DSC and Weathering Test of Composite formed of Six Configurations of RPPCP and RGF materials

Bikramjit Singh, Gajendra Dixit, Savita Dixit

Abstract*: The exploration of different materials is at its peak nowadays. This pace has not only gone towards discovering new material but inventing new, by making composites of different materials. Now this stream has gone into making composites of different polymers to make them suitable enough to compete and overtake metals. In this study, Polypropylene Copolymer (PPCP) is mixed with Glass Fibre Reinforced Polyester (GFRP) to form the Recycled PPCP or RPPCP. Further, a composite material is formed by the amalgamation of RPPCP and Recycled Glass Fibre (RGF) in different proportions. These samples of different proportions are created and tested in weatherometer and DSC analysis. In both of the tests, the outcome has been in favor of the sample with 70% RPPCP and 30% RGF proportion of the composite.

Keywords: Amalgamation, DSC (Differential Scanning Calorimetry), PPCP (Polypropylene Copolymer), RGF (Recycled Glass Fibre), RPPCP (Recycled PPCP), Weatherometer

I. INTRODUCTION

Polypropylene Copolymer (PPCP) is the polymer that is widely used for its mechanical properties for having better strength to weight ratio than metals. Basic properties of PPCP are that it is non-reactive, odourless, colourless and non-flammable [1]. New materials need to be safe for the environment and human interaction. This material, even after a long time inhalation under its environmental exposure, it remains non-hazardous. But still, for further handling and managing, it is kept in a cool and ventilated place, away from sunlight to avoid any kind of abnormal behaviour. This material is conveyed or moved from one place to another in 25 kg bags or 1 MT FIBC jumbo bags [2].

Next, the composite material is used named GFRP, i.e. Glass Fiber Reinforced Polyester. The polyester is reinforced with glass fiber and made into new composite material. It comprises of glass fiber and thermosetting resins. This is widespread globally for its tremendous properties and usage [3]. There are a large number of benefits that make this material suitable in many uses around the world. Its high strength makes it strong enough to withstand heavy loads. Some properties are that it is lightweight along with its design flexibility, low maintenance, and durability. It is made up of resins used as a base material, and then reinforcement of glass fiber in this plastic [4].

Recycling of Glass Fibre by mechanical grinding has been happening for several decades. There are certainly other techniques as well but thermal recycling is considered to be one of the best [5]. It's the most advanced to date, in terms of technical aspects. As not every recycled fibre is considered to be capable enough to provide sufficient strength and mechanical properties. With the help of thermal recycling, the waste of GRP after recycling is significant in giving performance level properties quite likely to match with new fibre [6]. Only a 20% difference in performance is measured between the recycling and fresh fibres with a considerable amount of cost reduction [7]. The weathering test is performed by the weatherometer. This process involves accelerated weathering conditions for the materials and is used to observe the changes in the various properties of materials. These properties can vary from mechanical to chemical or to physical as well. This is the exposure of the material to sunlight and different weathers artificially. It is also used for enhancing product endurance [7] . Further, DSC, i.e. Differential Scanning Calorimetry is the last step of the whole process. This is the thermal analysis of the heat flux that is produced by a material when given a certain temperature versus time [7]. The process is observed in comparison with another material but in general practice, it is measured as a difference in heat flux of the material kept on a pan and an empty pan. Both of them are given the same temperature and results are noted. It is performed by a device named Differential Scanning Calorimeter and is known as power compensating DSC (Differential Scanning Calorimeter) [8]. In this study, new material is manufactured by the amalgamation of PPCP, GFRP, and RGF. First PPCP and GFRP are mixed to form RPPCP, i.e., Recycled PPCP. Further different proportions of RGF (Recycled Glass Fibre) and RPPCP are used to find out the best combination among the different proportions of volume of two materials. Moving on, the weathering test is performed on this material of different proportions and then finally, DSC (Differential scanning calorimetry) analysis is performed to find out the best blend of material in terms of heating and cooling [2].

II. METHODOLOGY AND MATERIALS

A. Material

Glass fiber reinforced polyester (GFRP). Glass fiber is light in weight, extremely strong, and robust.

Revised Manuscript Received on January 15, 2020
* Correspondence Author
Bikramjit Singh *, Central Institute of Plastics Engineering and Technology, INDIA.
Dr. Gajendra Dixit, Department of Mechanical Engineering, Maulana Azad National Institute of Technology, Bhopal, INDIA.
Dr. Savita Dixit, Department of Chemistry, Maulana Azad National Institute of Technology, Bhopal, India.

