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Investigation of Mechanical Behaviour of Polypropylene Based Composite

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Abstract

Nowadays, composite materials are supplanting conventional materials because of their upgraded properties. Various research works suggest that composite materials have better properties when contrasted with the existing materials that are for the most part utilized in the automotive and aviation sector. This paper proposes the fabrication and investigation of the mechanical properties of eco-friendly waste plastic-based composites. In this work, the essential fortifications in particular are waste polypropylene and nylon 6,6 utilized in various compositions. The composite at different compositions was tested for structural integrity through compressive strength test and Izod impact test, assessed as per ASTM standards. The result shows that the addition of nylon 6,6 as reinforcement along with polypropylene increases the mechanical properties with the highest value of 2.53 kN for the compressive strength test and 4 joules for the Izod impact test.

Keywords: *Polypropylene, nylon 6,6, Injection molding, Compression strength, Impact strength*

1.0 Introduction

Plastics are the most versatile materials at any point imagined. Indeed, the word, "plastic," comes from the Greek word 'plastikos', meaning to mold or form, and has come to be utilized as an overall depiction for anything especially versatile or adaptable. Starting from the primary plastic, celluloid, which was created as a substitution for elephant ivory during the 1860s, a wide range of sorts of plastics, including nylon, polyethylene, and teflon have changed the production of business merchandise as diverse as nylon stockings and vehicle body parts. Albeit the utilization of plastic proceeds to develop and progressive new plastics are continually being created, concerns have been raised about the ecological impacts of utilizing and discarding so much plastic material, inciting the innovation of bio plastics. The contamination brought about by non-recyclable plastics (thermosetting plastic) is an enormous reason to worry. When shaped they cannot be remolded once more. This offers a magnificent chance to foster a superior nature of thermoplastics to supplant the current thermo-setting plastics. Along these lines, this project endeavors to create and study the composites produced using waste polypropylene and nylon 6,6 with a view to improving the present quality and standards of the existing plastics. This composite are gone to be made by Injection Molding Process. The polypropylene has some properties and nylon 6,6 has some properties and we are also going to study about the composites produce by combining of this two polymers.

A detailed study about the composite materials and their manufacturing is done below:

Fujiwara et al (2004) researched thermoplastic materials which, because of their inherent physical properties and low processing temperature have gained significant technological incentives and rapidly replaced more traditional materials such as steel and nonferrous metals, as well as natural polymers such as wood, cotton, and natural rubber. However, apart from a series of weak aspects including resistance against biodegradation, difficulties associated with recycling, melt processing, and blending with other polymers, thermoplastic materials have been well recognized over steel and other metals. Thermal, mechanical stability, and enhanced electrical insulation of these materials impose their wide range of high-temperature applications for defense, biomedical engineering, automobile, transportation, textiles, and commodity articles.

Polyakov et al (1985) identified among a wide range of thermoplastic materials, the most widely used are polyethylene, polypropylene, polyvinyl chloride, and polystyrene due to their relative case of molding into articles. Understanding the stability of these thermoplastic materials against thermal and thermal oxidative degradation constitutes an integral part of plastic molding technology that requires prior knowledge of single particle kinetics of their thermal degradations under non-isothermal conditions and their thermodynamic parameters. In this connection, a wide range of polymers including thermoplastic materials have been investigated for their non-isothermal kinetics and thermodynamics of decomposition for a long time. The kinetics, thermodynamics, and mechanism of thermal degradation of thermoplastic materials are governed by a series of factors particularly their molecular mass, structure, nature of substituents, crystallinity, and crosslinked density.

Karaduman et al (2001) studied the thermal degradation mechanism of LDPE harnessing a high-pressure autoclave surrounded by a furnace was investigated. In this work, the rates of formation of gas, liquid, and solid during degradation of PE plastic wastes in cyclohexane as solvent at 400 and 425°C have been experimentally determined. Four reaction mechanisms have been proposed and tested to estimate of gas, liquid, and solid. Proposed mechanisms are based on the assumption that the reactions are pseudo-first-order with respect to the reacting species. Pseudo-first-order rate constants for each of the indicated mechanistic steps have been calculated by nonlinear regression analysis. The best fit was obtained by a pure parallel reaction mechanism, and its activation energy was determined.

