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Investigation of the Mechanical Properties of Natural Rubber Using Bone Powder as Filler for Shoe Sole Production

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Abstract: Investigation into the use of cow bone powder as a filler mainly for the production of shoe sole was undertaken. The bone particles were crushed and sieved using a 120um sieve mesh size. For reinforcing effect, the cow bone particles were filled in the natural rubber matrix during compounding and cured. Varied weights of the powder were used and the mechanical properties of the composite were compared with those of carbon filled composite. The results obtained were promising as the properties are close to those of carbon filled rubber. Thus, bone powder can be used as a replacement for carbon black.

Introduction

Natural rubber(NR) is one of the important elastomeric and widely utilized to prepare many rubber products.It is often reinforced by incorporation of filler to improve its mechanical properties such as modulus, hardness,tensile strength, abrasion resistance and tear resistance etc.

Reinforcing fillers most often used are Carbon black and silica (SiO_2), calcium carbonate ($CaCO_3$) is also utilized as filler for rubber. Efficiency of the reinforcing filler depends on several factors such as particle size, surface area and shape of filler. Recently there has been a growing interest in the use of renewable resources such as bamboo and wood or products like rice husk,chitin and coir as fillers for polymers Benefits of these fillers include low cost, light weight, biodegradability and so on.

In Thailand, fishermen harvest cuttlefish for food skeleton of cattle fish is removed during cooking, which results in large amount of agricultural waste products of cuttlebone. Can cattle bone be used as a new biomass, since cattle bone is mainly composed of $CaCO_3$and chitin.

This project is based on investigation of the mechanical properties of NR using bone powder for shoe sole production. The natural rubber undergoes series of processes involving mixing with other ingredients(additives) to meet service requirement of the finished product at one hand processing requirement on the other hand.

Natural rubber has been chosen as the material to be used for the manufacture of shoe sole because of the inherent properties it possess e.g. hand wearing easier and cheaper to produce.

Cow bone powder is buildup of mineralizedmatrix which comprises collagen and a small amount of protein.

The properties of biomaterials are very impressive and in many cases can be compared directly to those of man-made materials such as the use of wood for engineering application. This ismore remarkable if we consider that biomaterials are entirely self-assembling

The introduction of mineral fillers such as bone powder which are finely dispersed in rubber induces substantial change in their physiochemical and mechanical properties, which are caused by the mobility of the macromolecules in the boundary layer, the orienting behavior of fillers surface and by different types of filler polymer interaction.

In the rubber industry, fillers that are commonly in use are carbon black and calcium carbonate. Carbon black is derived from petrochemical source, however the unstable price of crude oil has led to the research for fillers that are derived from other sources (ski 1970) thus fillers from mineral and organic sources have been developed to replace some grades of Carbonblack. On account of their low cost availability in large feed stock agricultureby –product which has been estimated at more than 200,000 matrix ton per annum, representing an underutilized renewable resources.

There is therefore the need to develop fillers from other sources particularly renewable resources to replace some grades of carbon black.

Materials, Equipments and Methodology

Materials

MATERIALS	SOURCE
Natural rubber	NILEST
Zinc oxide	NILEST
Steanic acid	NILEST
TMQ	NILEST
Filler(bone)	NILEST
Processing oil	NILEST
MTBS	NILEST
Sulphur	NILEST
Carbon black	NILEST

Apparatus/Equipment

EQUIPMENT	SOURCE
Two-roll mill	NILEST
Hydraulic press machine	NILEST
Hardness tester (SHORE A)	NILEST
Tensometer	NILEST
Mould	NILEST
Knife	NILEST
Hand glove	NILEST
Abrasion machine	NILEST

Methodology

The cow bone was collected from the waste stock (abattoir) at zango in samaru, the bone was treated with dilute Hcl to remove fleshy part, excess fat and dungs afterward rinsed in water and placed under the sun to dry.

After sun-drying, the bone was placed in the oven at 250^{o}C for 8hrs for further drying. After thorough drying, it was crushed by a crushing machine and then milled with mortar and pestle into powdered form to their particle sizes. After milling to a granular form, a sieve of 120µm mesh size was used to sieve the bone powder to the particle size.

Formulation Table

The act of developing a recipe for a desired product is termed formulation.The table below shows the formulation for each sample produced.

Formulation for NR with carbon black(control)

Ingredients(pphr)	Control	A	B	C	D	E
Natural rubber (NR)	100	100	100	100	100	100
Zinc oxide	5.0	5.0	5.0	5.0	5.0	5.0
Stearic acid	2.5	2.5	2.5	2.5	2.5	2.5
TMQ	1.5	1.5	1.5	1.5	1.5	1.5
Carbon black	50	-	-	-	-	-
Bone powder	-	10	20	30	40	50

Processing oil	2.0	2.0	2.0	2.0	2.0	2.0
MTBS	2.5	2.5	2.5	2.5	2.5	2.5
Sulphur	2.5	2.5	2.5	2.5	2.5	2.5

Compounding Ingredients for Natural Rubber

By compounding it simply means the incorporation of all the necessary ingredients formulated on natural to form a homogenous mix.