It's bulk strength, stiffness and weight properties are also very favorable when compared to metals [9]. The recycled Glass fiber obtained from grinding and crushing of waste FRP products in the form of powder and fibers, out of which the fiber material was recollected which was used as a reinforcement material obtained after the different processing steps. Processing of remaining leftovers of Glass Fibers in this study includes various steps which include cleaning, grinding and further drying.

Polypropylene Co-Polymer (PPCP). PPCP (Polypropylene Co-Polymer) is a non-reactive product stable at normal ambient storage conditions. It usually does not get decompose in the presence of air. Due to its versatile nature, it is an inexpensive material and can be used easily in the fabrication process. In this study waste, PPCP after the complete processing procedure is utilized as a matrix material for preparing the composite.

B. Methods

Processing of waste GFRP. Processing of GFRP products involves several steps for preparing the reinforcement in the study include the cleaning of the GFRP product which is performed with pressurized water containing the mixture of caustic soda and clean water. In the next step, the grinding operation is performed on the dried GFRP product to obtain in the form of grains comprising fibre length in the range of 30-40mm. Further, the crushing process is carried out by utilizing steel rollers (manufactured by J.J Industries, Indore) and for the grinding purpose, scrap grinder (Made by J.J Industries, Indore) having four moving blades and two fixed blades is utilized.

Processing of waste PPCP. The waste PPCP products are obtained from scrapyards that are initially grounded and then it is processed in an extruder in granular form. Thereafter it is pre-dried in the tray dryer with forced hot air circulation oven.

C. Manufacture of the waste GFRP and PPCP composites

Characterization of GFRP and PPCP. To prepare processed Recycled Glass Fiber (RGF), GFRP and PPCP into mass or group agglomerate (Made by J.J Industries, Indore) of 25kg output is utilized. Further, the obtained agglomerated mixture is then fed into the heated mold having Outer area 12'' X 12'' in dimension with 5'' X 5" area of core and cavity, which is loaded on a PLC controlled Hydraulic Compression Molding Machine (Manufactured by Hind Hydraulics, Mumbai) having Maximum clamping tonnage of 40 tons and a maximum temperature range of 350 °C.

The composite sheets obtained of different volume ratios were prepared to perform the testing and result evaluation procedure on them. Five different composite sheet samples were prepared using the above experimental methodology with different volume fractions. They were 100% RPPCP, 90 % RPPCP-10% RGF, 80% RPPCP-20% RGF, 70% RPPCP-30% RGF, 60% RPPCP-40% RGF, 65% RPPCP-35% RGF. The composition of RPPCP and RGF is explained below in table 1:

Table- I: Comparative study between passive and active systems.

S. No.	Percentage of RPPCP	Percentage of RGF	Final Ratio
1.	100%	0%	100% RPPCP
2.	90%	10%	90 % RPPCP-10% RGF
3.	80%	20%	80% RPPCP-20% RGF
4.	70%	30%	70% RPPCP-30% RGF
5.	60%	40%	60% RPPCP-40% RGF
6.	65%	35%	65% RPPCP-35% RGF

The equipment used in the experiment in order to obtain the composite sheets as the output is shown in Fig: 1.

Fig. 1.Experimental Equipment (Agglomerate, Mold, and Compression Molding Machine respectively) utilized in the process of preparing the composite sheets

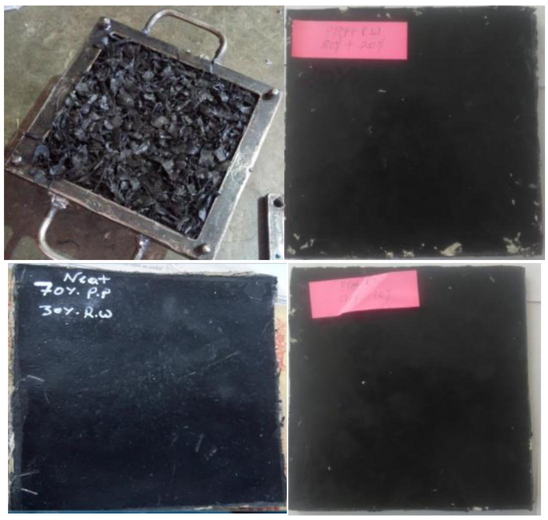

Fig. 2.Preparation of samples for further mechanical, chemical and weathering Tests.