Weidner and Long et al (1995) Electrophilic substitution of cyclopropenium ions on aromatic polymers offers a unique opportunity to introduce polar functionality in a controlled manner to conventional, nonpolar polymers was studied. Phenylcyclopropenone substituted polystyrene with predictable chemical composition and narrow molecular weight distribution was prepared. Scanning electron microscopy demonstrated the absence of branching or cross-linking in these functionalized polystyrenes during the electrophilic substitution of the parent homopolymer. 13C-NMR confirmed that the degree of phenyleyclopropenone substitution was both highly efficient and predictable over a broad compositional range. The Tg of the polymers was found to vary linearly with mole% phenylcyclopropenone substitution of the polystyrene. TGA indicated that thermal decarbonylation of the appended cyclopropenones occurred at approximately 180°C. Weight loss vs. temperature profiles correlated reasonably well with levels of substitution based on 13C-NMR analysis, confirming that decarbonylation of the calculated cyclopropenone substituents was the predominant thermal decomposition pathway.

Costea et al (1990) presented some aspects of the non-isothermal kinetics of the thermoxidative decomposition of a polymethyl methacrylate, PVC, polyvinyl acrylate, and polyvinyl alcohol. Both the apparent activation energies and the pre-exponential factor depend on conversion and exhibit a pseudo-compensation effect. Oh et al (2009) studied the kinetics of the thermal decomposition of PVC by a conventional TGA technique under various heating rates in flowing nitrogen. The kinetic model that accounts for the effects of scission of the polymeric chain at any time was proposed to describe the thermal decomposition of PVC. The thermal decomposition was found to be a complex process composed of at least two steps for which kinetic values can be calculated. The kinetic analysis of PVC gave apparent activation energy for the first step of 159.7 kJ/mol, with a value of 189.6 kJ/mol for the second step.

Nair et al (2016) when the DTA of polystyrene is carried out in the air in a platinum sample holder, an anomalously high endothermic effect is observed. This effect was found to be related to gas-phase catalytic styrene oxidation occurring on the surface of both operating and reference platinum sample holders. Yu et al (2006) reported that three different types of polymer composite can be categorized: firstly is completely miscible blends, secondly partially miscible blends, and lastly fully immiscible blends. Miscible can be defined as where the two or more liquids can be mixed together. Besides that, polymer composites either exist in a homogeneous or heterogeneous state. In homogeneous blends, the average properties of the blend components are the final properties which imply that the properties are divided equally. Meanwhile, in heterogeneous blends, the properties of all blend components are present.

Srimurugan et al (2018) investigated mechanical behaviour of Nylon-polycarbonate, Nylon-GFRP composite and found that hybrid composite shows better mechanical behaviour. Vijaya Ramnath et al (2017) investigated the mechanical properties and behavioural change of Kenaf based hybrid composites and proved the improvement in the mechanical properties.

Based on the above review it is concluded that few work has been carried out using polypropylene based composite. hence, this work aimed in fabricating and investigating mechanical behaviour of polypropylene and nylon based hybrid composites..

2.0 Materials and Methods

2.1 Material Selection

2.1.1 Polypropylene

Polypropylene (PP), otherwise called polypropylene, is a thermoplastic polymer. Polypropylene is the world's second-most generally created engineered plastic, after polyethylene. In 2013, the worldwide market for polypropylene was around 55 million tonnes. It has a properties like chemical resistance, elasticity and toughness, etc, this is the reason to choose this material. The grade of PP used here is polypropylene Homopolymer. This type of polypropylene is used in general applications. Semi-crystalline Homo PP-H polypropylene is used here. Table 1 shows the properties of polypropylene.

