

UTILIZATION OF POLYETHYLENE SCRAPS IN RUBBER FORMULATION TECHNOLOGY FOR MANUFACTURE OF LOW COST RUBBER PRODUCTS

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INTRODUCTION

Sri Lanka is one of the nine major producers of Natural Rubber (NR) in the world. In terms of productivity, it is now the third best. Presently, Sri Lanka produces about 150,880 metric tons of rubber annually, exporting about 20% - 30% .The value of Sri Lanka's rubber industry exports has been growing steadily. If Sri Lanka is to retain and improve its position in the fast expanding and increasingly competitive global rubber business in the next years, it has to adopt new technologies and practices, keeping in mind economical usage of valuable natural resources. In spite of impressive progress in the Sri Lankan rubber industry, there are still a lot of possibilities for optimization of rubber formulation technologies in order to use natural rubber economically and bring down high production cost. One of the ways to achieve this goal is usage of large quantities of non-reinforcing fillers such as calcium carbonate (CaCO₃) and China clay which are widely distributed in Sri Lanka. These fillers act as diluents, and when added in large quantities in order to reduce cost, they usually produce a negative effect on strength characteristics of rubber compounds such as tensile, abrasion resistance, impact and tear resistance. One of the possible reasons for deterioration could be attributed to reduction of polymeric content that seems to be insufficient to bind dispersed fine filler particles and form continuous polymer- filler matrix. In order to overcome this problem it was proposed to use low density polyethylene (LDPE) scraps to increase polymeric content in rubber compounds heavily loaded with mineral fillers. Polyethylene waste, mostly partially degraded after being exposed to prolonged sun radiation represents a large part of plastic environmental pollution in Sri Lanka. Such LDPE scraps melt at comparatively low temperature, that could be easily achieved during compounding and still be safe for rubber. LDPE melts being compatible with natural and synthetic rubber extend polymeric content allowing the compound to absorb increased amounts of inert filler. LDPE is not a new material for rubber compounder. It is used, for an example, with EPDM rubber to improve dielectrical properties of rubber compounds (1). It was reported , that LDPE -natural rubber blend threaded with poly-(methyl methacrylate) modified water hyacinth fiber gave a high value of tensile strength, Young's modulus, glass transition temperature and melting temperature (2). LDPE is used in dynamically vulcanized elastomers to improve impact resistance and stiffness (3). Even in practice experienced mixer operators charge the banbury with some chemicals being packed in polyethylene bags. They do not remove packaging as it dissolves in rubber compounds during mixing. In spite of this the data on application of LDPE scraps in low cost compounds have not been published in commonly available literature and the present study would be interesting for rubber compounders as well as for researches in the related fields.

METHODOLOGY

Natural rubber under Technically Specified Rubber (TSR) of SLR- 20 grade was purchased from Yatideriya Rubber Factory, Undugoda, managed by Associated Specialty Rubber Private Limited, Sri Lanka. Commercial grade chemicals were bought from the local market. They included: LDPE recycled material gray grade, locally produced calcium carbonate of Lakcarb Calcite 0001 grade, silica granules of Mansil commercial brand, silane coupling agent, stearic

acid, paraffin wax, zinc oxide, accelerators, sulfur and others. Six rubber compounds were prepared as per formulations given in Table 1. All compounds were filled with calcium carbonate. They differed by concentration of LDPE that varied from 0 pphr to 90 pphr.

Table1. Rubber compound formulations

Formulation	F-0	F-20	F-25	F-30	F-40	F-90
Ingredients	pphr	pphr	pphr	pphr	pphr	pphr
SLR-20	100	100	100	100	100	100
LDPE	0	20	25	30	40	90
Fillers - Silica	40	40	40	40	40	40
PG	4	4	4	4	4	4
Silane coupling	4	4	4	4	4	4
Stearic acid	2	2	2	2	2	2
Parafine wax	1	1	1	1	1	1
Zinc oxide	5	5	5	5	5	5
CCO ₃	100	100	100	100	100	100
CBS accelerator	2	2	2	2	2	2
Sulphur	3.5	3.5	3.5	3.5	3.5	3.5
Total	261.5	281.5	286.5	291.5	301.5	351.5

It should be noted, that all formulations were made free of antioxidants, as compounds were not planned to be stored for a long period of time. All rubber compounds were prepared using a laboratory scale internal dispersive mixer. Compounding of master batch was done in two stages. On completing 24 hour's maturation, the 2-nd stage master compound was sulfured in an open two roll mill. Rheological properties of prepared compounds were determined with oscillating disc rheometer "Monsanto" R100 at temperature of 180°C. Rubber samples for testing physical and mechanical properties were cured in compression moulds fixed to the platens of a laboratory type "MOORE" hydraulic press preheated to 150 °C along with plates. After de-molding and cooling, the specimens were tested to determine tensile properties (ASTM D412), specific gravity (ASTM D297), hardness (ASTM D2240 00), rebound resilience (ASTM D2632) and abrasion resistance (ASTM D5963).

