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Manufacturing and Mechanical characterization of Injection moulded PET Glass fibres specimens with varying % of glass fibres.

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Abstract— the main aim of doing this project is to get a proper understanding regarding the Extrusion, Injection molding machines and processes. In the process of literature work, I learned that Mold temperature, Pressure (Injection pressure, holding pressure, pressure at the gate), Velocity of injection and Gate position play a very important role in the properties of the final component, especially when fibres are involved. Due to the limited resources, in this project only the Injection velocity has been varied and the difference in the mechanical properties of the specimens has been analysed. Polyethylene terephthalate along with Glass fibres is been used to carry out the manufacturing process because it is one of the widely used materials in the market and exhibits good properties compared to other plastics. It can also be easily handled.

Index Terms— Injection molding, Polymers, Glass Fibres, Extrusion, Compounding, Polymer mechanical testings, Reinforcement, Tensile, Charpy, Impact tests.

1 Introduction

Plastics: Plastics possess a great advantage over other materials used in various fields. The plastics constitutes of multiple compounds. The main advantage of plastic over other materials is that there is no need to rely on the limited types of materials available in nature i.e. plastic products can be engineered according to the required properties and can provide a combination of multiple specific properties unlike any other materials, offering best set of performances for the present and the future innovations. They possess properties like lightweight, robust, hygienic, resistance, flexible, shape memory, etc. In order to improve the performances of the plastics, they can be reinforced or mixed with certain materials like fibres, fillers, etc. which improve the performance of the plastic products in almost every aspect.

Glass Fibers: The fibres used in the reinforcement of the plastics are of different types and are used individually or combined according to the specification of the products. According to the availability of fibres, they can be classified into different types- Natural fibres, Animal fibres, Mineral fibres and manmade fibres (1). Each individual fibre is chosen according to the need of the product. In this project, we are using the glass fibres. The main advantage of glass fibres over other fibres is that it provides high corrosion resistance, light weight, economical, high strength, flexibility, etc. It has one seventh of weight to strength ratio which is a key property. It is very much flexible i.e. it can be used to manufacture all kinds of products using different manufacturing processes at a very low cost. There are two kinds of glass fibres based on the length of the fibres- short and long fibres. Both have their respective advantages and disadvantages but, here we are using short fibres due to limitation of the machines to manufacture long fibre plastics.

Polyethylene terephthalate: The matrix material used in the manufacturing of glass reinforced plastic is Polyethylene terephthalate. It is one of the most common plastics whose application varies across different industries. Polyethylene terephthalate: is a very mouldable material compared to other plastics. It is due to its versatility in being able to be moulded with ease despite of its semi-crystalline nature. It has very low melt viscosity that is it flows easily with low viscosity filling all kinds of melds with ease and thereby reducing the cycle time (2). It is a relatively inexpensive material, possesses high flexural strength because of its semi-crystalline nature, has a low coefficient of friction, resistant to moisture and wide range of chemicals, has good fatigue resistance and strong impact strength, good resistance towards electricity and can be easily repaired if damaged.

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2 STATE-OF-THE-ART:

2.1 EXTRUSION

Extrusion is a process used to create objects of a fixed cross-sectional profile. A material is pushed through a die of the desired cross-section. The two main advantages of this process over other manufacturing processes are its ability to create very complex cross-sections, and to work materials that are brittle, because the material only encounters compressive and shear stresses **(3)**. It also forms parts with an excellent surface finish. According to the numbers of screws in an extruder, the extrusion machine can be characterised into three types- single screw extruder, twin screw extruder, multi-screw extruder.

2.1.1. SINGLE SCREW EXTRUDER

Single screw extruder is more widely used for general plastics and recycled plastics which have no effect, or which are not dependant on the compounding ability. Due to the advantage of less hear of friction, more uniform shearing, larger conveying capacity of screw, more stable extrusion is possible.

