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Studies on the Mechanical Properties of Thermoplastic Elastomer (Polypropylene / Natural Rubber Blends)

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Abstract: The mechanical properties of thermoplastic elastomer polypropylene (PP)/Natural rubber [NR] blend have been investigated. It was prepared using two-roll mill at 190°C. The basic additives used were PP, NR, TMQ, MBT, processing oil, stearic acid and zinc oxide, except sulphur. The blend composition was fixed at the ratio of 0, 90/10, 80/20, 70/30, 60/40, 50/50 (PP)/(NR). By varying the filler loading mechanical properties (i.e Hardness, Abrasion, Water absorption, and impact showed that during hardness test, increase in PP Loading with less natural rubber will increase the hardness result while for 50/50 shows that the was an increase in the hardness test due to equal quantity. Impact test shows that increase in PP Loading with less natural rubber will increase the impact strength while decrease in PP Loading with high natural rubber will decrease the impact strength .Water absorption test shows that samples with Natural rubber loading absorbed water more than those with high PP loading. Abrasion test result shows that some samples increased in the graph e.g 70/30, 80/20 based on in- homogenous mixed.

Keywords: Polypropylene, Natural Rubber, Water absorption and Blends

Introduction

Thermoplastic elastomers sometimes referred to as thermoplastic rubber are class of copolymers or a physical mix of polymers (usually a plastic and a rubber) which consist of material with both thermoplastics and elastomeric properties. Thermoplastic elastomers show advantages typical of both rubbery materials and plastic materials. The benefits of using thermoplastic elastomer are the ability to exhibitmoderate elongations and return to its near original shape creating a longer life and better physical range than other material. The principal difference between thermoset elastomer and thermoplastic elastomers is the type of cross-linking bond in the structures in facts, cross linking bond is a factor which impacts high elastic properties. (Kuchner and Marcel, 2016)

These materials that combine elastomeric properties with many of the attributes of thermoplastics have available to industrial for over twenty years. A wide acceptance of thermoplastic elastomers has taken place due to growing experience backed by convincing case studies in many sectors of industrial activities.(Levensator, 2016).New generation materials that have been developed to meet the demands of ever more discriminating consumption isin tons. The materials have a structural transformation achieved by physical cohesion forces and are called thermoplastic elastomers. (Levensator, Alex 2016)

Thermoplasticelastomers normally consist of two polymers, a polymer (thermoplastic in nature) which is frozen at the temperature of use and a polymer (rubber) that is in its rubbery state at the temperature of use. The frozen polymer forms bonds using physical cohesion force. By heating the frozen polymer to be molten and a product can be shaped (Kuener and Marcel 2016).

Polymer Blends

The definition of polymer blends has been described in various ways from a brief explanation to a specific one. (Utracki and Favis, 1989) defined polymer blend as mixture of two or more polymer or copolymer materials. (Utracki, 2002) stated that polymer blend is a mixture of two or more macromolecular species. (Deanin, 1977) in the 70's defined polymer blends as mixture of two or more polymers intimately in single continuous solid phase. The latest, Kumar and Gupta (1998) noted that polymer blends are physical mixture of two or more polymers that are commercially prepared by mechanical mixing which can be achieved through rotor-cam compounder and screw extruder.

In general, polymer blend could be derived into few types of polymer materials mixture through various type of mechanical compounding or solution mixing, for example:

i. Plastic - Plastic mixture
ii. Rubber - Rubber mixture
iii. Plastic - Rubber mixture

In the development of new multiphase polymeric materials, the goal of combining the favorable properties from each of individual material is not an easy task due to low combinatorial of entropy of mixing, immiscible of blend and, etc. This usually will give rise to two-phase system, which is mostly characterized by a coarse and unstable phase morphology and poor interfacial adhesion between the phases. The poor interfacial adhesions could also be affected by differences in material characteristic such as polar-polar and non-polar attraction, vast difference in molecular weight, amorphous or crystallinity of material phase as well as the suitable blend ratio of blend composition will result in different compounded properties. There is number of polymer pairs that were foundcompletely miscible to give homogeneous single phase, with properties proportional to the ratio of the two polymer in the blend,(Gabriel and George,1999) and several of these blends were exhibited commercially importance. For example, PVC/ ENR-50 blends (SenakePerera et al., 2001), blends of poly-phenylene ether with polystyrene (Liu and Baker, 1992); (Paul et al., 1988) were reported. When two polymers are miscible down to segmental level, single homogeneous phase are formed, it will exhibit a single glass transition temperature, Tg from the compound and shows thermodynamically miscible. This usually gives compounder quick economical control over balance of properties for different applications. (Varghese and Alex 2004)