Weathering conditions. Polymer composites are being utilized instead of metal all around the globe for their metal-like strength and low weight. Thus, it has to go through harsh weather conditions to compete with metal and for applicability in real life. For this, mechanical tests such as tensile tests and impact tests were performed. These properties were first measured in the normal state and then after performing the weathering test. Then the resistance to weather conditions was studied as per the ASTM-G23 by utilizing a QUV weatherometer of the USA. The created specimen samples were put under ultraviolet rays for a time of 192 hours utilizing the accelerated method of weathering to predict the life of the specimen samples. The results showed excellent conditions of the specimens due to the presence of carbon black in the PPCP material. The mechanical properties such as tensile strength and impact strength showed negligible variations in the material after the weathering test.

Fig. 3.Ultra Violet Weathering Resistance Machine

DSC (Differential scanning calorimetry). DSC analysis has been performed on the different proportions of RPPCP and RGF. It is seen that the chains of carbon-hydrogen are undergoing change and elongated by the incorporation of heat, pressure and other ingredients or constituents present in the structure of the composite which results in realignment extension and increment in the crystalline property of the composite material. Due to this, the mechanical properties are improved. This test was carried out by DSC 8000 (Perkin Elmer, USA) as shown in fig: 4.

Fig. 4.DSC 8000 (Perkin Elmer, USA)

III. RESULT

DSC test was done on the prepared six samples. These six samples vary in different mixing proportions of the RPPCP and RGF. These proportions are presented in table 1.

As tests were performed on six samples, first observation from 100% RPPCP and 0% RGF to 70% RPPCP and 30% RGF shows a trend of increasing area of the triangle formed by the graph. This trend shows as the area increases, the enthalpy required to break the bond also increases. This relation between area and enthalpy is defined in eq. 1, where ΔH is the enthalpy, K is the calorimetric constant and A is the area under the curve. This increase of enthalpy shows the increase in strength of bond inside the material, thus increasing the crystallinity of the material and moving towards crystalline nature away from amorphous.

$$\Delta H = K \times A \quad \text{(eq. 1)}$$

Further, when the samples 65% RPPCP – 35% RGF and 60% RPPCP – 40% RGF are observed, it was vice versa of the first trend. The area subsequently started decreasing which shows the decreasing enthalpy needed to break the bond. As the enthalpy decreases, the crystallinity is also decreased and material moves towards being amorphous. These patterns can be observed in fig: 6 which is a comparison graph of enthalpies of six samples. Table 2 shows the areas acquired by different samples in the DSC test and associated enthalpy with it.

Table- II: Areas and Enthalpies of different samples in DSC analysis

S. No.	Percentage of RPPCP-RGF	Area under the curve for Heating	Enthalpy Absorbed	Area under the curve for Cooling	Enthalpy Released
1.	100% RPPCP-0% RGF	158.3540 mJ	31.6078 J/g	164.3350 mJ	32.8670 J/g
2.	90% RPPCP-10% RGF	253.8020 mJ	50.7604J/g	247.0009mJ	49.4002J/g
3.	80% RPPCP-20% RGF	370.3017 mJ	74.0603 J/g	296.3675 mJ	59.2735 J/g
4.	70% RPPCP-30% RGF	459.9624 mJ	91.9925 J/g	502.1228 mJ	100.4246 J/g
5.	65% RPPCP-35% RGF	342.9685 mJ	75.2546 J/g	348.4965 mJ	72.6849 J/g
6.	60% RPPCP-40% RGF	316.2346 mJ	64.8562 J/g	329.4759 mJ	66.7581 J/g

Fig: 5 shows the DSC graph of the 100% RPPCP and 0% RGF. The observation shows the area formed at 166 ^{0}C is 147.2763 mJ. The enthalpy absorbed at this area is 29.4553 J/g.

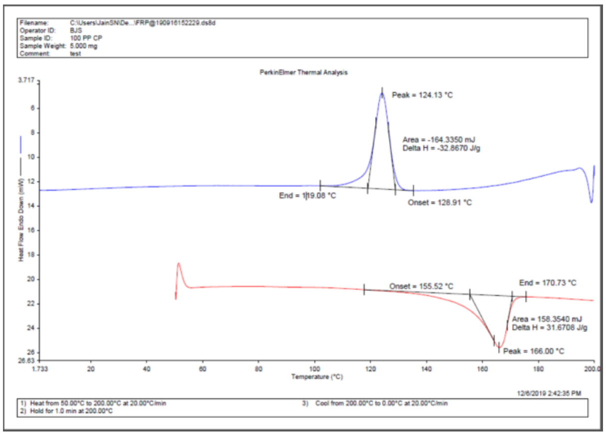

Fig. 5.DSC Graph of Sample 1 – 100% RPPCP and 0% RGF

Sample 4 in which 70% RPPCP and 30% RGF is mixed turns out to be the best in observations. After this, the values of area and enthalpy started decreasing. Fig: 6 shows the DSC graph of this sample. The observation shows the area formed at temperature 166.7 0C is 459.9624 mJ. The enthalpy absorbed in this area is 91.9925 J/g.

