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Enhancing Adhesion between layers of Babylon tyre

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Abstract :-

There are three types of adhesion difficulties faced by the Babylon Tyre manufactured: bonding the inner liner to the fabric cord, bonding the tread to the breaker bandage, and bonding the sidewall to the bead apex. We have investigated the adhesion between layers of tyre by using maleic anhydride (MA) in an elastomer while using phenolic resin, resorcinol, or novolak in another elastomer to understand the role of (MA) as an adhesion promoter. The cure rate slowed down when MA was added to the rubber compound, but changes in the physical properties were not significant. An improvement in adhesion was seen in presence of MA with phenolic resin (PH) and with (resorcinol) more than MA with novolak. Esterification reactions are the postulated mechanism for the observed promotion of adhesion.

الخلاصة:-

تواجه صناعة إطار بابل ثلاثة أنواع من الصعوبات وهي : أولا التصاق طبقة الكشن (الطبقة الداخلية) للإطار بطبقة النسيج وثانيا التصاق طبقة الجزء الملامس للأرض بطبقة الباندج وثالثا التصاق طبقة الجدار الجانبي للإطار بطبقة البيد. لقد قمنا ببحث التلاصق بين طبقات الإطار من خلال استخدام حامض الماليك اللامائي في مطاط مرن بينما يستخدم الفينولك رزن والريسورسينول و النوفولاك في مطاط أخر لفهم دور حامض الماليك اللامائي كمحفز للالتصاق. حيث لوحظ أن سرعة الفلكنة قلت عند إضافة حامض الماليك اللامائي إلا أنة لم تلاحظ أية تأثيرات معنوية على الخواص الفيزياوية. وقد أمكن أحداث تحسين ملحوظ في التلاصق في حالة وجود حامض الماليك اللامائي مع الفينولك رزن ومع الريسورسينول أكثر من وجود حامض الماليك اللامائي مع النوفولاك. تعتبر تفاعلات الاسترة هي الميكانيكية السائدة للتحفيز الملا حظ للالتصاق.

Keywords: Adhesion, Maleic anhydride, peel strength

Introduction

Pneumatic, or air- filled, tires are used on vehicles as diverse in form and function as air planes, bicycles, tractors, sizes, race cars. Accordingly, they encompass a wide rang of sizes, designs, materials, and construction types. Nevertheless structural elements that are common to all of these tyres are the casing, bead, and tread band[1]. The casing- often called the carcass- is the structural frame of the tyre. It usually consists of directionally oriented cods banded together by rubber into layers, called plies, which give the tyre strength and stiffness while retaining flexibility. The number of plies is determined by tyre type, size, inflation pressure, and intended application. Plies oriented mainly from side to side are "radial", which plies oriented diagonally are "bias". In the area where the tread is applied, the plies in the radial casing are usually covered by a relatively stiff steel belt or a steel belt covered by a circumferential nylon cap ply[2]. The steel belt is made by using fine wire twisted into cables as cords. For the inflated tyre to be retained on the wheel rim, the plies are anchored around circumferential hoops made of multiple strands of fine, high - tensile wire located at the inner edges of the two sidewalls where they mate with the rim. These two hoops, called beads, are pressed against the rim flange be inflation Pressure, thereby seating and sealing the tyre on the rim[3] .Encircling the tyre is the tread . This a thick band of rubber that forms the tyre surface, from its crown (its largest radius) to its shoulders (the areas in which the tread transitions on the sidewalls). The tread is the only part of the tyre that comes in contact with the road surface during normal driving. The tread consists of (a) ribs- circumferential rows of tread rubber designed for noise suppression and traction, and (b) grooves circumferential Channels essential for traction, directional control, and cool running[4]. The polymer- polymer adhesion of uncross linked elastomer (i.e. polymer with a glass transition temperature blow room temperature) used in the tyre industry is directly related to the cohesion of the different layers of a tyre before the final cross linked process , and is a key parameter for these materials . Despite this industrial relevance only few studies[5,6] have been carried out on what is typically called " tack " and many aspects of the problem remain poorly understood .Maleic anhydride (MA) has been shown to promote adhesion between elastomers and a variety of substrates, and the work here demonstrates that using maleic anhydride (MA) in rubber compounds can help to overcome some of the adhesion difficulties encountered in tyre construction. Maleic anhydride (MA) is shown to promote adhesion between layers of the tyre, when used in conjunction with phenolic or hydroxyl functional materials, provides bonding between elastomers[7]. The construction of Babylon tyre presents manufactures with three adhesion problems. The first is bonding the inner linear to the fabric cord. The second is bonding the sidewall to bead apex. The third is bonding the tread to the breaker bandage. In this work, the adhesion promoter used consists of maleic anhydride (MA), resorcinol, phenolic resin, and novolak. The effect of bonding materials on curing was studied. The adhesion peel strength between the layers of tyre was measured .The effect of bonding materials on mechanical properties also was studied.

