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Comparative analysis of composites made from Polyester-LDPE wastes and mix of Polyester-Wool with LDPE wastes

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ABSTRACT: During the manufacturing process of textile fibres into yarns, fabrics and apparel products, process wastes are generated in each of the production stages. Although the amount of generated wastes varies from natural fibres to synthetic fibres, the wastes generated from synthetic fibres are more dangerous to human health and the environment at large. So, in this research it has been tried to produce composite products from polyester and polyester-wool mix textile reinforcements with LDPE matrix wastes. The fabrication is made with compression moulding machine at a melting temperature of 160^0c, a pressure of 1.5MPa for 5 minutes. So, based on the testing and characterizations made, composites made from 100% polyester-LDPE wastes exhibit higher results in impact resistance and compression strength tests. However, composites made from 63% polyester, 35% wool & 2% elastomer-LDPE wastes shows higher results in tensile and flexural strength tests.

Keywords: *Polyester, wool, LDPE, wastes, composite, mechanical tests*

1. Introduction

Because of the different nature and characteristics of the manufacturing process of textile products, the waste generations are also varied. Although natural fibre processing leads to the generation of higher amount of wastes, the wastes generated from synthetic fibre processing do have greater impacts on human health and soil fertility [1]. Among the synthetic fibres which are used for the manufacturing of different grade textile yarns, fabrics and apparel products, polyester is the most primarily used and so is the generated wastes from this synthetic fibre [2]. Wool is one of the protein fibres which is collected from hairs of different animals like; sheep, rabbits, goat, etc. Keratin is a protein polymer wool is comprised from. As the fibre has good insulating and wicking property, it is widely used for making of sweaters and suiting products. Companies processing wool fibre do generate wastes during raw wool production, Scouring stage and during yarn and fabric productions. Here, both soft and hard wastes can be generated plastics are categorized as thermoset and thermoplastics.

Once the waste is generated, the later one is most suitable for recycling and make use of it to be applicable for different advanced products. This is due to the fact that thermoplastics can be melted, re-heated and shaped to different molds [3] & [4]. These plastic products are widely chosen worldwide since they are having vast applications of home and industrial product ranges [5]. Among these thermoplastics, there is low density polyethylene (LDPE), which is a translucent material having different application areas of; drinking package and container, laundry bags, trays, etc [3] & [4]. Thus, to minimize the damages occurring from the stated textile and plastic wastes, proper waste management techniques of re-using and recycling has to be followed and implemented [6] & [7]. Neway in his works has tried to fabricate composite panel boarding products from jute-LDPE wastes and flax-LDPE wastes. The researcher has found that composites made from flax-LDPE wastes shows a comparatively better mechanical performance properties of; impact resistance, tensile, flexural and compression strength. The composite products have also been compared with commercially available fencing and boarding products [8] & [9]. So, in this research work, it is planned to fabricate composite panel products by using polyester and polyester wool textile wastes as reinforcement and LDPE plastic waste as resin matrix and perform mechanical characterizations for doing comparative analysis.

2. Methodology

For conducting the research work the following materials, machines and equipment have been used:-

2.1 Materials:-

Polyester wastes,

Polyester-wool mix wastes,

LDPE wastes,

2.2 Machines:-

Compression moulding machine,

2.3 Equipment:-

Tensile, compression, flexural and impact strength testing equipment

Table 1: Sources where the inputs are collected from

S/no.	Types of textile wastes	Sources where the wastes are collected from	Types of plastic wastes	Sources where the wastes are collected from
1	100% polyester selvedge and fabric wastes	Al-Asr textile plc	LDPE	Yared, Dawit & Ermias plastic recycling share company
2	63% polyester, 35% wool & 2% elastomer sliver, yarn and fabric wastes	Sunshine Ethiopia wool textile plc		

