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# Development of New Automobile Components Based on Thermoplastic Elastomers from Recycled Polyethylene and Natural Rubber

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**Abstract:- Now a days, rubbers and plastics are widely used in wide variety of t applications and this is why the recent decades are sometimes called the "Plastic Age". However, their waste are non-biodegradable and remain long period of time in environment cause hazardous negative impacts. Polymer recycling is the only remedial measure currently available to reduce the environmental impacts. Thermoplastic Elastomers are novel constructional polymers, which are physically cross linked materials made up of a Thermoplastic and Elastomer. In present study, Recyclable Polyethylene was blended with Natural Rubber in different proportions using two roll mill and semi-automatic compression moulding machine at 185°C. The main aim of this study was to investigate the effect of blend ratio on physical, thermal, mechanical, rheological properties of PE/NR blends. The result showed that, when rubber content in the blend increases, the tensile strength and modulus decreases. But they shows excellent elongation, flexural strength and impact resistance, which is widely used in many fields like automotive, construction, electrical appliances etc. The study also proved that the blend with high Natural Rubber content had low Melt Flow Index and Vicat Softening Temperature than the blend with low Natural Rubber. The obtained results recommend that PE/NR blend can be used for environmental remediation from postconsumer PE wastes and to realize new goods with high performance for various applications.**

## I. INTRODUCTION

Plastic industry faces a major challenge in this decade to find an proper way to deal with an enormous quantity of waste plastics, which causes environmental hazard. From the point of environmental issues, plastic recycling is the most efficient way to manage these waste materials. Thermoplastic elastomers are one of the most versatile plastics in today's market.

The emergence of thermoplastic elastomers bridges the gap between thermoplastics and conventional elastomers. Thermoplastic elastomeric materials are a physical mixture of polymers (a plastic and a rubber) and they exhibit both the properties of plastics and rubbers. And also they exhibits high elasticity of thermoset vulcanized rubber at room temperature and good process ability of thermoplastic at high temperature. Due to this special property, TPE is also referred as "third-generation rubber". TPEs are environment friendly and are very easy to recycle.

Thermoplastic elastomer compounds can be obtained by three different structures and morphologies. They are block copolymers, rubber or thermoplastic blends, dynamically vulcanized rubber blends. The processing methods used for thermoplastic elastomers are extrusion, blow moulding and injection moulding techniques. The viscosity of thermoplastic elastomer is significantly lower than the viscosities of traditional rubber elastomers, which offers many processing advantages for thermoplastic elastomers as compared with natural rubbers. The uses of TPE materials are continuously increasing day by day, due to their huge applications in automotive, construction, industrial, consumers, electronics etc.

## II. OBJECTIVES

The main aim of the study is to construct a new cost-effective Thermoplastic Elatomer using Recyclable Polyethylene and Natural rubber for automobile bumper application. In line with the main objective, the study specifically aims to:

- Test and study the mechanical properties (Tensile strength, modulus, elongation and Flexural strength) of the PE/NR blends developed by using two roll mixing mill and semi-automatic compression molding machine.
- Invsetigate Melt Flow Index, Vicat Softening temperature of the obtained themoplastic elastomer from Polyethylene and Natural Rubber blend.
- And also evaluate that, adding of Natural Rubber to PE/NR blend raise the imapct resistance of the resultant sample.

## III. MATERIALS

**POLYETHYLENEBAGS:** Polyethylene is one of the most widely used plastic types and is made from the polymerization of ethylene gas. These are categorized as high density, low density and linear low density. Polythene bags are normally made from thin plastic ( LDPE and LLDPE), used to store or protect food or household articles. The matrix selected in this study was 1.5Kg of recyclable linear low density polyethylene bags.

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**NATURAL RUBBER**: Natural rubber is one of the important polymer for human society. And it is an essential raw material used for the creation of more than 40,000 products. It is obtained from latex, a milky liquid which is present in either the latex vessels (ducts) or in the cells of rubber-producing plants. 1Kg of Natural Rubber RSS grade 4 was used in this study, due to its low cost and ready availability.