Materials

Natural rubber, zinc oxide, stearic acid, TMQ, polypropylene, MBT, processing oil, was gotten from department Nigerian Institute of Leather and Science Technology, Zaria Kaduna state.

Apparatus

The apparatus used for this work are listed below:

Sieve, Beaker, Pettish dish, Weighing balance, Mould and Scissors

Table 1: Equipment and their Source

S/N	Equipment/Apparatus	Manufacturer	Model Number
1	Two roll mill	Reliable rubber and plastic machinery company	5185
2	Hydraulic hot press	Carver Inc. Hydraulic press	3851.0
3	Hardness tester	Mover durometer	5019
4	Weighing balance	Mettle instrument LTD	AE200

Table 2: Formulation

Ingredient	PPHR					
	1	2	3	4	5	6
Zinc oxide	5.0	5.0	5.0	5.0	5.0	5.0
Stearic acid	2.0	2.0	2.0	2.0	2.0	2.0
MBT	3.0	3.0	3.0	3.0	3.0	3.0
TMQ	1.5	1.5	1.5	1.5	1.5	1.5
NR	00	10	20	30	40	50
PP	00	90	80	70	60	50

Compounding of Natural Rubber

The two roll mill was turned on and the temperature was set to 165^{o}C, after which the nip was tighten before the rubber material was be fed in through the nip of the rollers and was allow to pre-masticate in order to allow the total melting of the polypropylene, the the natural rubber was added and allowed the molecular weight to be broken down and the other compounding additive were added appropriately and cross mixing was done using a knife and the nip of the rolls was adjusted to a desire thickness and the compounded material was sheeted out and kept for some 24hours for stress relaxation.

Pressing of the Compound

The pressing of the compounded material was done on a hydraulic press(model 3851-0).The temperature of the machine was set at 160^{0}C and the mould was pre-heated for 20minute, the compounded material was placed into the mould and was charged into the hot press at pressure of 3.2KN, the mould was left for about 15minute and the material was allow to flow and occupy the shape of the mould cavity then the sample was taken for mechanical test.

Mechanical Properties of the Composite

Hardness Test

This test was carried out in accordance with ASTM D412, 1983

Abrasion Test

The test was carried out manually using sand paper. Firstly each sample measured before the operation goes on by placing on a sample holder and rub for 200 times.

Water Absorption Test

Water absorption test was used to determine the amount of water absorbed under a specified condition. For the water absorption test the initial weight of the samples was taken and the sample were fully immersed in a container with water for 24hours and the final weight was taken to determine the amount of water absorbed by the samples after 24hrs.

Impact Strength Test

The Izod impact testing machine was used. The specimens were placed across the parallel jaw in the machine. Heavy pendulum was then released from a known height to strike the samples on its downward swing which fractured the sample, the energy absorbed was noted and recorded.

Tensile Test

Tensile test was carried out using a sample with a dumb-bell shape of required standard dimensions according to ASTMD 638 were cut and clamped between the upper and lower jaws of the type of tensometer and the machine was loaded. The samples were stretched in the vice until the sample ruptured. The values of the breaking load and elongation were recorded and the procedure was repeated three times for each sample and average values were recorded.

