# Study of Materialistic & Thermal properties of Polypropylene and Banana Fiber Reinforced Composite

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**Abstract**

Banana fibers are used as reinforcement with polypropylene matrix based composite. Banana fibers have been procured from many sources and are selected for reinforcement of High density polypropylene because of their low cost, high aspect ratio and fairly good mechanical properties. The composite has been prepared by using compression moulding and stirrer. The mechanical properties of the composite are analyzed by using tensile and Impact tests. The thermal properties of the composite are determined using Thermo-Gravimetric Analysis (TGA) and Differential Scanning Calorimetry (DSC). The tests conducted on the composite indicates that the mechanical and thermal properties of the HDPP composite have been improved when it is reinforced with banana fiber.

**Keywords: Compression moulding; HDPP (High Density Polypropylene); reinforcement; Impact test; TGA; DSC.**

## 1. Introduction

In modern era, the composite materials are in high demand in industries due to its properties such as high stiffness and strength, corrosion and chemical resistance, ease of fabrication, economically efficient and eco friendly behavior. Current researches majorly concentrate on the mechanical and thermal properties of the developed composite materials [1-3]. Most of the composites based on thermoplastic are developed from polypropylene and polyethylene[4].

A composite material may be defined as a combination of two or more constituent materials with significantly different chemical or physical properties that, when combined, produce a material with different characteristics from the individual components [5-6].

High Density Polypropylene is the majorly used matrix material for the composite material development due to its properties such as good adhesion, excellent mechanical properties, chemical stability, low cost, high hardness and adhesive strength, high damping properties.

In order to improve the scope of its use, it may be blended with various inorganic fillers. It has been observed that high loadings of macro sized fillers are needed to increase the tensile strength while only small amount of nano-sized fillers such as titanium, calcium carbonate, silica, fibers are sufficient to improve the toughness of the composites[7].

This work evaluates reinforcement of high density polypropylene using banana fiber. It is well known that lots of banana is produced and after gathering fruit body part of banana plant which contains banana fiber is wasted in India. The wasted banana fiber is mixed with high density polypropylene in order to find commercial applications. High density polypropylene is mixed into with banana fibers at 10 % by weight in order to form high density polypropylene composite. The composite is compression moulded for specific time and temperature. High density polypropylene and banana fiber reinforced composite has better mechanical and thermal properties than others. Colom et al prepared HDPE composite using a compounding step at 200 Centigrade in crucible and moulding step at 150 Centigrade in a compression Die for up to 50 minutes and 4 hours for cooling in air[8].

Chrissafis et al.[9] have observed that addition of $SiO_2$ nanoparticles enhances the mechanical and thermal properties of the composite materials. PMCs are light weighted with high stiffness and strength along the direction of the reinforcement. Therefore they are useful in aircraft, automobiles, and other moving structures [10].

## 2. Experimental procedure

Banana fibers have been selected for reinforcement of HDPP. Banana fibers have special properties for binding. So we have chosen the banana fibers. A composite sample has been prepared by mixing homogeneous liquid of HDPP and banana fibers The following tests are performed on the composite in order to analyze thermal and materialistic properties.

### 2.1 Materialistic properties

#### 2.1.1 Density

It is defined as mass per unit volume. Its measuring procedure is based on ASTM D792-00. This involves firstly getting weights of a suitable size specimen in air ( $W_a$ ) and then its weight in water ( $W_W$ ). The density can be obtained from these weights and by densities of air and water. Air's density is assumed negligible and that of water is $1 g/cm^3$ the density of composite is then given by $W_a / (W_a - W_W)$

#### 2.1.2 Constituent Weight and Volume Fractions

These are very important characteristics of composite that influence their properties. These can be obtained by following ASTM D3171-99. This method is also called as matrix dissolution method or matrix digestion method. It requires a careful selection of the medium that will dissolve the matrix but will not attack the fibers. When it is dissolved in the medium , the residue containing the fibers is then washed, dried and weighted . now its weight is subtracted from total weight of composite to find the weight of matrix.

#### 2.1.3 Water Absorption

This test indicates the tendency of a material to absorb or hold water. There is a difference between "absorb" and "adsorb", which is involved in this test. Actually, as far as this test is concerned and as far as practical meaning is concerned, there is no difference. We measure both what is absorbed (taken into the individual constituents) and/or what is absorbed (held on the surface of the individual constituents) by the composite system. A low value (less than 1.0%) indicates a system where water would run off and material would dry quickly. A high value (over 5.0%) indicates a system where considerable water would be absorbed and would dry slowly. The values are expressed as percent weight gained (a loss would indicate a soluble material and unsuitable as a flooring material) from before immersion to after immersion, with the time and temperature of immersion carefully noted. A reasonable limit of how porous a floor should be is about 5% maximum absorption.