2.1.2. TWIN SCREW EXTRUDER

Fig: Double screw extruder used for compounding process

Double screw extruder is more suitable for plastic material compounding and modification. In the twin screw extruder, the screw element combination can be done along with accurate metering of feeding hopper can be for various plastic compounding. Advantages of twin-screw extruder over single screw extruders are: Due to these following advantages, twin screw extruder is used to compound Polyethylene terephthalate and Glass fibres (4).

- The power consumption of the twin screw extruder is about 30% lower than single rod extruder.
- It is self-cleaning function, i.e. it makes the material obtain a complete surface renewal during the degassing section.
- The twin screw extruder operates on the principle of positive displacement of material, so high viscosity or low viscous materials can be added and due to the presence of multiple hoppers, fibres and fillers can be easily compounded to engineer the properties of the material.
- It is also suitable for heat- sensitive materials.
- It has excellent compounding and plasticizing ability.

2.2 INJECTION MOLDING

Injection moulding process is one of the most common process for manufacturing the plastic parts in the large volume. In the injection moulding process, the compounded pellets were used as the raw material. In this process when the raw material is taken the automatic Hooper and the required melting point temperature for the plastic material along with the glass fibres were given as the input to the machine. The proper mould temperature, mould cavity pressure, holding pressure, flow speed, volume was properly uploaded and then the composite was manufactured (3). In this when the fibres were used for the reinforcement then varying the flow rate will be the key factor for the arrangement of the fibre and this determines the mechanical strength of the composites and other properties. During the process it is very much important to note the required volume and actual volume of the melt flow to protect the mould from the damage. Proper melt temperature should be given as the input and also the proper and uniform cooling system should be arranged for the manufactured composite with the required properties without any shrinkage and Warpage in the material.

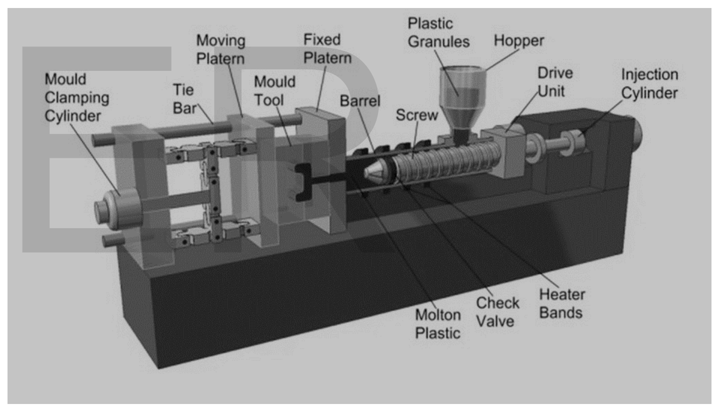


Fig: Schematic diagram of Injection Moulding machine (2)

2.3 TENSILE TESTING MACHINE:

As demonstrated in this document, the numbering for sections upper case Arabic numerals, then upper case Arabic numerals, separated by periods. Initial paragraphs after the section title are not indented. Only the initial, introductory paragraph has a drop cap. Tensile strength measurement is one of the most important mechanical properties to be measured in the injection moulding composites. The main parameters are the yield strength, tensile modulus, and the strain percentage of the material. ISO 527 is the standard used for the tensile strength measurement with the load of 1N/mm/min (5). There are different test speeds are available and depends on the speed of the test conducted the corresponding result parameters are also gets varied. The grip to grip separation will be varied depends on the usage of the material and 15N should be applied for tightening to have the proper grip to the material. The Universal tensile machine will be coupled with the software and the specification of the composites can be entered, the speed of the test, load applied for the test can also be controlled in the software itself. Mostly in some machines the camera will also be coupled to see the elongation of the material. And finally, the graph flow of the experiment can be obtained from the software and the results can be analysed.

2.4 Charpy Impact strength testing:

Impact strength of the low-density polyethylene can be measured using the machine. Normally it consists of the hammer and it will be used for striking the specimen which is on the specimen holder. The selection of the striker is mainly depending on the type of the material used or it can be selected through the calculations. At first any random hammer can be used for the experiment and depends on the result and calculations the decision should be taken to use the same or different hammer (6). In that we can able to do two test such as Charpy test and IZOD test. In the Charpy test the specimens should be placed horizontally with notch in the specimen and without the notch in the specimen. In the IZOD test the composite material should be placed vertically and its impact energy can be measured. In the end the coefficient of variance should be noted to have the proper reading for the test.

