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Improvement of Mechanical and Rheological Properties of Natural Rubber for Anti-Vibration Applications

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Abstract

This research aims to study and improve the passivating specifications of rubber resistant to vibration. In this paper, seven different rubber recipes were prepared based on mixtures of natural rubber(NR) as an essential part in addition to the synthetic rubber (IIR, BR_{cis}, SBR, CR)with different rates. Mechanical tests such as tensile strength, hardness, friction, resistance to compression, fatigue and creep testing in addition to the rheological test were performed. Furthermore, scanning electron microscopy (SEM)test was used to examine the structure morphology of rubber. After studying and analyzing the results, we found that, recipe containing (BRcis) of 40% from the natural rubber has the best mechanical and physical specifications to be used in applications that require the presence of rubber, resistant to vibration.

Keywords: *Ant vibration behavior, Natural rubber, Synthetic rubber, master batch.*

1. Introduction

Many kinds of machinery and engineering equipment suffer from vibrations and noise problems. These problems increase dramatically when there is no means to prevent vibrations or it damage after a short period. There are several ways to reduce the vibrations, control the natural frequency ,using barriers and enclosures , reduce wave vibration amplitude (through a method of effective system which include applying force with the same frequency and amplitude to the source of the vibration, but opposite phase direction and thereby the vibration force will be canceled in vibration sites) or applying passive systems which are cheap and easily to manufactured, such as air springs , mineral springs , dampers and rubber mounts [1,2,3].Rubber is a polymeric material which becomes flexible by vulcanization. Due to the flexible nature of the rubber compounds which enables it to dissipate energy used for the protection of engineering equipment, bridges, and buildings from the effect of vibrations[4]. There are two types of rubber, natural and synthetic. Natural rubber (NR) coming from latex is mostly polymerized isoprene with a small percentage of impurities in it. This will limit the range of properties available to it, although the addition of sulfur and vulcanization are used to improve the properties. Synthetic rubber is any type of artificially made polymer material which acts as an elastomer. The use of synthetic and natural polymer blends is a common method improve the mechanical and physical properties of rubber composites[4,5,6]. M.H. Almamoory studied the effect of humidity on the mechanical and physical properties of natural rubber (SMR 20) and synthetic rubbers (SBR 1502) and (BRcis). The results shows that, the negative effect of humidity on the properties of natural rubber is greater than its effects on the properties of synthetic rubbers[7]. Almamoory prepared recipe used for engine mounts consist from50% NBR + 8% Novolac + 20% Sio2 +20% C, his results showed that the resilience decrease with increasing of novolac [8]. Masomori designed a rubber magnetic dampers consist of (IIR) rubber and Ferrite Powder with practical size (5-10) µm to reduce the noise and vibrations generated in the iron bridges associated with railway lines instead of traditional dampers[9]. Ibrahim studied the effect of barium titanium ($BaTio_3$) on the mechanical properties of NBR rubber, they found that, the addition of ($BaTio_3$) as a filler lead to an increasing in the damping properties [10]. Ahmed Nemha prepared a new rubber composite materials(SBR with reclaim and Novolac) for vehicles mountings, hemaintain that, hardness and wear resistance was enhanced with the presence of Novolac[11]. V.S. Chavan studied the analysis of anti vibration mounts for vibration isolation in diesel engine generator set. Rubber and neoprene materials with and without several mount conditions are analyzed. The results shows that the neoprene material gives out the best vibration isolation and the dynamic stiffness is dependent on the frequency[12]. The major aim of this research is to study and examine the effect of rubber type on the mechanical behaviors of the seven selected rubbery blends for intivibration applacations and compare it with standard one that already used in Al-Dewaniya tires factory. The testing results will be the main factor for detecting the best blend choice for the intivibration mounts applications.