Results and Discussion

Results

Hardness Result

SAMPLE /F CONTENT	1ST TEST (SHORE A)	2ND TEST (SHORE A)	3RD TEST (SHORE A)	AVERAGE
0	39	39	38	38.6
90/10	94	94	90	93.1
80/20	92	93.5	94	92.6
70/30	90	92	90	90.6
60/40	79	90	98	89.0
50/50	76	77	74	75.6

Hint: Average Degree of hardness = $\frac{[A + B + C]}{3}$

Impact Test Result

PP LOADING	**THICKNESS (mm)**	**ABSORBED ENERGY (J)**	**IMPACT STRENGTH (J/mm)**
0	2	0.03	0.015
90	3	1.66	0.055
80	3	0.68	0.227
70	3	0.62	0.207
60	3	0.58	0.193
50	2	0.41	0.205

Impact strength (IR) = $\frac{\text{Absorbed energy}}{\text{Thickness of the sample}}$

Water Absorption Result

PP LOADING	**WD(INITIAL)**	**WW(FINAL)**	**%WA**
0	0.6	0.7	16.7
90/10	3.5	3.7	5.7
80/20	4.0	4.3	7.5
70/30	4.2	4.5	7.1
60/40	4.4	4.8	9.1
50/50	0.6	0.9	50

Hint – Water absorption = %WT = $\frac{WW- WD}{WD}$ X 100

Abrasion Result

SAMPLE	**M1**	**M2**	**% ABRASION**
Control	1.924	1.921	0.16
90/10	1.955	1.950	0.26
80/20	1.958	1.951	0.36
70/30	1.990	1.900	4.52
60/40	2.000	1.984	0.80
50/50	2.007	1.985	1.10

