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Effect of Ultraviolet (UV) Stabilizers on Rubber-Based Automotive Sealing Profiles

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Abstract

The sealing profiles for many visible and invisible automotive applications such as doors, windows, hoods and trunks are made of synthetic ethylene propylene diene monomer (EPDM) rubber. This combination of ethylene, propylene and unsaturated diene molecules exhibits high mechanical properties and forms a water-proof structure. With the progress of time, color change, cracking and staining can be observed on the surface of the sealing profiles used on the visible regions exposed to the sun due to the effect of high-intensity ultraviolet (UV) radiation and sunlight. The aim of this study was to investigate the effect of the UV stabilizers widely used in the plastics industry on the UV resistance of EPDM rubber. Plates of EPDM rubber were prepared by adding different types of UV stabilizers at different rates to an available EPDM formula. The effects of the UV stabilizers on the EPDM plates were measured by mechanical tests and the internationally recognized Florida outdoor aging test with climate conditions of high-intensity sunlight, high-intensity UV, and high temperature and humidity levels.

Key words: EPDM; UV; UV Stabilizers; Sealing profiles

1. Introduction

Ethylene-propylene-diene monomer (EPDM) rubber is a synthetic rubber formed by the combination of ethylene, propylene and unsaturated diene molecules. This EPDM rubber has a very wide range of applications such as automotive tires, side walls, sealings, cables, hoses, belts, roof barriers and sports equipment because of its good mechanical properties, saturated structure and resistance to aging, oxidation, low temperature and ozone [1-7] and it can be reinforced with different kinds of fillers to improve its properties [8-12].

The EPDM rubber is the fastest growing elastomer and its photo-stability is inherently low [13]; therefore, when these materials are exposed to natural or artificial aging, color change, cracking, surface staining and reduction of mechanical properties are observed [14]. The small number of impurities found within the rubber are sufficient to initiate photo-degradation, despite weak UV absorption. Consequently, carbon black is used in the formulation of sealing profiles made of EPDM rubber as carbon black decelerates the photo-degradation of cured elastomers [15].

There are different ways to protect the polymers against photo-degradation such as the addition of UV-absorbers, antioxidants and photo-stabilizers (UV stabilizers) [16]. The stabilizers should be well dissolved and well diffused in the polymer matrix [17]. Stabilizers suitable for EPDM include

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hindered amine light stabilizers (HALS) and UV absorbers (UVAs) such as benzotriazole and benzophenones [18].

The aim of this study was to investigate the effect of fillers on the UV-resistance and mechanical properties of EPDM rubber by adding different types of HALS and UVAs as fillers at specific rates to an available rubber formulation.

2. Materials and Method

2.1. Material

The material used in this study was ethylene-propylene-diene monomer, made by Standard Profile. Compounding was done using rubber-grade chemicals. The formulation of EPDM rubber is given in Table 1.

The HALS triazine derivative (Flamestab NOR 116) and bis (1-octyloxy-2,2,6,-tetramethyl-4-piperidyl) sebacate (Tinuvin-123) and the UVAs 2-(2H-benzotriazol-2-yl)-p-cresol (Tinuvin-P), 3-(3-(2H-benzotriazole-2-yl)-5-t-butyl-4-hydroxyphenyl propionate (Tinuvin-213) and 2-(2H-benzzotriazol-2-yl)4,6-bis(1-ethyl-1-phenylethylphenol) (Tinuvin-234) were supplied by the BASF company.

Table 1. Compounding Recipe of EPDM Rubber

Compounding Ingredients	Phr (parts per hundred parts of rubber)
EPDM	100
Carbon Black + White filler	175
Process Oil	65
Small Chemicals	10
Sulphur (S) + Accelerators	6.5
UVAs or HALS	0.5 – 1.0 – 1.5 – 2.0

2.2. Artificial weathering test

The artificial weathering test was carried out via weathering equipment (Atlas Ci4000) according to PV3930, Florida weathering standard. The samples were exposed for 100 h and 250 h. The cycle consisted of UV ($\lambda = 340$) radiation at 65 ºC and relative humidity (60 – 80%). The irradiance intensity was 0.50 $W.m^{-2}$.