As it shown in table 1, all the input wastes have been collected from domestic companies working on the specified inputs. All types of wastes are collected free of any charges and Al-Asr textile plc uses 100% polyester yarn as an input and with the use of its weaving machines, the company produces different types of suiting and pant fabrics. In doing so, process wastes like selvedge wastes which occurs from false selvedge ends and fringe length and fabric wastes cut from quality defected fabrics are generated. While, Sunshine Ethiopia wool textile plc, uses blends of 63% polyester, 35% wool & 2% elastomer yarn as inputs for producing suiting pant and jacket apparel products. While processing the stated input yarns; sliver wastes are generated from carding and draw-frame operations, yarn remnants will occur from loaded weavers' beams on looms and fabric wastes during cutting, pattern/marker making and sewing operations will be generated. The companies sell all the above stated wastes with scrap values ranging from 30-50 birr/kg. Besides, Yared, Dawit & Ermias plastic recycling share company collects different types of post-consumer plastic wastes and implements re-heating and re-shaping techniques to mold them to different plastic products.

Fig. 1 shows the collected polyester and polyester-wool wastes which will be used as reinforcement material and LDPE waste used as matrix material.

After collecting the waste materials, segregation and categorization is made based on the fibre types and their properties. For the LDPE waste also, cleaning is made with the use of detergent and exposed to sun-light for quick drying.

Figure 1 Collected polyester, polyester-wool and LDPE wastes

2.4 Composite fabrication

For composite fabrication, different researchers use the commonly applicable fibre to matrix volume fractions of; 70:30, 60:40 and 50:50. Using of the first two stated volume fractions do have negative effects on void formation, the strength and performance of composite products, etc. But using 50:50 fibre volume fraction makes the fibre and matrix material to equally contribute on the proper adhesion and bonding of the reinforcement with the resin and reduces the formation of voids. Hence, it makes the produced composite product to have a better mechanical properties. For such reason, 50:50 fibre volume fraction is chosen as the pre-set volume fraction and for producing 1kg of the product, the weight fractions of the fibre and matrix material has been determined by considering their densities, which is described in table 2:-

Table 2 Densities of the fibres and LDPE matrix

S/no	**Type of textile material**	**Fibre density (g/cm^3)**	**Type of plastic material**	**Matrix density (g/cm^3)**
1	Polyester	1.38	LDPE	0.91
2	Wool	1.307		

$W_{fibre} = [1+1/\{(V_f/1-V_f)*(den_{fib}/den_{resin})\}]^{-1}$ ……..Equation 1

Where, W_{fibre} is weight fraction of the fibre,

V_{f} is fibre volume fraction,

den_{fib} is fibre density and

den_{resin} is matrix density

So, the weight fractions have been calculated as:-

$W_{fibre} = 0.6$ & $W_{matrix/plastic} = 0.4$,

So, to produce 1 kg sample composite product; 0.6 * 1kg = 0.6 kg of polyester & polyester-wool fibre & 0.4 kg of LDPE matrix is required.

For fabrication of sample composite products, compression moulding machine which is found in a Research & Development department of African-bamboo plc is used. The products have been fabricated with a melting temperature of 160^0c, a pressure of 1.5MPa for 5 minutes.

2.5 Characterizations of the composite products

The composite products have been tested and characterized for tensile, impact, flexural and compression strength tests.

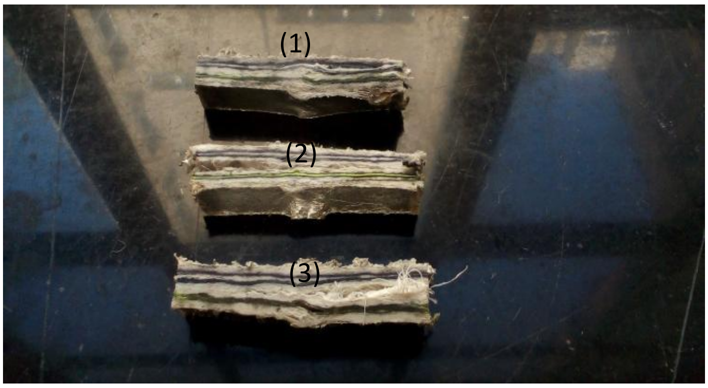
Figures from 2-5 shows tested specimens for impact resistance, flexural, compression and tensile strength tests.

