

Development of Low-cost Slipper by using NR/EVA Blend with Recycling Materials for reducing Environment Pollution in Footwear Industry

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ABSTRACT

This study aims to develop a low-cost slipper compound by blending low grade Natural Rubber (NR), Ethylene Vinyl Acetate (EVA), and recycled LDPE plastics granules with crumb rubber in different phr (parts per hundred rubber) amounts. Low grade natural rubber (off grade brown scrape) and ethylene vinyl acetate (19 wt.% of vinyl acetate) were used during formulation in order to reduce cost. During this compounding process, polymeric material and other chemical ingredients were masticated by using a kneader and two roll mills then sheet was prepared by using calendaring techniques, eventually curing was performed by using a compressing molding method. Blowing agents were used to obtain the Slipper sheets' inter cellular structure. Peroxide curing system has used due to natural rubber blend with ethylene vinyl acetate. When preparing compound batch, different phr amount of crumb rubber and recycled LDPE plastics granules blended. Firstly, crumb rubber sheets which were punctured and waste scrap sheets were obtained, then converted into 30 mesh size small particles by using grinding and crush method. Hardness and Abrasion tested of prepared slipper. After curing process higher hardness value observed when increasing crumb rubber phr. As particle size increases, there was a tendency of asymmetrical spread of compounding ingredients through the mixture and this was mitigated by additions of processing oils which increased the dispersion of the particles. In summary, through this work, ideal compounding formulation with phr values was able to determine that can be used to manufacture to low-cost slipper sheet at industrial scale.

KEYWORDS: Crumb-rubber, Ethylene-vinyl acetate, Natural rubber, Low cost compounds, Foot-wear waste.

INTRODUCTION

In recent years, there has been an evolutionary trend of sustainable product development which includes major concepts of reduce, reuse and recycle. To achieve these objectives, many industries started to focus on turning wastes into useful products or valuable raw materials. The main objective of this study is to develop new “micro cellular slipper” adding waste material to EVA & NR blend. This research will lead the ordinary footwear industry to a new path as through this, it emphasizes the new process of recycling footwear industrial waste and a production of low-cost slippers to market. Most of raw materials currently using are much costly due to various reasons such as operation cost, shipping cost, which make impossible for foot wear industries to produce low cost products (Yehia, 2004). The quality of raw material directly affects the quality of final product. Through the findings of this study footwear producers are able to produce low-cost slippers of high quality. In addition, footwear industrial waste disposal remains an economic, social, and ecological challenge worldwide. The inappropriate disposal of waste leads to a considerable volume of garbage being burnt which causes air pollution. Additionally, footwear industrial waste also increases the danger of disease transmission and reduces sustainability. This research intends to use industrial waste in effective way. This will help to footwear producers to become more competitive in footwear industry locally and globally and also to fulfill customer needs and to maintain and improve their customer base. Therefore, this research work was carried out to check the suitability of the addition of recycled scrap for the production of a new low-cost slipper. With the manufacturing process, a considerable amount of punch scraps and off-cuts, saving inside the foot-wear industry as waste material of products. By using two machinery technics, these waste materials will be recycled. For this research, crumb-rubber selected only one categorized product and it produces more than other products. Also, that product is produced from natural rubber and petroleum source by-products and therefore it affects the global green concept and also its effect on the waste management of the industry. Therefore, firstly particles size of these waste materials (particle size is 30mesh) will reduce by the recycling method, (Normally, in the footwear industries, this rubber crumb with a particle sizes up to 0.6mm can be used as an additive (Pirolo et al., 2013), and then it adds different quantities as a filler with the NR/EVA blend for a manufactured new slipper. To produce new slipper will use EVA and NR low-cost blend with various types of chemicals. By that, under the several of the compound and mixing formulation, by using single step compression molding method will manufacture (MC) sheets of the slipper. Some advantages from the customer's side are better rubbery feeling during wearing, low compression set, and better abrasion resistance and desirable hardness will offer by that EVA/NR blend. The production of micro-cellular expanded soling material has played a vital role in the rubber processing industry as it is directly used in the footwear industry. Micro-cellular expanded soling sheets are produced with organic nitrogen-releasing chemicals (blowing agents) by an expansion process. And that produce microcellular structure can be stabilized long as by cross-linking structure. To obtain this, a "peroxide curing" system will use as the most common curing method. The "Dicumail Peroxide" (DCP) is used as the main curing agent. By controlling the quantities of blowing agents and

