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COMPARISON OF MECHANICAL BEHAVIOUR OF PP COMPOSITES FABRICATED BY PLASTIC INJECTION MOULDING

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Abstract

The development of high-performance materials made from natural resources is increasing worldwide. Polymer composites have a great potential for advanced applications. Polypropylene (PP) is one of the most extensively produced polymers, especially widely used as automotive parts due to its good impact resistance as well as processability. In the present study two conventional ceramic powders (Al_2O_3 and TiO_2) and one industrial wastes (Marble dust) have been used as the filler materials. Polypropylene composites were fabricated by varying different weight percentages (5%, 10%, 15% and 20%) of Alumina (Al_2O_3), Titanium dioxide (TiO_2) and Marble powder by using Injection Moulding Technique.

Then the fabricated composites were characterized by mechanical characterization such as Shore hardness test and Izod impact test. ASTM standards for Shore hardness and Izod impact strength were followed.

The inclusion of Alumina, Titanium dioxide and Marble powder into the Polypropylene led to an enhancement in hardness. The maximum value of shore hardness was found in PP- marble powder (20 wt.%) which was 30.35% higher than shore hardness of virgin PP. Adding Alumina and Titanium dioxide in PP composites, reduce the impact strength of the composites, however integration of Marble powder in PP, increases impact strength of the PP composites.

Keywords: **Composite materials, Alumina, Titanium dioxide and marble powder, injection moulding.**

INTRODUCTION

Globally it is seen that the development of high-performance materials made from natural resources is increasing day by day. Polymer composites have a great potential for advanced applications to fulfil the emerging need of automobiles and other growing industries. In the era of sustainable materials, the usage of polymer composites has been increasing. A composite material is synthesized of two components, known as a matrix system. Polymers such as thermoplastics and thermosets can be used as a matrix material to form a composite, as well as metals, ceramics and carbon. At the same time, the matrix system works as a binder for the filler system; fiberglass, graphite, aramid, silica and aluminium can be used for this purpose[1]. Both matrix and filler retain their individual identities when they join to form a composite and directly affect the properties of the final composite [2]. Elasticity and Impact strength of Polypropylene shows elasticity over a wide range of deflection in comparison to other plastics, but it shows plastic deformation early in the deformation process, so it is normally considered a good strength material.

MATERIALS AND METHODS

Four different ratios of 5 wt. %, 10 wt. %, 15 wt. % and 20 wt. % of filler Alumina, TiO2 and marble powder were added into virgin Polypropylene (PP) and thus composite materials were fabricated with injection moulding machine as shown in figure. 1-3. With a spring-loaded needle-like indenter, the resistance of a material to penetration measured known as Shore hardness. Hardness of plastics is normally measured by Shore scales. **Shore A** type scale is used for testing Elastomers (rubbers) and other soft polymers. **Shore D** scale is used for hard elastomers and other thermoplastic materials. Shore hardness is tested with an instrument called Durometer which is shown in Figure 4.

MECHANICAL CHARACTERIZATION

The variation in mechanical properties such as Shore hardness and Izod Impact Strength of alumina, T**i**O_2 and marble powder filled Polypropylene composite were analyzed.

Fig. 1 Fabricated PP-Al_2O_3 composites by Injection Moulding

Fig. 2 Fabricated PP-TiO_2 composites by Injection Moulding

Fig. 3 Fabricated PP-Marble Powder composites by Injection Moulding

3.1 Effect of Shore Hardness on Alumina filled Polypropylene composites

Figure 5 shows the hardness variation with filler content for Alumina, TiO_2 and marble filled PP composites. It reveals that hardness increases with increment in alumina filler content in PP matrix. This increase in particulate may be attributed to stiffer and more brittle than the resin matrix. According to investigation of Kumar et al. [5], the hardness test compacts the matrix and reinforcement arrangement, which results in improved stress transfer and resistance to indentation. The improvement in hardness of the composites reinforced with alumina filler from 0 wt. % to 20 wt. % in a step of 5 wt. % is 56, 58, 64, 68 and 70 respectively. The maximum hardness in alumina filled polypropylene composites was observed 70 for 20 wt. % and minimum hardness was observed 56 for virgin PP matrix material.

Figure 4 Shore (Durometer) hardness Test

3.2 Effect of Shore Hardness on TiO_2 filled PP composites

The variation in shore hardness with different filler content in PP- TiO_2 composites reveals that hardness increases with increase in TiO_2 filler content in PP matrix (Fig 5). An increased hardness may be because of a more rigid structure at the material's surface, which creates greater resistance to indentation that resulting in the hardness of the composites showing higher values. This behaviour is due to an increased crystallinity.