2.5.1 Izod impact resistance test:

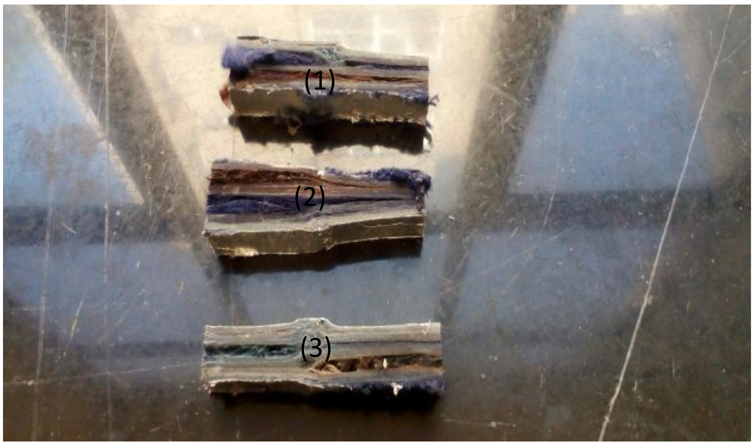
Test method:ASTM D256

This test measures the strength of the composite product to absorb energy while a sudden impact energy is applied on. while the impact is applied, the composite is supposed to be tough to resist fracture.

For testing, pendulum impact testing machine is used equipped with star impact testing machine software version 2.0, with specimen thickness of 14mm; width of 12.6mm and length of 64mm. Fig. 2 (a1, a2 & a3) shows composites made with 100% polyester-LDPE, from the fig. it is seen that specimens 2a1 & 2a2 shows the highest impact energy absorption than fig. 2 (b1, b2 & b3) of polyester-wool mix-LDPE composite, which are fully fractured and exhibits a lower impact resistance energy value.



(a) Composite specimens of Polyester-LDPE for impact test



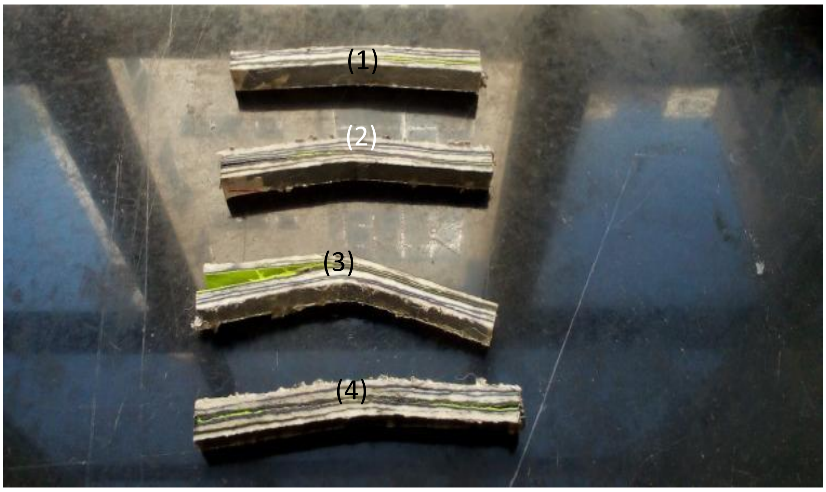
(b) Composite specimens of polyester and wool-LDPE for impact test