2.3. Appearance studies

The change in sample appearance was first evaluated visually and then with gloss measurements. The gloss values were determined by a gloss meter (BYK) using a 60º incidence angle.

2.4. Evaluation of mechanical properties

The mechanical properties were evaluated by tensile, tear and hardness tests. The tensile specimens were assessed according to DIN 53504 and the tear specimens according to DIN ISO 34-1 at room temperature (23 ºC) with a cross-head speed of 200 mm min^{-1} using a computer-controlled universal testing machine (Zwick Roell Z010). The indentation hardness (shore A) of the exposed side of the plate samples was determined by means of a pocket hardness meter according to DIN ISO 7619-1. At least five samples were tested in order to get a reliable result.

2.5. Evaluation of thermal aging behavior as a permanent set

The permanent set tests were realized by aging 22 h + 2 h at 100 ºC according to DBL 5571. Test specimens were measured with a gauge (Mitutoyo) and calculated using the following equation:

$$\text{Permanent set } (\%) = \frac{h_i - h_f}{h_i - h_0} \times 100$$

where h_i is the height of the sample before thermal aging, h_f is the height of the sample after aging and h_0 is the compression distance. At least three samples were tested in order to get a reliable result.

3. Results and Discussion

The mechanical tests and Florida aging were performed on 21 different EPDM rubber plates that were prepared by adding different types of UV stabilizers at different rates to an available EPDM formula. The composition of the plates is given in Table 2.

Table 2. Composition of the plates

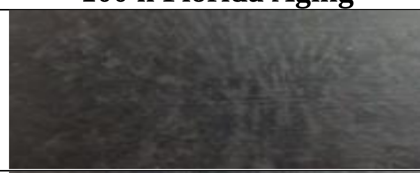
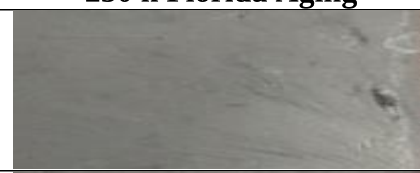
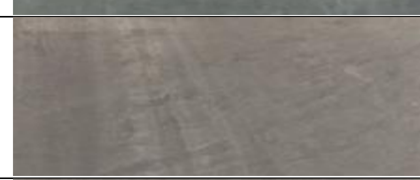
EPDM Plates	EPDM (+vulcanizers)	Tinuvin-P	Tinuvin-213	Tinuvin-234	Flamestab NOR 116	Tinuvin-123
1	x					
2	x	0.5 phr				
3	x	1.0 phr				
4	x	1.5 phr				
5	x	2.0 phr				
6	x		0.5 phr			
7	x		1.0 phr			
8	x		1.5 phr			
9	x		2.0 phr			
10	x			0.5 phr		
11	x			1.0 phr		
12	x			1.5 phr		
13	x			2.0 phr		
14	x				0.5 phr	
15	x				1.0 phr	
16	x				1.5 phr	
17	x				2.0 phr	