3.3 Effect of Shore Hardness on Marble filled PP composites

Similarly, the Shore hardness changes of different filler contents in PP-Marble composites indicate that the Shore hardness increases with the increase in the filler content of the marble powder in the PP matrix. This is the indication of the better reinforcement of the Marble micro particles in the PP-matrix (fig 5). The betterment in hardness of unfilled composites reinforced with marble powder filler from 0 wt. % to 20 wt. % in a step of 5 wt. % is 56, 67, 70, 72 and 73 respectively. It was observed that the max. shore hardness of 73 units was obtained PP-Marble - 20 among all the 12 composites.

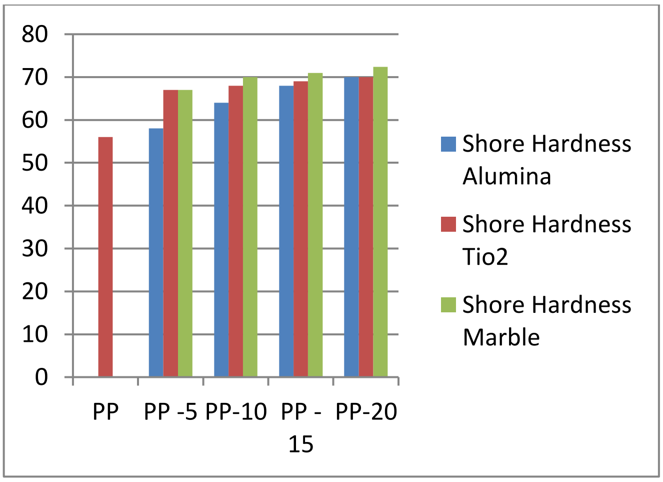

Fig 5 Comparison of Shore hardness of fabricated PP composites

3.4. Effect of Impact Strength on Alumina filled Polypropylene composites

The variation of impact strength with filler content for alumina filled PP composite is shown in Figure 6. It describes that the impact strength decreases as the filler content in the PP matrix increases. The reason for the decrease in impact strength may be the inherent ductility of the matrix, the void content, the weak interphase supporting filler/matrix debonding, and the proper inter-particle distance. Stress concentration firstly leads to debonding of filler particles and void formation. According to D. Kumar et al. [6] particle content affects the distance between particles and the stress state of the matrix polymer around the void. As the filler content increases from 0 wt.%, the impact strength decreases from 36 J/m to 21.32 J/m. % To 20 wt.% in polypropylene-based composites. The maximum impact strength of the original PP matrix was observed to be 36 J/m, and the minimum impact strength of the 20 wt.% alumina filled PP composite was observed to be 21.32 J/m. Pedrazzoli et al. [7] and Akil et al. [8] reported similar observations by using polypropylene composite materials.

