Study the Effect of Mica as Filler in Natural Rubber properties

Abeer Adnan Abd
Babylon University/College of Materials Eng.
Abeer.abdabeer@yahoo.com

Abstract:

In the current, Studying the effect of mica upon the characteristics of curing system of natural rubber (NR) rubber has been carried out by using oscillating disk rehometer according to the ASTM D-2084 specification. Results indicate that the addition of cheap material (Mica) to natural rubber in proportions of (4, 8, 12, 16, and 20) % of mica enhanced the hardness, the tensile strength and reometric properties of the rubber. The mix of NR/mica (100: 20) shows promising mechanical properties than other composition. The result showed that the curing time, scorch time and minimum torque decreased with filler content increase therefore the processing time decreased. Also the tensile strength, maximum torque, specific density and hardness advanced with the filler content increase. The hardness developed significantly from (40) to (46) shore (A) when mica content was increased therefore the modulus increased and the elongation decreased. The maximum tensile strength and the minimum wear rate at (10) % of mica.

Keywords: Mica, filler ,NR rubber ,mechanical properties**.**

الخلاصة:

في البحث الحالي تم دراسة تاثيرالمايكا على خواص الانضاج لمطاط (NR) وذلك باستخدام reometric oscillating disk وطبقا للمواصفة العالمية D2084 ASTM اظهرت النتائج ان اظافة الماكا الرخيصة الثمن لمطاط (NR) وبنسب (٤،٨،١٢،١٦،٢٠)% حسنت الصلادة و مقاومة الشد و خواص الانسياب للمطاط . ان خلط المايكا مع المطاط بنسبة (٢٠/١٠٠) قد اظهر الخواص الميكانكية المرغوب بها اكثر من باقي النسب . النتائج اظهرت ان زمن الانضاج والاصلاد العزم الاصغر يقل مع زيادة محتوى المالى لذلك زمن التصنيع يقل .بالاضافة الى ذلك ان مقاومة الشد والعزم الاكبر والكثافة النوعية تزداد مع زيادة محتوى المادة المالئة و الصلادة تطورت بشكل ملحوظ من (٤٠-٤٦)shore A عندما تضاف المايكا لذلك معامل المرونة يزداد والاستطالة تقل.اكبر مقاومة شد واقل معدل بلى يحدث عند اضافة (١٠)% من المايكا.

الكلمات المفتاحية: والميكا، و حشو ، NR المطاط ، الخواص الميكانيكية

The aim of the work: enhance the rubber mechanical and thermal properties to use in sealants, tires , electrical and thermal insulators, heat resistance gloves, cooker ware and coats and fasten the processing technology.

Introduction:

The use of filler particles in polymer matrices are of great importance in many branches of industry. A lot of investigations were produced mainly by tires, brake disk ,seals and electrical insulators manufacturers, as the mechanical properties of rubber compounds are essential for rheological and mechanical properties of rubber [Nhasar,2009; Sreekanth1, 2009;Mandeep,2005]. Mica is a distinguished of low cost mineral, noted for its easy cleavage into thin, highly flexible, resilient plates with outstanding electrical, heat and chemical resistance [Ubirajara, 2001].

The possibility of partial replacement of carbon black and silica by mica, a well-known class of low cost platy mineral, in rubber without significant damages to its chemical properties therefore it has good abrasion and tensile resistance [Harper 2001, Ming Tian ,2008]. Micas having different compositions differ in their fine structural features, and in particular, is amorphous cations in octahedral and tetrahedral of 2:1 layers, distribute with different degrees of order-disorder. Reconstruction of the cation distribution patterns in terms of short- and long-range ordering is one of the main problems in determination of actual mica crystal structures. Most filler grade mica is first collected as flakes by flotation from ore that contains several minerals [Hongda Wang, 2002 ; Besson,1997].

Mica is largest single use is in polyolefins and as an asbestos substitute in brake linings and gaskets, and as a mold lubricant and release agent in the manufacture of tires and other molded rubber goods because its resistance to high temperature service conditions due to crystalline structure which contain aluminum silicate therefore electrical and thermal properties enhanced by using mica. Similar trend has been done by [Sreekanth *et. al*., 2009;Harper ,2002] in which the mica added to thermoplastic polyester.

