Comparison between Polyimide and Bismaleimide Effect on Mechanical Properties and Ageing Resistance of Nitrile Rubber

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ABSTRACT

Nitrile rubber composites were prepared by the addition of asbestos, bismaleimide (BMI) and polyimide (PI). The effect of asbestos, bismaleimide and polyimide on mechanical properties and ageing properties were studied.

The results showed a little decrease in tensile strength from 17.3 Mpa of pure NBR composite to 16.95, 11.78 and 11.95 for NBR/PI(25) composite, NBR/Asbestos(25) and NBR/BMI(25) composites respectively. Elongation results showed an increase from 331% for pure NBR composite to 367% for NBR/Asbestos (25) then decreased to 245% in NBR/Asbestos (100). NBR/BMI elongation increased as filler content increased reaching 393% for NBR/BMI (100). NBR/PI elongation decreased as filler content increased reaching 217% for NBR/PI (100).

Hardness results showed an increase from 64.25 for pure NBR composite to 80, 82.5, 87 for NBR/Asbestos (100), NBR/BMI (100), NBR/PI(100) composites respectively.

The prepared composites found to offer a high percentage of retention of physical properties after aging in high temperatures.

Compressions set results show good recovery properties where the compression set of pure NBR composite, NBR/BMI (25), NBR/PI (25) and NBR/Asbestos (25) are 5.97%, 15%, 11.9% and 7 respectively.

Keywords: Polyimide, bismaleimide, ageing resistance

INTRODUCTION

Attempts have been made to prepare rubber composites suitable for high temperature applications and to understand how high temperature fillers influence the thermal stability of the elastomeric materials.

Thermal stability means the ability of a material to maintain the required properties such as strength, toughness, or elasticity at a given temperature. A detailed understanding of how polymers break down on heating is important in the design of elastomeric materials with improved properties for particular application.[1]

Compound formulation development and reformulation provide a means to rapidly meet new regulatory requirements, respond to competitive concerns, improve existing products, and facilitate new product development[2].

Large amounts of rubber materials are used in modern industry. Rubber has unique properties like the ability to resist large deformations without break(it stretches easily several times and even more than fifteen times in some cases), and recovery to almost 100% instantly etc[3]. This makes it important and necessary for many products, like tires, hoses, gaskets, washers, vibration dampers, conveyor belts, etc.

Nitrile rubber, also called nitrile-butadiene rubber, an oil-resistant synthetic rubber produced from a copolymer of acrylonitrile and butadiene. The uses of nitrile rubber include non-latex gloves for the healthcare industry, automotive transmission belts, hoses, O- rings, gaskets, oil seals, V belts, synthetic leather, printer's roller, and as cable jacketing; NBR latex can also be used in the preparation of adhesives and as a pigment binder.

More than 50% of the O-rings sold are Nitrile O-rings, commonly used in hydraulic/pneumatic motors, cylinders, pumps and valves.NBR is also employed in textiles, where its application to woven and nonwoven fabrics improves the finish and waterproofing properties[4].Attempts have been made to prepare high temperature rubber composites as can be seen from previous works[5-13].

Bismaleimide and polyimide are high temperature polymers that are introduced as filler for improving thermal resistance of nitrile rubber.

Table1. The composition of the rubber composites

Recipe	*Pure composite*	*NBR/asbestos*	*NBR/BMI*	*NBR/PI*
Ingredients	*Phr**	*Phr**	*Phr**	*Phr**
NBR	100	100	100	100
asbestos		(25, 50, 100)		
Bismaleimide			(25, 50, 100)	
polyimide				(25, 50, 100)
Zinc oxide	5	5	5	5
Stearic acid	2	2	2	2
TMQ	2	2	2	2
MBTS	1.5	1.5	1.5	1.5
TMTD	0.5	0.5	0.5	0.5
Sulfur	1.5	1.5	1.5	1.5
Carbon Black 320	40	40	40	40
Castor oil	10	10	10	10

* phr = parts per hundred parts of rubber.

MATERIALS AND METHODS

Materials Used

Nitrile rubber (NBR), zinc oxide, stearic acid, tetramethylthiuramdisulfide (TMTD), mercaptobenzothiazoldisulfide (MBTS), caster oil, sulfor, 2,2,4-trimethyl-1,2-dihydroquinoline (TMQ). Carbon black (N 326), used in this study was supplied by Babylon tire company.