Instruments used in this study was Melt Flow Index Tester, VST apparatus, Universal Testing Machine, Izod and Charpy Impact Tester, Semi-Automatic Compression Molding Machine and Two Roll Mixing Mill.

## IV. METHODS

**Preparation of Blends**

Six series of Polyethylene and Natural Rubber (PE/NR) blends were prepared by melt blending of NR with Linear low density polyethylene (LLDPE) bags in a mixing apparatus by varying its composition from 0 to 25 wt% (NR). 200g of Polyethylene and Natural rubber was taken for blending. Six compositions of PE and NR were prepared by changing the concentration of polyethylene bags and Natural Rubber. The implemented compositions of blends are given below in the table.

**TABLE NO: 1 COMPOSITIONS OF PE/NR BLENDS**

| SI.NO | PE:NR RATIO | PE (GRAM) | NR (GRAM) |
|---|---|---|---|
| 1. | 100:0 | 200 | 0 |
| 2. | 95:5 | 190 | 10 |
| 3. | 90:10 | 180 | 20 |
| 4. | 85:15 | 170 | 30 |
| 5. | 80:20 | 160 | 40 |
| 6. | 75:25 | 150 | 50 |

The mixing of Polyethylene and Natural Rubber were done on a two roll mixing mill (open mill). A mill consists of two rolls rotating towards each other. The gap between the mil rolls can be varied between 2 to 20mm.

### i. Mastication operation of Two Roll Mill

Set the roll gap opening into 2mm. And the roll temperature was maintained at 185°C ± 2°C. Add Polyethylene bags into the roll nip .Using a hand knife, make two ¾ cuts from each side of polyethylene sheet and allow them to move through the nip quite a few times until a smooth rolling band is formed on the nip. Now the polyethylene sheet is sufficiently masticated and thus becomes softer.

Fig. 1: Mastication operation of Two Roll Mixing Mill

### ii. Addition of Natural Rubber into masticated polyethylene.

Natural Rubber was cut into small pieces and then added into molten polyethylene. Then make two ¾ cuts from each side. Cut through the rubber at one end of the roll to the other end for in order to ensure he homogeneous end to end blend. Then this homogeneous sample (semi liquid form) were placed on preheated semi-automatic compression molding machine.

Fig. 2: Addition of natural rubber into polyethylene matrix

### iii. Preheating Stage of Semi-automatic Compression Moulding Machine.

Preheating of semi-automatic compression molding machine is useful in molding because, it allows rapid heating of sample, reduces expensive molding time and also helps to remove moisture and other volatiles prior to molding. The mold of semi-automatic compression molding machine was preheated under 185°C.

Fig. 3: Preheating Stage of semi-automatic Compression Molding machine

### iv. Application of Heavy Duty Silicone Spray on Mould

Before sample ( semi liquid form) was placed on mold, heavy duty silicone spray were applied on mold. Silicone spray is also known as mold release spray . It provide defect free and faithful reproductions from complicated moulds.

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Fig. 4: Heavy Duty Silicone Spray

v. **Moulding stage**

The sample blend were placed inside the heated mold cavity and then mold is closed. Predefined pressure were continuously applied on to the molding. And maintain semi - automatic compression molding temperature at 185°C, until the final product was obtained. While compressing occur, the material will start to come out as it comes into contact with the heated mold.

Fig. 5: Different stages of molding.

**vi. Finishing operation of Semi-automatic Compression Moulding Machine**

Finishing operation of machine depends upon the product were comes out after curing. During the compression, polyethylene and natural rubber mix (sample) were came out from the mold as a flash which can be removed after cutting. In my study, square shaped mold was used for obtaining final product.

Fig. 6: Final stage of semi-automatic compression Molding Machine.