Micas surface contain silica group (Sio_4) which dehydration with water to produced saline functional group (-SiOH) .its acidic in nature and behave as carbocyclic acidic group by reaction with amines and alcohol. This reactions has active effect on vulcanization systems of rubber product properties because the viscosity decreased and the wettability of filler increase therefore the filler particles diffuse through the elastomers chains [Veder *et. al*.,1964; Hiroshi *et. al*.,2012]

Recently, mica started to be considered as filler in the plastics and rubber industry to modify the properties of rubber and plastic products [M. Ehsani,2005], the filler often plays a significant role implying a material intended primarily to occupy space and act as a cheap diluent of the more costly elastomer. Most of the fillers used today offer some functional benefit that contributes to the processability or utility of the rubber or plastic product.[Roes *et. al*.,2009;Harper, 2001]

The characteristics which determine the properties that filler will impart to composite are particle shape, particle size, surface area and particle-matrix compatibility. Particle-matrix compatibility relates to the ability of the polymer to coat and adhere to the filler.[Yilmaz ,2008; Vrltnn,1964; Blow, 1998; Ming,2008]

2. Experimental work (Preparations)

Firstly, the research is done in the laboratories of Babylon Tires Factory, during the mastication process the mixing and homogenizing all constituents which used with the rubber in order to prepare the recipe by using laboratory mill, and the ingredients used with rubber were shown in Table (1).

Table (1) Formulation for Rubber Compounding [James, 2005].

Materials	**Amounts(phr)**
NR	100
ZNO	1.5
Stearic acid (SA)	1
Sulfur	2.25
Accelerator (TBBS)	0.7

Then the sequence below is followed for preparation:

1. The average particles size range of mica powder is (5-40) μm determined by using LBZA device to determine the required size [D50:11.17 μm] as shown in figure (1).
2. the rubber passed rubber between mill rollers at 70^{o}C, then the rubber recipe had been cooled to room temperature, finally the sulfur and accelerator TBBS had been used.
3. Samples tested: The samples were tested according to ASTM D-2084 by using device in which there is oscillating disk which there is oscillating disk oscillate in (1.6 Hz) and with constant capacity (1.3 degree) around the center point which form shear strain on the tested samples . The torque required to oscillate the disk proportion with young modules therefor the device gives indicates about curing characteristics. Similar trend have been done by Auoda . Al-braihy by using kaolinite filler with rubber.
4. For measuring hardness and resilience the samples had been prepared by preheating dies up to 100^{o}C with dimensions for the die equal to (180 ×200 ×6.5

mm), next the die is filled with rubber recipe and put under hydrostatic compaction, then the recipe had been pressed under 500 Psi and 160^{o}C for 15 min to complete the vulcanization, after that the samples had been cooled for (10-15 hr) and finally they were ready to be tested according to the ASTM-D 2240 (shore A hardness).

5. ASTM-D 3182 and D-13192 standards had been followed to prepare the samples of tensile strength and elongation respectively. First the die is heated and filled with rubber recipe, next it is pressed under 500 psi with 145^{o}C for 45 min, and then after the completion of vulcanization we had extracted the slices and let them to cool for 12 hr in order to be tested .Similar trend have been done by Auoda . Al-braihy by using kaolinite filler with rubber.
6. ASTM-D 5963 standard had been followed to prepare the samples of wear resistance.

