increase in the CRI values was observed. The changes in these values were majorly seen in the DE2080 and DE4060 blends, which are rich in EPDM content. The effect of the homogenizer on T_g values are also worth to mention that they are approached to each other which means that an increase in the miscibility of the blends. However, according to the swelling test results any numerical increase could not be observed in the cross-link densities. Slippage between the polymer chains observed with addition of the 10 phr homogenizer. These values also supported with the change in the T_g values of the elastomer blends. Addition of 10 phr homogenizer also caused an increase of the ts_2 and tc_{90} values.

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REFERENCES

1. Ünal Şentürk, G., Ersoy Meriçboyu, A. Development of an intermediate layer for multilayer hoses used in turbo lines of motor vehicles, *Journal of Applied Polymer Science* 2018; 135, 46525.
2. Ünal, G. 2014. A Multilayer Hose. Patent Number: WO2014002009
3. Pichaiyut S, Vennemann N and Nakason C. Influence of curing systems on dynamically cured epoxidized natural rubber / thermoplastic polyurethane blends. *J Elastom Plast* 2015; 47: 28–51.
4. Agwuncha SC, Owonubi SJ, Sadiku ER, Zwane RDS, Manjula B, Jayaramudu J, Ojijo VO, Aderibigbe BA and Raghavendra GM. Immiscible polymer blends stabilized with nanophase. In: Thomas S, Shanks R and Chandrasekharakurup S (eds) *Design and applications of nanostructured polymer blends and nanocomposite systems.* Elsevier Inc, 2016, pp. 215-217.

5. Jurkowska B, Jurkowski B, Nadolny K, Krasnov AP, Studniev YN, Pesetskii SS, Koval VN, Pinchuk LS and Olkhov YA. Influence of fluorine-containing lubricant on properties of NR/BR rubber. *Eur Polym J* 2006; 42: 1676-1687.
6. Hess WM, Herd CR and Vegvari PC. Characterization of immiscible elastomer blends. *Rubber Chem Technol* 1993; 66: 329-375.
7. Wongthong P, Nakason C, Pan Q, Rempel GL and Kiatkamjornwong S. Styrene-assisted grafting of maleic anhydride onto deproteinized natural rubber. *Eur Polym J* 2014; 59: 144-155.
8. Baranwal KC and Son PN. Co-Curing of EPDM and diene rubbers by grafting accelerators onto EPDM. *Rubber Chem Technol* 1974; 47: 88-99.
9. Chang YW, Shin YS, Shun H and Nah C. Effects of trans-polyoctylene rubber (TOR) on the properties of NR/EPDM blends. *J Appl Polym Sci* 1999; 73: 749-756.
10. Sirqueira AS and Soares BG. Mercapto-modified copolymers in elastomer blends. IV. The compatibilization of natural rubber/EPDM blends. *J Appl Polym Sci* 2002; 83: 2892-2900.
11. Wang W, Dou R, Zhou Y, Li LP, Yin B and Yang MB. The influence of mixing order on the phase inversion and crystallization behavior of polyamide 6/maleic anhydride-g-ethylene–propylene–diene rubber/high-density polyethylene blend, *J Elastom Plast* 2015; 47: 608-624.
12. Zhang H, Datta RN, Talma AG and Noordermeer JWM. Maleic-anhydride grafted EPM as compatibilising agent in NR/BR/EPDM blends. *Eur Polym J* 2010; 46: 754-766.
13. Ismail H and Supri AG. Rheological behavior, tensile properties, morphology, and thermal stability of recycled poly(vinyl chloride)/acrylonitrile butadiene rubber (PVCr/NBR) blends: The effect of maleic acid. J Elastom Plast 2008; 40: 113-126.
14. Soares BG, Oliveira M, Meireles D, Sirqueira AS and Mauler RS. Dynamically vulcanized polypropylene/nitrile rubber blends: The effect of peroxide/bis-maleimide curing system and different compatibilizing systems. *J Appl Polym Sci* 2008; 110: 3566-3573.
15. Sirisinha C and Prayoonchatphan N. A study of carbon black distribution and properties in br/nbr blends: roles of commercial homogenizer and slipping agent. *Polym-Plast Technol* 2001; 40: 577-592.
16. ASTM D 2084:2011: Standard Test Method for Rubber Property - Vulcanization Using Oscillating Disk Cure Meter.
17. ASTM D1646:2015: Standard Test Methods for Rubber—Viscosity, Stress Relaxation, and Pre-Vulcanization Characteristics (Mooney Viscometer).
18. DIN 53505:2000: Testing of rubber - Shore A / Shore D hardness test.
19. DIN 53504:2009: Testing of rubber - Determination of tensile strength at break, tensile stress at yield, elongation at break and stress values in a tensile test.
20. DIN 53508:2000: Accelerated aging of rubber.
21. Kwak SB and Choi NS, Thermo-oxidative degradation of a carbon black compounded EPDM rubber hose. *International Journal of Automotive Technology* 2011; 12: 401-408.
22. Nair AB, Kurian P and Joseph R, Ethylene–propylene–diene terpolymer/hexa fluoropropylene–vinylidinefluoride dipolymer rubber blends: Thermal and mechanical properties. *Mater Design* 2012; 36: 767-778.
23. El-Sabagh SH, Compatibility study of natural rubber and ethylene–propylene diene rubber blends. *Polym Test* 2003; 22: 93-100.