% abrasion = $\frac{(M1 – M2)}{M1}$ * 100

M1 = mass before abrasion
M2 = mass of sample after Abrasion

Fig. 1: Graphical Illustration of Average Degree of Hardness

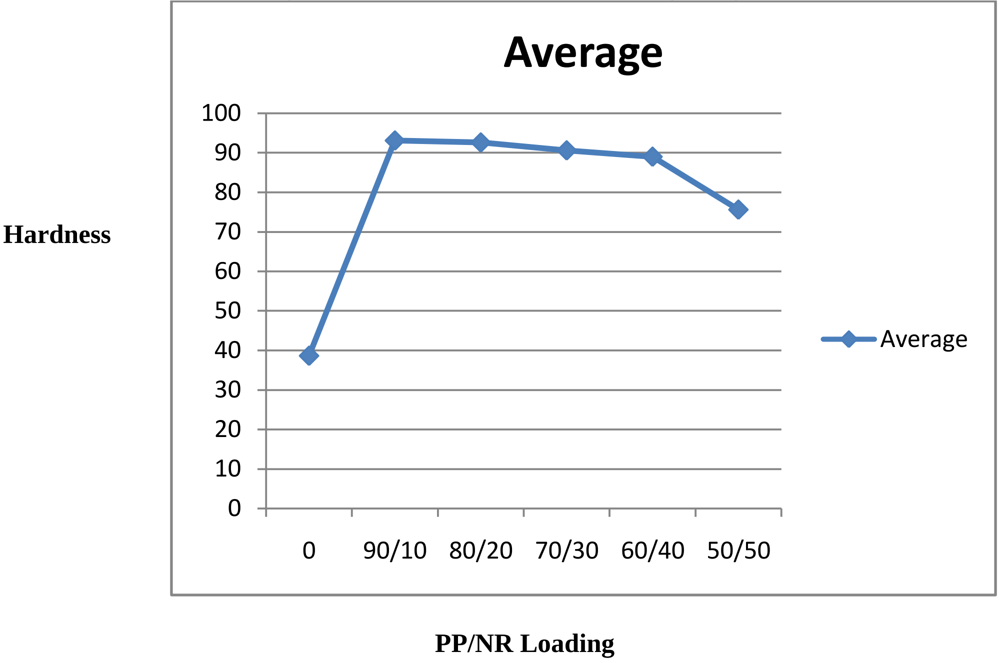


Fig. 2: Graphical Illustration of Impact Strength

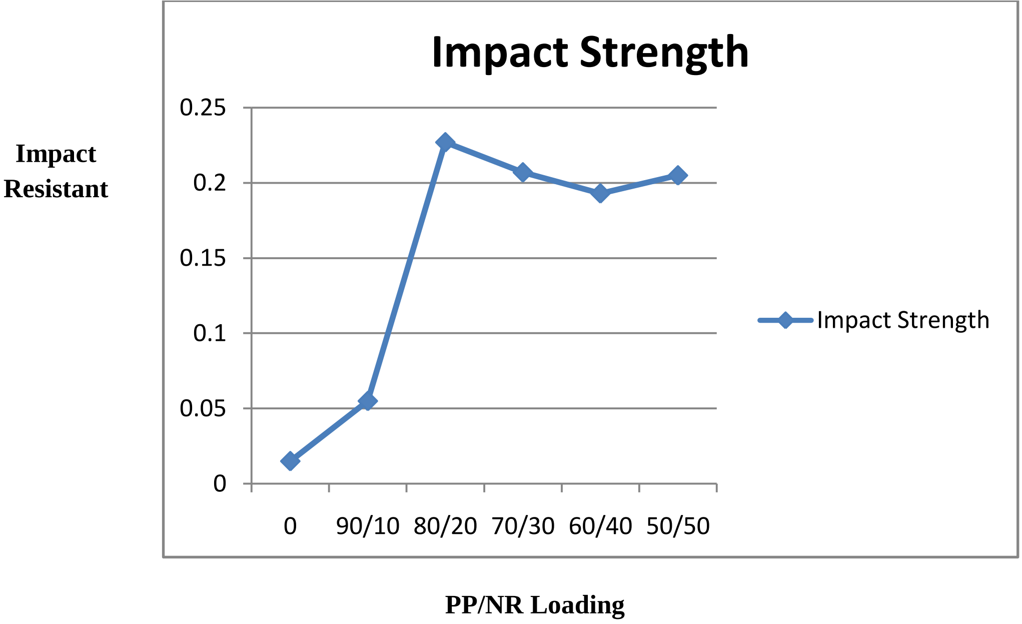


Fig. 3: Graphical Illustraion of Percentage of Water Absorption

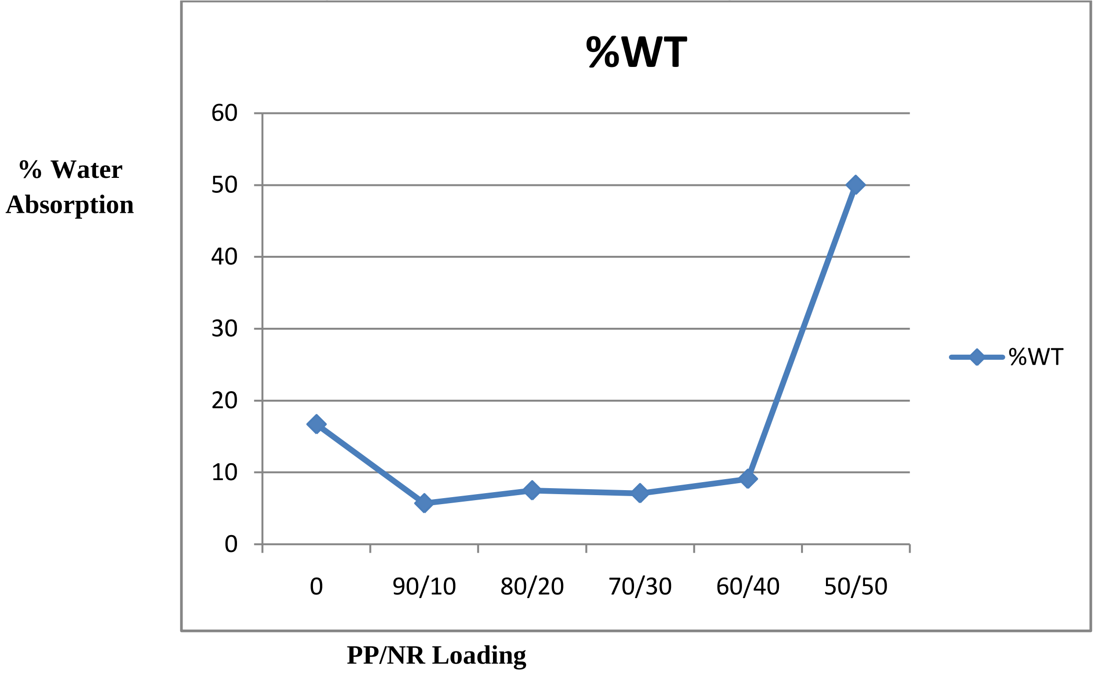
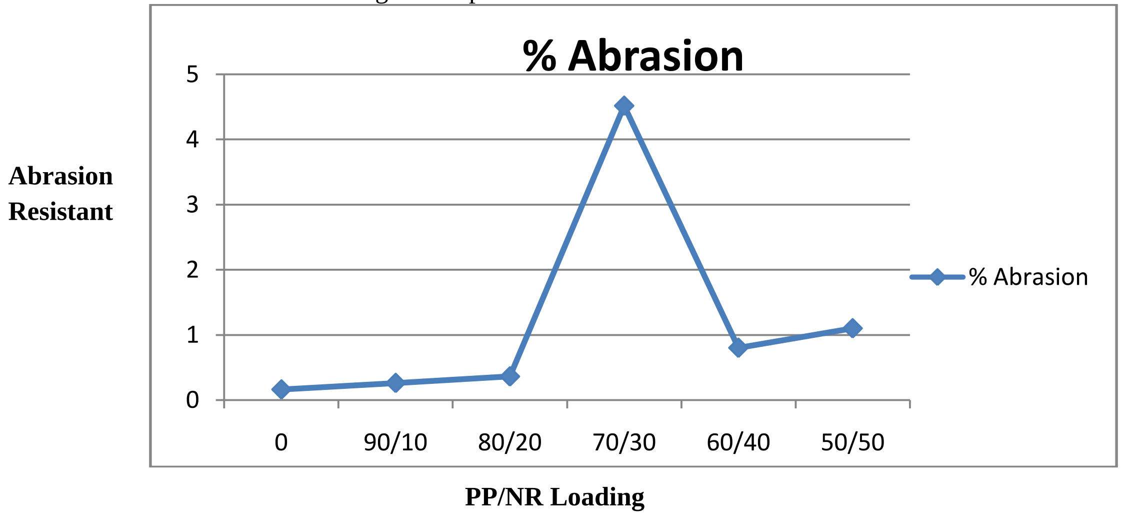