3. Results and discussion:

3.1 Rheometric properties Test:

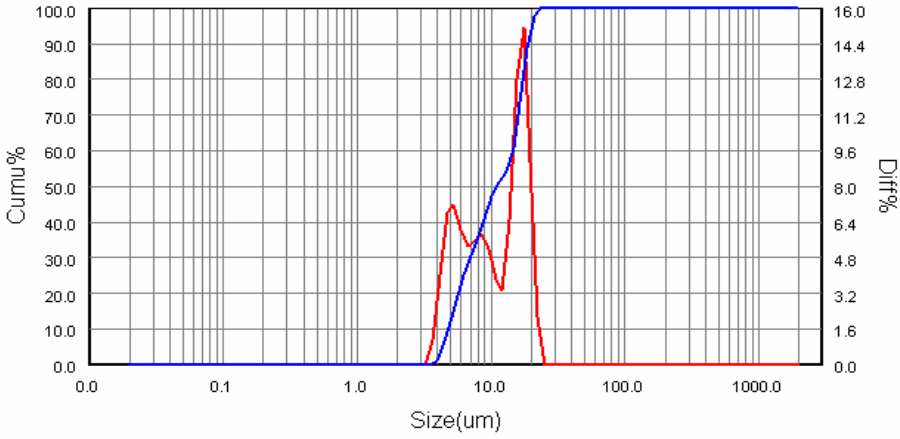
Table (2) shows the rheometric parameters obtained for the SBR formulations without mica, with 4, 8, 12, 16 and 20 phr of mica as filler. The curing system studied at a temperature of 175°C. The minimum torque (ML), which is proportional to the viscosity of the uncured compound, increases by the addition of the filler until (4%) then decreased because the weak Vander Waals bonds between mica layers; therefore the process ability increased due to easy mica layers slipping during processing .On the other hand, the maximum torque (MH) values increase with mica loading, and the maximum value obtained at a concentration of about 20 % as shown in figure (1).

By adding mica the scorch time decreased which reduce the sample product time also the curing time decreased because the interaction between the molecules increased and the curing reaction facilitates by filler content increase so that the manufacturing process being faster.

The filler content increases even more the density of the system. The density increased because the minimum average particle size (5- 40)µm therefor its fill the spaces between chains by the addition of the filler.

Table (2) represent the rheumatic properties.

Sample *number	Mica content (%)	Curing time(min.)	Scorch time(min.)	ML(Ib.IN)	MH(Ib.IN)	Specific density
1	0	2.05	1.2	3.5	27	1.018
2	4	1.99	1.03	4.5	28.61	1.028
3	8	1.95	1.05	3.52	28.2	1.037
4	12	1.85	1.05	2.86	29.5	1.049
5	16	1.81	1.12	2.46	30.98	1.052
6	20	1.8	1.16	2.41	31.2	1.067



Diam um	Percent
0.000-3.472	0.00
3.472-4.296	4.16
4.296-5.317	11.59
5.317-6.581	11.07
6.581-8.145	9.85
8.145-10.08	9.91
10.08-12.47	6.56
12.47-15.44	13.14
15.44-19.10	24.31
19.10-23.65	9.41

Figure (1) represent LBZA analysis test for mica.

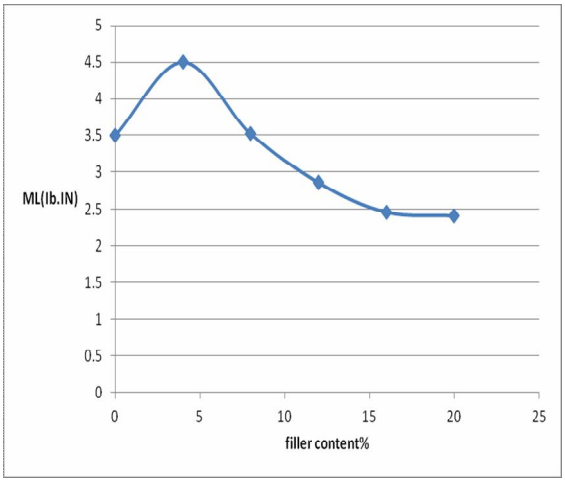


Figure (2) represents the relationship between the minimum torques versus filler content (phr).