Polyimide (PI) and Bismaleimide (BMI) used in this study were supplied by Taizhou Huangyan Donghai Chemical Company.

Preparation Method

The formulation of the rubber composites are given in TableI.Mixing was carried out in a two-roll mill. The ingredients were added according to ASTM D3182-89. Vulcanization was done in 150 °C and the time required was 15 minutes which gives the best properties.

CHARACTERIZATION AND TESTING

Mechanical Tests

Tensile test of dumbbell specimens of the vulcanizates were carried out at a crosshead speed of 500 mm/min, according to ASTM D412. This test also enables us to obtain elongation at break values of the vulcanizates.

Hardness Measurement

Shore A hardness of the vulcanizates was measured according to ASTM D 2240 method. Five different spots of a sample were measured to give an average value.

Compression Set

Compression set test was done according to ASTM D395. Samples were compressed to 0.25 of its thickness for 22 hours in compression set device then it is left for 30 min before taking the final thickness of the samples.

Hot Air Ageing

Vacuum oven is used to carry out this test, samples of tensile specimens are aged at 100 °C for 70 hours according to ASTM D 573. Tensile, elongation and hardness tests are performed to predict ageing results.

RESULTS AND DISCUSSIONS

Mechanical properties

Figure1 (a) shows the variation in tensile strength as a function of filler composition of three types of nitrile rubber composites. The pure nitrile rubber composite without any addition exhibits higher tensile strength. The general effect of increasing filler content was decreasing tensile strength as seen from figure1(a). It is also well known that if there is adhesion between the polymer and the filler, the tensile strength of the composite increases. If there is no or weak adhesion, tensile strength decreases.

In NBR/asbestos the cause of reduction in tensile and elongation may be due to the presence ofnumber of failure-initiating and stress concentration sites. In NBR/BMI the tensile strength decreases and the elongation increases figure1(b). This may be because BMI reduce crosslinking. This may reduce tensile strength and increase elongation at break. In NBR/PI composites the elongation decreases as PI content increase this is due to the formation of discrete polymer networks represented by the PI rich domains dispersed in the rubber matrix.

Figure2 shows the relation between the hardness and filler content added to NBR in which we notice the increases in the hardness with increasing the filler content in the rubber and the increase is not linear but as a curve which may be attributed to the presence of hard particles between rubber chains which increase its ability to resist penetration.