The main ingredients used for the formulation for each sample are;

i. **Base polymer**: (natural rubber); this form the base matrix of each sample on this research
ii. **Filler:** the use of non-reinforcing filler(bone powder and reinforcing filler(carbon black) brings about prominent reinforcement of natural rubber vulcanizates.
iii. **Vulcanizingagent**: (sulphur); this is the main cross- linking agent added into the rubber molecule to form 3-dimensional structure.
iv. **Activators** (zinc oxide, stearic acid); this is incorporated to the rubber matrix to further hasten the vulcanization reaction performed by the accelerator.
v. **Accelerator**(AMBTS); this is added to the rubber matrix to speed- up the vulcanization reaction and hence reduce the cure time.
vi. **Antioxidant** (TMQ); this is incorporated to the rubber matrix for maximum ageing protection.
vii. **Processing oil**(light oil); this is incorporated to the matrix of the rubber to reduce the friction that occurs between the rolls and rubber

Mastication

This involves the softening of rubber through the combine action of heat and mechanical rupture of the long polymer chain prior to the mixing of the different ingredients. This is necessary to subject the natural rubber to a process of breakdown of the molecular chains.

Mixing/Curing

After weighing of ingredients carried out on a weighing balance, followed by mixing of the ingredients on the NR which was initially act to a temperature of 70^{o}Cafter which the rolls of the mills was adjusted and the nips tightened.

Initially the ingredients for rubber compounding were not all added atthe same time into the rubber matrix, a suitable order of incorporation of the ingredients was used to thoroughly and efficiently mix them into the rubber.

The rubber was thoroughly masticated to reduce its viscosity softened to assist incorporation of the other ingredient and to enhance flow.

After mastication for 3 minutes, the rubber began to form a band. The co-activators were first added and allowed to mix for 2 minutes, afterward the antioxidant which was also allowed to mix for 2 minutes. The filler was added and then the processing oil was allowed to mix for 2-3 minutes, then accelerator was added and allowed to be mixed for about 2minutes ensuring that the materials were cross-mix diagonally with a mixing knife. The curing vulcanizing agent was added for cross-linking to take place for about 2 minutes.

After the incorporation of the ingredients, the nip was loosened to ease the removal of the compounded rubber from the rolls and was kept in a clean plate for stress relaxation.

The hydraulic press was then switched on and allowed to heat up to about 150^{o}c.The processing oil was rubbed on the surface of the mould and foil-paper for easy flow and removal of the samples, the mould was filled with the sample and was placed in-between the platens of the hydraulic press and closed maintaining a temperature of 150^{o}c. The sample was left to cure for 10 minutes. After curing was achieved the samples were removed from the mould trimmed off and ready for analysis to be carried out the same compounding procedure process is applicable for each formulation

Procedure Assessment

Hardness Test

The hardness of the rubber vulcanizates was measured using ASTM 1415 method on shore A Durometer. Force was applied on the sample surface; the corresponding deflection of the pointer which indicates the international Rubber Hardness Degree (IRHD) was read and recorded.

Abrassion Resistance Test

The measurement of abrasion resistance of the vulcanizate was carried out using MARTNDALA WEAR AND ABRASSION TEWSTER to 103-1386-2 method. This was carried out at the atmospheric condition of relativehumidity 65± 2 %, temperature of 20±2°C over 24 hours. The test specimen were subjected to a rotational grinding action of 4 abrasion surfaces which turns against the surface of the specimen mounted on a revolution platform. The specimen was first weighed and then ran for 2,000 rubs of revolution after which the specimen was re-weighed and the volume of the material was calculated from the density of the material. This is applicable for each sample revolution runs to ruptures.

Results

Table 1. Abrasion Test

S/N	Loadings (G)	Initial Weight (G)	Final Weight (G)	Weight Lost (G)
1	10	3.15	2.71	0.98
2	20	2.38	2.11	0.27
3	30	2.73	2.67	0.13
4	40	2.68	2.49	0.19
5	50	1.97	1.89	0.08
6	Carbon black	2.66	2.56	0.09

