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Full Length Research Paper

Effects of glass spheres on the mechanical characteristics of NR-SBR type elastomers

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In this study, the effect of glass spheres on the physical and mechanical properties of NR-SBR elastomer-based shoe sole material was investigated. In the experiment, the blend of natural rubber (NR-RSS3) and styrene butadiene rubber (SBR 1502) in certain amounts were considered to use. Therefore, 2 newly developed glass sphere blends were prepared and tested. The new blends exhibited much better mechanical properties than the traditional ones. The results showed that glass spheres between 5 -13.5% in the new blends resulted in 23 to 31% decrease in the material cost. Additionally, the new blends exhibited higher mechanical properties compared to that of traditional ones.

Key words: Elastomers and rubber, vulcanization, physical properties.

INTRODUCTION

Elastomers, so called natural and synthetic rubbers, are widely used in automotive and other industries for their many special properties. Elastomers are usually mixed with different materials to increase the values of physical properties. Especially, in industrial elastomers, considerable amount of filler materials is put in blends as a cost reducer and physical property riser. Today, many inorganic materials are used as filler materials (Babbit, 1978). But, many researchers are still searching for new filler materials to be used in elastomers (Savran, 1998).

Savasci et al. (1998) pointed out that the ideal filler materials in elastomers exhibited an increase in bending strength, ultimate tensile stress, and toughness and a decrease in cost. Therefore, in elastomers, materials such as carbon black, silica, calcium carbonate, caolen, barite, talc, magnesium carbonate, and aluminum hydroxyl are usually preferred. On the other hand, different filler materials such as wood fibers, mica powder, rice husk, asbestos, aluminum powder, fibers of coconut, shredded paper and shredded-cloth were reported in scientific researches for their use.

Oksman et al. (1988) reported that wood flour having 420 nm sized and polypropylen (PP) components affected bending strength negatively. It was also reported that wood flour decreased the cost, and polypropylen blend increased the strength but reduced elongation capability rate. For the same blend, elasticity modulus increased 70%.

Ichazo et al. (2005) investigated the rheological, mechanical and ageing effects of wood flour in Natural Rubbers (NR). They compared the results with carbon added blend. In the research, 15 - 30% wood floor was used in NR. It was reported that the filler material in 250 - 300 nm size did not decrease the ageing material properties, and increased the failure stress. Therefore, the researchers strongly suggested that wood flour could be used in NR as semi-strengthening filler material.

On the other hand, Egwailhide et al. (2007) used carbon graphite and coconut fibers in natural vulcanized rubber. The resulting material was investigated for its mechanical, physical, and chemical properties. Moisture, ashes, and ph values of coconut fibers were characterized according to the material surface effects. Properties such as torsion strength and forming capability of the material in heat with coconut fiber fillers came out to be better. At the same research, it was realized that coconut fibers hardened the vulcanized rubber.

Friction wearing and elastic resistance were decreased insignificantly. It was observed that the resistance to volumetric enlargement changed with respect to amount of filler material added. Similarly, carbon black was also indicated as another alternative filler material. It increases the resistance to volumetric elongation. It was also

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observed that carbon back filler materials made NR interfacial bonding stronger.

Sumaila et al. (2006) investigated tensile stresses and impact property of polyurethane by adding wood cellulose between the ratios of 2 - 10%. They reported that tensile strength was enhanced and impact strength was worsted when the filler amount was increased. In the meantime, for compression strength, 4% filler added blend gave the best results, but 8% filler added blend gave the worse.

Siriwardena et al. (2001) studied white rice husk ash (WRHA); filler derived from burning rice husk and filled ethylene-propylene-diene-terpolymer. PP/EPDM/White rice husk in rubber was observed to decrease the product deformation. In addition to that, it enhances the material viscosity. It was reported that by adding 4% filler material, smooth surfaces were obtained.

Findik et al. (2003) studied the mechanical and physical properties such as tensile strength, hardness, wear, carbon black, ozone resistance, density and rheological properties of an industrial rubber. The authors prepared 12 different rubber blends using SMR-20 type of natural rubber and SBR-1502 type of styrene–butadiene rubber in different proportions, keeping fixed the total rubber quantity specified in the standard testing recipe. The authors found that in the HAF added blends, the hardness and the elastic module increased as the NR rate increased, and in the ISAF added blends, the tensile strength and the % elongation values were enhanced.

