Analysis of Mechanical Properties of PP-Composites Fabricated by Injection Moulding

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***Abstract*- Polymer composites have a wide potential for various innovative applications. Due to high processability, Polypropylene (PP) is most widely used low melting point polymers by the manufacturing industries. In the present research, two ceramic micro fillers Alumina, titania (Al_2O_3 and TiO_2) and one marble industrial wastes (Marble micro dust) from Rajasthan have been used as the micro filler materials. By using Injection Moulding method, PP composites were fabricated having 5%, 10%, 15% and 20 weight percentages of filler Alumina (Al_2O_3), titania (TiO_2) and the Marble micro dust. Then the fabricated composites were investigated by bending strength and compressive strength with procedure of ASTM standards. It was investigated that among the three series of PP composite, max. bending strength was identified in PP-marble composite which was 65 MPa. Compressive strength (CS) of Polypropylene composite/ compounds with altered weight % (from 5 to 20 wt. %) having Al_2O_3, titania and white Marble micro dust obtained in increasing trend with 98.5-122 MPa, 114-172 MPa and 104–159 MPa respectively. Thus, it was observed that the max. CS was 88.26%, more than the virgin (unfilled) Polypropylene which was observed in titania- combination with 20 weights %.**

Keywords–: Injection molding, Composite materials, bending strength, compressive strength and marble micro-dust

1. INTRODUCTION

Natural resources are continuously consuming by humans to meet their needs. However, their importance in environmental sustainability has only recently been appreciated. Thus, it become necessary to produce sustainable destinations for the new materials to mitigate this trend and to improve its commercial worth. Globally it is seen that the growth of sustainable and process- able materials prepared from the regular assets are growing day by day. Polymer composites, are becoming an essential part of today's materials due to the benefits such as high endurance, low weight, corrosion resistance, and quicker assembly of their parts. New compounds has a excessive possiblity for cutting-edge uses to fulfil the emerging need of growing industries. It was investigated that new & better materials, the use of PP composites has been in demanding for automobile industires [1-2].

Alumina, which is too hard and abrasive -resistant, has effective micro filler in the PP composites having even dispersion and improved molecules interface between the reinforcement and parent resin matrix [3]. Alumina has strong resistance to acid, better dielectric properties and improved thermo-mechanical properties.

It has been shown by many researchers that titania (TiO_2) fine particles conferred noteworthy protection from Ultra rays to PP, extending better life of the products. This material is included in many cosmetic preparations to reflect light away from the skin. Epoxy PP films filled with Titania particles enhance elastic modulus upon Ultra rays' irradiation. Titania is easy to consume, very much stable and environment friendly solid. Due to combination of its excellent characteristics, it exhibits exceptional properties such as chemical stable, superior electrical properties, non-toxicity and photo stability. It has better photocatalytic characteristics and the great capability to absorb ultra-rays.

According to reports, India accounts for 14% of global white and grey marble production. Globally, India is the 3rd largest producer of natural white and grey marble, accounting for 70-85% of this volume in Rajasthan [4]. During the process of mining, the marble is subjected to cutting and sawing operations. These operations produce marble micro-dust as a waste. It was investigated that approx. 25% of excavated marble finishes as the marble slurry as a waste. According to reports, in Rajasthan, approximately 14 million Metric Tons of marble was mined, resulting in 3-7 million metric tons of marble slurry [5]. When this marble slurry is processed, it takes a huge land area. This waste affects the environment by reducing soil porosity and therefore land fertility. Thus there has been an astonishing increase in slurry-waste production. Therefore, finding appropriate application areas for these types

of slurry-waste is an extremely important job for researchers.

Few studies have exploited marble micro-dust by using waste into polymers to obtain an inexpensive useful component. Compared with other plastics, polypropylene's bending and impact strength exhibit better results over a wide deformation range, so it is generally considered a good strength material. Following Table-1 shows the comparison of present study and work studied earlier by the researchers.