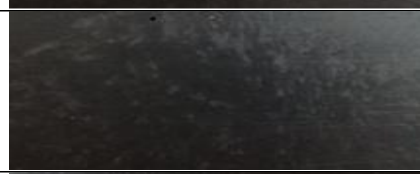
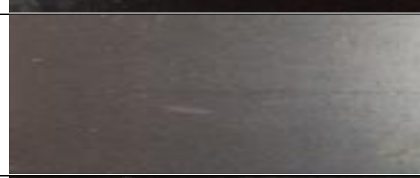
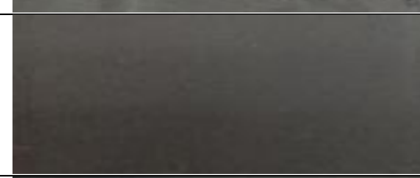
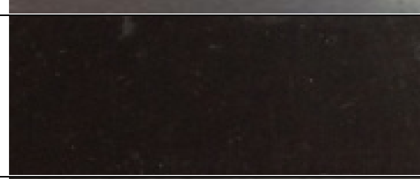
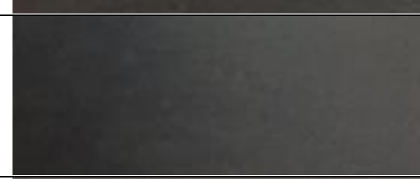
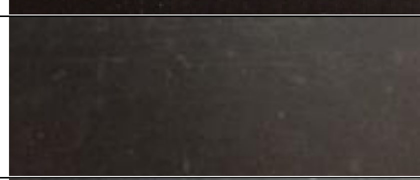
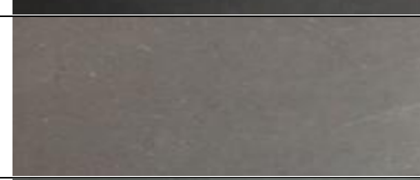
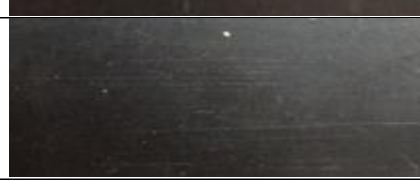
18	x	0.5 phr
19	x	1.0 phr
20	x	1.5 phr
21	x	2.0 phr

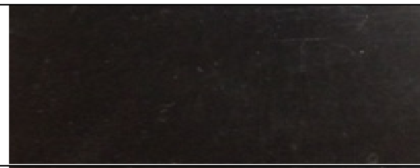
3.1. Change in appearance

The change in appearance of the EPDM plates exposed to an artificial weathering environment for 100 h and 250 h was first evaluated visually. Table 3 presents the visual control results of 21 plates after 100 and 250 h of Florida aging.

Table 3. Visual control results of EPDM plates

EPDM Plate	100 h Florida Aging	250 h Florida Aging
1		
2		
3		
4		
5		
6		
7		

8		
9		
10		
11		
12		
13		
14		
15		
16		
17		

18		
19		
20		
21		

Surface cracks and color changes can be observed on the surfaces after 100 h and 250 h of Florida aging until EPDM plate 14. The surfaces of plates 14 through 21 were more protected against UV-light than those of the others.

Gloss is an important parameter characterizing surface optical properties and is defined as the specular reflection ability of a material surface under a particular standard source and using a particular incidence angle. The effect of UV-stabilizer types and rates on surface specular gloss is presented in Figure 1.