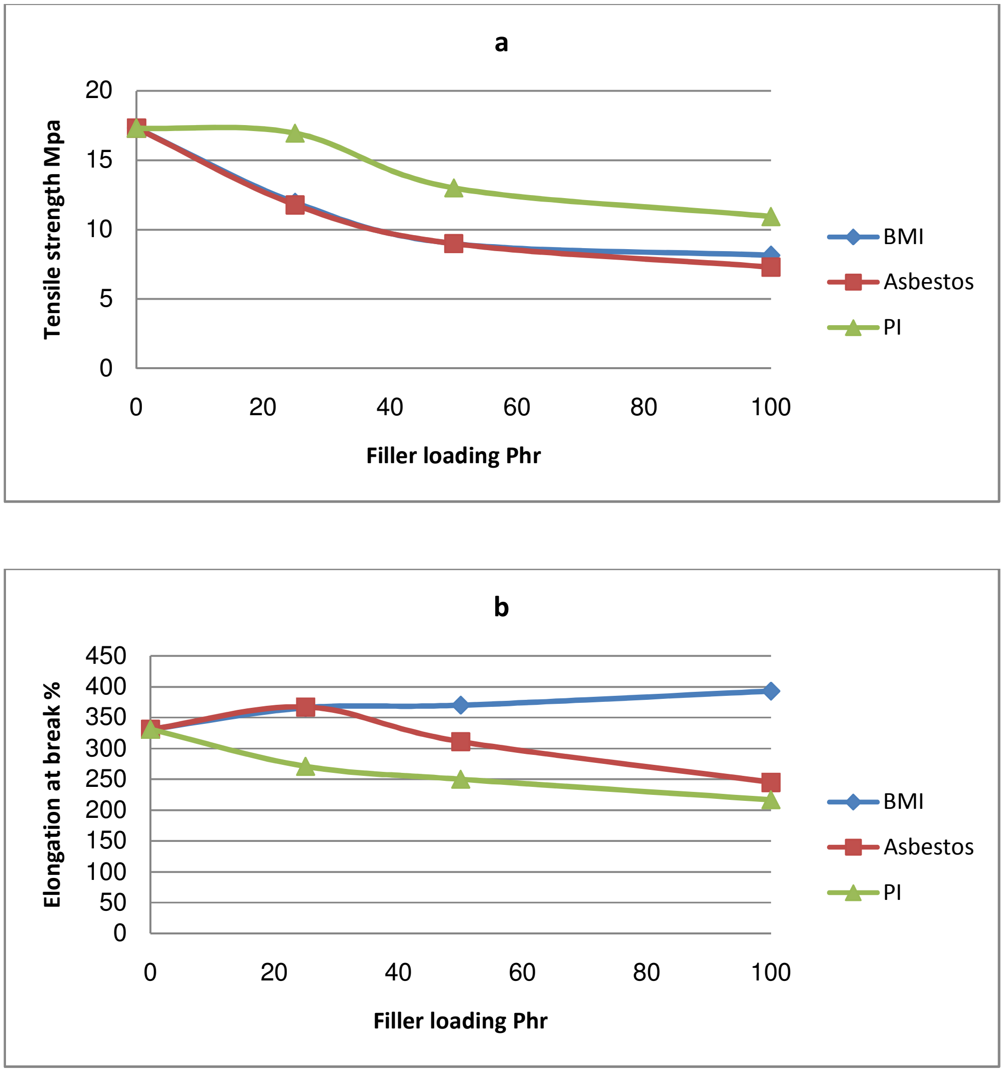


Figure1: Mechanical properties of NBR composites with different loading (a) tensile strength (b) elongation at break.

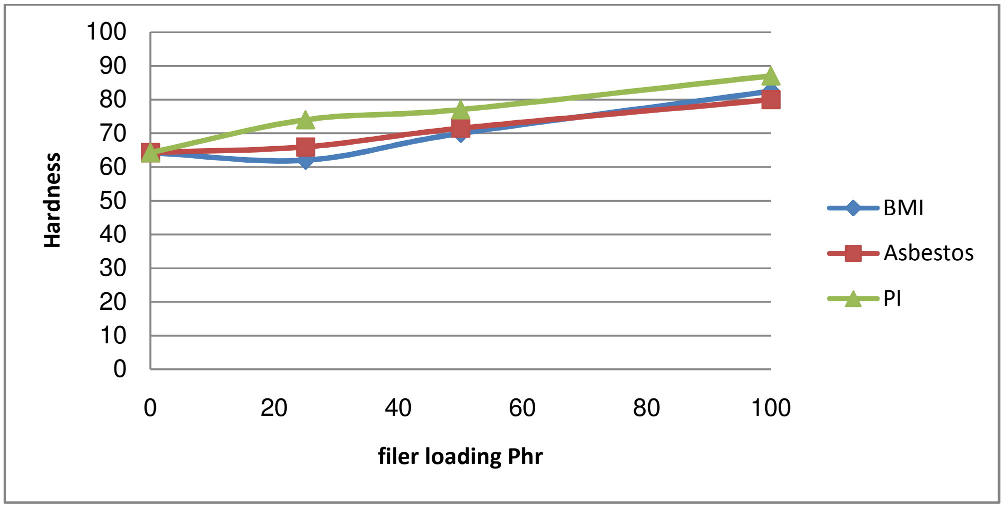


Figure2: hardness of NBR composites with different loadings.

Compression set

The compression set of NBR/BMI is good in low BMI content, but in high BMI content (50 and 100 Phr) the compression set is poor figure 3. The compression set of NBR/asbestos and NBR/PI is good in low filler content (25 and 50 Phr) but its poor for NBR/asbestos(100) and NBR/PI(100). Compression set is the permanent deformation remaining after removal of the load. Reduction in crosslink density of NBR composites as filler content increase may be the cause of poor compression set properties.