Table 1:

Sr. No.	Comments	Ref. no.
1	In the research of Mallakpour et al. [1] solution blending technique and sol-gel techniques were used for fabrication of Polymer-Alumina composites. They showed that the dispersal is a very important aspect which gives better mechanical properties like tensile and bending strength along with the Elastic modulus.	1
2	Sathishkumar et al. [2] shown in their study about the hand lay-up and compression moulding methods which exhibits improvement in mechanical and tribological behaviours by glass fiber having alumina with 10 weight %.	2
3	Mashaly et al. [4] , Kore et al. [5] and Yen et al. [13] investigated about marble composites, and found that the marble composites could be utilized for industrial construction purpose as they give improved physical and mechanical properties like compressive and bending strength.	4,5, 13
4	Mirjalili et al. [7] investigated that due to better and homogenous distribution of PP-Alumina fine particles (1,3 and 5 weight %), they provide good strain-swing through mechanical loading which gives good morphological and mechanical properties in the compounds.	7
5	Turnšek et al. porous alumina-composites were prepared with an emulsion-templating procedure and after compacting and sintering the better mechanical stability were obtained in the composites [8].	8
6	Kumar et al. [3] and Arao et al. [9] used the injection moulded methods for fabrication of composites. Accoding to Arao et al. [9] injection moulded PP-carbon fiber with larger diameter alumina particles showed high strength due to better dispersion of alumina in PP matrix. In their research high bending strength and elastic modulus was obtained of the fabricated composites.	3,9
7	Omar et al. [10] studied that the compressive strength, modulus and hardness proportionally increase with the increase in strain-rate in the PP-composites.	10
8	Duan et al. [11] and Kumar et al. [14] investigated the experimental results exhibits the addition of TiO_2 enhances compressive strength of composite with the improvement in the shrinkage behaviour of the composite. 5% TiO_2 gives better results.	11,14
9	Zu-hua et al. [12] investigated with the help of scanning electron microscopy (SEM) that the existence of micro crack confirm that PP fiber can effectively use for the bridging pores - defects and it prevents the growing ways of micro-cracks, showing great improvement of mechanical properties.	12

2. MATERIALS AND METHODS

In the present study, weight ratios of 5 - 20 wt %. in the increasing steps of 5 wt. % micro filler alumina, Titania, and marble micro micro-dust were added to virgin polypropylene (PP) to make composites as shown in Figure 1-3, with an injection molding machine having capacity of 100 tons. The three-point bending test method is used, most commonly the transverse bending test, in which a composite's standard specimen is bent till the yield point. The bending strength shows the highest stress taken by composite at the time of its failure.

In this study, three-point bending tests of specimens were carried out for each composition of PP and micro filler with the help of a Universal Testing Machine (UTM) as shown in Figure 4. The size of the sample was 65×12×2 mm^3. It is performed as per standard of ASTM D-790 [6].

3. MECHANICAL CHARACTERIZATION

The variation in mechanical properties such as bending strength (flexural strength) and compressive strength of alumina, Titania and marble micro-dust filled PP composite were analysed.

3.1 Bending strength of Al_2O_3 filled PP-composites

Bending strength variety for unfilled and alumina filled PP-composites is shown in Figure 5. It uncovers that bending strength enhances with addition in alumina micro filler content in the polypropylene resin matrix. The reason behind the increase in bending strength may be that addition of micro filler content enhance the interfacial adhesion between Al_2O_3 and the PP resin matrix, which was not strong enough according to Mirjalili et al. [7]. Bending strength for virgin PP was observed at 51.8 MPa with the addition the of alumina micro filler from 0 wt. % to 5 wt. %, the bending strength increases from 51.8 MPa to 53.04 MPa. Further addition of the micro filler 5 wt. % to 10 wt. % shows increase in bending strength was 53.04 MPa to 56.11 MPa, similarly further increase of micro filler from 10 wt. % to 15 wt. % shows increase in bending strength to 58.22 MPa. Further, increase of micro filler from 15 wt. % to 20 wt. % shows increase in bending strength upto 59.26 MPa.

