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Using EVA Foam Waste to Enhance PVC Performance in Shoes Industries

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ABSTRACT

The shoes industry generates an elevate amount of waste, being large part of these the poly [ethylene-co-vinyl acetate] EVA, a polymer widely used in the form of expanded thermoset. The EVA most used by the shoe industry contains around 18~28% content of (VAc) and today still there are no appropriates solution to their destination and recycling. The residual de-vulcanization is present as an alternative that may allow it is use again as raw material in the shoe industry. According to the literature, an effective way to improve the properties of polyvinyl chloride PVC is making a blend with EVA. However, being thermoset the shoe industry EVA waste is not suitable for this purpose. The objective of this project is characterize the wastes of EVA foam shoes industry.de-vulcanization the waste in order to produce a material closer to the virgin one and make possible the manufacturing of compatible blends of EVA waste with PVC waste, enable it is use by shoe industry.

Key words: EVA Foam, PVC, Waste, Recycling Shoes

INTRODUCTION

Plastic Waste started to attract increased public attention, now it is become a global problem and one that must be addressed in order to solve the world's resource and energy challenges [1, 2]. EVA is a co-polymer made from two different monomer types being ethylene and vinyl acetate. In a foam state, EVA has rubber like properties, making it useful where cushioning is important such as in midsoles, sock liners, and unit soles in footwear. In EVA, the relative amount of vinyl acetate to ethylene influences polymer properties. Higher vinyl acetate content tends to make the polymer softer and more rubbery, while lower vinyl acetate content tends to make the polymer harder and more crystalline [3]. Recycling rate of EVA foam is generally very low, companies are also very few .EVA is commonly used in midsoles of shoes. As such, the application requires a good aesthetic appearance and retention of physical properties while achieving as high content as possible of recycled scrap foam. Usually they used the thermo mechanical method, initially prepared the formed EVA waste by shredding and then heat them to the range from 80 to 200 °C; it would be the best if the temperature [4].

Many researchers have proposed alternative approaches to solve environmental problems due to the progressive rate of waste generation. Some of them studied physical recycling and that means EVA are re melted to form new plastic objects, and other in chemical recycling, it means possible to convert the copolymer of EVA and back into monomers and also study the mechanical properties of EVA recycle compare with EVA virgin.

Eunha Kim et al. (2015) investigated Vinyl acetate (VA) contents of poly (ethylene-co-vinyl acetate) (EVA) analyzed by infrared spectroscopy (IR), nuclear magnetic spectroscopy (NMR), and thermogravimetric analysis (TGA) were compared. Four grade EVAs supplied by Aldrich Co. and four grade EVAs manufactured by DuPont Co. were used. For IR analysis, VA contents were determined using calibration curve (absorbance ratio of 1739 cm^{-1}/2922 cm^{-1} or 609 cm^{-1}/1464 cm^{-1}) of reference EVAs. Correlation coefficients of the calibration curves were not sufficiently high ($r^2 \leq 0.96$). For NMR analysis, VA contents were determined using peaks of CH_3, CH_2, and CH. VA contents determined by NMR analysis were less than those marked by suppliers more than 10%. For TGA, VA contents were determined using weight loss through deacetylation. VA contents determined by TGA were slightly different with those marked by suppliers. Difference in the VA contents determined by different Analytical methods was discussed, and difference in the analytical results according to the EVA suppliers was also examined [5].

NIKE, INC (2014), this paper interest in a method of recycling scrap ethylene-vinyl acetate (EVA) foam involves foaming and cross-linking a blend containing virgin EVA resin and scrap EVA foam, as well as a cross-linking agent and blowing agent for the EVA resin. The blend Further contains a compatibilizers, which is a hydrogenated petroleum resin, that means using the compatibilizers, suitable foamed articles can be made that contain up to 30 parts of recycled foam per 100 parts of virgin resin, in addition to the improved aesthetic appearance, improves shrinkage and elongation of the resulting foamed articles, and also. Improves the split tear performance, as measured by standard industry tests [6].

Gama N, Godinho B et (2022) produced elastomeric materials from 100% recycled feedstock's were produced. Residues of polyurethane (PU) foams (from 0 to 100%) were blended with residues of ethylene-vinyl acetate (EVA) derived from the shoe-soles industry (from 0 to 100%) to produce films by hot compression. The experimental values obtained by the characterization of the blends were compared with the predicted values derived from the rule of mixtures [7].

The main objective of this study is to reduce the environmental pollution. which comes from accumulation of EVA foam waste that used in footwear industries. mix EVA foam waste with PVC waste to optimize the ratio of PVC cost. and investigate the performance of EVA/PVC compound compared with pure PVC. And make economic value to EVA foam waste. And find other application for EVA foam waste (construction field).