Fig. 4: Graphical Illustration of Abrasion Resistance



Discussion

Hardness as measured in this study is the relative resistance of the surface of the sample to indentation by an indentor of specified dimension under a specified load, it is generally known that the PP increases the hardness of the material. The hardness result as shown as in hardness result indicates that the higher the PP loading the better the hardness as the PP loading range from (0,90-50), except for 50/50g shows that there was an increase in the hardness test due to equal quantity.

Gavan (1969) defines abrasion as the unwanted progressive of substance from the surface of a body brought about by a mechanical action from the rubbing of one surface against another, the abrasion of the PP and the nature of the interface and strength of adhesion between the phases.The result obtained in abrasion indicates resistance of the vulcanized decreases with increased polypropyleneas the PP concentration may be attributed to the strength of adhesion between the polymer and the filler. Some samples increased in the graph e.g70/30, showing the least abrasion resistant and 80/20 based on in appropriate homogenous mixed

The result obtained from water absorption test indicates that the more the PP loading, the lesser water is been absorbed, some did not even absorb water because of the plastic. i.e Plastics mostly don't absorb water because of its property in it, as the amount of polypropylene was reducing the water absorption was continually increasing from 5.7% to 50% respectively.

The result obtained from impact test indicates that the impact strength tends to increase with decreasing PP loading except for the control sample and 90/10g of PP that increases more in strength.

Conclusion and Recommendation

Conclusion

The main aim of this work is to study the mechanical properties of thermoplastic elastomers (polypropylene/Natural rubber) blends and also to compare the result of various test performed on the blends. The result indicates that mechanical properties of the vulcanizates are largely influenced by varying PP loading and the mechanical properties [i.e hardness, abrasion, water absorption, and impact test] showed that during hardness test, increase in pp loading with less Natural rubber will increase the hardness test. Impact test shows that increase in pp with less natural rubber will also increase the impact strength. Water absorption test shows that increase pp loading less water absorbed.

Recommendation

This research works reveals certain properties of the filler (PP) in order to modify and establish these findings; the following recommendations have been put forward for further research.

1. Further work should be done on compression test to reveal some essential properties of the PP.
2. Further work should be done on Tensile strength and elongation at break to also see essential properties of the PP.

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