### 2.2 Thermal Testing

#### 2.2.1 Thermal Conductivity test using LASER Flash

The LFA 447 NanoFlash is based on the well-known flash method. In this method, the front side of a plane-parallel sample is heated by a short light pulse. The resulting temperature rise on the rear surface is measured using an infrared detector. By analysis of the resulting temperature versus-time curve, the thermal diffusivity can be determined. LFA 447 offers a variety of flash systems to cover a broad range of applications and temperatures from -125°C upto 2800°C. LFA 447 is designed as a cost-effective, easy-to-operate, highly accurate instrument for testing between room temperature and 300°C. The tests were conducted according to ASTM E 1461.

**Fig. 2.2.1** LFA 447 used for thermal conductivity, thermal diffusivity and bulk density

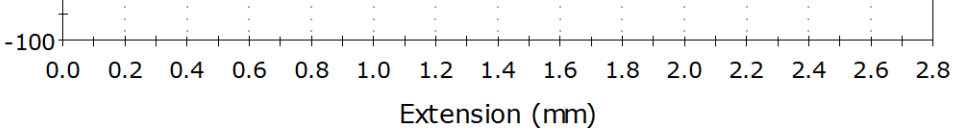
### 2.2.2 Differential Scanning Calorimetry (DSG) and Thermo-Gravimetric Analysis (TGA)

STA 6000 offers simultaneous measurement and analysis of weight change and heat flow of sample materials of pharmaceutical tablets or polymers. By combining flexible differential temperature analysis (DTA or DSC) with proven thermo gravimetry (TG) technology, the STA 6000 enables to generate accurate and reliable results while simplifying data interpretation. The tests were conducted according to ASTM E 1269.


**Fig. 2.2.2** STA 6000 used for DSC and TGA test

## 3. Results and discussion

The materialistic and thermal tests have been performed on the sample prepared and the results obtained are discussed below:

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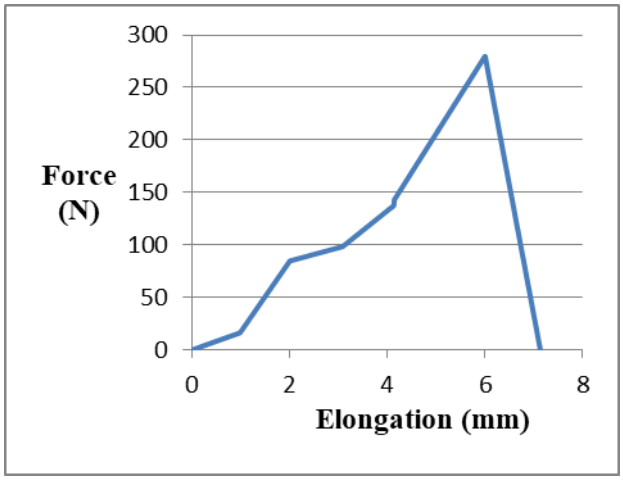