curing agents can make various hardness and densities with properties with the micro-cellular structure. Also, during addition of some non-reinforcement filler, those also affect to properties of the microcellular structure. The manufactured sheets are normally supplied in the form of semi-finished large sheets from which the soles will subsequently cut out. The offcuts (punched scrap) can be reused as a raw material like filler.

The applications of microcellular range from toys to important engineering applications. Some of the applications are sound absorption, vibration isolation, insulation, padding, floor backing, wall lining, footwear components, cushioning, and many more applications. For applications where physical properties are critical and high weight is required, then low density is normally used and for applications where some engineering requirements are needed, then higher density is used. In footwear applications compression set and density are important and therefore the microcellular used is normally medium density and of medium harder products. According to the above data, this research will hope to produce a micro-cellular structure with low-cost slippers using recycle material and then will hope to control the cost of slippers using this recycled material with good properties.

METHODOLOGY

For this study, used followed (Table 1) fundamental compound formulation. According to this formulation and different phr amount of crumb rubber quantities were added.

Table 1. Fundamental Compounding Formulation

Ingredient	phr
Natural Rubber (Off grade brown scrape 4A)	10
Ethylene-vinyl acetate (19 wt.% of vinyl acetate)	30
LDPE	25
LDPE recycled grade white	35
Calcium Carbonate	100
Stearic Acid	2
Zinc Oxide	3
Blowing Agent	3
Di-Cumyl Peroxide	1
30 Mesh "A" product Crumb	100

Development compound sample formulation

Using a fundamental formulation a different set of samples will be prepared and will be checked on their physical and mechanical properties (Specific gravity, Hardness, Abrasion) of cured samples. Different phr amount of crumb rubber add to the rubber compound i.e. 100, 75, 50, 25, 15 and 10. And will investigate maximum phr amount of crumb rubber and LDPE granules can be used.

Crumb rubber preparation

Crumb rubber is manufactured by using larger solid waste rubber into small size particles like powder or small granules. Particle size determined by mesh size. This crumb rubber is produced by using mainly three types of techniques. Such as ambient processes, cryogenic processes and wet grinding processes. As a 1st step, select the known waste slipper rubber sheets. Then clean and turned into small particles by using grinding process until required mesh size.

Mixing and preparation compound

1st step: - Material weighting

Select the batch size and prepare the compound formulation. And phr value converts to Kg then raw materials weigh by proper scales.

2nd step: - Mixing

Bulk polymeric martial masticate by kneader and other additives are added to the mixture according to the formulation sequence. After the masticating and mixing process, compound further mix by using a two-roll mil machine to improve mixing properties.

3rd step: - Calendaring and cutting

Masticated compound properly convert to sample sheet.

4th step: - Curing

Prepared Compound sheet cure by using compression molding press under the constant temperature and pressure with proper time.

5th step: - Sample test

Finally cured sheets sample's physical and mechanical properties will be checked according to proper standard.

RESULTS AND DISCUSSION

This chapter will discuss about obtained results from prepared samples according to the various quantities of material used. Prepared sample properties will be dependent upon used recycling material quantities and filler content. Used main recycling materials were LDPE recycled grade and 30 mesh crumb rubber. Physical and mechanical properties of samples were observed which consist of various quantities of crumb rubber with recycling LDPE granules. Prepared samples properties will depend upon used recycling material quantities and filler amount. According to crumb rubber, recycling LDPE granules and filler amount, properties and quality of sheets were changed. With the high amount of crumb rubber quantities, the sample is taken high hardness because these recycling materials act as a filler, and in the formulation contained Calcium carbonate 100 phr. Fundamental sample and sample "A" contain crumb rubber and Calcium Carbonate per 100 phr. Due to that, the formulation contains a higher amount of filler quantity. Therefore, the sample is taken with high difficulty. Follow table (Table 2) show the used recycle materials and a filler.