Figure 2 Composite specimens after impact resistance test

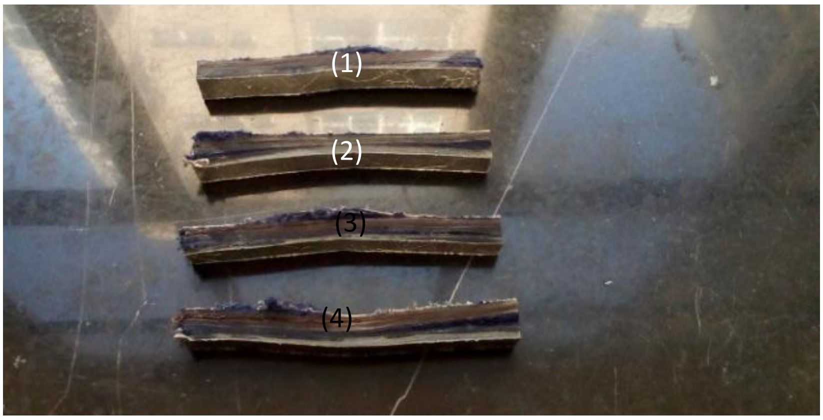
2.5.2 Flexural strength test:

Test method: ASTM D 790-03

It is a bending strength or modulus of rupture, showing the composite products' ability to withstand deformation under bending stress. A universal testing machine having Origin pro version 8.5 software has been used. With a load rate of 5mm/min and specimen thickness of 14mm, width of 12.7mm, length of 127mm and gauge length of 85mm specimen has been tested. Fig. 3 (b1, b2, b3 & b4) are composites made with polyester-wool mix LDPE. Here, specimens 3b1, 3b2 & 3b3 shows a much lesser bending and higher flexural strength performance than fig. 3 (a1, a2 & a3) of 100% polyester-LDPE composite products. However, specimens 3a4 & 3b4 exhibits comparable bending performances.



(a) Composite specimens of Polyester-LDPE for flexural test



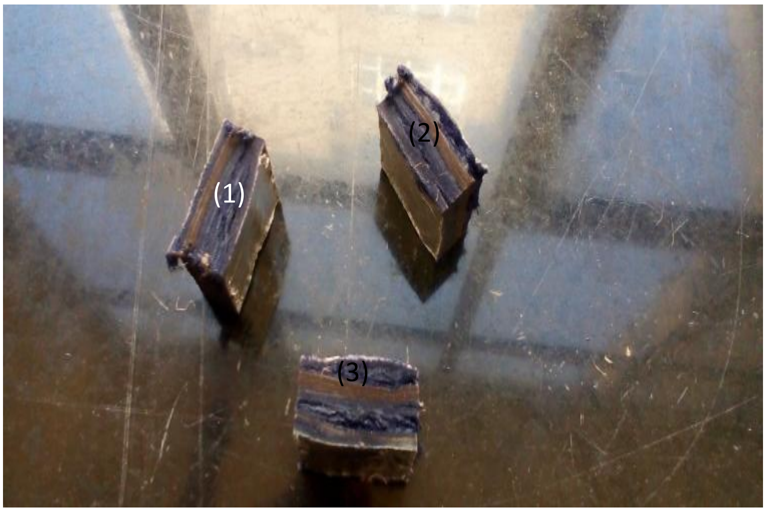
(b) Composite specimens of polyester and wool-LDPE for flexural test

Figure 3 Composite specimens after flexural strength test

2.5.3 Compression strength test:

Test method: ASTM D 3410

This tests shows the composite products' capacity to resist the maximum compressive loads that reduces the sizes of specimens before failure is occurring. A universal testing machine having Origin pro version 8.5 software and with a load rate of 2mm/min is used. Specimen thickness of 14mm, width and length of 25mm has been tested for this characterization. As there is little fracture and size reduction in Fig. 4 (b1, b2, b3 & b4), which is composite specimen made from 100% polyester-LDPE, it withstands a maximum compression load than fig. 4 (a1, a2 & a3) of composites made from mix of polyester-wool with LDPE matrix, which are more fractured and reduced in size.