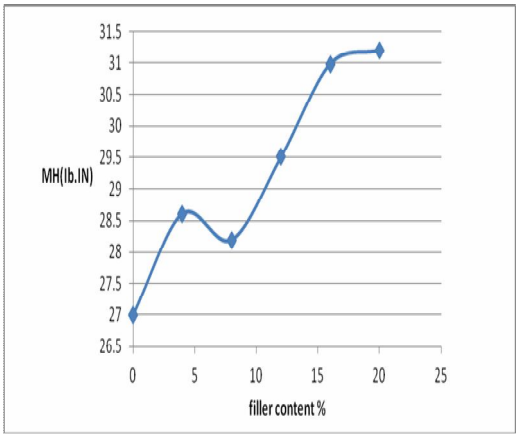


Figure (3) represents the relationship between the maximum torques versus filler content (phr).

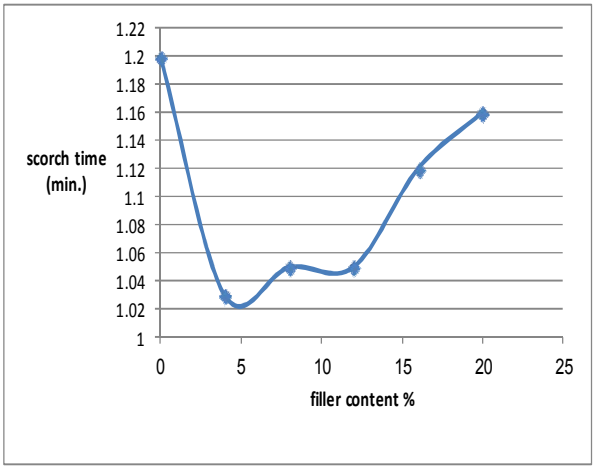


Figure (4) represents the relationship between the scorch times versus filler content (phr).

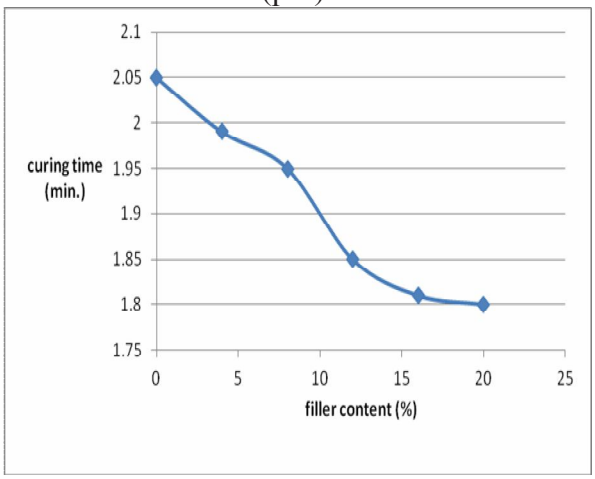


Figure (5) represents the relationship between the curing times versus filler content (phr).

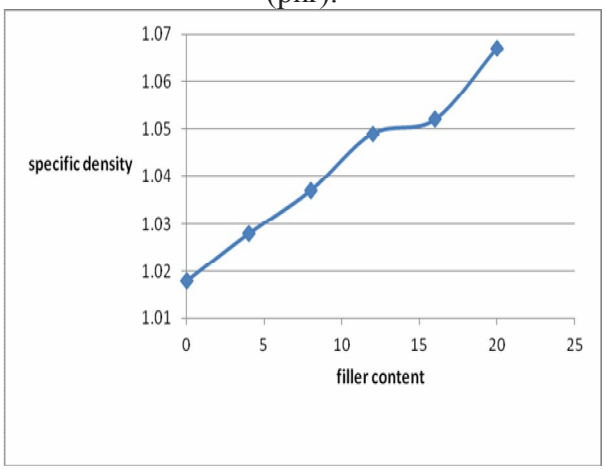


Figure (6) represents the relationship between the specific densities versus filler content (phr).

3.2 Mechanical properties Test:

Table (3) represents the mechanical properties of vulcanizes (formulations without mica, with (4, 8, 12, 16, 20) % of mica. The hardness of the samples increases with the increase of the ratio of the filler as shown in figure (7). The hardness increases when the filler ratio increases due to the density increase. Similar trend have been done when mica was added to NBR rubber by Nashar, A.A.Ward (2009).