3 Procedure

Polyethylene terephthalate with glass fibre percentage of 0%, 10%, 15%, 20% and 25% are prepared and then tested. The procedure involves multiple steps:

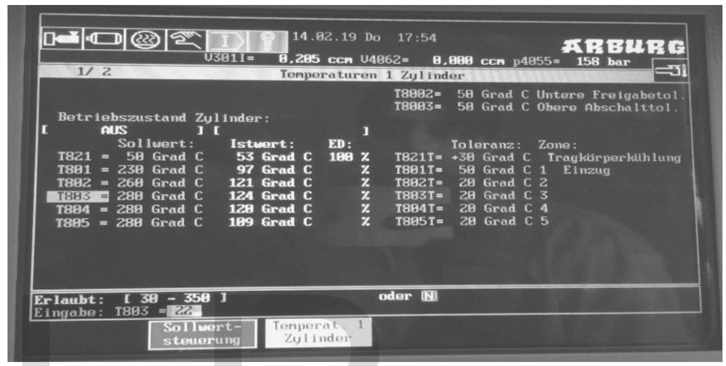
1. Extrusion: Compounding or mixing pure Polyethylene terephthalate with different percentages of glass fibres and then cutting the extruded products into small pellets.
2. Injection Molding: The pellets from the extrusion process are given as a feed into the injection molding machine and dog bone specimens are made with proper settings.
3. Mechanical Testing: The specimens from the injection molding are tested by conducting Tensile test, 3-point bending test and Charpy impact tests.

3.1 Extrusion

The extrusion machine consists of 11 different stages from feeding to the output of the material. The pure PP to be compounded is fed into the primary hopper and the glass fibre strands are fed into the secondary hopper. The % of fibre required to be compounded can be configured in the settings of the extrusion monitor (4). After the feeding % of respective fibres, the melting temperatures of the different heating zones is adjusted according to the melting temperature of the plastic and the rate of extrusion is also set. Once the material comes out of the Mold, the material is quenched in water and later passed through a blower which dries the material. The material from the blower is passed into the cutter which cuts the material into pellets suitable for feeding the injection molding machine.

3.2 Injection Molding

The plastic pellets compounded with glass fibres are fed into the hopper of the injection moulding material. The pellets from the hopper pass through a rotating screw which carry forward the pellets into the heating zone. The melting temperature for the compounded material can be given in the system which is coupled to the machine, and the cooling valve should be turned on to cool down the high temperature plastic material. The mould temperature can also be varied with the external motor, by changing the required temperature. Once the material is melted, the melted plastic is prepared to be shot into the mould cavity. The temperatures before the material enters the mould cavity are given at 5 degrees more than the actual melting temperature of the material to avoid back pressure from the mould cavity.



Before injecting the important thing is to note the required volume per shot volume and the actual volume of the material available for the shot. Depending on that the amount of material volume to be injected is varied to avoid flash. The experiment was conducted with different injection velocities to observe the change in fibre orientation which influence the mechanical properties of the specimens. The injection velocities used for the manufacturing process were 10m/min, the holding pressure of the mould is about 600 bars for the time of 5s and the mould temperature is about 50 degree centigrade.

3.3 Testing & Analysis

3.3.1. Tensile & 3-Point Bending Testing:

Tensile strength measurement is one of the most important mechanical properties to measure the yield strength, Maximum tensile modulus of the material and its strength required for the material to get breakdown. The tensile test is normally performed in the universal testing machine with the two grips separated away at a distance depends on the size of the material used. The universal testing machine is coupled with the test expert II software and a camera is also connected to it to visualize the elongation of the material by focusing in it. Usually for the dog bone specimens from the injection moulding should have a grip to grip separation should be 110mm and the amount of the force should be given for the proper holding of the specimen should be around 1N/min. The specimen can be fixed between the two grips depends on the standard for the tensile test

ISO 527 for the composites (7). The specimens were in the range of 3.8 mm thickness, 9.7mm of width was taken. The specifications of the specimen should be provided to the software and other inputs such as test speed, amount of load should be applied etc. were controlled. The test was conducted for the test speeds of 5 mm/min.