Table 1: Properties of Polypropylene

S.No	Property	Polypropylene
1	Density(Kg/ýÿ3)	905
2	Tensile Strength (Mpa)	25 – 33
3	Tensile modulus (Gpa)	1 – 1.4
4	Hardness ("R" scale)	90
5	Notched Izod impact (KJm)	0.07

Table data collected from Synergy Polymers India Private Limited

Table 2: Properties of Nylon 6,6 (30% Glass filled)

S.No	Properties	ASTMtest method	Nylon 6,6 (30% glassfilled)
1	Density (Lb/in^3)	D792	0.049
2	Specificgravity	D792	1.35
3	Tensilestrength (psi)	D638	27,000
4	Tensilemodulus (PSI)	D638	1,400,000
5	Tensile elongation atbreak (%)	D638	3
6	NotchedIzod impact (ft-Lb/in)	D256	2.1

Table data collected from Synergy Polymers India Private Limited

2.1.2 Nylon 6,6 (30% Glass filled)

Nylon 6,6 tends to ingest dampness however it is the most un-penetrable to gas/mineral oil/ fluorocarbon- refrigerant. It is good Impact strength, toughness, and high mechanical strength, high crystallinity brings about a sharp liquefying point, making its mechanical properties less impacted by temperature. Table 2 shows the properties of Nylon 6,6 (30% Glass filled).

Figure 1: Injection Molding Machine

3.0 Fabrication of Composite

3.1. Injection Molding

Injection molding is a manufacturing process for delivering parts by infusing material into a form. Injection molding can be performed with a large group of materials, principally metals, glasses, elastomers, sweets, and thermoplastic and thermosetting polymers. Molds are made by a mold producer (or toolmaker) from metal, as a rule, either steel or aluminum. The adaptability of infusion shaping is worked with by through broadness of plan contemplations and conceivable outcomes.

3.2 Fabrication

The plastic composite to be manufactured is pointed toward working on the mechanical properties of waste polypropylene. By working on those mechanical properties, these new polymer composite can really supplant and reuse polypropylene and furthermore can perform better compared to a few different thermoplastics. Essentially, two moldings of plastic are done in which one is a plastic composite and the other is a single polymer.

- The first mold is done only with waste polypropylene.
- The second mold is waste polypropylene and compositions of nylon 6,6 (30% glass filled). Table 3 shows the three types of composite samples fabricated with their compositions.

Figure 2: Molding Die

Table 3: Types of composite samples fabricated

S.No	Sample ID	Composition
1	1	Waste polypropylene 100% (1Kg)
2	2	Waste polypropylene 95% (950 g) + nylon 6,6(30% glass filled) 5%(50 g)
3	3	Waste Polypropylene 90% (900g)+ nylon 6,6(30% glass filled)10% (100g)
4	4	Waste Polypropylene 85\%(850g)+ ny 6,6(30% glass filled) 15% (150g)

3.3 Molding 1 (Waste Polypropylene)

Polypropylene is loaded in the hopper and the injection molding is carried out at 220°C using only polypropylene.

3.4 Molding 2 (Waste + Polypropylene Flakes + Nylon 6,6 (30% glass filled) Pellets)

In this process, Polypropylene and Nylon 6,6 (30% glass filled) is loaded In the hopper. Also, three different compositions are fabricated here as follows:

1. Waste Polypropylene 95% (950g) + Nylon 6, 6 (30% glass filled) 5% (50g)
2. Waste Polypropylene 90% (900g) + Nylon 6,6 (30% glass filled) 10% (100g)
3. Waste Polypropylene 85% (850g) + Nylon 6,6 (30% glass filled) 15% (150g)

4.0 Testing of Composites

The mentioned tests were conducted to find the mechanical properties of composites and the results were analyzed. The composite samples obtained were tested for its mechanical properties namely;

1. Compressive strength and
2. Impact strength

4.1 Compression Test (ASTM D 695)

A compression test is any test where a material encounters restricting powers that push inward upon the specimen from opposite sides or is generally compressed, “crushed”, squashed, or smoothed. The test sample is generally placed in between two plates

Figure 3: Compression Testing Machine

that circulate the applied load across the whole surface area of two opposite faces of the test and afterward the plates are moved together by a universal test machine making the sample flatten. A compressed test is typically abbreviated toward the applied powers and expands toward the path opposite to the power. A compression test is basically something contrary to the more normal tension test. The sample was prepared as per ASTM D 695.