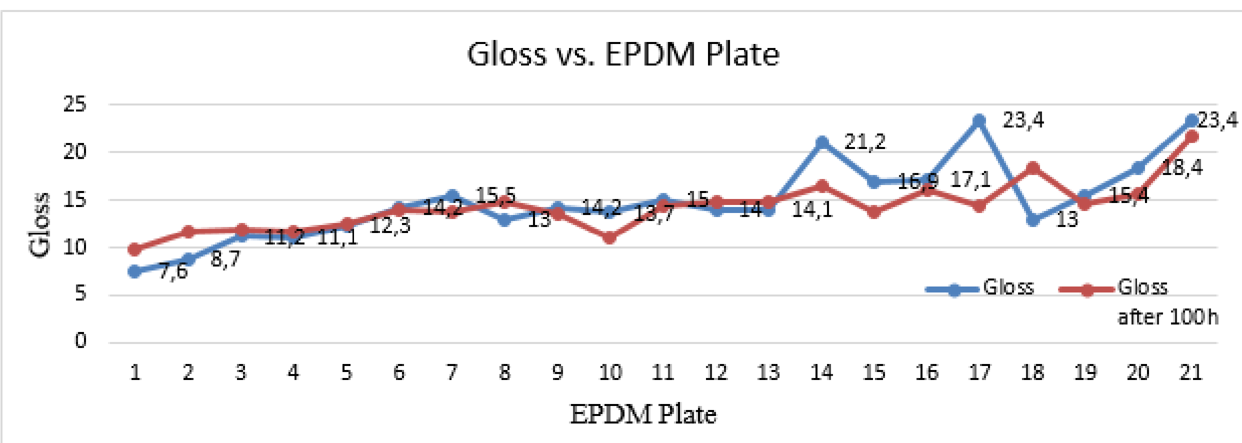


Figure 1. Effect of UV stabilizers on surface gloss

It can be observed that the gloss values of plates 14 through 21 are higher than those of the other plates before and after aging, which means that plates 14 through 21 reflected more light than the other plates because of their smoother surfaces.

3.2. Evaluation of mechanical properties

The effect of the UV-stabilizer types and rates on the mechanical properties of the EPDM plates is represented by the comparison of the tensile and tear strength, elongation, and hardness values. Figure 2 presents the comparison of the tensile and tear strength values of the EPDM plates prepared with different types and different rates of UV stabilizers. As seen below, the tensile and tear strength values of the plates are very similar; thus, it can be observed that the tensile and tear strength did not depend on the type or rate of the UV stabilizers.

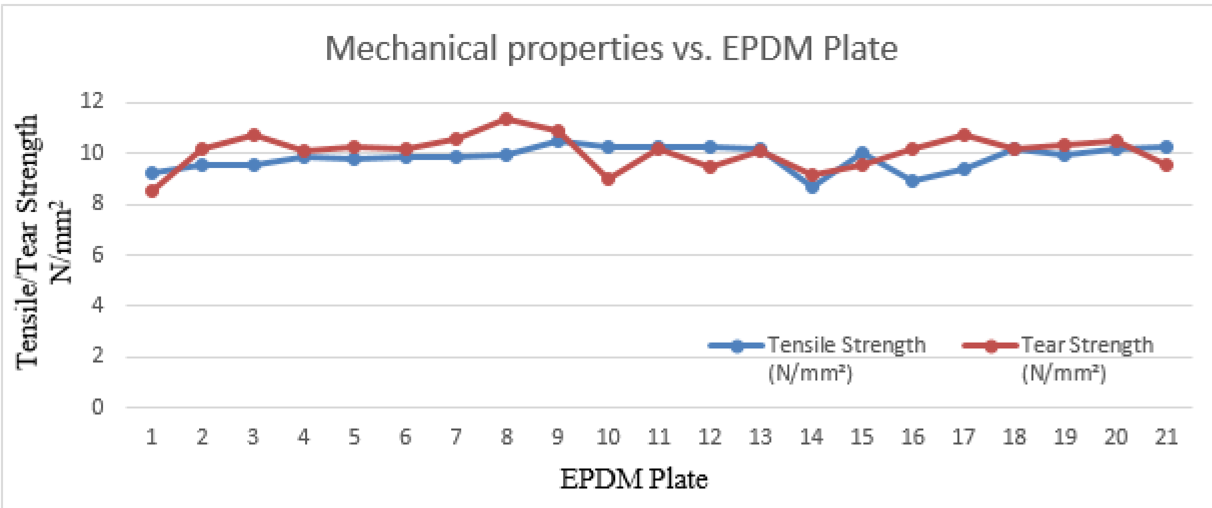


Figure 2. Effect of UV stabilizers on the mechanical properties of tensile and tear strength

The effects of the type and rate of UV stabilizers on the elongation and hardness values are presented in Figures 3 and 4, respectively.