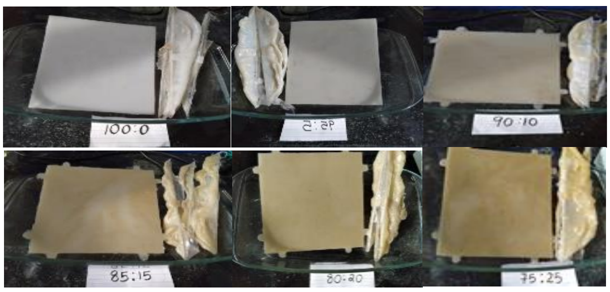


Fig. 7: These are the images of final products obtained from Six different ratios of PE/NR blends.

## V. LABORATORY TESTS

**Tensile test**

The tensile strength of a sample was measured using dumbbell shaped test specimens at a crosshead speed of 50mm/min at 25 ± 2°C using universal testing machine with computer aided testing machine. The ISO 527/ IS 12235 standards and ASTM D 638/ASTM D 790 were used to measure tensile strength and elongation at break, respectively. The average value of the mechanical parameters were calculated by using at least two samples. The testing speed of machine was set as 50mm/minute along with load 50KN and the test was performed at room temperature. The test specimen dimensions are 115mm×25mm×2.8mm as shown in the figure (29).

Fig. 8: Test specimen for Tensile Test

Flexural test

The Flexural properties were determined by three point bending test and were performed in accordance with ASTM D 638/ASTM D 790 using universal testing machine. The span length was set as around 50mm. Testing speed was set as 5mm/min and carried out at room temperature. The specimen dimensions are 65mm×12.7mm×3mm. Flexural strength and Modulus can be measured by using this instrument.

Fig. 9: Test specimen For Flexural Test

**IZOD Impact test**

The Notched impact test was carried out using IZOD AND CHARPY Impact tester. The tests was performed according to ISO 180, method ASTM D 256 using INSTRON (Impact harmer with a mass of 1.3Kg). The striking rate of Impact testing machine was 3.2m/s. A notch of 2.8mm width with an included angle of 45° was generated on the sample. The thickness of the sample was 3mm and length and breadth of the sample was 63.7mm and 12.7mm respectively.

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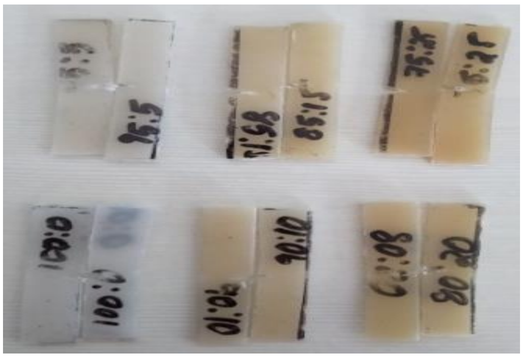

Fig. 10: Test specimen For Izod and Charpy Impact Test

**VICAT Softening Temperature (VST) test**

The VST test was performed by means of a HDT/VICAT equipment. This test was conducted according to IS 12235, method ASTM D 1525 with load 1Kg and temperature 2°C. Specimens with thickness of 6mm and length and breadth of 1mm were used in this test.

Fig.11: Test specimen for VST test

**Melt Flow Index test**

The measurement of the melt flow rate was performed on the MFI tester equipment according to the standard ISO 113, method ASTM D 1238. This test was carried out at 190°C temperature, with a load of 2.16Kg. The specimen should be cut into granules and the preheating time of MFI tester set as 10minute. The die diameter of MFI tester was 2mm and cutting time fixed as 4seconds in this test.

Figure: 33, Test specimen used for MFI

## VI. RESULT AND DISCUSSIONS

### MELT FLOW INDEX

The Melt Flow Index is a measure of the melt flow of a polymer extrudate in g/10min when subjected to a load of 2.16 Kg. As shown in graph (12) given below, the melt flow index value of the neat Polyethylene was 0.975g/10min. However, the adding of Natural Rubber contends to the Polyethylene resulted in lower MFI values. The Melt Flow Index value of the 75:25 ratio of PE/NR blend shows lower value ( 0.6607g/10min) when compared to the MFI values of other ratios of PE/NR Blends.