Finally, Jolene et al. (2000) investigated the change in properties when 10% CaCO3 was replaced by mica or silica, according to a specific formulation while keeping SBS as the elastomeric matrix. The obtained failure strength values were found 5.8 Mpa in SBS/silica, 5.48 in SBS/$CaCO_3$ blend and 5.41 in SBS/mica blend. Hardness values were measured 62 Shore-A for all three blends. The best tearing resistance was told to be 25 N/m for SBS/silica blend.

On the other hand, it was pointed out that the highest wearing values were detected for 378 mm^3 in SBS/mica blend and mica powder was an alternative filler material because silica is more expensive than mica powder and CaCO3.

In this research, instead of traditional filler materials, glass sphere in addition to carbon graphite were used as new filler in NR/SBR elastomer materials. Especially, the effects of glass spheres in physical and mechanical properties of elastomer materials were investigated. Density, hardness, wearing, failure strength, elongation, bending capability, and tearing measurements were performed. All research works were fulfilled in industrial environment. At the end of the study, classical formula and newly developed G0, G1, G2, and G3 formulas were compared, and further suggestions were given.

MATERIALS AND METHODS

In the experiments, glass spheres (SiO_2) in 28 µm grain size and 2.85 g/cm^3 density were used as a filler and stabilizer material. The contents and ratios of classical and G blends used in the tests have been given in Table 1. According to the table, the blends were prepared from NR and styrene butadiene.

In classical blend, caolen is selected as a main filler material while FEF N 550 is used as an adding material. However, in newly developed blends namely, G0, G1, G2, G3, the adding material was chosen as HAF N 330 and 28 µm sized glass spheres (Quartz 75) as the filler material. In this study, rates of rubber and filler materials in G blends were balanced according to the Table 1. Particularly, caolen was only used in the classic and G0 blends. However, FEF N 550, aromatic oil, and MBT mercapto were used only in the classical blend.

In addition, active zinc, acid strearic, DEG, CZ, sulphur, and TH fillers were added to classical and glass sphere blends. Approximately 6% parafinic oil, HAF N330 and Silicasyl, were mixed into the glass sphere blend. For experiments, the classical blend, the new developed blend without filler (G0) and three glass sphere blends with different stabilizers were prepared. Amount of glass sphere and rates in the blends G1, G2 and G3 were determined to be at 5.0, 9.4 and 13.5%, respectively.

In blend preparing process, firstly, NR and SBR rubbers were put into initial blending process according to the formulations as given in Table 1. After that, by adding small amount of stabilizer and catalyst supplements which are difficult to mix, the process was continued until homogenous blend was obtained. In the next step, a portion of carbon black and glass spheres with acid strearic were added to the process. After adding inorganic oil as a softener, then, the remaining glass spheres and carbon black were mixed with the blend. At the next step, sulphur and additional catalysts were added until homogeneous blend was obtained. The blend was exposed to an appropriate vulcanization process. In the final step, test samples were cut from the material sheets that were prepared in bambury machine.

The samples were tested for failure strength, percent elongation rate, bending capability. Then, wear, hardness, and density values were investigated. Finally, production costs were calculated for each blend and the findings were also compared with that suggested by the international standards.

RESULTS AND DISCUSSION

According to international standards, density value is required to be maximum 1.5 g/cm^3. In the results, all glass sphere filler supplemented rubber material of both standards and classical blends showed an increase in density values. These increases were between 1.14 - 1.29 g/cm^3 as shown in Figure 1. Also, hardness value is required to be shore A 55. Filler materials are harder than the classical blend. So, if the rate of filler material increases, the hardness of the test part increases too. It was also found that in test parts with glass sphere filler, the rate of elongation was at standard values and 37% less than that of classical blend (Figure 2).

Classical blend does not match the standard requirements. As expected, an increase in hardness was measured in test materials with fillers. According the standards, tearing strength is required to be 6 kg/mm^2. Resulting values in all rubber with glass sphere filler material have indicated an increase between 21 - 32% (Figure 3). Also, minimum amount of wearing occurred in G0, then CF, G1, G2, and G3. Finally, the production cost of the new material with glass sphere fillers was decreased by increasing the amount of filler. By

Table 1. Rates of rubber and filler materials in the formulae.