(a) Composite specimens of Polyester and wool-LDPE for compression test

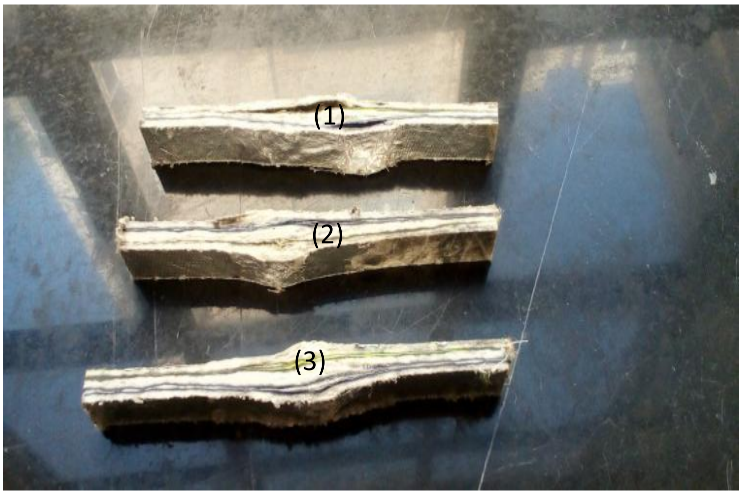
(b) Composite specimens of polyester-LDPE for compression test

Figure 4 Composite specimens after compression strength test

2.5.4 Tensile strength test:

Test method: ASTM D 638-10

It is the maximum amount of stress that a composite product can resist breaks when it is being pulled by a tensile load. A universal tensile testing machine having Origin pro version 8.5 software with a load rate of 2mm/min has been used. The specimen has thickness of 14mm, width of 19mm, length of 165mm and gauge length of 105mm. Fig. 5 (a1, a2 & a3), i.e. composite made from 100% polyester-LDPE shows a lesser amount of breaking stress that it can not withstand the applied tensile load and gets de-laminated at the middle than fig. 5 (b1, b2, b3 & b4) of composite made from mix of polyester & wool with LDPE matrix.



(a) Composite specimens of Polyester-LDPE for tensile test

Composite specimens of Polyester and wool-LDPE for tensile test

Figure 5 Composite specimens after tensile strength test

3. Results and Discussion

For each mechanical characterizations, numbers of specimens have been tested and the mean values has also been calculated.

so, after the tests conducted, the following results have been achieved:-

Tables from 3-6 shows the test results for the 100% polyester-LDPE & polyester-wool mix-LDPE composite products. In the tables, the specimen dimensions have been specified which is prepared according to the stated test methods.

Table 3 analyzes results for impact resistance tests. 3 specimens for 63% polyester, 35% wool & 2% elastomer-LDPE composites and 4 specimens for 100% polyester-LDPE composites have been tested and the mean values for toughness and impact resistance energy of the polyester composite is calculated to be 0.32 and 38.7J respectively, which is higher than the mix composite with values of 0.28 and 33.8J respectively. This is due to the fact that impact resistance load is matrix-dominated property. So, in this mechanical test, the strength of the reinforcement fibres is highly influenced by the adhesion and bonding of the reinforcement with the resin matrix. Composites made from 100% polyester-LDPE shows a better bonding than the mix composites and this is because polyester fibre has better compatibility to bond with LDPE than wool fibre with LDPE. Hence, mixing polyester fibre and wool reduces the adhesion with LDPE and therefore its toughness and impact resistance energy gets lowered.