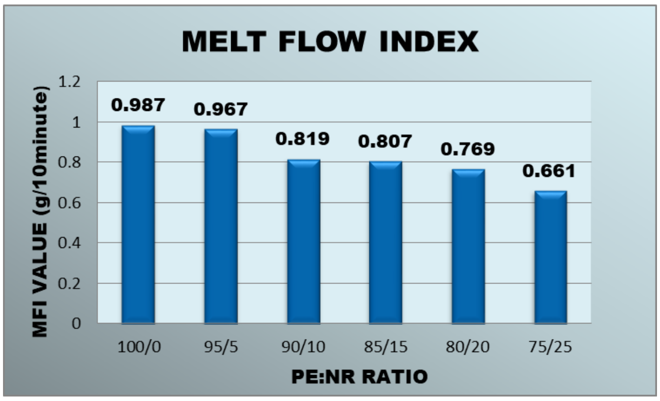


Fig. 12: shows the MFI values of PE/NR blends with varying compositions of NR

Melt Flow Index (MFI) value corresponds to reciprocal of viscosity and molecular weight. So, Low value of MFI imply high molecular weight and high viscosity grade. When we compared Natural Rubber and Polyethylene, Natural Rubber has higher molecular weight. Due to this reason, adding of Natural Rubber to PE/NR blends show lower MFI value than Neat PE (100:0) . When the flow per unit time (MFI) decreases, Viscosity increases (Nevatia et.al, 2001). We know that, viscosity depends mainly on interfacial adhesion between the individual blend components. In case of elastomer introduced into the Recyclable Polyethylene matrix, the interfacial adhesion increases. This is mainly due to the immiscible styrene block from the elastomer part are introduced into the PE matrix and making it difficult to flow resulting in an increase in viscosity (Ecaternia et.al, 2017).

### VICATSOFTENING TEMPERATURE (VST)

The Vicat Softening Temperature (VST) is a temperature in which, a flat-ended needle penetrates the specimen to a depth of 1mm under a specified load of 1Kg. And the temperature represents the point of softening to be expected when a material is used in an elevated temperature application. Figure (13) represent the VST values of PE/NR blend with Natural rubber content of 0, 5, 10, 15, 20, 25 Wt%.

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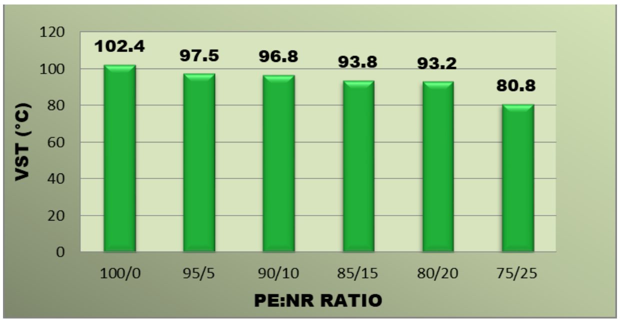

Fig. 13: shows the VST values of PE/NR blends with varying compositions of NR.

The needle penetration values are decreases significantly when Natural rubber is mixed with Recyclable Polyethylene. As compared with the value of neat Polyethylene (PE/NR : 100/0), the values of PE/NR blends show a slow decreasing trend. The decrease in VST values is good in accordance with the increase of Elongation at Break. Similar trend was also observed in (Ecaterina, 2017). This study show a slow decrease in VST values as compared with unmodified PE when compared with VST values of RPE/NR blend.

**TENSILE PROPERTIES**

The Tensile Properties give information about the behavior of the material when it is subjected to stretching or pulling force before it falls. In this study, the mechanical properties such as Tensile strength, Elongation, Young's Modulus of polyethylene and natural rubber (PE/NR) blend were checked. The influence of elastomer on the elongation at break of recyclable polyethylene is shown in figure (14). Elongation measures the deformation that occurs before a material eventually breaks when subjected to a tensile load.