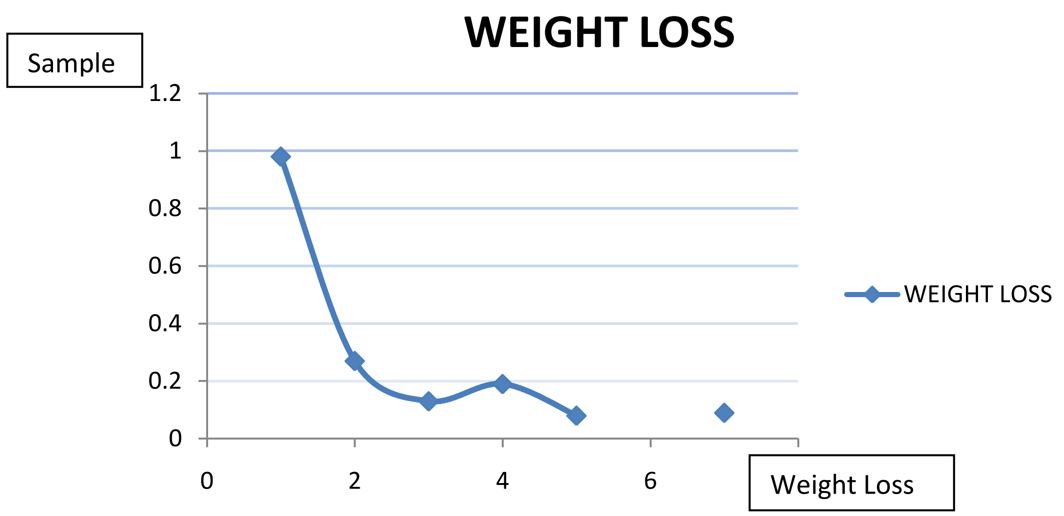
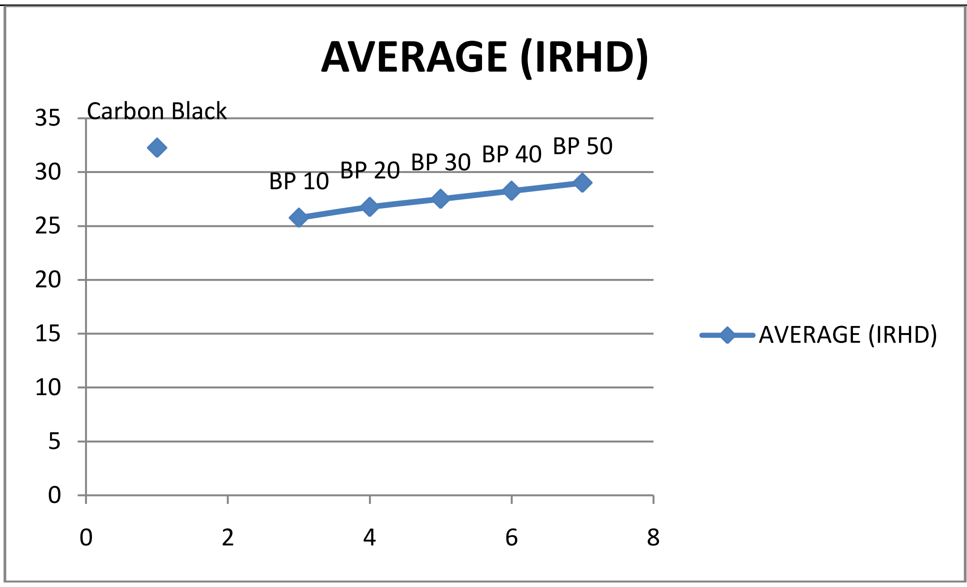


Table 2. Tensile Strength Test

	EXTENTION (mm)	LOAD (N)	STRESS N/m^2
Control	211	270	1.28
10	170	70	0.41
20	161	106	0.66
30	151	112	0.74
40	139	121	0.87
50	125	129	1.03

Table 3. Hardness Test

Filler Content	1st Test(IRHD)	2nd Test(IRHD)	3rd Test(IRHD)	4th (IRHD)	Average(IRHD)
Carbon Black	31	33	34	31	32.25
Bone powder 10	26	27	28	22	25.75
Bone powder 20	26	28	28	27	26.75
Bone powder 30	28	29	26	27	27.50
Bone powder 40	30	28	28	27	28.25
Bone powder 50	28	28	30	30	29.00



Discussion

From the abrasion test, It was observed that, the control sample(50g of carbon black) have high abrasion resistance than the sample filled with bone powder whose abrasion resistance increases with filler loading.

The sample filled with carbon black gave the highest hardness. By the incorporation of bone powder as filler, it was observed that the percentage increases of the filler loading increase with increase in hardness. The harder the sample, the further it will push the indentor pine and the higher the numerical reading. For example when the filler loading is 10g and the hardnesswas 25.75 IRHD but when the Filler loading is increases to 20g hardnesswas 26.75 this result suggest that bone powder is of reinforcement and has inherent reinforcement potentials

The tensile strength of a material is the maximum load that the material can support at any time when being stretched it is the behavior of the material under load [extension].
From the result it is observed that the extension decrease with increase filler loading and the stress increase with filler loading. The modulus increase with filler loading.

Conclusion

The cow bone, an agricultural waste as filler on natural rubber has been investigated. This research work shows the possibility of utilizing the low cost bone, an agricultural waste as an alternative for the commercially used filler known as carbon black for shoe sole production which is hoped will be cheaper,reduce environmental pollution, create employment and lead to the conversion of waste to wealth.

Recommendation

It is recommended that the machine required in determining the characteristics properties of the polymer samples such as tensile strength and abrasion resistance be made available to aid carrying out results.

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