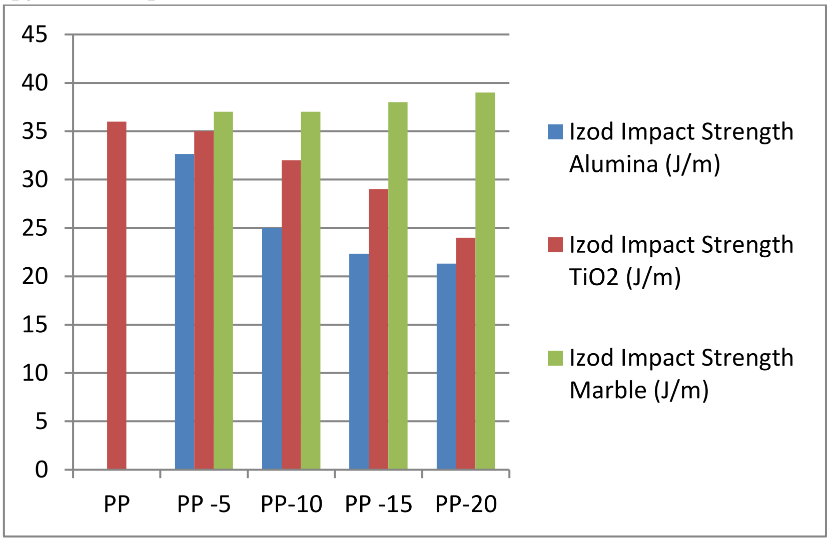

Fig 6. Comparison of Impact Strength of fabricated PP composites

3.5 Effect of Impact Strength on TiO_2 filled Polypropylene composites

Variation in impact strength for virgin PP and TiO_2 filled PP composites are shown in Figure 6. It was observed that Virgin PP, PPT-5, PPT-10, PPT-15 and PPT-20 have impact strength to be 36, 35, 32, 29 and 24 J/m respectively. It reveals that impact strength going to decrease with increment in filler TiO_2 in the PP matrix; it was due to the brittleness and hardness of the inorganic micro level particles. Generally elastic modulus, tensile strength, stress at break increase while the impact strength reduces. It was clear that all composites having impact strength less than impact strength of virgin PP. According to Daneshpayeh et al. [4], addition of a small amount of TiO_2 micro particles (max. 4 wt.%) enhanced the mechanical properties of composites. However, due to the agglomeration of particles, deterioration takes place in the mechanical properties by the further addition of the TiO_2 micro particles in composite.

According to Zohrevand et al., [9] presence of anhydride-modified polypropylene AM-PP provides uniform dispersion of the particles, primarily with the TiO_2 volume having less than 5 wt.%. By increasing TiO_2 volume, the amount of aggregates raises and the surface morphologies of the compatibilized and uncompatibilized specimens became analogous. According to Patel and Dhanola, [10] the good bonding strength between matrix, microfillers, and fiber and flexibility of the interface molecular results in absorbing and dispersing more energy, and prevents the early initiation of cracks more effectively.

3.6. Effect of Impact Strength on Marble filled PP composites

The variation of impact strength with filler content for Marble powder filled polypropylene composite is shown in Figure 6. It shows the impact strength improvement with increment in filler content into PP matrix. The reason behind increment in impact strength is inherent ductility of the matrix and strong inter-phase supporting the filler/matrix bonding. Marble powder having 5 and 10 wt.% consist impact strength to be 37 J/m and 38.5 J/m. Similarly, marble powder having 15 and 20 wt.% consists impact strength 39.7 and 40.6 J/m respectively.

Similar results were obtained by Ahmed et al. [11] during the study of behaviour of the effects of silica on the properties of marble filled natural rubber composites. In another study by Ahmed et al. [12] curing characteristics and mechanical properties of natural rubber hybrid composites reinforced with marble powder-Silica and marble powder-rice husk derived silica, were studied. The results from this study showed that the performance of rubber hybrid composites with Marble-Silica and rice husk as fillers has better mechanical properties compared with the case where only marble was used as single filler. The addition of silica and rice husk in marble composites improves significantly the tensile strength; tear strength hardness, modulus and crosslink density of the composites.

CONCLUSION

The incorporation of alumina, titanium dioxide and marble powder into the PP led to an enhancement in hardness. The hardness of PP composites filled with different weight-percentages of Alumina, Titanium dioxide and marble powder particle were in the range of 58-70, 67 - 70 and 67 - 73 respectively. The maximum value of shore hardness of PP composite was 73 indicated by PP composite filled with 20 wt.% marble powder. It is 30.35% higher than shore hardness of virgin PP. The impact strength of PP composites filled with different weight-percentage (0, 5, 10, 15 and 20 wt. %) of alumina and titanium dioxide decreases as the filler content increases. In PP-alumina composites, the impact strength decreases from 36 J/m to 21.32 J/m which was due to the increasing void content. Similarly, in PP-TiO_2 composites PPT-5, PPT-10, PPT-15 and PPT-20 have Impact strength to be 35, 32, 29 and 24 J/m respectively. On the other hand, adding of marble powder increases impact strength of PP composites. Marble powder having 5 and 10 wt.% consist impact strength to be 37 J/m and 38.5 J/m. Marble powder having 15 and 20 wt.% consists increasing trend of impact strength from 39.7 to 40.6 J/m respectively. Thus, PPM-20 has 11.33 % higher impact strength than virgin PP.

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Renewable energy and sustainable development are the key technologies to offer solutions to the ever-increasing environmental pollutions and depleting conventional fuel reserves. With an aim to discuss the state of art technologies pertaining to the renewable energy domain, RTU (ATU) TEQIP III Sponsored 3rd International Conference on New and Renewable Energy Resources for Sustainable Future (ICONRER-2021) was organized by the Department of Mechanical Engineering, Swami Keshvanand Institute of Technology, Management and Gramothan, Jaipur in collaboration with Rajasthan Technical University and Department of Mechanical Engineering, Assiut University, Assiut (Egypt) from February 11 to 13, 2021. ICONRER is a series of the conference started in 2017 and it was 3rd event of that series.

असतो मा सद्गमय

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