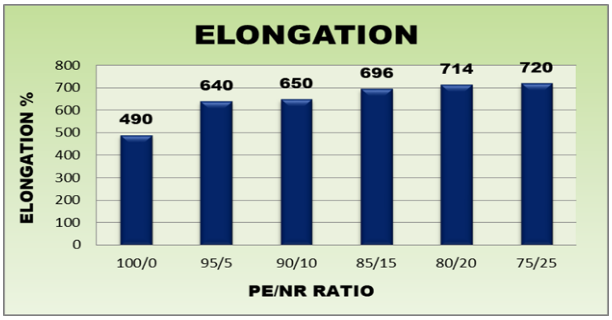

Fig. 14: The parameter of Relative Elongation at Break of PE/NR blend with NR content of 0,5,10,15,20,25 Wt% are depicted in this graph.

From this graph we can understand that, adding of Natural Rubber to Polyethylene contributes an increasing trend in the value of relative elongation at break of PE/NR blend. When 25g of Natural Rubber was added to 75g of Recyclable Polyethylene, the relative elongation at break were increased into 720%, when compared to the relative elongation at break value of neat Polyethylene (490%), due to the elastomer component that favors the mobility and flow of Recyclable Polyethylene. So we can observe that, the increasing trend of elongation at break improves the ductility of the resulting blend (PE/NR blend). (Yupaporn, 2009) reported that, adding of NR to Polypropylene composites, show a drastic increase in the value of elongation at break. This was observed in the PP composites with rubber content more than 20% by weight.

As the content of Natural Rubber increased, the tensile strength and young's modulus of the PE/NR composites decreased than these value for neat Polyethylene (100:0) are depicted in figure (15 and 16). The Tensile strength is the measure of load that can be handled by a material before it stretches and breaks. And Young's Modulus measure the stiffness (the ratio between stress and strain) of a material at the elastic stage of the tensile test (Sergey and Maciej, 2019). When the tensile strength and Young's modulus decreases, the elongation at break increases and vice versa.

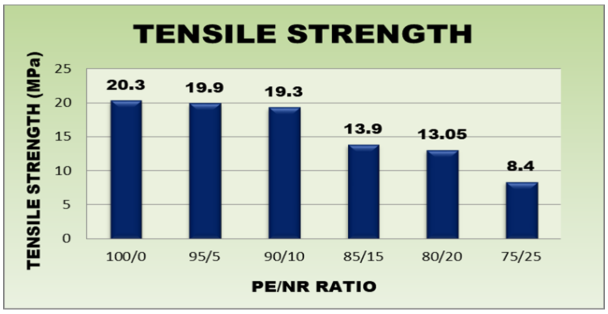

Fig. 15: The Tensile strength of PE/NR blend with NR content of 0,5,10,15,20,25 Wt% are depicted in this graph.

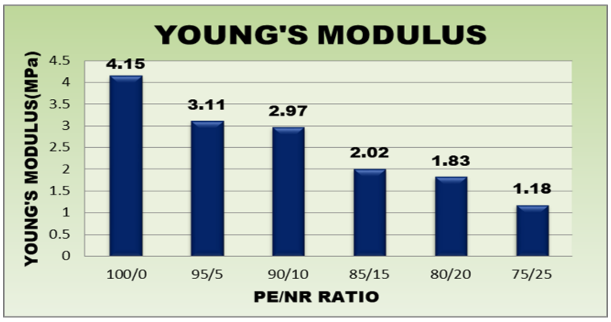

Fig. 16: The Young's modulus of PE/NR blend with NR content of 0,5,10,15,20,25 Wt% are depicted in this graph.