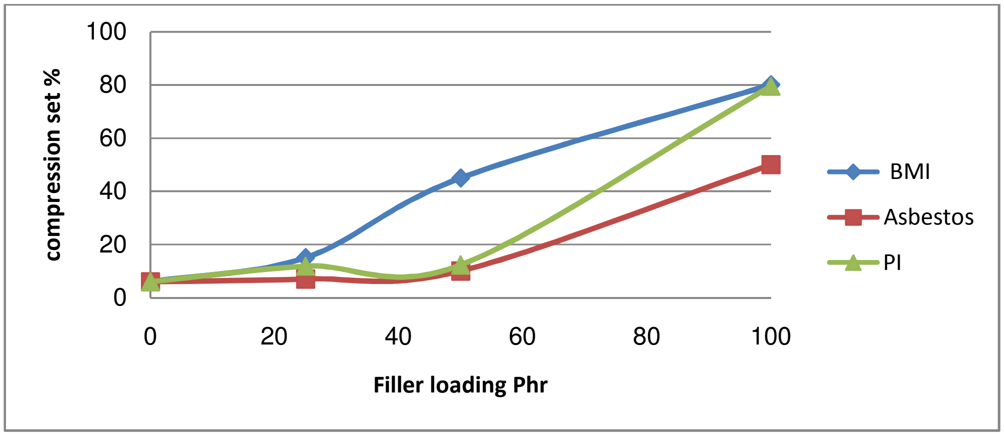


Figure3: compression set of NBR composites with different loadings

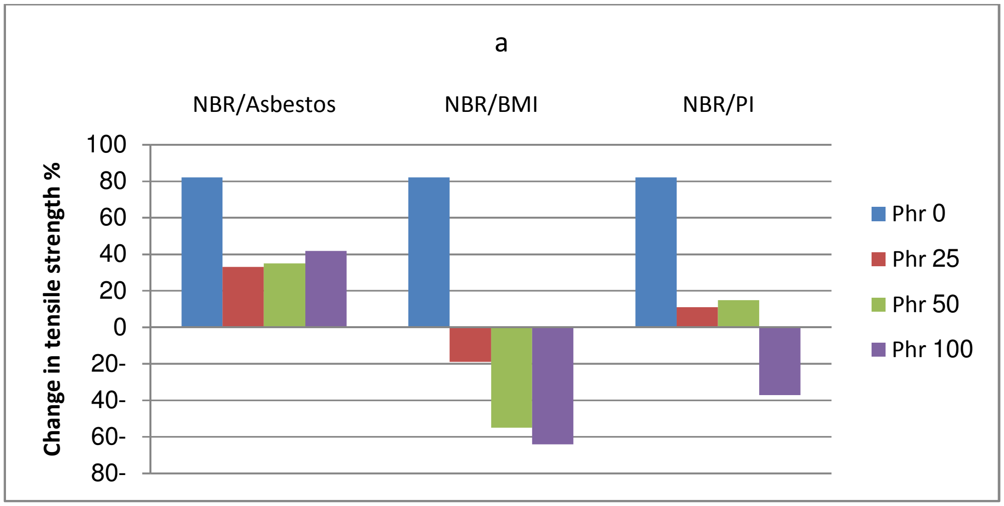
Hot Air Ageing

Figure 4, figure5 show the change in mechanical properties of NBR composites after ageing. The initial values for NBR composite were equal or marginally poorer than Pure NBR composite. However, as the samples are aged for longer periods the effect of Asbestos, BMI and PI becomes evident.

The change in tensile strength of pure NBR composite is very high this is due to the oxidation reaction between the free radicals from broken double bonds (due to the action of heat) and the oxygen in air, this reaction decreases double bonds and hence reducing mechanical properties. In NBR/Asbestos the change in tensile strength is lower than pure one and this change increases as asbestos content increase inspite of the presence of temperature resistant asbestos, this may be due to the deterioration of matrix material.

In NBR/BMI and NBR/PI the change in tensile strength is very little especially in low content and it is much better than NBR/Asbestos. This is due to the outstanding thermal properties of BMI and PI and the good dispersion their particles in rubber matrix.