**Fig. 3.1.1** Force V/s Elongation curve with 0% banana fibers

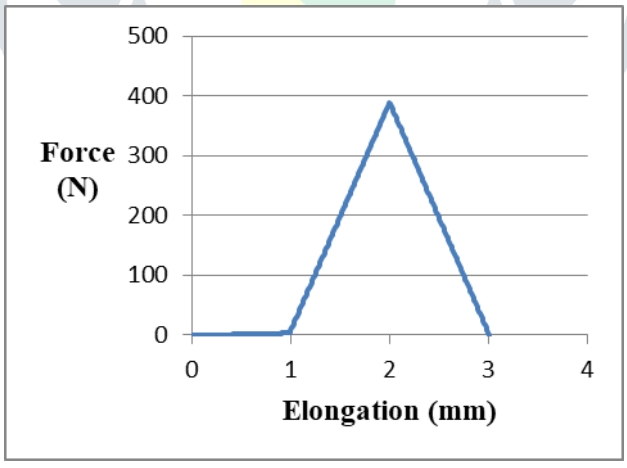


**Fig. 3.1.2** Force V/s Elongation curve with 5% banana fibers

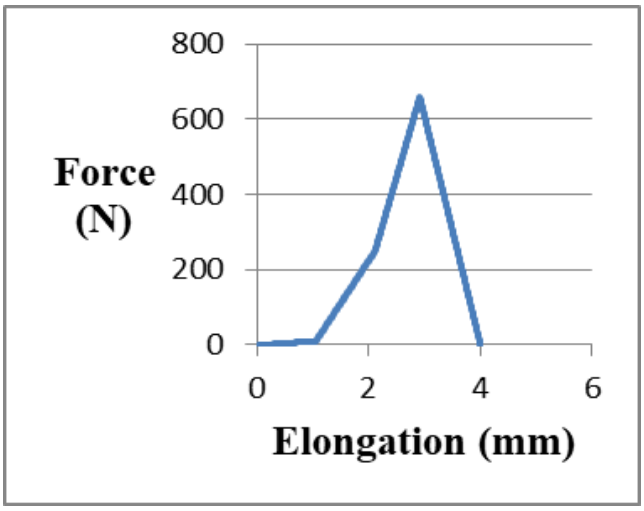


**Fig. 3.1.3** Force V/s Elongation curve with 10% banana fibers

**Table-3.1:** The obtained Tensile Strength of different composite samples

| SPECIMEN | TENSILE STRENGTH (MPa) | | |
|---|---|---|---|
| | SAMPLE A | SAMPLE B | SAMPLE C |
| 1 | 2.913 | 4.077 | 6.416 |
| 2 | 3.737 | 4.625 | 8.781 |
| 3 | 3.397 | 5.331 | 7.972 |
| AVERAGE | 3.349 | 4.677 | 7.723 |

**SAMPLE A:** HDPP composite with 0% banana fibers
**SAMPLE B:** HDPP composite with 5% banana fibers
**SAMPLE C:** HDPP composite with 10% banana fibers

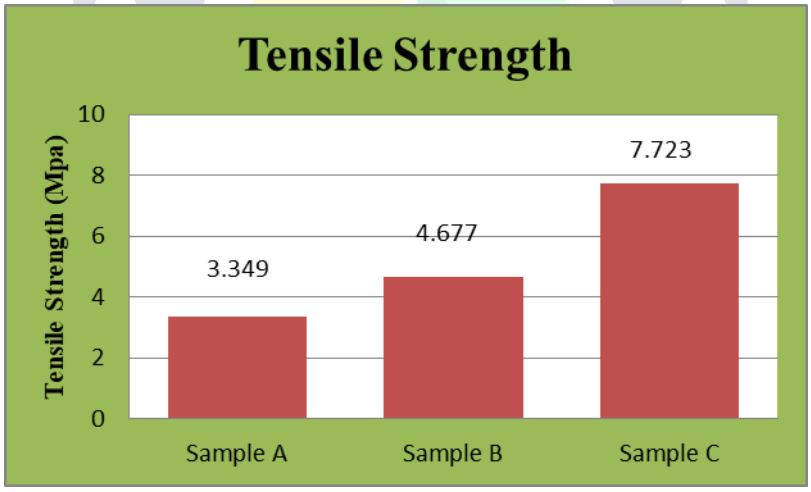


**Fig. 3.1.4** Comparison of Tensile Strength with the variation of the % of banana fiber

From the above results the tensile strength is increased by 39.35% and 130.6% with the addition of 5% and 10% addition of banana fiber respectively due to the high strength of banana fiber.

**3.2 Impact Test:**
On the basis of test conducted on respective samples, the results of impact test are as follows:

**Table-3.2:** The calculated impact strength of different composite samples

| SPECIMEN | IMPACT STRENGTH (J/m) |
|---|---|

| | SAMPLE A (0% banana fiber) | SAMPLE B (5% banana fiber) | SAMPLE C (10% banana fiber) |
|---|---|---|---|
| **1** | 171 | 211.7132 | 251.9235 |
| **2** | 171 | 214.7136 | 237.4328 |
| **3** | 169.5689 | 205.8392 | 259.6667 |
| **AVERAGE** | 170.5229 | 210.7553 | 249.6743 |

