FEASIBILITY STUDY ON THE PRODUCTION OF TIRE BY RECYLING TECHNIQUE

S.Kamalakannan

Associate Professor and Head of the Department, Department of Civil Engineering, IES College of Engineering

ABSTRACT

End-of-life tires constitute one of the biggest environmental concerns in terms of environmental pollution and resources conservation. This study aims to determine the best proportion of reclaimed rubber and crumb rubber to be added as part of the constituents used in the manufacturing of three different tire parts in order to produce standard products from a mix of both recycled and original ingredients. Batches were prepared into which reclaimed rubber and crumb rubber were added to the formulation of three different tire parts, in addition to one batch as reference according to the original formulation. Savings in raw material and in energy resulting from the use of reclaimed rubber was calculated: In addition to the raw material and energy conservation, the process was found to be cost-effective.

Keywords: *Crumb rubber, inner liner, reclaimed rubber, side wall, tire recycling, tread*

---

1. INTRODUCTION

End-of-life tires constitute one of the biggest environmental concerns in terms of environmental pollution and resources conservation. They may cause fire hazard, trap rain water creating potential breeding grounds for mosquitoes, and occupy large volume in landfills. Besides, they have a virtually unlimited life span and need long time for natural degradation due to the cross-linked structure of rubbers and the presence of stabilizers. Tire ingredients include rubber, reinforcing chemicals, oils, processing aids, resins, vulcanizing agents, activators, and accelerators. Reduction can be achieved by technological developments in tire design and materials that prolong the tire life span and decrease its weight. On the other hand, Khait and Carr reported that reclaimed rubber could be used as alternative to virgin rubber but this would result in a reduced elasticity. Ryan stated As regards recycling, about 65-75% of tire weight is rubber (natural or synthetic) and carbon black found mainly in the tread, sidewall, and inner liner compounds of the tire. Recycling alternatives include retread, pyrolysis, rubber modified asphalt, compacting rubberized concrete, shredding, crumbing, and reclaiming. Crumbing is a procedure in which scrap tire is converted into "crumb rubber" through removing steel belts, bead wire, and fabrics and produce tire chips. This study aims to determine the best proportion of reclaimed rubber and crumb rubber to be added as part of the constituents used in the manufacturing of three different tire parts (tread, side wall, and inner liner) in order to produce standard products from a mix of both recycled and original ingredients.

2. MATERIAL AND METHODS

The study was conducted in the laboratory unit. Batches were prepared into which reclaimed rubber and crumb rubber were added to the formulation of three different tire parts (tread part, side wall part, and inner liner part), in addition to one batch as reference according to the original formulation as follows:

1. First, concerning the incorporation of reclaimed rubber and crumb rubber in the formulation of the radial tread, nine batches were prepared. Batch number one represented the reference one with no recycled material. In batches two, three, four and five, reclaimed rubber was added as 5 phr, 10 phr, 15 phr, and 20 phr respectively. In batches six, seven, eight and nine, crumb rubber was added as 5 phr, 10 phr, 15 phr, and 20 phr respectively.
2. Second, concerning the incorporation of reclaimed rubber and crumb rubber in the formulation of the radial side wall, nine batches were also prepared. Batch number one represented the reference one with no recycled material. In batches two, three, four and five, reclaimed rubber was added as 15 phr, 20 phr, 25 phr, and 30 phr respectively. In batches six, seven, eight and nine, crumb rubber was added as 15 phr, 20 phr, 25 phr, and 30

phr respectively.

3. Third, concerning the incorporation of reclaimed rubber and crumb rubber in the formulation of the radial inner liner, eleven batches were prepared. Batch number one represented the reference one with no recycled material. In batches two, three, four, five and six, reclaimed rubber was added as 20 phr, 25 phr, 30 phr, 35phr, and 40 phr respectively. In batches, seven, eight, nine and ten, eleven crumb rubber was added as 20 phr, 25 phr, 30 phr, 35phr, and 40 phr respectively.

Virgin raw materials were borrowed from the tire production company and preparation as well as testing of different formulations was done in the Company pilot plant. The above mentioned amounts in phr of both reclaimed rubber and crumb rubber were selected for the study based upon findings of Gandhi H and Kumar S and of Antonio EM, [13] who reported that the best applicable phr for rubber recycling in new tire production is as follows: 5-20 phr, 15-30 phr, and 20-40 phr for tread, side wall, and inner liner respectively. Batches were analyzed according to testing methods and standards and according to American Society for Testing and Materials (ASTM) standards to select the optimum percentage that can be introduced in new tire formulation preparations. Eight tests were used to analyze the prepared batches. These are:

1. The vulcanized rubber tension property test: (reference: ASTM D-412-98a-R02) It is a stress-strain test. It gives two stress parameters (300% modulus stress value and tensile stress at break value) and one strain parameter which is the elongation percentage at break.
2. The vulcanized rubber abrasion resistance test: (reference: ASTM D-2228-02) It is a comparison test for the abrasion resistance percentage between every sample batch and the reference “original” batch. It gives abrasion resistance percentage value compared to 100% of the reference batch. This test was done for tread batches only.
3. The vulcanized rubber rebound property test: (reference: ASTM D-1045-02) It is a comparison test for the rebound property percentage between every sample batch and the reference “original” batch. It gives rebound property percentage value compared to 100% of the reference “original” batch.
4. The vulcanized rubber density “specific gravity” test: (reference: D-148 Trenco) It gives the specific gravity value in gram per milliliter.
5. The vulcanized rubber density “durometer hardness” test: (reference: ASTM D-2240-03) It gives the durometer hardness value in SI unit.
6. The oscillating disk cure meter test: (R 100) (reference: ASTM D-2084-01) It is used to determine the vulcanization characteristics of vulcanizable rubber compounds. It gives two torque (stiffness) parameters in deci newton per meter (dN.m) unit: minimum torque (L min.) which is the measure of the stiffness of the unvulcanized test specimen taken at the lowest point of the curve, and maximum torque (L max.) which is the measure of the stiffness or shear modulus of the fully vulcanized test specimen. It also gives two times parameters in minute per minute (m.m) unit: scorch time (Tsc.) which is the measure of the time at which vulcanization begins, and cure rate (C.R.) which is the measure of optimum cure based on the time to develop some percentage of the highest torque or difference in torque from the minimum.
7. Rotorless cure meter test: (MDR 2000) (reference: ASTM D- 5289-95-R01) It is used to determine the vulcanization characteristics of vulcanizable rubber compounds. It gives two torque (stiffness) parameters in (dN.m) unit; minimum torque (ML) which is the measure of the stiffness of the unvulcanized test specimen taken at the lowest point of the curve and maximum torque (MH) which is the measure of the stiffness or shear modulus of the fully vulcanized test specimen.

3. RAW MATERIAL AND ENERGY CONSERVATION

Global studies on the increased demand on both raw materials and energy resources have reported that these demands will lead to material depletion and climate changes. Recycling of reclaimed or crumb rubber into new tires could save raw material and energy. First, as concerns raw materials, consumption of all kinds of raw materials would decrease, but emphasis will be put on SBR (Oiled Styrene Butadiene Rubber), SMR (natural rubber), Polybutadiene (1,4 cis Polybutadiene Rubber) and carbon black as they are the major ingredients used in the production of tires. Adding 15 phr reclaimed rubber to the tread formulation would save about 7.7% of each of SBR, Polybutadiene and carbon black. This could lead to an annual saving of about 745,140 L.E. Adding 25 phr reclaimed rubber to the side wall formulation would save about 12.8% of each of SMR, Polybutadiene and carbon black, leading to an annual saving of 205, 349 L.E. Adding 25 phr reclaimed rubber to the inner liner formulation would save about 13% of each of SMR, SBR and carbon black, resulting in approximately 328,000 L.E. saving per year. Second, regarding energy conservation, and as a result of raw material saving, use of reclaimed rubber in new tires would result in saving of the energy used to manufacture these raw materials, leading to a total energy conservation of 9593 GJ/ year according to production capacity

(Table 6). On the other hand, the energy consumed for the production of reclaimed rubber is 32 GJ/ton. By subtracting the energy used for the production of 100 tons reclaimed rubber (58.4 tons for tread, 18 tons for side wall and 23.2 tons for inner liner as shown in Table 4), total energy conservation resulting from reclaimed rubber recycling into new tires would equal 6393 GJ/year (9593GJ/y -3200 GJ/y).

4. CONCLUSION

End-of-life tires could be recycled into new tires. Reclaimed rubber could be used as 15 phr in radial tread compound and as 25 phr in either radial side wall or radial inner liner compounds. Crumb rubber could be used as 10, 20 and 25 phr in radial tread, radial side wall or radial inner liner compounds respectively. Incorporating higher amounts of either reclaimed or crumb rubber would lead to violating the standards specified in vulcanized rubber tension property test and in oscillating disk cure meter test. Savings in raw material and in energy resulting from the use of reclaimed rubber was calculated: As concerns raw materials, adding 15 phr reclaimed rubber to the tread formulation would save about 7.7% of each of Styrene Butadiene Rubber (SBR), Polybutadiene and carbon black. Adding 25 phr reclaimed rubber to the side wall formulation would save about 12.8% of each of natural rubber, Polybutadiene and carbon black. Adding 25 phr reclaimed rubber to the inner liner formulation would save about 13% of each of natural rubber, SBR and carbon black.

5. REFERENCES

[1]. U.S. Environmental Protection Agency. Office of Compliance Sector Notebook Project. Profile of the rubber and plastic industry 2nd Edition, EPA/310-R-05-003; 2005. | Pdf

[2]. Reisman JI, Pechan EH. Air emissions from scrap tire combustion. Washington: US EPA, 1997. | Pdf

[3]. Perederii MA, Tosodikov MV, Malikov IN and Kurakov YI. Carbon sorbents from waste crumb tires. Solid Fuel Chemistry. 2011; 45:102-9. | Article

[4]. State Council of Educational Research & Training (SCERT) (ed). Rubber technology. Government of Kerala Department of Education; 2005. | Book

[5]. Chemical Hazards Program, Environmental Health Branch. Recycling and reusing scrap tires. Georgia Department Community Health, Division of Public Health. | Pdf

[6]. Zhang X, Lu CH and Liang M. Preparation of rubber composites from ground tire rubber reinforced with waste-tire fiber through mechanical milling. Journal of Applied Polymer Science. 2007; 103:4087-94.

[7]. Zhang X, Wang T, Ma L, Chang J. Vacuum pyrolysis of waste tires with basic additives. Waste Management. 2008; 28:2301-10. | Article

[8]. Soltani S, Naderi G and Ghoresishy MHR. Second life. Tire Technology International. 2010; 52-5. | Website

[9]. Gent AN and Campion RP (ed). Engineering with rubber: how to design rubber components. German: Munich Hanser; 2001. | Book

[10]. OECD Emission Scenario Document. Additives in the Rubber Industry. Germany, Berlin: Umweltbundesamt (Federal Environmental Agency); 2003.