RESULTS AND DISCUSSION

Rheological curves were obtained for three samples taken out of each prepared rubber compounds. Rheological characteristics included minimum torque value T_{min} and maximum torque value T_{max} , scorch time t_{10} and optimum cure time t_{90} . (Table 2).

The observed maximum torque was influenced directly by the cross-linking density. But, for LDPE that was not participating in chemical bonds formation its influence on maximum torque was relatively low with some reduction due to dilution of compound resulting in reduction of total cross linking density. The scorch time corresponding to 10% curing (t_{10}) increased with increasing in LDPE content in composition. This fact is very important for rubber processor as a safety period of compound usage was improved. Optimum cure time corresponding to 90% curing (t_{90}) was decreased initially due to reduced viscosity and better mobility of rubber chains and further proportionally increased with increasing plastic content. Mechanical and Physical properties of experimented rubber compounds are given in table 3.

Table2. Rheological characteristics

N	Formulas	t ₁₀	t ₉₀	T _{max}	T _{min}
1	F-00	1.04	1.52	88.78	3.50
2	F-20	1.02	1.50	88.00	3.77
3	F-25	1.20	1.62	86.00	3.80
4	F-30	1.28	1.66	85.99	4.00
5	F-40	1.44	2.00	85.16	4.50
6	F-90	1.60	2.30	75.10	6.20

Table 3. Properties of rubber compounds

Formulation	F-0	F-20	F-25	F-30	F-40	F-90
LDPE content , pphr	0	20	25	30	40	90
Tensile strength, MPa	10.5	11	10	7.5	7	4.98
300% Modulus, (MPa)	8.99	10	9.0	8.5	7	4.98
100% Modulus, (MPa)	7	7.8	6.61	6.0	5.5	4.0
Elongation at break ,%	533	394	291	380	402	410
Hardness, (Shore A)	82.3	86.2	89.3	88.6	88.7	92.5
Specific gravity,g/cm ³	1.362	1.359	1.329	1.324	1.311	1.221
Rebound resilience,%	42	40	41	36	34	30
Abrasion loss,mm ³	180	175	185	188	190	220

Tensile strength, elasticity modulus at 100% elongation and elasticity modulus at 300% showed highest values for the composition containing 20 pphr of LDPE. This indicates that presence of LDPE in the amount of 20 pphr promoted reinforcement of natural rubber with calcium carbonate filler. The reason for this could be associated with better distribution of filler and curatives throughout the highly filled rubber matrix. Elongation at break reduced with increasing LDPE content and achieved minimum level of 291% when concentration of LDPE in composition was 25 pphr. This behavior could be explained by restriction of mobility of rubber molecules due to formation of additional physical and chemical bonds between rubber and filler. Further addition of LDPE to rubber compound improved its flexibility, as hard filler was diluted with polymeric matrix. The incorporation of LDPE caused an increase of compound hardness value. For LDPE Shore D hardness is 55 and after converting to the hardness in scale A, this value comes to 95, while for natural rubber Shore A hardness is 55 only. This fact is very important, as it gives a good opportunity for rubber producers to raise compound hardness keeping its specific gravity at low level. With addition of LDPE rebound resilience decreased. This property is dependent mainly on elasticity of the base polymer in compound. The elasticity of natural rubber is better, when compared to other synthetic rubbers and general use plastics. It is obvious that

incorporation of plastic dropped down rebound resilience and it should be noted that this drop was not significant until LDPE content did not exceed 20 pphr.

It is well known that chemical cross links do not favor abrasion resistance, while physical bonds introduced by reinforcing fillers are of mobile nature, so they allow more creep and dissipate frictional energy. As LDPE facilitated physical reinforcement of rubber with mineral fillers some improvement in abrasion resistance was observed, however when LDPE amount exceeded 20 pphr abraded material loss increased, because no additional physical cross-links were formed.

CONCLUSIONS/RECOMMENDATIONS.

The above research was carried out to guide local rubber producers in development of cost effective natural rubber based formulation technology with utilization of LDPE scraps.

The major conclusions that can be drawn from the research carried out are:

1. It is possible to mix LDPE scraps with natural rubber compounds in commonly used internal rubber mixing machines.
2. Addition of LDPE to rubber compounds improved green strength of unvulcanized rubber.
3. With introduction of LDPE the safety period of sulphured compounds can be extended.
4. It is possible to increase compound hardness keeping specific gravity of compound at a low level.
5. .With respect to the mechanical properties of vulcanized rubber compounds, the concentration of LDPE in rubber compounds should not exceed 20 pphr in order to achieve some improvement in tensile strength and abrasion resistance as further increment of LDPE content would lead to deterioration of those properties.

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