Formulations	Classical formula (KF)%	G 0 WT%	G 1 WT%	G 2 WT%	G 3 WT%
NR - RSS3	18.22	10.91	11.18	10.65	10.17
SBR - 1502	20.8	32.62	33.43	31.85	30.42
NR+SBR	39.02	43.53	44.61	42.40	40.59
Total of additional filler	2.3	0	5	9.4	13.4
HAF N330	0	38.7	39.7	37.6	35.8
Silicasyl	0	9.5	9.5	9.5	9.5
FEF N 550	17.93	0	0	0	0
Caolen	22.4	7.23	0	0	0
MBT Mercapto	1.65	0	0	0	0
Total Filler	42.63	45.84	48.33	50.6	52.7

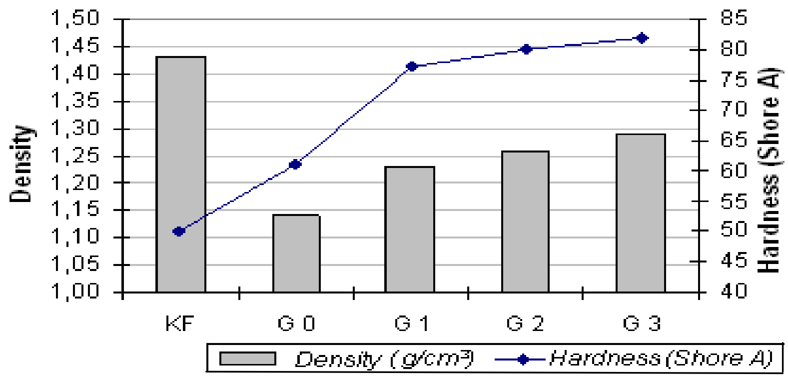

Figure 1. Changes in hardness and density values for classical and new formulas.

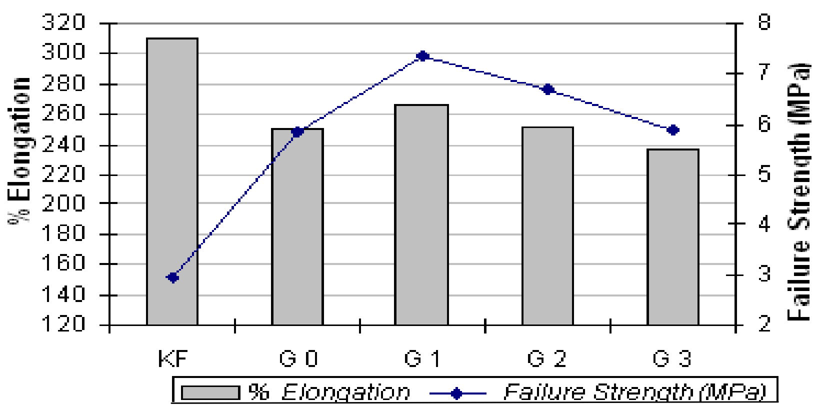

Figure 2. Elongation and failure strength in test parts for classical and new formulas.

comparing the costs, it can be seen that, the gain was up to 24 - 31% (Figure 4). In the meantime, SEM investigations show that, the number of particles changes in NR/SBR type elastomers in which glass-sphere filler material is mixed at the ratio of 5.15, 9.4, 13.4, 5.15% glass-spheres and 9.4% filler added elastomers appear to be less densely distributed in the matrix.

However, glass particles are observed to be much denser as the ratio of filler material increases. Moreover, from SEM pictures, it can be seen that glass particles

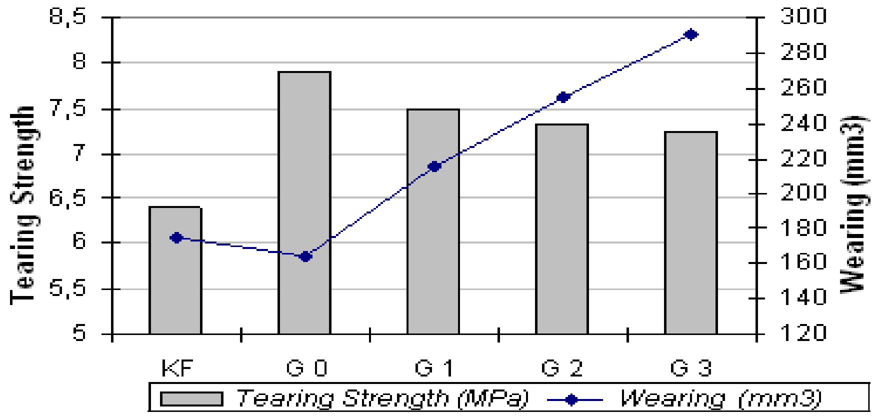

Figure 3. Changes in tearing strength and wearing amount for classical and new formulas.