3.2 Bending strength of Titania filled PP-composites

Figure 5 shows variation in bending strength of PP and Titania-filled PP-composites. It can be exhibited that the composite PPT-5, the bending strength is

58.9 MPa, which is 13.8 % more than that of the Polypropylene.

Likewise, the bending strengths of composites 10 wt.%, 15 wt.%, and 20 wt.% are 57.4, 56.3, and 50.8 MPa, respectively. Therefore, a further increase in the Titania micro filler content in the PP matrix reduces the bending strength, as there are some parameters that affect the bending properties of the PP-composite. It was investigated by the researchers that affecting parameters are extent of micro filler's molecules spread in the parent matrix; the interfacial cohesion and the need for stable morphology to resist higher stresses during the formation of the micro filler matrix interface. A treated layer is formed on the upper surface of the Titania particles, making it the same hydrophobicity as PP.

According to investigation of Turnšek et al. [8], low wt.% Titania addition results in a decrease in bending strength due to fragile molecules adhesion between filler and resin matrix. Weaker interface adhesion results in a larger degree of particles-voiding. The high content of titanium dioxide particles in the matrix will cause the PP matrix to thin crack, resulting in early failure of the sample. With further addition of Titania micro fillers, the composite became more and more brittle, due to weak bonding.

Figure 1 Fabricated PP-Alumina composites

Figure 2 Fabricated PP-Titania composites

Figure 3 Fabricated PP-Marble Micro-dust composites

Figure 4 UTM machine

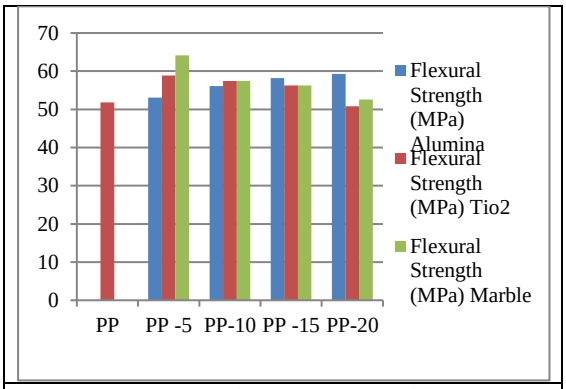

Figure 5 Comparison of Bending strength of fabricated PP composites

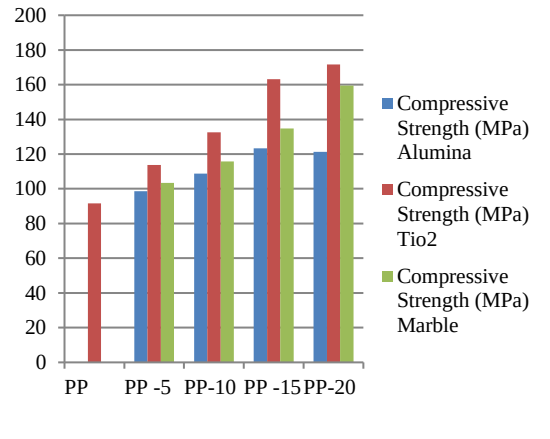

Figure 6 Comparison of Compressive Behaviuor of fabricated PP composites

3.3 Bending strength of Marble Micro-dust filled PP-composites

The change in bending strength of unfilled and marble micro dust PP- compounds are shown in Figure 5. It can be ovserved that the composite with 5 wt.%, the bending strength is 65.0 MPa, which is 25.48% better from the Polypropylene. Likewise, bending strengths of compounds with 10 wt.%, 15 wt.%, and 20 wt.%, are 57.5, 56.4, and approx. 52.56 MPa, respectively. Therefore, an additional increase in the micro-dust filler content in the Polypropylene decrese the bending phenomena, as there are several parameters (like interface moleculer tension) which affect the bending characteristics of mixtures materials.