***The average value of above results are tabulated in the graph.***

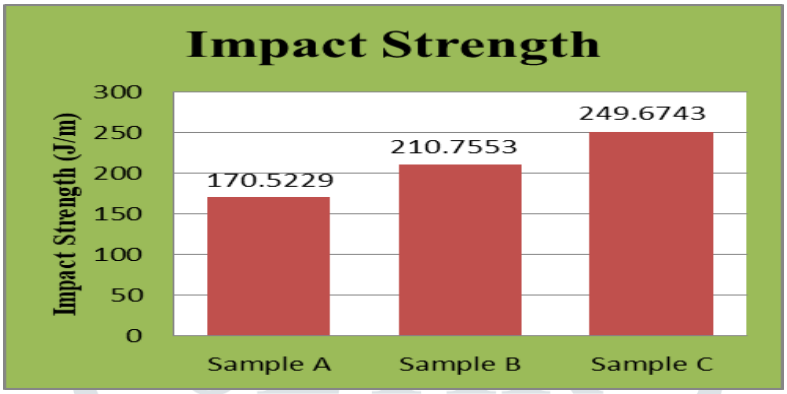


**Fig. 3.2.1** Comparison of Impact Strength with the variation of the Silica nanoparticles

From the above results the Impact strength is increased by 23.58% and 46.42% with the addition of 5% and 10% addition of silicon carbide respectively due to the high strength of silicon carbide.

### 3.3 Thermal Conductivity test using LASER Flash

The thermal conductivity of composites Sample A, B, C are tabulated in the graph.

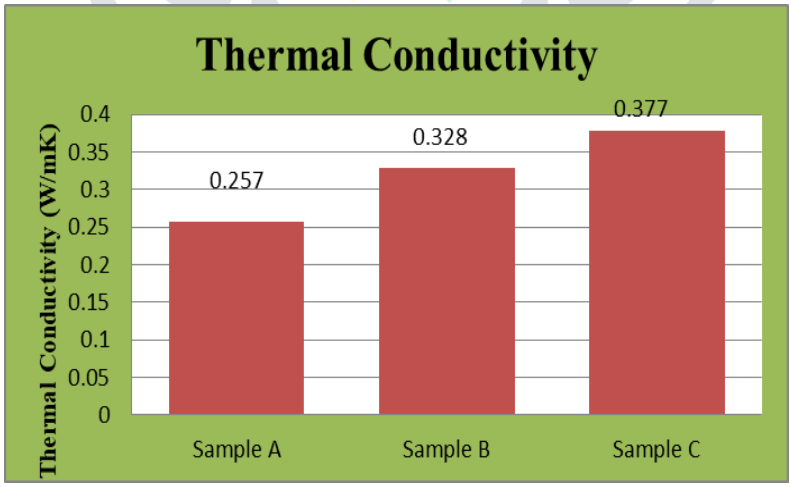


**Fig. 3.3.1** Comparison of Thermal Conductivity with the variation of the banana fibers

### 3.4 DSC and TGA test using STA

DSC and TGA test is carried out in simultaneous thermal analyzer in the temperature range of $30^0$C-$100^0$C with the heating rate of $1^0$C/min. For maintaining the variation of temperature above the atmospheric condition liquid nitrogen is used with the rate of 20ml/ min.