Although, asbestos has better thermal resistance than BMI and PI but its interaction with NBR matrix is weak and it may requires special surface modification (which increase its potential to harm workers on this material), also the curing of BMI and PI inside NBR network gives the composite stronger interaction and hence high thermal stability.



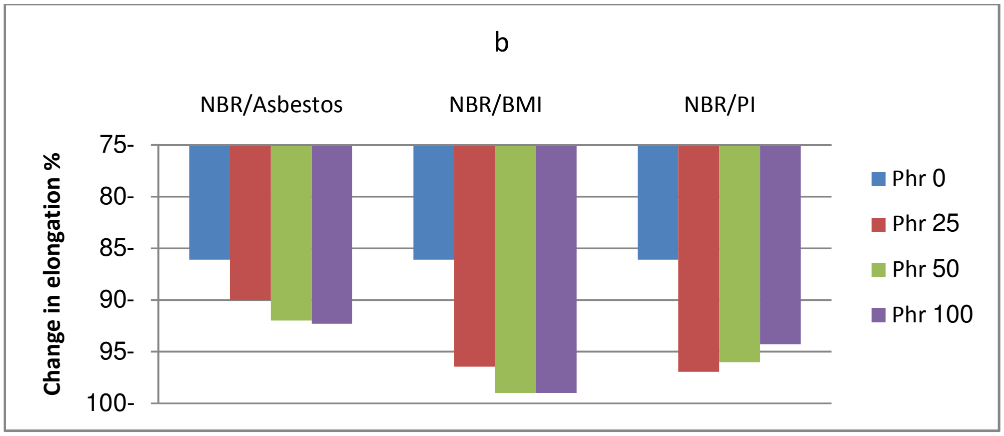


Figure 4: Change in mechanical properties after ageing in 100 C° for 70 hrs (a) change in tensile strength (b) change in elongation.

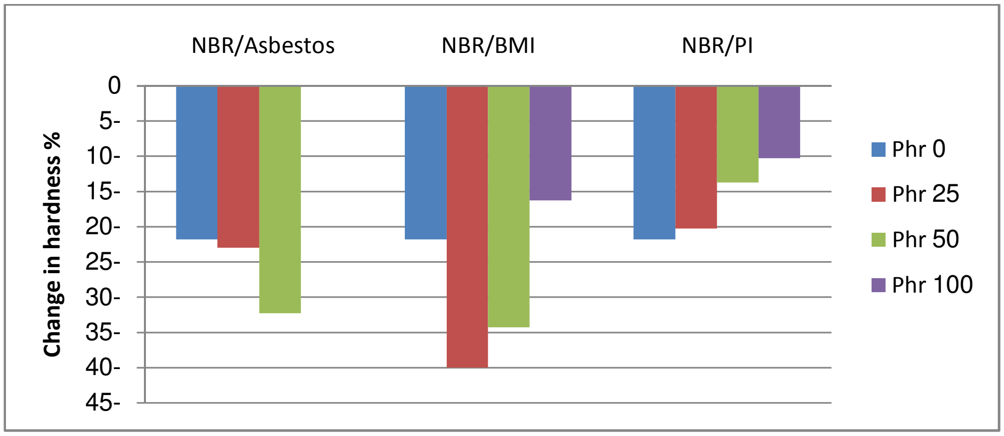


Figure 5: Change in hardness after ageing in 100 C° for 70 hrs.

CONCLUSIONS

NBR composites where prepared by the addition of Asbestos, BMI and PI as a high temperature filler.

Mechanical properties for the prepared composites are good but not better than that of pure NBR composite, but after ageing in 100 °C for 70 hours, NBR/asbestos showed a good stability in properties and NBR/BMI and NBR/PI revealed better stability than NBR/Asbestos. The good stability of mechanical properties proves that the prepared composites can hold for long periods under high temperatures.

Hot air ageing results show a high thermal stability of NBR/Asbestos composites, NBR/PI composites and NBR/BMI (25) this ensures that these composite have a much longer life than Pure composite.

Compression set values show a good results for NBR composites in low filler content this proves that the prepared composites are suitable for the intended application for engine gaskets.

Specific gravity results show an increase in the specific gravity of the prepared composites. This is due to the addition of high specific gravity fillers to NBR rubber.

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