MATERIALS AND METHODS

Materials

Some experiments have been done for EVA foam waste with flexible PVC waste to recognize the ability of using it in shoes field Materials used:

EVA foam waste

It is waste of shoes industry made of Ethylene vinyl acetate (EVA) gathered from RANI factory about 10 kg.

Fig. 1 EVA foam Waste

Poly vinyl chloride (PVC)

Waste of shoes industries made of flexible PVC, gathered from Abd-ELAziz factory about 20 Kg.

Fig. 2 PVC Waste

Additives

The bulk properties of a polymer can often be altered considerably by the incorporation of additives. additives may be divided into four groups, solids, rubbers, liquid sand gases, the last of these being employed for making cellular polymers. In terms of function there are rather larger numbers of groups, of which the following are the most important Such as Fillers, Plasticizers and softeners, Lubricants and flow promoters, Blowing agents. And Cross-linking agents [7, 8].

Additives used

Calcium carbonate ($CaCO_3$) Non-reinforcing filler added to cheapen the mixture and usually do not enhance the properties, just used for modifying, amount used about 10g from ALTOUM factory. Di-Iso- Octyl- phthalate (DOP) It is internal lubricant used to lubricate the polymer during processing, these materials are often at least partially miscible with the polymer melt and used about 10~15m [9].

Sulfur: It is chemical additive used to change properties "cross-linking" and vulcanization rubber chains, obtained from ALTOUM factory about 15g.

Talc: Is a clay mineral composed of hydrated magnesium silicate with the chemical formula $H_2Mg_3(SiO_3)_4$, gathered from ALTOUM factory (20g).

Cyclohexane: Is a cycloalkane with the molecular formula C_6H_{12} cyclohexane is mainly used for the industrial production of adipic acid and caprolactam. Cyclohexane is sometimes used as inorganic solvent, obtained from industrial engineering and technology chemistry lab.

Carbon black: Is a material produced by the incomplete combustion of heavy petroleum products such as FCC tar, coal tar, ethylene cracking tar and small amount from vegetable oil Carbon black is mainly used as a reinforcing filler in tires and other rubber products (ALTOUM factory, 20g).

Equipment's

The equipment has been used in this the research work are the following:

Rolls and Injection machine

Two types of rolls have been used to compress EVA foam waste so as to remove blowing gas, these are: Cold roll (in Al Toum and AL Yarmouk factories) and Hot roll (in yaw lee factory) and Normal injection machine used to shape EVA foam waste with PVC waste in shoes form (in Abdul-Aziz factory).

Fig. 3 Rolls

Fig. 4 Injection Machine

Sensitive Escapement and Cylinder

Used to countrified the samples in order to determined the value of density. Cylinder Used to measure the volume

Fig. 5 Sensitive Escapement

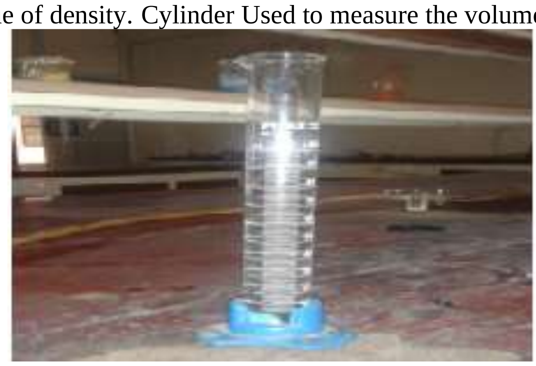

Fig. 6 Cylinder

Cutter and Tensile Testing Machine:

Fig. 7 Tensile Testing Machine

Fig. 8 Cutter Machine

Methods

Sample Preparation Many samples have prepared by using above equipment. First sample The EVA foam waste was compressed between two hot rolls gives thin sheet and cut the sheet into small pieces that mixed with PVC in different ratio, Second sample EVA foam waste compressed between the cold rolls in addition of sulphur that give brittle sheet "incoherent" , then carbon black was added . Another sample compressed between cold rolls without additives, gives coherent sheet and cut into small pieces, then mixed with PVC in different ratio, Third sample Eva foam waste was compressed between two cold rolls then injected in injection machine without mould to reduce air volume then compressed cut and mixed with the PVC in different ratio. Fourth sample EVA foam waste has compressed in cold rolls in addition of calcium carbonate, DOP oil and talc that give soften and incoherent result and cut into small pieces then mixed with PVC in different ratio. EVA foam waste has been compressed in same above condition with fuel oil and gives no result and Fifth sample Eva foam had been cut into small parts and placed in the cyclohexane solution at 70 0C in order to dissolve it but it is failed.