The heat flow for sample A, B and C are shown in the following figures

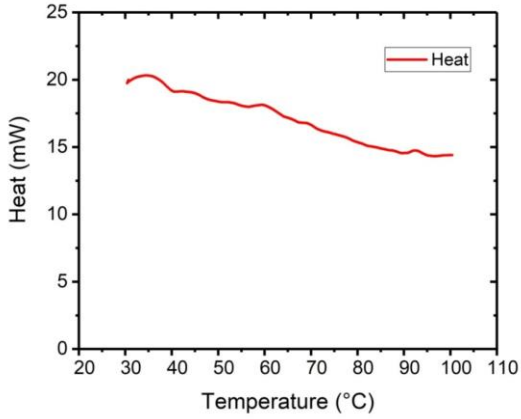


**Fig. 3.4.1** Heat flow V/s temperature for Sample A

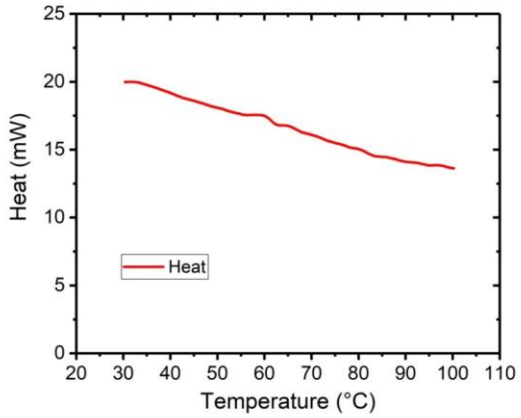


**Fig. 3.4.2** Heat flow V/s temperature for Sample B

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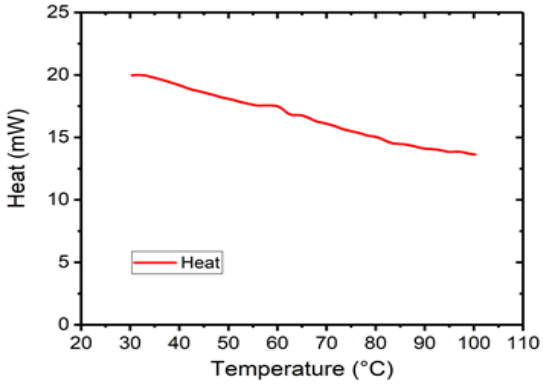


**Fig. 3.4.3** Heat flow V/s temperature for Sample C

## 4. Conclusions

The HDPP and banana fiber composite was synthesized for the composition of three different samples containing HDPP 10% by weight by varying banana fibers in Matrix as follows (Sample A) 0% by wt. banana fibers , (Sample B) 5% by wt. banana fibers, and (Sample C) 10% by wt. banana fibers. Three specimens of each sample were tested for obtaining the mechanical properties and one specimen for each sample for thermal properties according to ASTM standard. DSC and TGA tests were conducted for the heat flow and thermal stability in STA6000 apparatus. The conclusions are as follows:

- From tensile testing results it is observed and concluded that tensile strength is increased by 39.35% and 130.6% with the addition of 5% and 10% addition of banana fibers respectively.

- From Impact testing (IZOD method) it is observed and concluded that the Impact strength is increased by 23.58% and 46.42% with the addition of 5% and 10% addition of banana fibers respectively.
- From the results the thermal conductivity is increased by 27.63% and 46.69% with the addition of 5% and 10% addition of banana fibers respectively.
- From STA we observed that thermal stability increases with increasing banana fibers.

## 5. Acknowledgement

At this moment of accomplishment, first of all I would like to show deep sense of gratitude to my guide **Mr. Vinay Pratap Singh**. This work would not have been possible without his guidance, support and encouragement. Under his guidance I successfully overcame many difficulties and learned a lot. Despite of all difficulties, he used to review my thesis progress, give his valuable suggestions and made corrections. His unflinching courage and conviction will always inspire me, and I hope to continue to work with his noble thoughts.

## 6. References

[1] Bledzki AK, Gassan, J. Composites reinforced with cellulose based fibers. J Prog Polym Sci.1999;24(2):221–274

[2] Peijs T. Composites turn green. E-Polymers. 2002;T_002:1–12.

[3] Marcovich NE, Villar MA. Thermal and mechanical characterization of linear low-density polyethylene/wood flour composites. J Appl Polym Sci. 2003;90:2775–2784.

[4] Li Z, Gao H, Wang Q. Preparation of highly filled wood flour/recycled high density polyethylene composites by in situ reactive extrusion. J Appl Polym Sci. 2012;124(6):5247–5253.

[5] Fazeli, M.; Florez, J.; Simão, R. (9 November 2018). "Improvement in adhesion of cellulose fibers to the thermoplastic starch matrix by plasma treatment modification". *Composites Part B: Engineering*. **163**: 207–216.

[6] *Smart Composites: Mechanics and Design (Composite Materials)* R. Elhajjar, V La Saponara (, A. Muliana , Editors , CRC Press 2017 ISBN-10: 1138075515

[7] Tjong SC. Structure and mechanical properties of polymer Nano composites. Mater Sci Eng Rep. 2006;53(3):73–197.

[8] Mohsen Mohseni Tabar Taghi Tabarsa Mehdi Mashkour Abolghasem Khazaeian Using silicon dioxide ($SiO_2$) nano-powder as reinforcement for walnut shell flour/HDPE composite materials. Received: 2 February 2015 / Accepted: 6 April 2015 Indian Academy of Wood Science 2015.

[9] Chrissafis K et al. Thermaldegradation mechanism of HDPE nano composites containing fumed silica nanoparticles. Thermochim Acta. 2009;485(1):65–71.

[10] Chung DDL. Continuous carbon fiber polymer-matrix composites and their joints, studied by electrical measurements. Polym Compos. 2001;22(2):251–269.