Table 2. Material composition for samples

Material	Fundamental sample quantity	Sample A	Sample B	Sample C
Crumb-rubber	100	100	25	50
Recycle LDPE granules	35	40	-	-
CaCO ₃	100	100	100	100

In sample A (Figure 1), reversing curing characteristics observed due to the high filler amount. This may occurred when increased recycle material phr, these materials also act as filler. Also, after preparation, the sample compound showed several visual defects. Such as air bubbles, surface cracking, poor forming, and less bond strength.

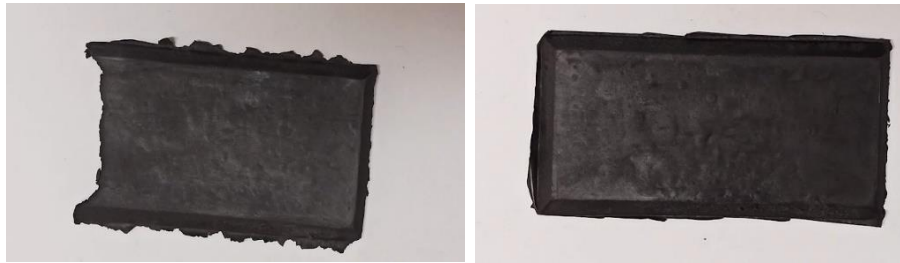


Figure 1.Prepared samples A

Therefore, B and C pilot samples will be developed by using less recycling materials amounts. When developed B and C samples, LDPE recycled grade white is not used to reduce the effect of high filler content. In the B formulation, a 25phr crumb rubber part is used, therefore, sample B properties as curing, forming behavior and surface finishing better than A and C. When preparation sample C (Figure 2) is not properly foamed and its hardness also increased. We concluded that due to crumb rubber quantities increasing in the sample, its hardness increased. And these CR are not properly distributed through the compound with the larger quantity. Therefore, the sample is not properly foamed, and some defects occurred in the sample. Because sample C compound also does not properly formed.



Figure 2.Prepared samples C

After that fundamental formulation as used in formulation B and samples B formulation developed as D, E, F, G. Using the B sample compound, prepared three samples under the different cure times and find to suitable cure time. According to sample properties and visual appearance, the proper curing time we were gotten 7 minutes. Because the sample foaming characteristics and surface finish are better than other curing times. Then large-scale samples tried, using different quantities of crumb rubber. Here again observe different defects. We concluded with increased crumb rubber quantities were not properly distributed during large size batch preparation. Therefore, more air bubbles are prepared, and some samples are shown to quickly shrink. And increasing with crumb rubber quantities prepared some samples show quickly shrink. The reason assumed when increased crumb rubber quantities the bond strength poor due to crumb rubber mixing engage and distribution problems. Some samples are gotten more hardness and reversing. Because, crumb rubber was vulcanized using sulfur with an accelerator system. When using their recycled waste materials as raw materials, the remaining quantities of sulfur and accelerator system can affect to the new sample's curing process. Therefore, when sample compounding, the DCP amount is reduced. Because DCP used as curing agent and crumb rubber available, non-vulcanized chemicals therefore we reduce the DCP phr amount. Further to improve mixing properties of compounds, sample G was modified by using a master batch of natural rubber and crumb rubber. Because, when crumb rubber added directly compound it's not properly dispersed because bulk rubber needs more masticate time. Problem is when masticating this rubber generated heat, that heat affects the other chemicals. Therefore, master batch preparation is more efficient. During compound preparation, need processing oil. This oil reduces surface tension and helps to distribute crumb rubber throughout the compound. Therefore, phr amount of processing oil also increased to 4 phr. When increased crumb rubber, rubbery feeling and properties gradually decreased. Therefore, we observed layer separation, shrinkage and harder feelings by prepared samples. Therefore, 19wt% vinyl content EVA instead 26 wt. % vinyl content EVA to increase rubbery properties and bond increase to bond strength. After preparing and trying larger sample series, finally sample formulation G (Table 3) was a success than previous sample formulations.