The effect of mica loading on tensile strength, elongation at break, and young modulus are presented in figures (8, 9 and10). It's clear that the values of elongation at break increased until 10% of mica and then slightly decreased with additional filler loading. This may be due to the fact that NR matrix allows more rheological flow due to good filler- rubber interaction. After adding more filler the material is stiffer and harder due to that the filler particles hinder the chains movement so the elongation decreased. The introduction of filler into the vulcanization provides additional resistance to elongation. Filler with low surface activity will increase resistance to elongation by the viscous drag its surface provides to the polymer trying to stretch and slide around it. Mica particles are platy shape and higher surface area, greater aspect ratio (mean diameter of the plate face to the thickness of the plate), and higher loading (the latter two effectively increasing the surface area exposed to the elastomer) and the crosslinks decreased with filler content increased will all increase the modulus.

The increase of tensile strength until 8% of mica due to good filler-rubber interaction and high aspect ratio of platy filler which restrict stress growth through the matrix also mica contain saline functional group (-SiOH) which reduces the viscosity of rubber therefore the wettability increase. Strong rubber-filler interaction would increase the effectiveness of the stress transferred from rubber matrix to filler particles dispersed in the rubber matrix. On the other hand the decrease of the tensile strength at higher filler content can be also related to poor dispersion of filler on the rubber matrix as the filler concentration increased as the filler particles agglomerate as shown in figure (7).

The wear resistance decreases with mica content increase till (8%) of mica. The reason behind that is Mica have high thermal resistance higher than rubber because it's crystalline structure which contain aluminum silicate and filler particle which are considerably harder than the surrounding matrix and can thus insulate the rubber against wear. The small filler particle size (5-40) μm and platy particle shape increase the contact area between mica and rubber matrix which give good bond and adhesion also affect abrasion resistance. Loss of large or poorly bound filler particles by abrasion exposes the relatively soft surrounding elastomer matrix to wear. The effect is acute on the edge of the depression left by the dislodged particle reduces the wear resistance as shown in figure (11).

Table (3) represents the mechanical properties.

Sample number	Mica content (%)	Hardness (I.R.H.D)	Tensile strength(MPa)	Elongation	Modulus at 300 (%) extension	Wear (%)
1	0	40	16.6	595	2.11	8.5
2	4	42	19.2	608	2.2	7.7
3	8	43	22.5	619	2.4	6.1
4	12	44	16.1	538	3.3	7.2
5	16	45	11.5	456	3.7	7.8
6	20	46	10.1	423	3.7	8

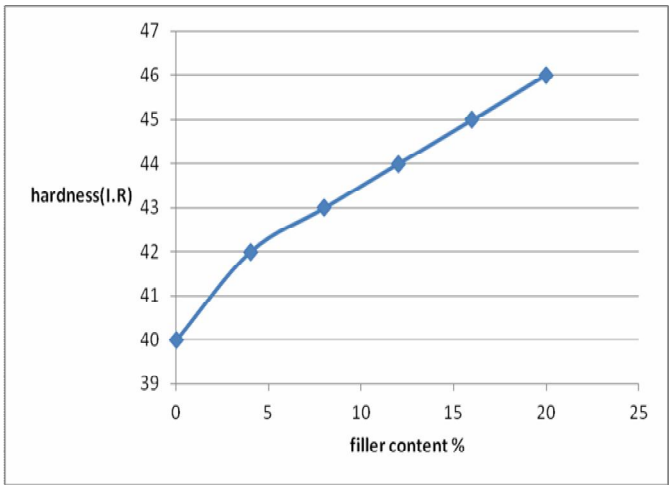


Figure (7) represents the relationship between the hardness versus filler content (phr).