In this study it was observed that, adding of Natural Rubber show a drastic reduction in tensile strength form 4.15 (PE/NR: 100/0) to 1.18 (PE/NR: 75/25). This may due to the phase change of Natural Rubber from dispersed to continuous phase. In a lower loading of Natural Rubber, Polyethylene phase may be continuous ( Pal and Bahadur, 2017) . when the rubber content of the blend increases, then the blend shows continuous rubber phase, whereas low content of rubber shows a dispersed rubber phase. (Jami et.al, 2006) revealed that the reduction of modulus causes an increase in the flexibility or elasticity of soft matric. Typically, in case of polymer and rubber blend, the mechanical properties like tensile strength, modulus and elongation depend upon the relative proportions of the two constituents as well as the composition of rubber. A higher proportion of rubber results in blend with high elongation (ductility) but reduces the tensile strength and vice versa. The similar result was obtained for Ramin and Denis, 2019. Their result revealed that increased rubber content, decreased the mechanical strength and stiffness but increased the elasticity and ductility. However, several studies reported that the addition of a rubber phase into a thermoplastic matrix results in lower overall mechanical properties (strength and modulus).

**IMAPACT STRENGTH**

Impact strength is the ability of a material to absorb the applied energy or it may also defined as the ability to resist the fracture under stress applied at high speed. As shown in graph (17), the IZOD Impact Strength increased for all compounds (PE/NR Blends) compared to that for neat Recyclable Polyethylene (13.917 KJ/$m^2$) with a spectacular increase in the case of PE/NR (75:25 ratio) (27.781KJ/$m^2$).


Fig. 17: The Impact strength of PE/NR blend with NR content of 0,5,10,15,20,25 Wt% are depicted in this graph.

This increase is mainly due to the elastomeric phase that absorbs and transfers the force at impact from the continuous phase of Recyclable Polyethylene matrix. In addition, the flexible interface helps to prevent the development of cracks between rubber and polyethylene. Consequently, the impact resistance of PE/NR blends is significantly improved, in good accordance with the increase of Natural Rubber content. (Buys et.al, 2018) reported that the addition of NR to PE/NR blends improved the impact the strength of the blends. Similarly (Yupaporn, 2009) revealed that Adding NR to PE composites shows a significant increase in the impact strength was observed in the PE composite with rubber content more than 20% by weight.

**FLEXURAL STRENGTH**

Figure(18) presents the flexural strength values of all the PE/NR blends. Flexural strength is the ability of a material to withstand bending forces applied perpendicular to its longitudinal axis and it is equal to the maximum stress in the outer fibers at the moment of break.

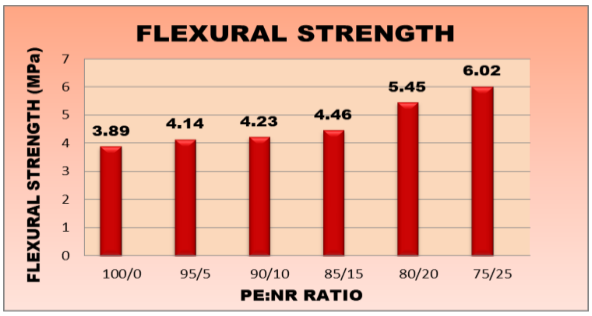


Fig. 18:The Flexural strength of PE/NR blend with NR content of 0,5,10,15,20,25 Wt% are depicted in this graph.

It has been observed from this graph, there are increases in values of flexural properties with increasing percentage ratios of Natural Rubber in PE/NR blends. The ratio 75:25 of PE/NR blend shows two times higher value (6.02MPa) of flexural strength compared to recyclable neat Polyethylene ratio 100:0 (3.89MPa). The values of graph shows an inverse trend to that for the tensile modulus as shown in figure (18). An increase in flexural strength is observed in PE/NR blends. This is mainly due to rubber particles in blends are found to increase their energy absorption under the flexural loading conditions (Rahul and Dwayne, 2006). Similar result was obtained in (Sukanya et.al, 2010), in this study Polyethylene waste were collected from municipality solid waste was melt blended with Reclaimed Rubber (RR) in different proportions resulted in an increment in flexural strength value in presence of RR.