Experimental

Toll manufactured master batches of rubber compounds were obtained (Tables 1, 2, 3), and small portions of the master batches were modified as needed for the study. The modifications were made on a tow- roll mill per ASTMD-3182 .The maleic anhydride (MA), resorcinol, phenolic resin (pH), and novolak in this research as bonding system. The cure properties of the formulations were measured with a Monsanto Rheometer ODR 2000 at 160 c°. The T90 time, which denotes the time for 90% cure and the maximum torque were determined from the rheographs according to ASTMD - 2084.The hardness of vulcanizates was measured using a shore A durometer according to ASTMD 2240, tensile properties were determined by a tensile tester (Tensometer 10) according to ASTMD – 412.

Peel test

Parts for testing adhesion between rubber layers of the tyre were made de stacking tow 152 mm × 152 mm squares (each of a different elstomers and weighing 60 gm), and a 38 mm wide stripe of release film was placed between the two rubber sheets at one end of the stack, providing a means to place the parts in the test grips. The resulting sandwich was placed in a physical slab mold and cured at 160c°under approximately 250 psi of pressure. These parts were cured to the T90 of the slowest curing materials. The cured parts were cut into 19 mm × 152 mm strips and pulled on the SATEC tester at 51 mm / minute.

Table (1)

Formulations of Inner liner and fabric cord containing different types of bonding materials.

Ingredient	**Inner liner**	**fabric cord**	
	Phr (A)	**Phr (B)**	**Phr (C)**
NR	**100**	**100**	**100**
R.R	**28**	**17**	**17**
Zinc oxide	**4**	**4**	**4**
Stearic acid	**2**	**2**	**2**
6PPD	**-**	**1.5**	**1.5**
HAF N660	**58**	**47**	**47**
Process oil	**6**	**7**	**7**
MBS	**0. 75**	**0.8**	**0.8**
Sulfur	**2.6**	**2.8**	**2.8**
PH	**2**	**-**	**-**
MA	**-**	**-**	**1.5**

a: Reclaimed rubber
b: Phenolic resin

Table (2)
Formulations of tread and breaker bandage containing different types of bonding materials.

Ingredient Breaker bandage Tread

Phr (D) Phr (E) Phr (F)

NR	75	100	100
BR – cis	25	-	-
Zinc oxide	5	5	5
Stearic acid	2	1.8	1.8
Wax	1	-	-
6ppD	0.5	-	-
TMQ	1	-	-
HAF N326	-	53	53
HAF N373	62	-	-
Process oil	8	6	6
MBS	-	0.5	0.5
Sulfur	2.6	1.4	1.4
CBS	1.5	-	-
Resorcinol	1.4	-	-
MA	-	-	1

Table (3)
Formulations of sidewall and bead apex containing different types of bonding materials.

Ingredient Sidewall Bead apex

Phr (G) phr (H) phr (I)

NR	100	74	74
BR – cis	-	13	13
SBR 1502	-	13	13
Zinc oxide	4	5	5
Stearic acid	2	2	2
6PPD	0. 7	1	1
TMQ	0.7	2	2
Wax	-	1	1
HAF N373	52	55	55
Process oil	13	6	6
MBS	2.5	0.67	0.67
Sulfur	3	2	2
Novolak	13	-	-
MA	-	-	5 5

Results and discussion

Effect of the bonding system on the physical properties of the rubber compounds. The cure rates of the rubber compounds varied with the loading amount of bonding system as listed in the table (4). The t90 time Decreased with loading of Maleic anhydride (M A) at 1.0, 1.5, and 5 phr, while the increase in TS2 time was relatively small. Since the maleic anhydride (M A) has carbonyl groups that can Stabilize radicals, the cure rate of he rubber compounds containing maleic anhydride (MA) decrease due to the lowering activity of sulfur radicals. The maximum torque increased highly with loading of Maleic anhydride (MA), because the maleic anhydride acted as a co agent in both of the compounds. That is, Its addition increased the crosslink density of the formulation as evidence by increased maximum torque. The maximum torque increased highly with loading of Maleic anhydride (M), because the maleic anhydride acted as co agent in both of the compounds. That is, its addition increased the crosslink density of the formulation as evidence is increased maximum torque.The changes in the physical properties of vulcanizates with the maleic anhydride (MA) loading were not considerable (Table5) .consistent trends in hardness. Elongation at break and tensile strength of vulcanizates increased slightly with the maleic anhydride (MA) loading. The loading of maleic anhydride (MA) into the rubber compound reduced cure rate. Due to the interaction between radicals and delocalized electrons of maleic anhydride (MA).

