Tensile Behaviour of Hybrid Polymer Composites – An Experimental Study

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Abstract

In recent years, developments of hybrid polymer composites by adding the natural and synthetic resources as reinforcement materials are significantly increased to enhance the required properties of the composites. In this research work, effects of Nano alumina particles and water hyacinth particles addition into the HDPE polymer matrix for its tensile properties were studied through experimentation. Fine Nano alumina particles are used as filler and the well water hyacinth particles are used as reinforcement materials. Hybrid composite specimens were prepared by varying the weight percentage of filler and reinforcement materials and keeping the HDPE’s weight percentage as constant. Hybrid composite boards were fabricated by using hydraulic type injection moulding machine. Hybrid polymer composite specimens for tension test is cut away from the hybrid composite boards as per the ASTM standards with the help of water jet machining process. Experimental results reveal that the limited addition of fine Nano alumina and water hyacinth particles into the HDPE polymer matrix improves the tensile properties of the hybrid composites significantly when compare to the pure HDPE polymer composite.

1 Introduction

In recent years the usage of polymer materials for both domestic and industrial purpose are drastically increased due its superior properties than other materials. In order to fulfil the huge demand and immediate requirements for the lightweight materials to the society, different polymeric materials were introduced day-by-day by adding the different reinforcement materials with them. High Density
Polyethylene (HDPE) is one of the most promising lightweight polymeric material due to its higher bonding behaviour with natural and synthetic reinforcement materials. Different researchers are attempted to enhance the mechanical properties of the High Density Polyethylene (HDPE) by adding the different kind of reinforcement materials with it. Loading rate of mechanical strain and the amount of reinforcement materials which are the two key factors greatly affected the yield stress and ultimate compression strength of the composites [1]. Addition of water hyacinth particles in 6 wt% into the HDPE matrix exhibited the superior strength during tensile load application and reveals the better Young’s modulus values than other combinations [2].

Superior mechanical properties were established by adding the sisal fiber as reinforcement materials with the High Density Polyethylene (HDPE) matrix [3]. Addition of sawdust particles in smaller sizes with HDPE matrix exhibited the superior mechanical properties than that of larger size of sawdust particles [4]. Higher interfacial bonding between the reinforcement particles and recycled HDPE matrix composites were found in XRD analysis [5]. Tensile strength and Young's modulus of the natural rubber and chicken feather particles reinforced with recycled HDPE matrix composites were found maximum [6].

Chemically modified water hyacinth particles which added with the poly (methyl methacrylate) matrix reveals the superior tensile strength and Young's modulus values than others also the bonding between water hyacinth particles and poly (methyl methacrylate) matrix were found good in SEM analysis [7]. Strength of the composites during the tensile test and modulus of tension were found maximum in low density polyethylene/acrylonitrile butadiene styrene matrix reinforced with modified water hyacinth particles than that of an unmodified water hyacinth particles reinforced composites [8].

Lower elongation, higher strength and higher modulus of elasticity were observed in high density polyethylene (HDPE) matrix/water hyacinth particles reinforced composites with NCO-polyol coupling agent also the distribution of reinforcement material i.e. water hyacinth particles in the high density polyethylene matrix were found good through SEM analysis [9]. Strength of the composite specimens during the tensile test was noticed maximum in recycled high density polyethylene/natural rubber/chicken feather fiber composites with caprolactam also lower elongation was observed during the same tensile test on these composites [10].

In this experimental work, an innovative approach is initiated to improve the tensile properties of the water hyacinth particles and nano alumina particles reinforced with HDPE matrix composites.

2 Materials and Methods

Matrix material and one of the reinforcement materials which is used in this experimental work i.e. High Density Polyethylene (HDPE) and Nano alumina powder was purchased from Covai Seenu and Company Ltd, Coimbatore, Tamilnadu, India. Another reinforcement material i.e. water hyacinth powder is directly procured from the eco green unit, Coimbatore, Tamilnadu, India.

| Sl.No. | High density polyethylene (wt %) | Nano alumina powder (wt %) | Water hyacinth powder (wt %) | Sample description |
|-------|---------------------------------|---------------------------|-----------------------------|--------------------|
| 1.    | 100                             |                           | 0                           | Pure HDPE          |
| 2.    | 95                              | 01                        | 04                          | Sample - A         |
| 3.    | 95                              | 03                        | 02                          | Sample - B         |
| 4.    | 95                              | 05                        | -                           | Sample - C         |