4.2 Izod Impact Test (ASTM D 256)

Izod influence testing is an ASTM standard strategy for deciding the effective opposition of materials. A turning arm is raised to a particular level and afterward released. The arm swings down hitting the sample, breaking the sample. The energy consumed by the sample is determined from the level

Figure 4: IZOD Impact Machine

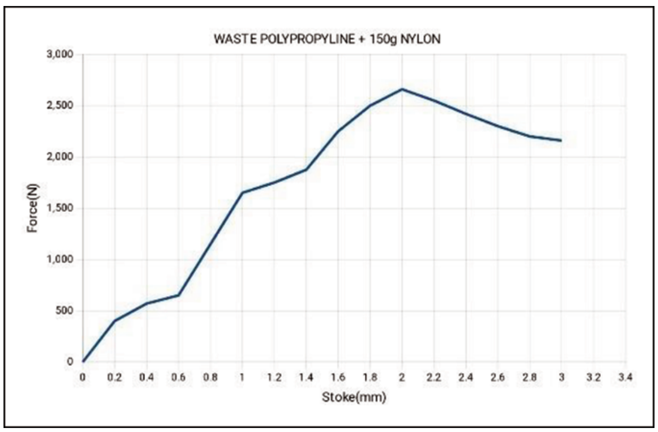

Figure 5: Waste Polypropylene+150g Nylon

the arm swings to the subsequent hitting of the sample. An indented test is utilized to decide influences on energy and notch sensitivity. Impact tests are utilized in concentrating on the durability of