Table 3. Formulation of Sample G

Ingredients	phr
OG -NR and Crumb rubber MB	50
Ethylene-vinyl acetate (26 wt.% of vinyl acetate)	40
LDPE	25
Calcium Carbonate	100
Stearic Acid	2
Zinc Oxide	3
Blowing Agent	4.5
Di-Cumyl Peroxide	0.9
Processing oil	4
Master batch of SBR	10

In newly prepared samples it was observed that defects were reduced and properties were improved than previous samples (Figure 4 and Figure 5). Prepared samples has shown below (Figure 3).



Figure 3. Prepared Sample G sheet

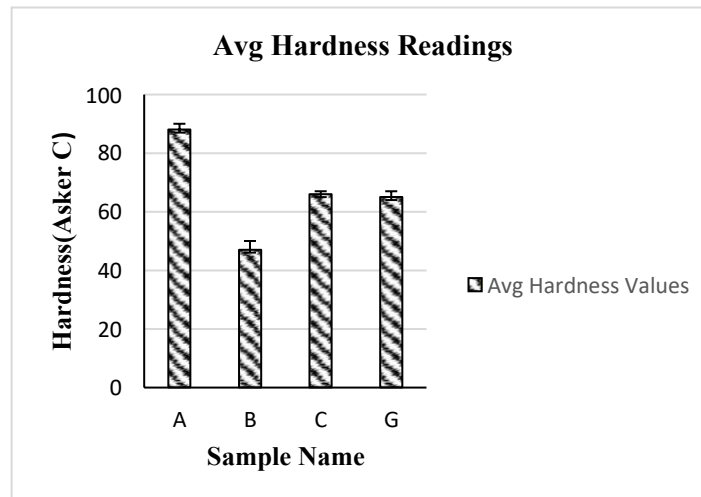


Figure 4. Hardness values of samples

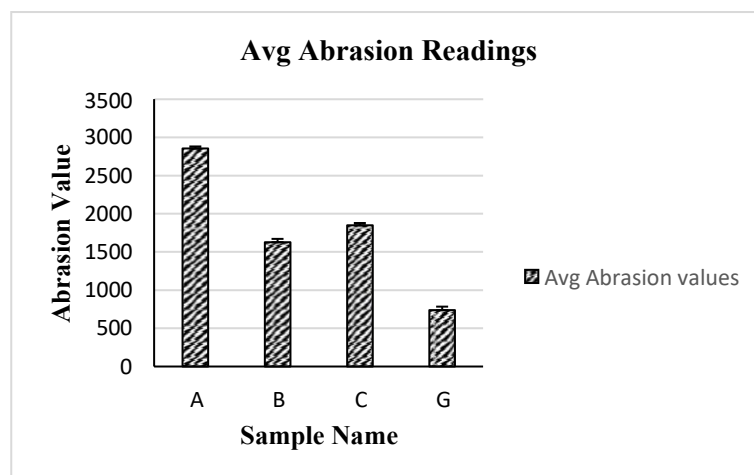


Fig 5. Abrasion values of samples

CONCLUSION

This project done by using natural rubber and EVA with recycling materials. Here, samples were prepared by using different quantities of recycling materials. Properties of samples were dependent upon recycling materials' quantities added and mixing properties. When recycled material quantities increase, samples get high hardness with more processing defects. And also, here the size of used crumb rubber

particles is 30 mesh-size. Therefore, it's tough to mix with natural rubber and other materials. Due to that reason, samples were composed of more air bubbles and bond strength was reduced and layer separations were. Therefore, to improve mixing properties, a master-batch will be prepared by using NR and crumb rubber. Also, EVA (26wt % VA) was used to improve bond strength because when high VA content of EVA increases, its rubbery properties were also increased. Therefore, it prevented shrinkage after the curing process. Additionally, 4phr processing oil was used for the final formulation development. Due to that, sample mixing properties also increased and which showed during visual inspections and in physical laboratory test results. This sample sheet was prepared at a low cost by using low priced materials with crumb rubber.

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