3.3.2. Charpy Impact Testing:

Impact strength is used to measure the amount of energy required for breaking the composite material. The impact strength measurement tests are of two type Charpy test and IZOD test. In this experiment I have conducted only the Charpy test without the notch in the specimen. Usually the notch in the specimen will determine the stress concentration factor, plastic deformation of the material without the brittle nature and it makes harden at the point of the Notch to get break and obviously it will absorb more energy. Without the Notch in the specimen it will get deform other than getting break completely. With these specimens they were placed horizontally to the striker with the specimen size of 80*10mm and the pendulum gets oscillated with the striker in the end of the pendulum. The usage of the correct pendulum for the composite materials depends on the calculation of acN (1).

$$a_{cN} = (E_c / H*B_N)*10^3 \;\ldots\ldots\ldots\ldots (1)$$

E_c: Impact energy (KJ /m^2),
H: Thickness (mm),
B_N: Width (mm)

4. Results & Analysis

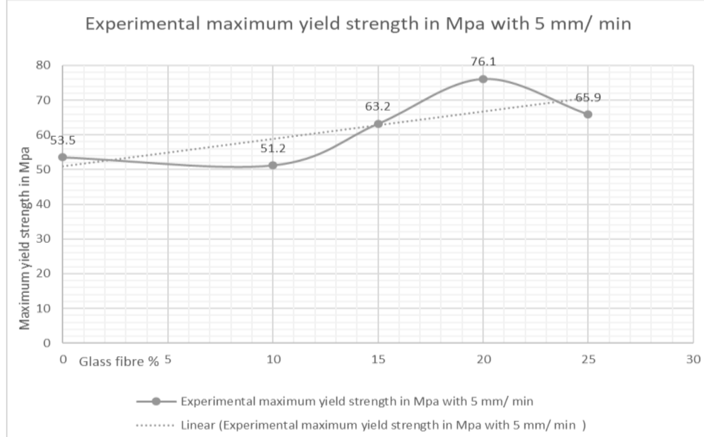
All the tests were performed on Polyethylene terephthalate as matrix material with 0%, 10%, 15%, 20% & 25% Glass fibres and with injection velocities of 10 m/min.

4.1. Tensile Testing

Tensile Testing was performed using speed of 5 mm/min with an increasing load of 1 N/min and an end to end separation of 115 mm. The results for all the specimens with different % of glass fibre.

Glass Fibre (%)	Experimental maximum yield strength in Mpa with 5 mm/ min
0	53,5
10	51,2
15	63,2
20	76,1
25	65,9

Table: Maximum Yield strength values of all the specimens.



Graph: Maximum Yield strength values of specimens with injection velocity of 10 m/min and tensile velocity of 5 mm/min.

From the above results data, it is clearly seen that for Polyethylene terephthalate with Glass fibres, as we increase the % of glass fibre the specimen showed greater tensile strength.

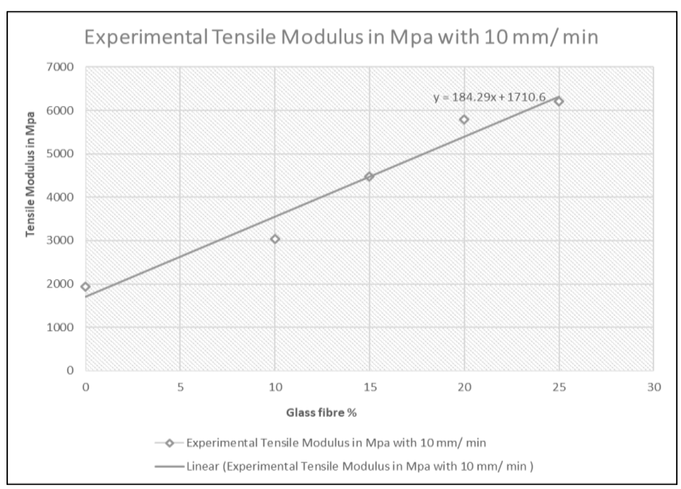
4.2. Flexural Testing:

The 3-Point Bending test was conducted on all the specimens with a pre-load of 0.1 MPa, flexural modulus of 2 mm/min and a test speed of 10mm/min. The results are as follows:

Injection Velocity (Test speed) (10 m/min)

Glass Fibre (%)	Experimental Tensile Modulus in Mpa with 10 mm/ min
0	1943
10	3033
15	4473
20	5796
25	6206

Tensile Modulus values of all specimens.



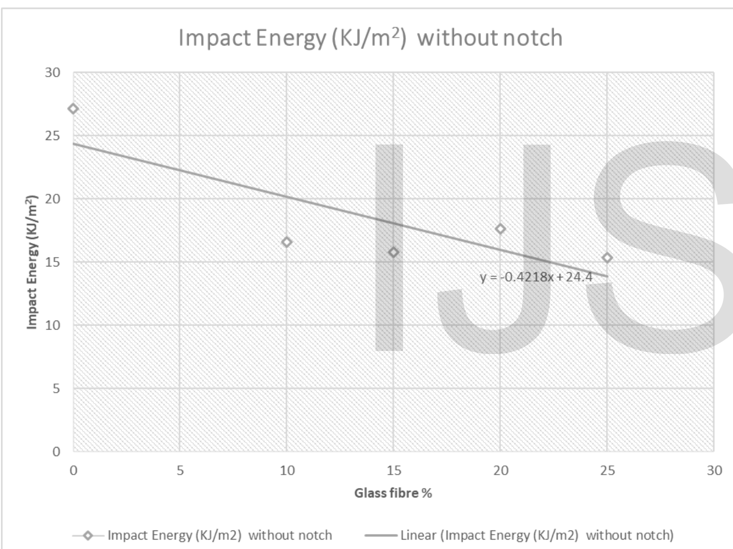
Graph: Tensile Modulus values of specimens with injection velocity of 10 mm/min.

4.3. Charpy Impact Test

The Charpy Impact Test was conducted on all the specimens with impact velocity of 2.9 m/sec and with the hammer weight of 1.189 kg (1). The results are tabulated as shown below,

Test No	Pure PET (10 m/min) Impact nergy (KJ/m2)	PET with 10 % of fibre (10 m/min)(KJ/m2)) Impact Energy (KJ/m2)	PET with 15 % of fibre (10 m/min) Impact Energy (KJ/m2)	PET with 20 % of fibre (10 m/min) Impact Energy (KJ/m2)	PET with 25 % of fibre (10 m/min) Impact Energy (KJ/m2)
1	29.98	21.72	14.81	15.21	14.45
2	17.79	11.6	18.07	20.92	15.21
3	33.64	16.47	14.45	16.74	16.35
Mean:	**27.13**	**17**	**15.77**	**17.62**	**15.33**

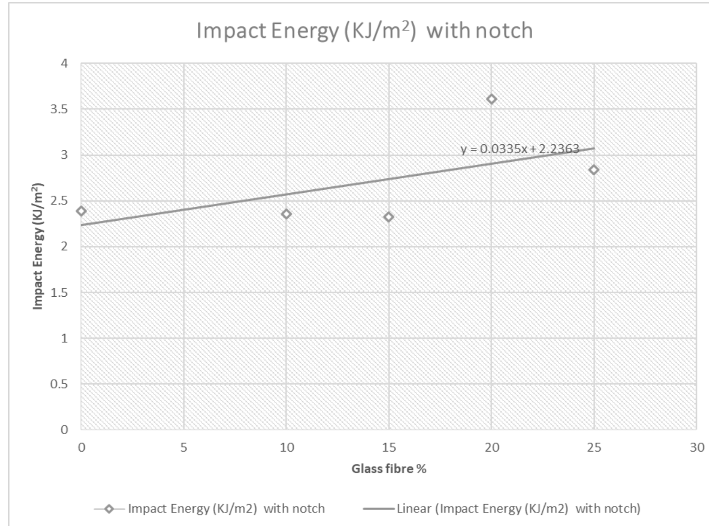
Table: Impact Energy values of all specimens without notch.