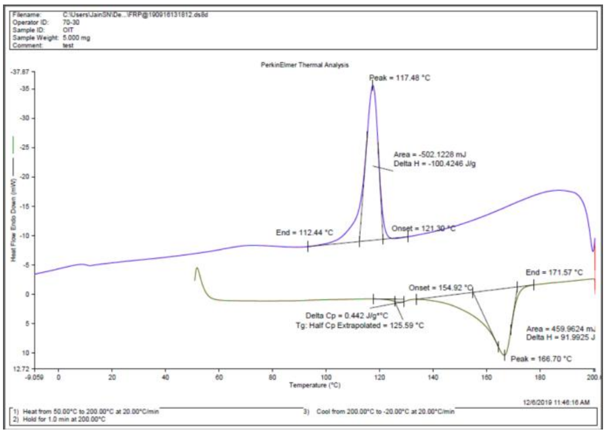

Fig. 6.DSC graph of Sample 4 – 70% RPPCP and 30% RGF

The trend of the increasing area along with the enthalpy and vice versa of the same, after a certain point, is shown as the comparison between values of enthalpies of six samples in the fig: 7 Comparison Graph.

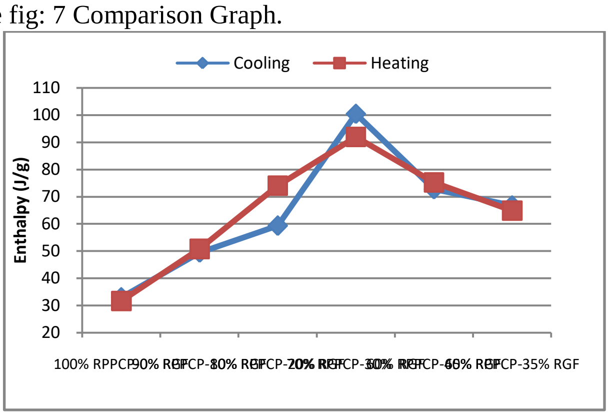

Fig. 7.Comparison Graph of Enthalpy Absorbed by Six Samples

IV. CONCLUSION

The workflow has begun with the manufacturing of the blend of two materials, i.e. PPCP and GF. These two were mixed to form a composite RPPCP or Recycled PPCP and Recycled glass fiber RGF. This composition is utilized to make different proportion along with RGF to form 6 samples. These samples having different proportions of two materials were then tested. First, weatherometer is used to test in accelerated weathering conditions. This test showed brilliant results on all specimens tested and the carbon black in the material is responsible for that. There was negligible variation in the tensile and impact strength of the material.

Similarly, the next DSC analysis was done on all samples of a composite of RPPCP and RGF. This test showed great results for sample 4 containing 70% RPPCP and 30% RGF. DSC shows that after forming a composite with different configurations of volume percentage, results are in a trend of increasing enthalpy up to sample 4 and then decreasing. From this trend, sample 4 turns out to be the best sample among six.

FUTURE SCOPE

This work focuses on the DSC analysis and weathering test of composite formed of two materials, i.e. RPPCP and RGF. There are further more possibilities for new tests to be performed.

- Several mechanical tests could be performed on the same material, such as flexural test, hardness test, fatigue test etc.
- Material can be improved by forming any other combinations of recycled waste of other polymers and fibers.
- Along with the experimental study, FEM analysis of the material has the huge scope in future. This software based study can be very helpful in terms of time saving, cost saving and extending the results over a period of time.

ACKNOWLEDGMENT

I would like to thankfully acknowledge my guide Dr. Gajendra Dixit and Co-Guide Dr. Savita Dixit for the kind support extended to me in preparing and finalizing my research paper for publishing in the esteemed journal. I would also like to express my sincere thanks to Mr Yogesh Sharma and Mr Neeraj Kumar for the timely support in helping me at times of troubles while preparing the paper.