2. Experimental Work

The rubber compounds used in this study were prepared from natural rubber (SMR-20) , styrene-butadiene rubber (SBR-1502),BR_{cis}, IIR and CR rubber. Carbon black (N330) filled recipes with other compounding materials such as filler; vulcanizing agent (sulfur) and accelerator were prepared with the compound formulations. The specification of the rubbers used in this work arelisted in table (1). In this work(seven) different recipes were prepared in the laboratory of Al-Dewaniya Tires Factory according to their specifications. Table (2) demonstrate the recipes content[13]. Rubber processing technology consists of compounding (mixing), shaping, molding and vulcanizing. Rubber is always compounded with additives: vulcanization chemicals, and usually fillers, anti degradants, oils or plasticizers. Mixing and mastication are conveniently done using two roll mills (Calender)The mixing operation was executed on two stages, as shown in table (3). The first one is called master batch. It consists of rubbersincludingactivators (Zinc oxide), Antioxidant(TMQ), reinforcing agent carbon black(C.B) and process oil. At the end of the first stage, carbon black is blended with process oil in order to have optimum dispersion and coupling with rubber. The second stage is called the final batch. It consists of the previous master batch, curing agent (Sulfur) and accelerators(CBS). These materials are added at the end of process to prevent pre-vulcanization which may occur due to the elevated temperatures as shown in table (3) .

Table 1,
Rubbers Specification [13].

rubber	Sp.Gr	T_g (°C)	Color	Hardness (Shore A)	Resilience	Tensile strength, MPa,
NR	0.934	- 72	red	20 - 100	Excellent	17.23 - 25
SBR	0.94	- 55	Yellow	40 - 85	Good	22.0 - 26
CR	0.92	-43	Yellow	20 – 95	Good	18 -24
BR_{cis}	0.915	-56	white	20 - 40	Excellent	23 - 27
IIR	0.931	-73	Yellow	40 -90	Good	15 - 20

Table 2,
Recipes Content[13].

Material	Standard (PPhr)	Stock1 (PPhr)	Stock2 (PPhr)	Stock3 (PPhr)	Stock4 (PPhr)	Stock5 (PPhr)	Stock6 (PPhr)	Stock7 (PPhr)
NR	100	95	80	60	40	-	70	-
SBR 1502	-	-	-	-	60	-	-	30
CR	-	5	-	-	-	-	-	-
BR_{cis}	-	-	-	40	-	-	30	-
IIR	-	-	20	-	-	100	-	70
Zinc oxide	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
(TMQ)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
wax	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
oil	5	5	5	5	5	5	5	5
C.B	48	48	48	48	48	48	48	48
(CBS)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Sulphur	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
CTP.100	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15

Table 3,
Schedule of Mixing Cycles[13].

Item No.	Description
	Stage (1) Master Batch
1	Passing rubbers through rolls several times with decreasing a mill roll opening to 0.5cm.
2	During whole operation, cutting of milled rubber diagonally, rolled or spiraled, and passed into nip in horizontal and vertical state alternatively several times for homogenization.
3	banding with mill opening 2.5cm to 0.5cm for several times, and repeat item (2).
4	Adding of stearic acid and zinc oxide.
5	Adding of antidegredants, and repeat item (2).
6	Adding half of each carbon black and process oil, and repeat item (2).
7	Adding the other half of each carbon black and process oil, and repeat item (2).
	Stage (2) Final Batch
8	Cooling the master batch to the room temperature.
9	Adding the accelerator.
10	Adding the sulfur to the master batch.
11	Sheeting the batch to a thickness of (0.5) cm.
12	Cooling the batch to room temperature.

3. Laboratory Tests

All the tests(except creep and SEM tests) were done in the labs of Babylon Tyres company. Table (4) lists the test methods and the equipments used during the present work.

Table 4,
Equipments and Standard Test Methods[13].