Table 3 Results for impact resistance test

S.no	Type of composite material	Specimen thickness (mm)	Specimen width (mm)	Cross-sectional area (mm^2)	Toughness	Impact resistance energy (J)
1	63% polyester, 35% wool & 2% elastomer-LDPE	14	12.6	176.4	0.31	37.822
2	63% polyester, 35% wool & 2% elastomer-LDPE	14	12.6	176.4	0.22	26.458
3	63% polyester, 35% wool & 2% elastomer-LDPE	14	12.6	176.4	0.31	37.271
Mean value					**0.28**	**33.850**
Std. deviation					**0.05**	**6.408**
1	100% polyester-LDPE	14	12.6	176.4	0.31	37.363
2	100% polyester-LDPE	14	12.6	176.4	0.33	40.598
3	100% polyester-LDPE	14	12.6	176.4	0.37	44.797
4	100% polyester-LDPE	14	12.6	176.4	0.26	32.065
Mean value					**0.32**	**38.706**
Std. deviation					**0.05**	**5.372**

In table 4 results for tensile strength tests have been analyzed. Here, 4 specimens have been tested for both types of composite products and the mean values have also been calculated. As tensile strength property is fibre-dominated, composites made with 63% polyester, 35% wool & 2% elastomer-LDPE shows a higher mean breaking load and tensile strength values of 3483.25 N and 13MPa respectively than 2932.75 N and 11MPa of the 100% polyester-LDPE composite. This is because, in the mix composite both the polyester and wool fibres contribute their strength share in resisting the applied pulling load. Hence, a lower strain is achieved.

Table 4 Results for tensile strength test

S.no	Type of composite material	Breaking load (N)	Specimen thickness (mm)	Specimen width (mm)	Cross sectional area (mm^2)	Tensile strength (MPa)	Strain (%)
1	63% polyester, 35% wool & 2% elastomer-LDPE	3219	14	19	266	12	18.8
2	63% polyester, 35% wool & 2% elastomer-LDPE	3587	14	19	266	13	16
3	63% polyester, 35% wool & 2% elastomer-LDPE	3644	14	19	266	14	16.5
4	63% polyester, 35% wool & 2% elastomer-LDPE	3483	14	19	266	13	22
Mean val.		**3,483.25**	**14**	**19**	**266**	**13**	**18.325**
1	100% polyester-LDPE	2446	14	19	266	9	17.6
2	100% polyester-LDPE	3053	14	19	266	11	21.9
3	100% polyester-LDPE	3370	14	19	266	13	33.4
4	100% polyester-LDPE	2862	14	19	266	11	19.2
Mean val.		**2,932.75**	**14**	**19**	**266**	**11**	**23.025**

In table 5 results for flexural strength tests have been computed and the mean strength values are also calculated. 4 specimens have been tested for both composite products. Flexural strength is also a fibre-dominated property. Since both polyester and wool fibres impose their strength in withstanding the applied bending load, composites made with 63% polyester, 35% wool & 2% elastomer-LDPE shows a mean ultimate flexural load and flexural strength values of 99N and 5.055MPa respectively. This is higher than the 100% polyester-LDPE composite with values of 90N and 4.6MPa.

Table 5 Results for flexural strength test

S.no	Type of composite material	Ultimate flexural load, F (N)	Specimen thickness, d (mm)	Specimen width , b (mm)	Support span length, L (mm)	Flexural strength, $3FL/2bd^2$ (MPa)	Strain %
1	63% polyester, 35% wool & 2% elastomer-LDPE	65	14	12.7	85	3.3	36.6
2	63% polyester, 35% wool & 2% elastomer-LDPE	152	14	12.7	85	7.8	17.3
3	63% polyester, 35% wool & 2% elastomer-LDPE	79	14	12.7	85	4	32.8
4	63% polyester, 35% wool & 2% elastomer-LDPE	100	14	12.7	85	5.12	13.45
Mean val.		**99**	**14**	**12.7**	**85**	**5.055**	**25**
1	100% polyester-LDPE	84	14	12.7	85	4.3	27.9
2	100% polyester-LDPE	97	14	12.7	85	4.96	22
3	100% polyester-LDPE	81	14	12.7	85	4.14	11.2