Pure HDPE specimen consists of 100 wt% pure HDPE particles. Sample – A consists 95 wt% of pure HDPE particles along with 1 wt% of alumina powder and 4 wt% of water hyacinth powder. Sample – B consists 95 wt% of pure HDPE particles along with 3 wt% of alumina powder and 2 wt% of water hyacinth powder. Sample – C consists 95 wt% of pure HDPE particles along with 5 wt% of alumina powder and 0 wt% of water hyacinth powder. The different matrix and reinforcement...
compositions, which are used to prepare the pure and hybrid HDPE polymer composite bars are shown in table.1 correspondingly. The different basic physical and chemical properties of the nano alumina powder is shown in table.2. Initially, the procured alumina power size in not meet out the required size. In order to fulfil the requirement, the procured alumina powder was processed in ball mill. The particle size confirmation test also carried out and the measured diameter of the nano alumina particles was found in the range of 100 nm.

Table 2. Properties of Nano Alumina (Al₂O₃) Powder

| Description      | Unit | Values |
|------------------|------|--------|
| Aluminium        | %    | 52.42  |
| Oxygen           | %    | 47.04  |
| Density          | g/cm³| 3.90   |
| Molar mass       | g/mol| 101.96 |
| Particle size    | nm   | 100    |

Before feeding these mixtures into the double screw extruder machine, HDPE particles were heated above its melting temperature. After heating the HDPE particles were changed into liquid stage. Required weight percentage of reinforcement materials i.e. Nano alumina powder and water hyacinth particles were added into liquid state HDPE. After the addition of both reinforcement materials into the liquid state HDPE matrix material, the entire mixture was thoroughly mixed in a blender machine for 30 minutes. A double screw extruder machine is used to prepare the composite mixture of both matrix and reinforcement materials in the form of smaller length pieces (1 to 2 cm) in length.

A hydraulic injection moulding machine is used to prepare the composite bars in the form of rectangular shape from the well prepared hybrid composite pieces as per the ASTM D638 standard for tensile test (165 mm in length, 13 mm in length and 6 mm in thickness). Hybrid composite bars which are attained from the hydraulic injection moulding machine is shown in figure.1. Hybrid composite specimens for tensile test (before test) were shown in figure.2. Tensile test specimens after the test were depicted in figure.3.
3 Results and Discussions

An experimental investigations on the HDPE polymer matrix which is reinforced with the limited amount of Nano alumina powder and fine water hyacinth particles was successfully carried out and the following results and discussions were made based on the experimental results. Peak tensile load for pure and hybrid HDPE polymer composite specimens were illustrated in figure.4.

![Figure 4 Peak tensile load for pure and hybrid HDPE composite specimens](image)

It was noted that the peak tensile load for pure HDPE, sample-A, sample-B and sample-C in the range of 4.64, 5.52, 5.32 and 5.40 kN respectively. Enhanced load shifting between the matrix and reinforcement material causes the highest tensile load capacity for the hybrid HDPE composites than that of pure HDPE specimens. Maximum tensile load of 5.52 kN was observed in sample-B and minimum tensile load of 4.64 kN was observed in pure HDPE composite specimen respectively.
Maximum displacement attained by the pure and hybrid HDPE composite specimens during the tensile test were illustrated in figure 5. Displacement of 7.00, 8.40, 8.00 and 8.90 mm were observed in pure HDPE, sample-A, sample-B and sample-C correspondingly. Higher concentration of alumina powder in the HDPE matrix causes the higher displacement magnitude (sample-C) than other three composite specimens. Maximum and minimum displacement of 7.00 and 8.90 mm were noticed in pure HDPE and sample-C specimen correspondingly.