3.4 Compressive Strength of Alumina-PP-composite

The compressive strength (CS) of alumina-filled PP -composites as a function of micro filler content is shown in Figure 6. It shows that the CS rises with the addition of alumina micro filler content to 15 weight % in the PP. But addition of more micro alumina exhibits a small reduction in the CS. According to Arao et al. [9] increased compressive strength can be due to the stronger link between the reinforcement and the PP matrix, which allocates this load between them. The CS of the unfilled PP was witnessed to be 91.36 MPa. Addition of alumina micro filler (5 wt.%), enhances the CS from 91.36 MPa to 98.5 MPa. Further it was observed that an increase in CS of 98.5 MPa to 108.82 MPa and 108.82 MPa to 123.25 MPa was obtained with 10 wt.% and 15 wt.% respectively of Alumina in the composite. But due to the occurrence of micro and nano-level of voids in the PP-composite further addition of filler decreases the CS from 123.25 MPa to 122 MPa. Researchers Arao et al. [9] and Omar et al. [10] observed same outcome for the particle-filled PP composites for 15 wt.% and they observed maximum compressive strength in range of 123.25 MPa in alumina micro filled PP-composite, which was 34.9% higher than PP resin.

3.5 Compressive Strength of Titania filled PP-composites

In the Figure 6, the compressive strength of Titania--PP-composites shown as a function of micro filler content. It can be perceived that with increasing micro filler, the CS of the compound also increased. The CS of the prepared composites 5, 10, 15, and 20 weigh percentages were 114, 132.5, 163.2 and 172 MPa, respectively. Therefore, the compound 20 wt.%, has the maximum CS, which is 88.26% more than that of pristine PP. This phenomenon occurs as the molecules of micro filler interact in a better way and makes good bonding.

Duan et al. [11] studied the addition of Titania to increase the CS of the polymer, which is relative to Titania filler. It can be observed by Zu-hua et al. [12], when 5 wt.% Titania was introduced, the strength enhancement effect of Titania on the PP was more obvious. The investigations show that the CS of PP composite of 32% (mass fraction) increases by 34%. It was investigated by researchers that the micro and nano level particle size of the micro filler plays significant role in improving the merged material's compressive strength.

3.6 Compressive Strength of Marble Micro-dust filled PP-composites

The compressive strength of marble micro-dust-filled PP-composites has shown in Figure 6. It can be detected that as the quantity of marble micro-dust filler increases, the CS of the PP-marble composite also enhances. The CS of the 5, 10, 15, and 20 weight percentage of the whicte marble micro dust PP-composites were 104, 115.7, 134.7 & 159 MPa, respectively. Therefore, among all Polyprpylene Marble micro-dust composites, 20 wt.% composite has the highest compressive strength, 74 % higher than PP resin. According to researchers, this enhancement in compressive strength occurs because of good spreading and improved micro level bonding between the micro marble dust & PP resin. Yen C. L. et al. [13] studied the compressive phenomena and other useful properties of ecological marble slurry. The possibility of substituting 45% of the costly mineral consumed in mass manufacturing of white cement combined with white marble-micro -dust was observed in the various experiments. Moreover, the same experimental conclusion was obtained by Kumar et al. [14] during study of the effect of marble-filled natural rubber composites.

4. CONCLUSION

In this study, it was exhibited that integrating alumina, Titania and marble micro-dust into PP improves the mechanical properties. The bending strengths of PP-Al_2O_3 composites with different weight percentages (from 5-20 wt.%) showed an increasing trend, ranging from 53.04 - 59.26 MPa.

In the PP-Titania composite, the bending strength increases initially, while further addition of micro fillers decreases the bending strength. Therefore, the composite PP-Titania having 5 wt.% exhibits the greatest bending strength among these composites.

The same results were exhibited in the PP Marble micro-dust composites as they likewise showed a decreasing tendency in bending strength, ranging from 65.0 - 52.56 MPa, respectively. The increase in micro filler loading led to weaken the correlation between micro filler particles and resin matrix. Therefore, among all three series of composites, the maximum bending strength of marble composite for 5 Wt.% was 65 MPa which was 25.4% higher than PP. It was due to less bonding with the molecules of filler and matrix and the deviated aspect- ratio spread of micro fillers, there was a downward trend obtained.

The compressive strengths of the Polyproplyene compounds having various percentages (5 to 20) of the Al_2O_3, Titania and the marble micro-dust are 98.5-122 MPa, 114-172 MPa and 104-159 MPa respectively. The maximum compressive strength is thus 88.26%, which is higher than that of PP with 20 wt.% found in the PP-Titania composite. It occurs due to good filler spread and good bonding between the Titania micro particles and the PP matrix.

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