REFERENCES

1. M. Yeshwanth, K. Srinivas, K. S. N. Murthy, and M. Jagadish, “Glass based Additives for Enhancement of PPCP Properties,” Int. J. Sci. Res., vol. 5, no. 6, pp. 1360–1365, 2016.
2. K. Mohan Babu and M. Mettilda, “Studies on Mechanical, Thermal, and Morphological Properties of Glass Fibre Reinforced Polyoxymethylene Nanocomposite,” J. Appl. Chem., vol. 2014, pp. 1–8, 2014.
3. M. Altin Karataş and H. Gökkaya, “A review on machinability of carbon fiber reinforced polymer (CFRP) and glass fiber reinforced polymer (GFRP) composite materials,” Def. Technol., vol. 14, no. 4, pp. 318–326, 2018.
4. A. Kumre, R. S. Rana, and R. Purohit, “A Review on mechanical property of sisal glass fiber reinforced polymer composites,” Mater. Today Proc., vol. 4, no. 2, pp. 3466–3476, 2017.

5. S. R. Naqvi, H. M. Prabhakara, E. A. Bramer, W. Dierkes, R. Akkerman, and G. Brem, "A critical review on recycling of end-of-life carbon fibre/glass fibre reinforced composites waste using pyrolysis towards a circular economy," Resour. Conserv. Recycl., vol. 136, no. November 2017, pp. 118–129, 2018.
6. R. M. Bajracharya, A. C. Manalo, W. Karunasena, and K.-T. Lau, "Glass fibre and recycled mixed plastic wastes: recent developments and applications," vol. I, pp. 9–12, 2014.
7. M. Nechifor, Photochemical Behavior of Multicomponent Polymeric-based Materials, vol. 26. 2016.
8. J. H. Lin, C. L. Huang, C. F. Liu, C. K. Chen, Z. I. Lin, and C. W. Lou, "Polypropylene/short glass fibers composites: Effects of coupling agents on mechanical properties, thermal behaviors and morphology," Materials (Basel)., vol. 8, no. 12, pp. 8279–8291, 2015.
9. M. S. EL-Wazery, M. I. EL-Elamy, and S. H. Zoalfakar, "Mechanical properties of glass fiber reinforced polyester composites," Int. J. Appl. Sci. Eng., vol. 14, no. 3, pp. 121–131, 2017.

AUTHORS PROFILE

Bikram jit Singh was born in Agra U.P on 26th Jan 1969.He is currently pursuing his PHd in Mechanical Engineering from MANIT Bhopal his area of research is Plastics polymers and composites .He is working as Technical Officer At Central Institute of Plastics Engineering And Technology under Ministry of Chemicals and fertilizers Govt of India since 1992. He has worked on numerous projects pertinent to development of substitutes to conventional materials in the field of defence, packaging and automobiles. He is currently working actively with the municipal corporation for effectively implementing Plastic waste management and its recycling into many useful products.

Dr. Gajendra Dixit was born on January 12th 1959. He is working as Professor and Head of the Department Mechanical Engineering, Maulana Azad National Institute of Technology Bhopal. He is B.E. (Mechanical); M.Tech.(Materials); Ph.D.(Composite Materials). He has an experience of more than 33 Years. His specialization in research area includes Materials, Design, Energy Composites and Mechanical Engineering. He has worked on numerous projects pertinent to development of the MANIT technology incubation and Development of Entrepreneurs" Govt. of India (150 lacs ongoing), "Up-gradation of handicraft machine" European Union (50 lacs) completed, "Development of brake drum testing machine" CSIR New Delhi (7.5 lacs) completed and "Modrob of Applied Mechanics lab" MHRD New Delhi (10 lacs) completed. He has a total number of 71 publications to his credit. He published 29 Papers in International Journals, 07 Papers in National Journals and 15 Papers in national Level Conference and 20 papers in international conferences. And his Book is also published "Application of Natural Fibre as Reinforcement in Recycled Polypropylene Bio composites" 2014 (www.scrivenerpublishing.com).

Dr. Savita Dixit was born on 3rd March 1963 . She is working as Professor and Head of the Department Chemical Engineering, Maulana Azad National Institute of Technology Bhopal. She is Ph.D. (Chemistry), M.Phil., M.Sc. Chemistry. She has an experience of more than 32 Years. Her specialization research area includes Natural products, Environmental Chemistry, Polymer and Composite material, Biodiesel, Alternative fuel. She has worked on 110 Papers of International Journals, 14 Papers of National Journals and 85 Papers of International Level Conference. She has completed 15 PhD's, 07 PhD (Ongoing), 06 M.Tech Thesis, 20 B.Tech Projects.