No	Test	ASTM	Equipment
1	Tensile Test.	D 412	Monsanto T10 Tensometer
2	Compression set test, using calibrated spring loading, Method A.	D 395 B.S.903,PT.A.6	Wallace Compression Set with constant (stress)
3	Hardness Test.	D 1415, D 2240	The Wallace Dead Load Hardness Tester
4	Rheological Test.	D 2084	Monsanto Rheometer ODR E2000
5	Dynamic Fatigue Test.	D 430	Wallace De Mattia Flexing Machine
6	Abrasion wear test	D 5963	Wallace Machine
7	Resilience test	D 903	Wallace Machine
8	Creep test	D 2990	Gunl Machine

4. Result and Discussion

Table (5) show the results of tensile, hardness, compression set ,flexing (fatigue),resilience and wear resistance, while Table (6) shows the results of rheological test. Also the result of (SEM) test demonstrate in figures(1to 3). The best tensile strength is found with the stocks (2 and 3).This result may be due to the good compunction between NR and BR_{cis} blends at this percentage. Also Stocks 1,2,3, 6, and 7 have acceptable modulus and elongation at break. All the stocks(except stock 4) have a suitable hardness values. The higher hardness value of stock 4 can be attributed due to the fact that SBR is a copolymer of styrene and butadiene groups and for this reason acting as a harder block to increase the degree of the hardness of the SBR which increase the blend hardness[14]. The best compression set value and flexing or fatigue value is found with the stocks(2,3 and 7). Also stocks (2,3 and 6) have the best results of wear resistance due to its minimum values of weighting losses. But the best result of resilience test found in stock 3. In the resilience test , the resulting value represent the amount of rebounded energy from the sample , So we can say that the stock 3 is the best for antivibration purposes due to the excellent damping properties. In addition to the mechanical properties we must be acquainted with the physical properties and cure specifications, the cure characteristics of the (seven) recipes are summarized in table (6). The scorch time t_{s2}(period of time before vulcanization starts, its unit is minute**.** milli-minute) for stocks 3 and 5 are the best(longest value) in comparison with the periods of the other stocks. The curing time t_{90} for stocks (2, and 3) are also the best, where these periods are shorter than the other stocks. The curing time t_{90} for stocks (2, and 3) are also the best, where these periods are shorter than the other stocks. A long scorch period means high processing safety, and a short cure period is required to prevent over-cure. The values of the minimum torque ML, range from 3.66lb-in in stock (1) to 9.47lb-in in stock (4), and the values of the maximum torque, MH, range from 28.16lb-in in stock (1) to 85.91lb-in in stocks (4). The torque difference between MH and ML,ΔM could be used as an indirect indication of the crosslink density and the stiffness of the rubber blend [15,16,17]. So, that is very logical in the value of stock 4 which have the higher value of ΔM.

Table 5,
Mechanical Tests Results.

Stock	Tensile strength (MPa)	Modulus at 200% (MPa)	Elongation at Break (%)	Hardness shore A	Compression set %	Flexing (cycle)	Resilience %	Friction weight loss(gm)
standard	18	2.6	500	40	8.8	54800	22	0.32
1	9.35	2.96	707	35	9.8	14300	24	0 .34
2	18.5	2.82	540	35	10.5	65800	23	0.22
3	21.9	2.5	650	42	12	83800	20	0.25
4	10.6	-	106	90	9	11200	39	0.0
5	11.7	1.14	408	33	20	10200	21	0.32
6	15	2.4	500	50	10	20700	26	0.14
7	11	2.81	400	40	8	60450	24	0.31

Table 6,
Rheological Test Results.

Stock	t_{s2} (m.m)	t_{90} (m.m)	M_L (lb-in)	M_H (lb-in)	ΔM (lb-in)
standard	1.1	2.17	3.50	28.16	24.66
1	1.04	2.13	3.66	29.63	25.76
2	0.96	1.73	4.12	38.62	34.5
3	1.0 9	2.11	4.69	31.41	26.72
4	0.83	2.17	9.47	85.91	76.44
5	1.10	2.31	5.35	32.14	26.79
6	0.97	2.43	5.10	32.93	27.83
7	1.08	2.15	3.80	32.93	29.13

Creep test was performed to determine the viscoelastic behavior of the selected rubber stocks. So, in this work, the test wasn't to study the failure types because of the long duration to failure [18]. This test was carryout in the labs of material engineering college ,Babylon university.