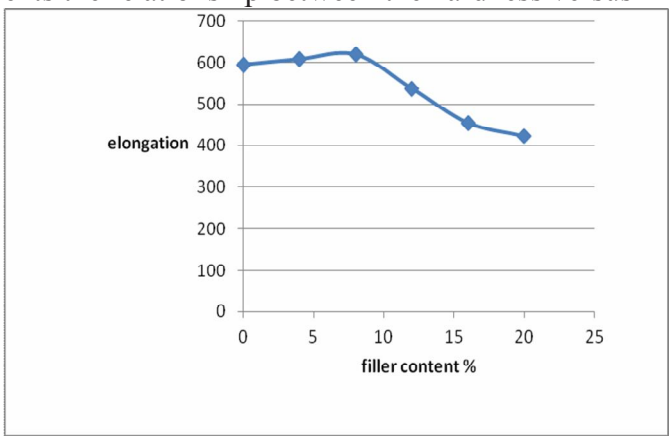


Figure (8) represents the relationship between the elongations versus filler content (phr).

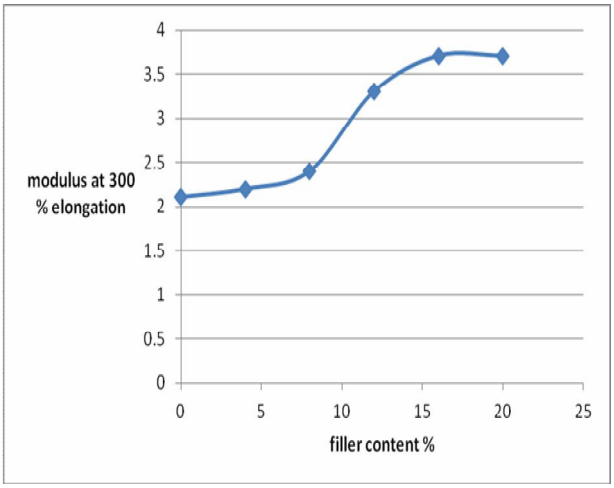


Figure (9) represent the relationship between elastic modulus versus filler content (phr).

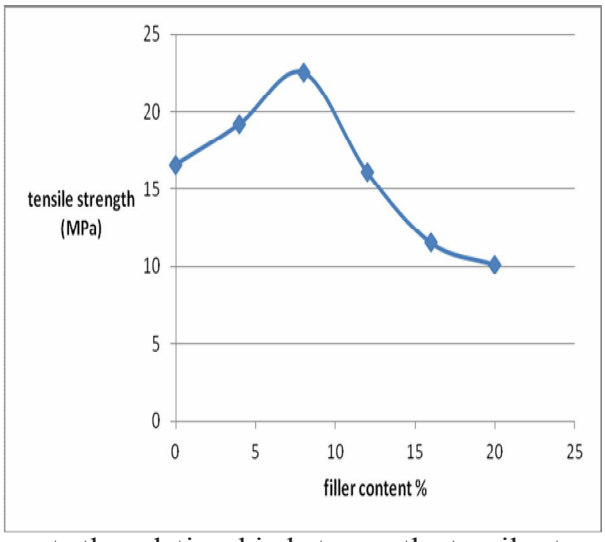


Figure (10) represents the relationship between the tensile strengths versus filler content (phr).

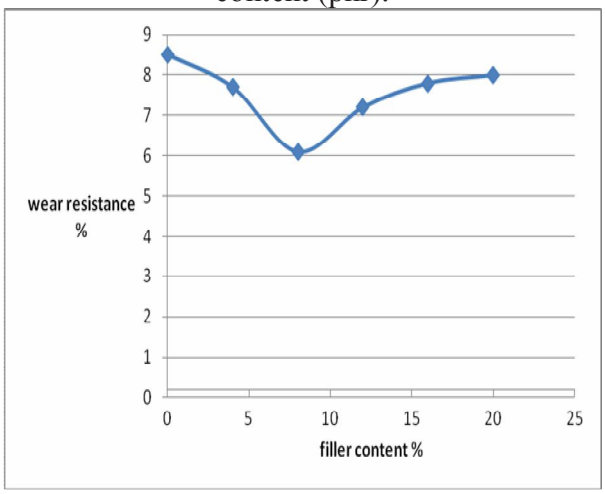


Figure (11) represents the relationship between the wear resistances versus filler content (phr).

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