Yield strength exposed by the pure and hybrid HDPE composite specimens were shown in figure 6. Stress exhibited by the pure and hybrid HDPE composite specimens during the yield point were observed in the range of 37.27, 41.92, 40.39 and 35.39 MPa correspondingly. Maximum and minimum yield strength of 41.61 and 53.08 MPa were noticed in pure HDPE and sample-A specimen disparately. Larger quantity of water hyacinth particles addition into the HDPE polymer matrix (sample-A) is the reason for superior yield strength than other three composites. Yield load observed by the pure and hybrid HDPE composite specimens were depicted in figure 7.

![Figure 5](image1.png)

**Figure 5** Maximum displacement attained by pure and hybrid HDPE composite specimens

![Figure 6](image2.png)

**Figure 6** Yield stress for pure and hybrid HDPE composite specimens
Load obtained by the pure and hybrid HDPE composite specimens during the tensile test at yield conditions were found in the range of 3.21, 4.36, 4.20 and 4.14 kN respectively. Maximum and minimum yield load of 3.21 and 4.36 kN was noticed in pure HDPE and sample-A specimen respectively. Higher concentration of water hyacinth particles into the matrix material is enhances the higher yield load carting capacity due to the superior interfacial bonding between the reinforcement and matrix. Maximum tensile strength exhibited by the pure and hybrid HDPE polymer composite specimens were represented in figure.8 correspondingly. Ultimate tensile strength for pure and hybrid HDPE polymer composites specimens were found in the range of 41.61, 53.08, 51.15 and 46.15 MPa respectively. Elongation percentage exposed by the pure and hybrid HDPE composite specimens were demonstrated in figure.9. Percentage of elongation obtained by the pure and hybrid HDPE polymer composite specimens during the tensile test were absorbed in the range of 1.44, 2.61, 2.17 and 2.17 correspondingly. Minimum (1.44) and maximum percentage of elongation (2.61) was found in sample-A, pure HDPE composite specimens respectively. Reduction percentage in pure and hybrid HDPE composite specimen’s area were represented in figure.10. The reduction of area during the tensile test were found in the range of 5.76, 7.69, 10.10 and 9.19 for pure and hybrid HDPE polymer composite specimens correspondingly. Maximum and minimum area reduction percentage of 5.76 and 10.10 was noticed in pure HDPE and sample-b hybrid composite specimens accordingly.

**Figure 7** Yield load for pure and hybrid HDPE composite specimens

**Figure 8** Ultimate tensile stress for pure and hybrid HDPE composite specimens

Ratio between the yield stress and ultimate tensile stress for Pure and hybrid HDPE polymer composite specimens were shown in figure.11 respectively. Pure and hybrid HDPE polymer composite specimen’s yield stress to ultimate tensile stress ratio were noticed in the range of 0.90, 0.79, 0.79 and 0.77 respectively. Maximum and minimum ratio of yield stress to ultimate stress ratio
of 0.77 and 0.90 were noticed in sample-c hybrid HDPE and pure HDPE polymer composite specimens considerably.

**Figure 9** Elongation percentage for pure and hybrid HDPE composite specimens

**Figure 10** Area reduction percentages for all composite specimens

**Figure 11** Yield stress to ultimate tensile stress ratio for all composite specimens
During the tensile test, the relationship between the load vs deflection is taken as a graph from the software. The load vs deflection graphs for sample A, B and C is shown in figure 12 to 14 correspondingly. Effective interfacial bonding between the matrix and reinforcement material causes the superior performance of hybrid HDPE composite specimens than that of the pure HDPE specimens during the tensile test. Narrow amount of water hyacinth particles addition into the HDPE polymer matrix leads to the enhanced tensile properties of the hybrid composite specimens significantly.
4 Conclusion

The following conclusions were made based on the experimental studies which is carried on a pure and hybrid HDPE composite specimens. Among the all four composite specimens, hybrid HDPE specimen-A exhibits the better tensile behaviour than other three composite specimens. Superior interfacial bonding between the reinforcement and matrix materials was the origins for better tensile behaviour of hybrid HDPE composite specimen. Limited inclusion of Nano alumina and water hyacinth particles quantity into the HDPE matrix is enhanced the tensile behaviour of the composites significantly due to an effective load shifting between the matrix and reinforcement materials. Matrix fiber-filler interaction is the major reason for the variation in tensile properties of the composites. Excess reinforcement quantity addition into the matrix material is reduce the tensile behaviour of the hybrid composites considerably.

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