Constant suitable load was applied and the deformation was recorded. The result of this test shows the minimum value of deformation occurs in stock 4 because the higher value of hardness due to the higher cross linking density[19]. So, the creep results are compatible with the pervious results. The result of this test demonstrate in table (7) below.

Table 7,
Creep Test Results.

stock	Deformation after 1hr(mm)	Deformation after 2hr(mm)	Deformation after 3hr(mm)	Deformation after 4hr(mm)	Deformation after 5hr(mm)	Deformation after 6hr(mm)
standard	1.12	1.15	1.20	1.40	1.40	1.40
1	1.85	1.87	1.95	2.22	2.22	2.22
2	1.15	1.18	1.21	1.40	1.40	1.40
3	1.33	1.35	1.42	1.50	1.50	1.51
4	0.2	0.21	0.23	.245	0.5	0.5
5	0.97	1.04	1.o45	1.15	1.20	1.21
6	1.05	1.08	1.01	1.20	1.30	1.30
7	1.11	1.14	1.19	1.22	1.31	1.31

The scanning electron microscopy (SEM) was Performed to examine the structure morphology of rubber[14]. This test was performed in the university of technology by using (Te scan VEGA Easy Probe) device The result of selected stocks was illustrated in figures (1 to 3). This test indicated that the blends of stock 3 are very homogenous systems (i.e., separation between the blends compounds are not exist). The component of standard stock represent tow phase as shown in figure (3)while the structure of stock 2 represent the intermeddle case. Relatively, that is a compatible with the experimental results.

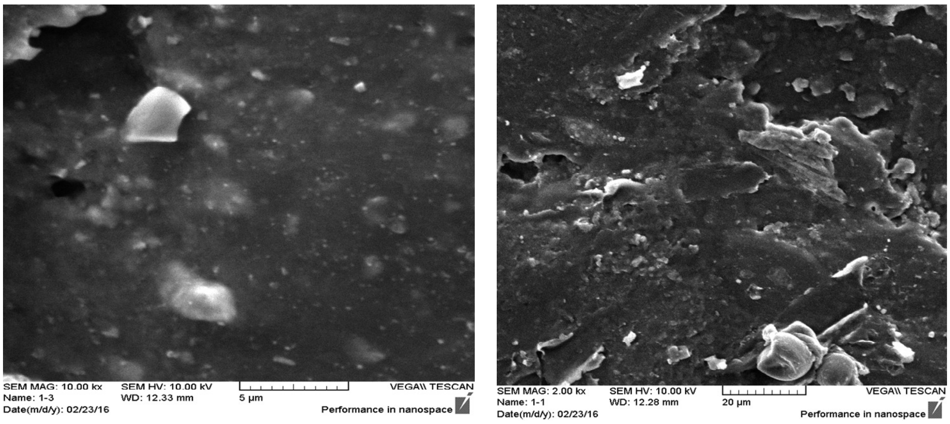

Fig. 1. SEM test for stock 2.

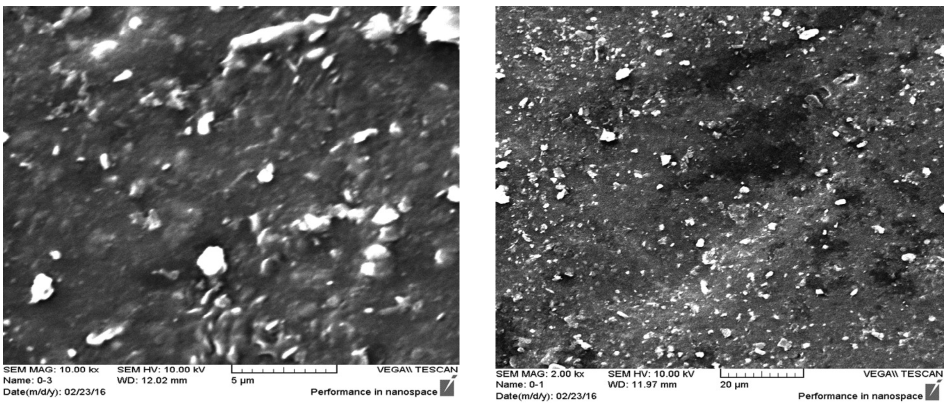

Fig. 2. SEM test for stock 3.