Table (4)

Cure properties of maleic anhydride acid (MA) containing rubber compounds from their rheocurves using an oscillating disc –type rheometer at 160 C ̊

Compounds	B	C	E	F	H	I
TS2[a]	1.1	0.1	1.47	1.33	1.31	1.15
T90[b]	1.8	1.24	3.06	3.42	2.63	2.52
Max. Torque	41	44.13	38	41.22	33	36.31
Min. Torque	3.13	3.35	3.10	3.25	2.57	2.86

a: Time required for 2% cure b: Time required for 90%cure

Table (5)

Tensile properties of the bonding system containing rubber Compounds.

Compounds	A	B	C	D	E	F	G	H	I
Hardness (Shore A)	55	55	53	55	64	63	85	75	56
Modulus at 300% Elongation (Mpa)	9.3	11.6	12.4	11.5	9	11	10	8.8	9.5
Tensile strength (Mpa)	15.2	14	15	21.3	13	14	13.6	20.5	21
Elongation at break (%)	462	370	400	466	287	310	175	521	540

Adhesion of layers compounds

The pneumatic tyre is a complex system of interacting components, each with its own properties for maximum effectiveness, yet the performance of the tyre Depends on the interactions of the components. The adhesions of inner liner to fabric cord, tread to breaker bandage, and bead apex to sidewall were evaluated be adding the maleic anhydride (MA) to fabric cord, breaker bandage and sidewall. The maleic anhydride acted as co agent in both of these compounds. That is, its addition increased the crosslink density of the formulations as evidence by increase the maximum torque and the modulus strength. The maleic anhydride (MA) also had a retarding effect on the cure rate of the materials. Adding 1.5 phr of maleic anhydride (MA) to the fabric cord increased the peel strength between the two compounds to 86 N/mm greater that the peeing strength in the absence of Maleic anhydride (See table 6). This may be to the reactive methylol groups which can make the molecules to condense, through the reaction of methylol groups with maleic anhydride to form stable methylene ester links[8]. Bonding tread to breaker bandage was accomplished be adding maleic anhydride (MA) to tread while adding resorcinol to breaker bandage. Adding maleic anhydride to tread increases the peel strength as high as that obtained when novolak was used with maleic anhydride as adhesion promoter. Logically, we conclude that the chemical interaction of the two adhesion promoters produce a marked increase in adhesion strength.Though the adhesion strength obtained between sidewall and bead apex was weak compared to these obtained between layers in this study. The reason for low adhesion results obtained because of the novolak has no reactive methylol groups in the molecules, and thus they require a Harding agent and heat for polycondensation[9].

Table (6)
Adhesion between layers of Babylon tyre

Numbers of formulation bonded	Peel strength (N / mm)
A to B	54
A to C	86
D to E	45
D to F	63
G to H	51
G to I	74

Role of maleic anhydride (MA) as adhesion promoter

In order to bond two layers in tyre, the effort was made through compounding to modify surface chemistry at the Adhesive interface so that reactive sites on the surfaces of each of two compounds would react with one another to form chemical bonds between the rubber compounds. Compounding with maleic anhydride (MA) provides bound sites for reactivity on one elastomers surface, while mixing phenolic resin, resorcinol, or novolak resin into a second compound provides bound hydroxyl sites on the second elastomers surface. When the two different rubber surfaces were brought into contact and cured, the maleic anhydride (MA) on the surface of one elastomer could react with the hydroxyl sites on the surface of the other elastomer to form a chemical bond between the two materials. The fact that maleic anhydride (MA) can react with hydroxyl sites to form Trans – ester linkages is well known and commonly practiced industrially.

Conclusions

Adhesion between layers of tyre is considerably enhanced if maleic anhydride (MA) was milled into one elastomer and a hydroxyl function material was milled into another elastomer, an Esterification reaction of maleic anhydride (MA) with hydroxyl sites would enhance the adhesion between the two elastomers. According to the pool strength obtained in the presence of maleic anhydride (MA) with different bonding materials the adhesion order can be written as follows:

Phenolic resin > Resorcinol > Novolak

We conclude that the chemical interaction of the two promoters produce a marked increase in adhesion strength.

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