Sample Processing

Prepared EVA foam waste mixed with PVC and molded by injection machine in shoes mould at temperature 150~2000C and pressure i different ratio. This process repeated many time for samples، ratio shown below respectively:

- 10%, 15% of EVA with 90%, 85%of PVC in the first sample.
- 10%, 15%, 20%of EVA with 90%, 85%80% of PVC in the second sample.
- 10%, 20%, 30% of EVA with 90%, 80%, 70% of PVC in the third sample.
- 20% of EVA with 80% of PVC in the fourth sample.
- Failed in the fifth sample.

Fig. 9 Sheet of EVA foam Waste

Fig. 10 EVA Foam With Additives

Fig. 11 EVA Foam Waste Injected

Standard Sample

Flexible PVC waste has injected and formed in shoes form in order to be tested and compared

Sample Test

Two types of test have been conducted for the different samples.

Tensile Test

the product cutter by tensile device lateral and longitudinal with 5cm long, the sample set in tl part" and the lower jaw" moving part", the device start move down with load until the sampl reading was recorded this test repeated for all samples.

Density Test

The density defined as the ratio between mass and volume by Kg/m3.Sample has been cut into small pieces, The weight measured by sensitive escapement, The beaker has been filled by water in specific point, Small pieces placed in the beaker and The volume has been measured**.**

RESULTS AND DISCUSSIONS

Results

The results of the previous experiments and tests as shown below:

Thickness = sub of thickness/number

Tensile =(load*gravity)/ Area

Area = thickness* width

Width = 10 mm

Standard sample
Thickness = (3.4+3.6+3.7)/3 = 3.57 mm
Tensile = (18.1*9.81)/35.7 = 4.97 N/mm^2
Elongation = (25.3-16.7) *100%/5 = 172%
Tensile and density tests have been done to PVC sample and the results are:

Table-1 Standard Sample Result

Sample	Density g/l	Area mm^2		Load Kg		Tensile Strength N/mm^2		Elongation %	
		L	W	L	W	L	W	L	W
Original	1.425	42.3	37	54.7	49.5	12.776	13.124	198%	162%

- Standard sample shows highest load and tensile strength properties.
- High density

First sample:
The properties of 15% better than 10%in load and tensile, but 10%best in elongation.
Second sample:
The 20% show best result than 10%and 15%, but unaesthetic.
Third sample:
20% is more acceptable and 30% is weak and inappropriate for this application
Fourth sample:
Oil sample is more flexible, aesthetic and high elongation, but it has weak load and tensile strength

Table-2 Comparative Table between all Samples

Samples	EEVA Wt%	Density Kg/m^3	Area mm^2		Load Kg		Tensile N/mm^2		Elongation	
			L	W	L	W	L	W	L	W
Standard	0%	1425	4.23	3.70	54.70	49.50	127.36	131.24	198%	162%
First sample	10%	1190	4.5	4.00	42.50	25.60	92.65	62.78	130%	88%
	15%	1150	5.015	3.85	46.30	23.00	117.97	44.80	122%	66%
Second sample	10%	110	3.60	4.13	15.20	15.90	41.42	37.77	76%	62%
	15%	1140	3.93	9.93	33.20	26.00	82.87	64.90	180%	104%
	20%	1110	3.43	4.20	44.50	37.60	127.27	87.82	238%	140%
Third sample	10%	840	3.37	3.57	18.80	18.10	54.73	49.74	204%	172%
	20%	790	3.67	3.77	22.80	22.40	60.94	58.29	196%	154%
	30%	750	4.00	3.93	14.30	10.90	35.07	27.21	130%	100%
Fourth sample	20%	7590	3.33	3.80	11.40	19.50	33.58	50.34	256%	154%

Fig. 12 PVC Waste

Fig. 13 Hot roll Sample 10% in First sample

Fig. 14 Hot roll Sample 15% in First sample

Fig. 15 Second Sample With 10% EVA

Fig. 16 Second sample with 20% EVA

Fig. 17 Injected Sample 10%EVA in third sample

Fig. 18 Injected 20%EVA in Third Sample

Fig. 19 Injected 30%EVA in Third Sample

Fig. 20 DOP Oil in Fourth Sample

DISCUSSIONS

Observed from above readings that the second sample has best properties compared with others. From load side the second sample (15%) is the best. From tensile strength side the third sample (20%) is best. From elongation side the oil sample is better. The third sample (30%) inappropriate for this application.

CONCLUSIONS

EVA foam represents important part in plastic production that lead to high consumption and big amount of waste causing problem in removal that waste. Different ways to remove EVA foam waste found in different application, the most important one is in shoes soles industry by mixing with flexible PVC waste by varying ratio and gave acceptable results. That means EVA foam waste can use in such application to reduce the amount of EVA waste.

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