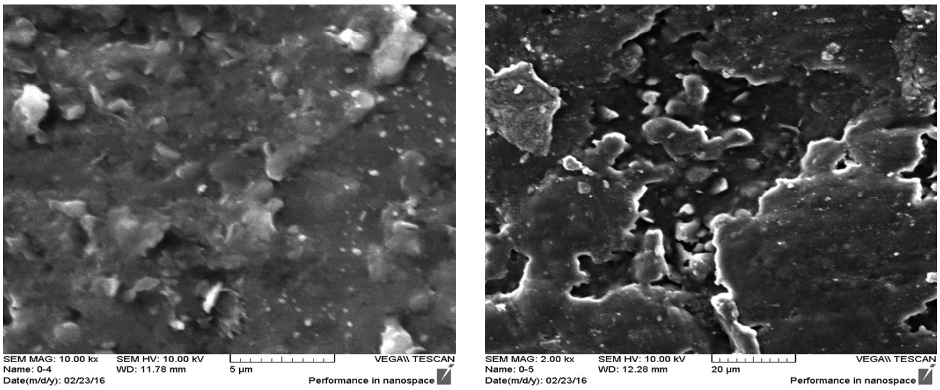

Fig. 3. SEM test for standard stock.

5. Conclusions

From this work , may be made the following conclusions:

1. Mechanical properties of (NR) is improved when it blended with the other rubbers and improvement in mechanical properties has advantages and disadvantages according to the engineering uses.
2. The mechanical properties such as tensile strength, elongation at break, compression set and hardness properties were strongly dependent on the blend structures, that is very clear with (SEM) test for the three selected samples.
3. Rheological test has a compatible result with the mechanical tests ,that is very understandable in the value of(ΔM), higher value of(ΔM) lead to the higher cross linking value.
4. Blend recipe which contains 40pphr (BRcis) with60pphr(NR) has the optimum properties which can be use in antivibration applications due to the excellent resilience properties for this types of rubber.
5. Blends contains40pphr (NR) with 60pphr(SBR) has the maximum value of hardness because the ability of (SBR) to achieve a high cross linking densities due to the its nature.
6. According to experimental results, for anti-vibration purposes , using of (NR with SBR) blends is unbeneficial because the poor damping properties due to the high stiffness. This blends can be use in the applications that required higher stiffness and lower resilience.

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تحسين المواصفات الميكانيكية والانسيابية للمطاط الطبيعي المستخدم في تطبيقات مقاومة الاهتزاز

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الخلاصة

يهدف هذا البحث إلى دراسة المواصفات التخميدية للمطاط المقاوم للاهتزاز وتحسينها. تم تحضير (سبع) عجنات مطاطية مختلفة بالاعتماد على عجنات من المطاط الطبيعي بوصفه جزءاً أساسياً فضلا عن المطاط الصناعي (IIR, BRcis, SBR,CR) وبنسب مختلفة. تم إجراء الاختبارات الميكانيكية مثل اختبار الشد والصلادة والاحتكاك ومقاومة الانضغاط والتصادم وفحص الكلال و الزحف إضافة إلى إجراء فحص الانسياب لمعرف الخواص الميكانيكية والفيزياوية للعجنات المحضرة . وتم أيضا إجراء فحص الـ (SEM) لدراسة شكل الترابط بين الخلائط المختلفة. وبعد دراسة النتائج وتحليلها وجد أن العجنة التي تحتوي على المطاط الصناعي (BR_{cis}) بنسبة 40% من المطاط الطبيعي هي التي تمتلك أفضل مواصفات ميكانيكية وفيزياوية لكي تستعمل في التطبيقات التي تتطلب وجود مطاط مقاوم للاهتزاز.