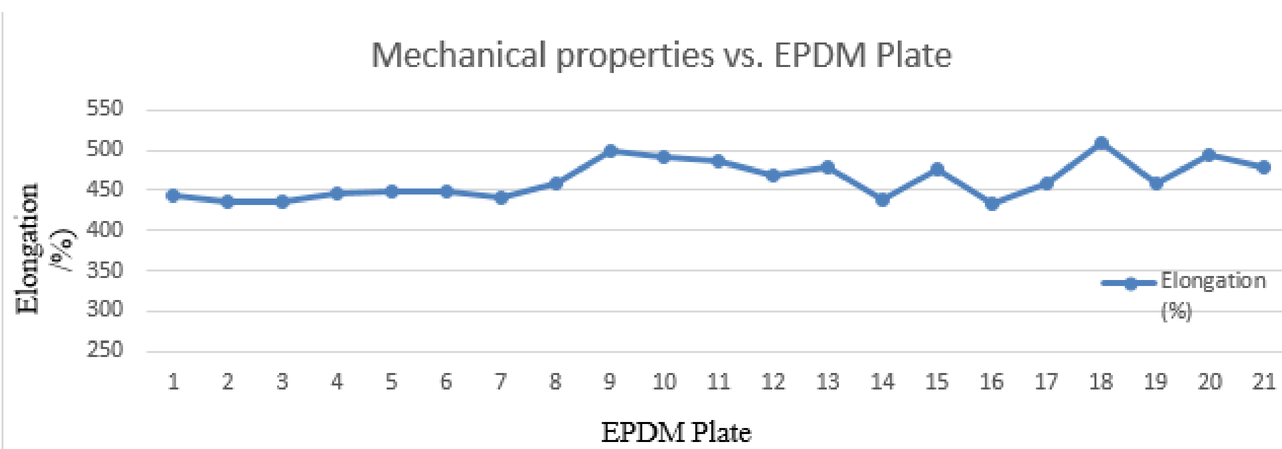


Figure 3. Effect of UV stabilizers on elongation behavior

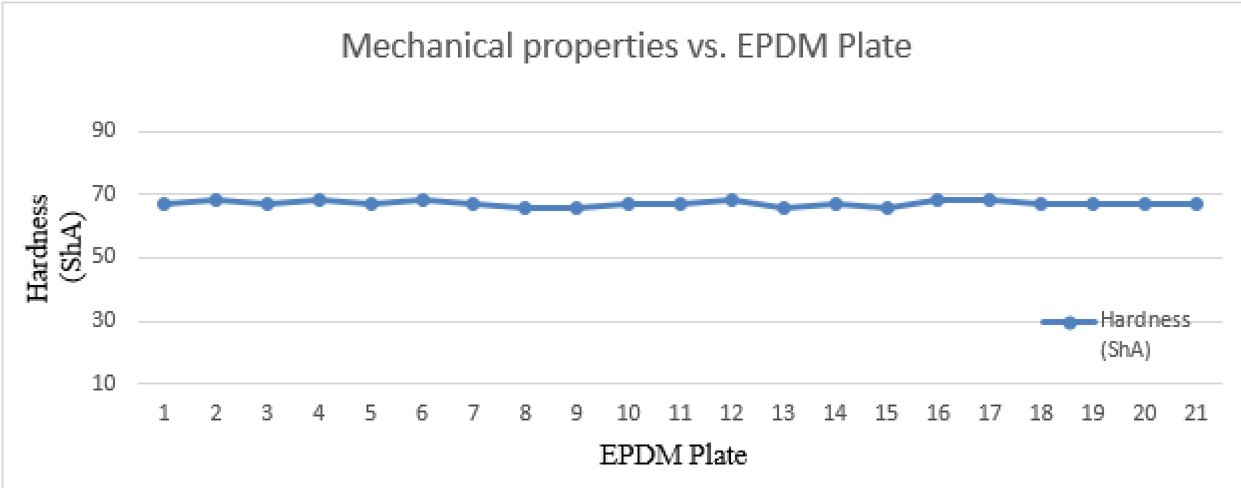


Figure 4. Effect of UV stabilizers on hardness

Figures 3 and 4 show that the elongation and hardness values are very similar. From this it can be interpreted that the types and rates of UV stabilizers had no effect on the elongation or hardness behaviors of the EPDM rubber.