Graph: Impact Energy (KJ/m2) specimens without notch.

Test Number	Pure PET (10 m/min) Impact Energy (KJ/m2)	PET with 10 % of fibre (10m/min) Im-	PET with 15 % of fibre (10 m/min)	PET with 20 % of fibre (10 m/min)	PET with 25 % of fibre (10 m/min) Impact Energy (KJ/m2)
1	2.64	2.97	2.57	3.48	2.71
2	3.39	1.48	2.20	4.26	3.48
3	1.13	2.60	2.20	3.09	2.32
Mean:	**2.38**	**2.35**	**2.32**	**3.61**	**2.83**

Table: Impact Energy values of all specimens with notch.



Graph: Impact Energy (KJ/m2) specimens with notch.

After the comparison of results from the above data, for the specimens with notch has a linear increase in the Impact energy compared to the specimen without notch. Whereas for the specimens with 20 % glass fibres it showed higher impact energy than the respective specimen.

5. Conclusion

The purpose of conducting the experiment has been fulfilled and from the data & results it can be clearly seen that the there is a constant change in mechanical properties of the specimens when we vary the percentage of glass fibre. Though there is no drastic variation can be seen in a simple dog bone specimen, there will be a significant change in the properties when complex parts are manufactured with different fibre volumes and with different percentages of glass fibres. The desired properties of the final specimen can be predicted by running a process simulation of the injection molding process and a lot of effort and capital can be saved in the manufacturing process.

6. Acknowledgement

The purpose of conducting the experiment has been fulfilled I am using this opportunity to express my gratitude to my family and friends who supported me throughout the course of this research project. I am thankful for their aspiring guidance, invaluably constructive criticism and friendly advice during the project work. I am sincerely grateful to them for sharing their truthful and illuminating views on a number of issues related to the project.

7. References

1. Ur Engineering Labs. *Our labs Blog spot.* [Online] 2019. https://ourelabs.blogspot.com/2017/01/charpy-impact-test.html.
2. RTP Company. *RTP Company Corporate.* [Online] 2016. https://www.rtpcompany.com/products/product-guide/polyethylene-terephthalate-pet/.

3. Global Sources. *Doaho Shanghai Co. Ltd.* [Online] 2021. https://www.globalsources.com/si/AS/Doaho-Shanghai/6008848347640/pdtl/Universaltest-machine---Computer-servo-Tensile-test-equipment--bending-strength-testingmachine/1077902080.html.

4. Kerke. Kerke Extrusion Equipment. *Kerke Extrusion Equipment Corporation Website.* [Online] 2017. https://www.kerkeextruder.com/2017/04/twin-screw-extruder-vs-single-screw-extruder/.

5. Techminy.com. *Extrusion Molding process for Plastic Extrusion.* [Online] https://techminy.com/extrusion-moulding/.

6. Teel, John. A Predictable Design Corporation. *Predictable Designs.* [Online] 2018. https://predictabledesigns.com/introduction-to-injection-molding/.

7. *Composite Fibers from Recycled Plastics Using Melt Centrifugal Spinning.* Nicole E. Zander, Margaret Gillan, and Daniel Sweetser. 2017, MDPI Materials, pp. 41-43.

8. Creative Mechanisms. *Creative Mechanisms Corporations.* [Online] 2020. https://www.creativemechanisms.com/blog/everything-about-polyethylene-terephthalate-pet-polyester.

9. VR. Beetle Plastics. [Online] 2019. https://beetleplastics.com/tag/Fiberglass-reinforced-polymer/.