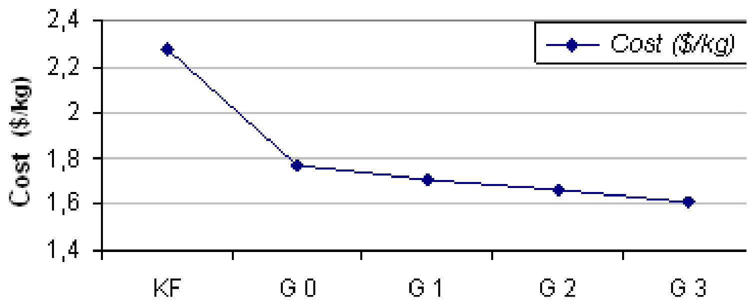

Figure 4. Change in production costs for classical and new formulas.

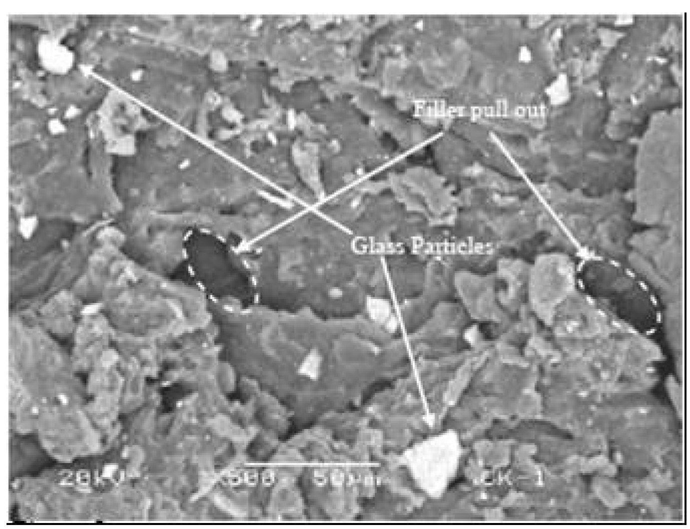

Figure 5. Worn surface of G1 specimen.

are irregular in size and shape (Figure 5). In Figure 5, the marks of ruptured filler particles during abrasion and the porosities occurring on the surface of elastomer can be seen easily. Additionally, active zinc particles used as an activator were observed in the matrix as bright white in color with its particle size smaller than glass-spheres.

Table 2. Physical and mechanical properties for CF and new formulas.

Physical and mechanical properties	Standard values (IS 5676)	KF (classical formula)	G 0 % 0	G 1 % 5	G2 % 9.4	G3 % 13.5
Density (g/cm^3)	Max. 1.5	1.43	1.14	1.23	1.26	1.29
Hardness (shore A)	Min. 55	50	61	77	80	82
Percent elongation	Min. 200	310	250	266	252	237
Wearing	Max. 250	175	165	215	255	291
Failure strength	Min 5.88 MPa	2.94	5.83	7.35	6.67	5.88
Tearing strength (ISO 20344-AC)	Min. 6 kg/ mm^2	6.4	7.9	7.5	7.32	7.24
Bending capability	Min 60 000 cycles	70 000	70 000	70 000	70 000	70 000
Price ($/kg)	-	2.322	1.77	1.708	1.665	1.608
Gain %	-	-	23.77	26.44	28.29	30.75

CONCLUSION AND FURTHER SUGGESTIONS

The test results showed that the important parameters in elastomer material's mechanical properties are elastomer type, formulation, type of the filler materials and the grain size (Table 2). During the tests, it was observed that density values fulfilled the lightness criteria required, the results were suitable for user's comfort and that hardness, bending capability, and tearing strength values were increased. As the amount of filler material was increased, percent elongation rate and failure strength values were also improved. All mechanical and physical values were in conformance with relevant standards except for wear on G3 blend. It has been seen that developed materials with new fillers cost 23 - 31% less. New developed G0 without filler material and G1, G2, G3 with filler material were considered to be suitable as shoe sole materials. For further research, the effect of different grain sizes and process conditions can be investigated.

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