3.3. Evaluation of thermal aging behavior as a permanent set

The effect of the UV-stabilizer rates and types on the thermal aging and compression behavior of the EPDM are represented as a permanent set. The permanent deformations of the EPDM plates were calculated after thermal aging at a specific compression.

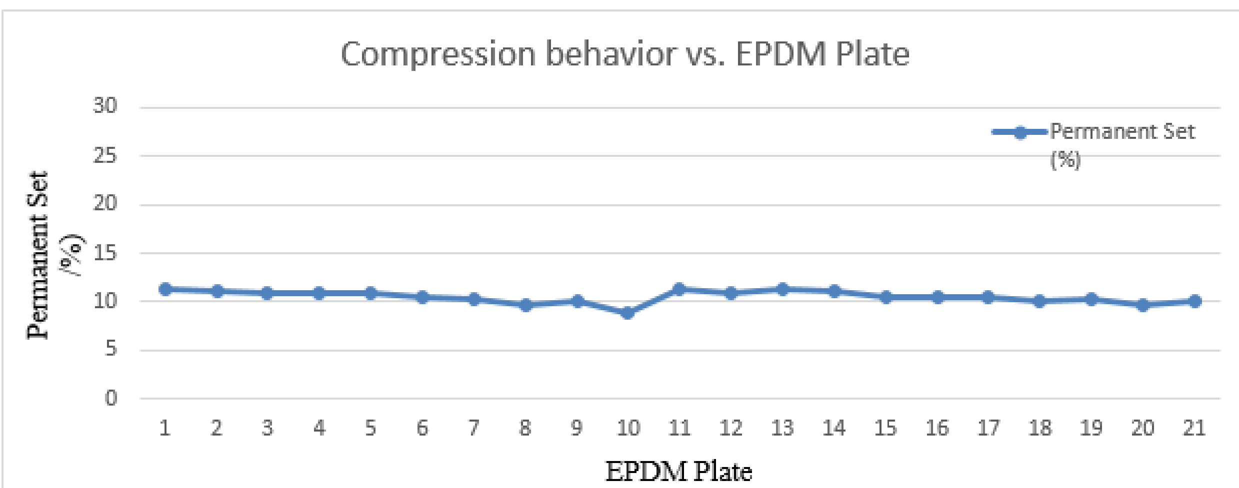


Figure 5. Effect of UV stabilizers on compression behavior

Figure 5 shows the comparison of the permanent set values of the EPDM plates. It can be observed from the similar values that the thermal aging and compression behavior of the EPDM rubber did not depend on the types or rates of UV stabilizers.

4. Conclusions

The comparison curves of the tensile strength, tear strength, elongation and hardness values showed that the types and rates of UV stabilizers had no effect on the mechanical properties of the EPDM rubber used in the production of sealing profiles for the automotive sector. Similarly, the permanent set results of the EPDM plates prepared by adding different types of UV stabilizers at different rates illustrated that the UV stabilizers did not change the thermal aging behavior of the EPDM rubber.

From the visual analysis of the change in appearance it was observed that the HALS materials had protected the surface against artificial weathering better than the UVA materials. Cracks and color changes could be seen on the surface of the plates prepared with UVA materials like in the available EPDM plates. In comparison, the HALS material made the surfaces smoother than the UVA materials, which resulted in more reflection and correspondingly, higher gloss values. Consequently, the Flamestab NOR 116 used to prepare the EPDM plates 14 through 17 showed the best results and will be analyzed more extensively in a future study.

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