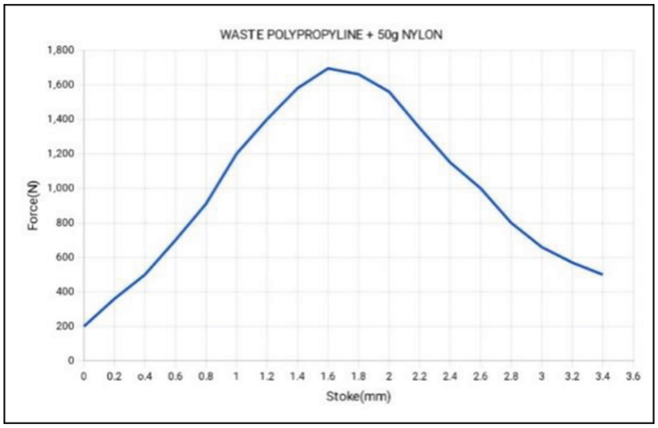

Figure 6: Waste Polypropyline+50g Nylon

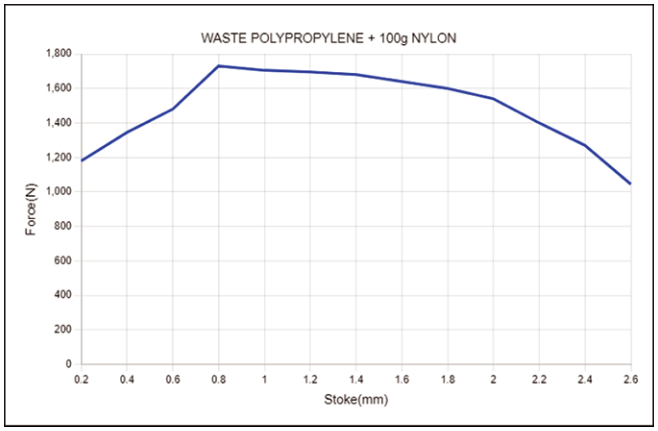

Figure 7: Waste polypropylene+100g Nylon

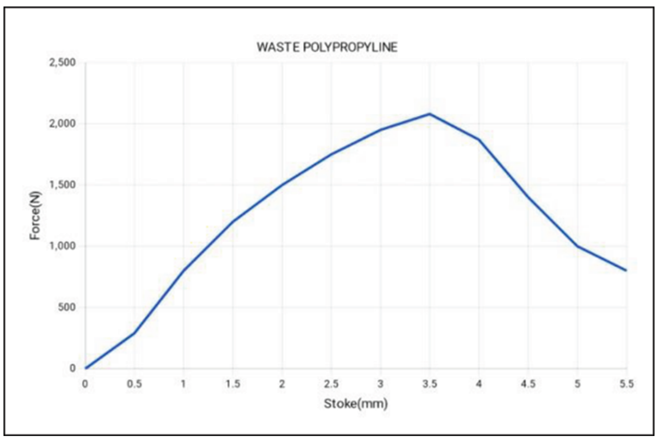

Figure 8: Waste Polypropylene

the material. A material's durability is a variable in its capacity to ingest energy during plastic deformation. Fragile materials have low strength because of the small quantity of plastic deformation that they can persevere. The impact value of material can likewise change with temperature. For the most part, at lower temperatures, the effective energy of a material is diminished. The size of the sample may likewise influence the value of the Izod influence test since it might permit a different number of imperfections in the material, which can act as stress risers and lower the impact energy. The sample was prepared as per ASTM D 256.

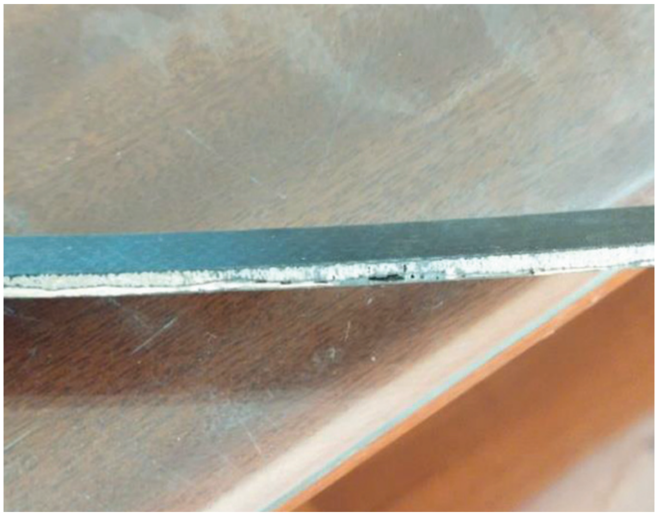

Figure 9: After compression Test

Figure 10: After IZOD Impact Test

5.0 Results and Discussion

5.1 Result of compression test

Figure 1 : Result of Compression Test

Figs. 3.1, 3.2, 3.3 and 3.4 show the compression test results for all the four samples and from analyzing the results it can be concluded that the addition of Nylon 6,6 (10% glass filled) 15% (150g) composition increases the compressive strength of the fabricated sample. This is mainly due to the ductile behaviour of Nylon which deforms slowly with respect to an applied force. Table 4 shows the results for compression test.

5.2 Result of Izod Impact Test

Table 5 shows the results for Izod impact test and it is observed that sample 1 has better impact resisting behaviour than the others. This is due to the presence of higher proportion of polypropylene in sample 1 as compared to the other samples.

Table 4: Compression test results

S.No	Sample ID	Compression load in KN
1	1	2.05
2	2	1.69
3	3	1.73
4	4	2.53

Table 5: Impact test results

S.No	Sample ID	Energy absorbed in Joules
1	1	4
2	2	2
3	3	2
4	4	2

6.0 Conclusion

This study was broadly completed to improvise the at present accessible eco-friendly plastics. On completing it, a new plastic composite (polymer composite) of 85% waste polypropylene and 15% nylon 6,6 (30% glass filled) is found to improve the mechanical properties of the current waste polypropylene. The recently found polymer composite of the above structure reports having an 18.97% increment in its compressive strength. Thus, it can be presumed that the recently found polymer composite of waste polypropylene with nylon 6,6 (30% glass filled) can possibly supplant polypropylene in the greater part of its applications as it has preferred mechanical properties over polypropylene.

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