S.no	Type of composite material	Ultimate flexural load, F (N)	Specimen thickness, d (mm)	Specimen width , b (mm)	Support span length, L (mm)	Flexural strength, $3FL/2bd^2$ (MPa)	Strain %
4	100% polyester-LDPE	98	14	12.7	85	5	30.7
Mean val.		**90**	**14**	**12.7**	**85**	**4.6**	**22.95**

In table 6 results for compression strength tests is shown. For this characterization, 3 specimens have been tested for 63% polyester, 35% wool & 2% elastomer-LDPE and 4 specimens for 100% polyester-LDPE composite products. Compression strength is a matrix-dominated property and because of the better adhesion & bonding between the 100% polyester and the LDPE matrix, their composite output shows a higher mean ultimate compressive load and compression strength values of 1590N and 6.36MPa, while the mix composite is only having 1316.7N and 5.3MPa.

Table 6 Results for compression strength test

S.no	Type of composite material	Ultimate compressive load (N)	Depth max. Compressive load is applied on (mm)	Specimen width (mm)	Cross sectional area (mm^2)	Compression strength (MPa)	Strain (%)
1	63% polyester, 35% wool & 2% elastomer -LDPE	1440	10	25	250	5.76	1.6
2	63% polyester, 35% wool & 2% elastomer -LDPE	1670	10	25	250	6.68	1.9
3	63% polyester, 35% wool & 2% elastomer -LDPE	840	10	25	250	3.36	1.17
Mean val.		**1316.7**	**10**	**25**	**250**	**5.3**	**1.55**

S.no	Type of composite material	Ultimate compressive load (N)	Depth max. Compressive load is applied on (mm)	Specimen width (mm)	Cross sectional area (mm^2)	Compression strength (MPa)	Strain (%)
1	100% polyester -LDPE	2140	10	25	250	8.56	1
2	100% polyester -LDPE	1600	10	25	250	6.4	1.3
3	100% polyester -LDPE	1640	10	25	250	6.56	3.7
4	100% polyester -LDPE	980	10	25	250	3.92	1.8
Mean val.		**1590**	**10**	**25**	**250**	**6.36**	**1.95**

Table 7 Summarized test results

S.no	Type of product	Mechanical properties			
		Impact resistance energy (J)	Tensile strength (MPa)	Flexural strength (MPa)	Compression strength (MPa)
1	63% polyester, 35% wool & 2% elastomer-LDPE	33.850	13	5.055	5.3
2	100% polyester-LDPE	38.706	11	4.6	6.36

So, as it has been shown in table 7, composite products made with 100% polyester-LDPE exhibits a higher impact resistance energy value of 38.7J and it also shows a higher compression strength value of 6.36MPa. But when we come to tensile and flexural strength performances, composite products made with 63% polyester, 35% wool & 2% elastomer-LDPE exhibits higher values of 13 and 5MPa respectively. Here, the big difference is occurred in impact resistance energy performance. However, the differences in other properties are small.

4. Conclusions

In this research work, composite products have been fabricated from 100% polyester-LDPE and polyester-wool mix - LDPE wastes. The composite products have been produced with the use of compression moulding machine at a melting temperature of

1600c, a pressure of 1.5MPa for 5 minutes. The products have been tested and characterized for impact resistance, tensile, flexural and compression strength characteristics. The composite products made from 100% polyester-LDPE & 63% polyester, 35% wool & 2% elastomer-LDPE wastes show an impact resistance energy value of 38.7J and 33.85J respectively, a tensile strength values of 11MPa & 13MPa respectively, a flexural strength values of 4.6MPa & 5.055MPa respectively and a compression strength values of 6.36MPa & 5.3MPa respectively. As tensile and flexural strength properties are fibre-dominant, composites made from 63% polyester, 35% wool & 2% elastomer-LDPE wastes perform better and since impact resistance and compression strength tests have matrix-dominant properties, composites made from 100% polyester-LDPE wastes exhibits higher values and this is due to the better adhesion and bonding between the polyester reinforcement and the LDPE matrix.

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