## VII. CONCLUSION

The use of Thermoplastic elastomeric materials (TPE) is continuously increasing, because of their huge applications in daily life. Encapsulation and over molding are most widely used applications of TPE materials. About 85% of plastic products in the modern world are made up of TPE materials. They provide competitive price performance as compared to other natural rubber products. All Thermoplastic elastomers are mainly depend on two major components, a hard thermoplastic and a soft elastomers. They also showing the advantages of both hard and soft phase ( plastic and rubber respectively). The selection of a TPE material for any particular application mainly focus on its physical, chemical, mechanical and electrical properties.

The goal of this thesis was to develop Thermoplastic Elastomer from recycled Polyethylene and Natural Rubber using Two Roll Mill and Semi-automatic Compression Molding Machine for automobile bumper application. And also study their mechanical , rheological and thermal properties.

According to the results obtained, several conclusions can be made.

The study proved that the PE/NR blend with high Natural rubber content had low Melt Flow Index and Vicat Softening Temperature than the blend with low Natural rubber. This may due to the high molecular weight of NR. Low MFI value imply high molecular weight and high viscosity grade. And lower VST values are good in accordance with the increase of Elongation at Break.

The result showed that increasing the rubber content in the PE/NR blend decreased the tensile strength and modulus but they shows excellent elongation at break. Typically, higher proportion of rubber gives a blend with high elongation (ductility) but reduces the tensile strength and modulus. So, the inclusion of NR into PE induces a decrease of the stiffness and strength and improves the ductility of resulting blend.

From the aspect of the improved Flexural and impact properties, The Thermoplastic Elastomer produced from PE/NR blend act as a potential candidate in the future application. Due to the excellent elongation, flexural strength and impact resistance, which can be widely used in many fields like automotive, construction, electrical appliances etc.

Normally Thermoplastic Elastomeric materials are environment friendly and very easy to recycle. In addition to that, this study reported a lower overall mechanical properties (strength and modulus) and low thermal resistance of a TPE. But the advantages offered by them like industrial applications such as oil and gas industry, rubber gaskets for window, door and gas seals in automotive industry etc. overcome the disadvantages, that's why their use is increasing day by day. So, the obtained results recommended that TPE developed from PE/NR blend can be used for both environmental remediation from postconsumer PE wastes and to realize new goods with high performance for various applications.

## VIII. SUGGESTIONS FOR FUTURE WORKS

It is expected that in the near future, academic and industrial research will mainly focus on the development of green and cost-effective TPE compounds based on recycled polymers. And their production from recycled materials reduces the negative effects of the waste which is generated from their disposal . It also leads to the production of new materials with lower costs. The thermoplastic elastomer market should be expected to grow drastically in the near future due to increased demand for green and low-cost compounds obtained from waste polymers.

Studies on PE/NR blend of recyclable Polyethylene and Natural Rubber was carried out in this work. Based on the experimental results in chapter 4,Thermoplastic elastomer prepared from PE/NR blends reducing the strength, stiffness and increasing the elongation at break, flexural strength, impact resistance by adding Natural rubber. Several studies reported that, vulcanized rubber and compatibilizer is used in PE/NR blend for enhance the tensile strength and stiffness of this blends. So it is suggested that, instead of Natural Rubber, the investigation on vulcanized Rubber on recycled Polyethylene using appropriate compatibilizer should be pay attention to. Agglomeration occurs with the process of forming Thermoplastic Elastomers. So, appropriate agglomeration agents should be studied and applied to the blends to improve the mechanical properties.

Thermoplastic elastomers is considered as the most promising fields of study. Several research works have been conducted on the morphological and mechanical properties of thermoplastic elastomer compounds. However, the lack of knowledge about the thermal, dynamic, mechanical, and aging behavior of these compounds highlights the need for more research on TPE preparation and their characterization.

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