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MECHANICAL AND MICROMECHANICAL STUDIES ON POLYPROPYLENE COMPOSITES FILLED WITH TALC PARTICLES

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Abstract

In this research, the influences of adding talc particles on tensile and micromechanical properties of compression molded polypropylene (iPP)/talc composites were investigated. It is observed that stress-strain relationship of iPP and iPP-talc composites is non linear. It is also observed that with the increase of talc content the tensile strength (TS) of PP-talc composites decreases but Young modulus (YM) of the fabricated product increases. With the increase of talc addition the microhardness (H) values increase for iPP- talc composites up to 30 wt% and after that it decreases. The maximum value of H is 132 MPa for composites with 30 wt% talc. Reason of increasing H is that, talc and iPP are well distributed up to 30 wt%. The reason of decreasing H value for 40 and 50 wt% talc is probably due to poor interfacial adhesion between the talc particles and the iPP matrix as well as inhomogeneous distribution of talc particles at higher loading.

Keywords: Composites, polypropylene, microhardness, micromechanical properties

Introduction

Polymeric materials have received intense research interests for their good mechanical properties and process ability, which allow it to accept numerous types of natural and synthetic fillers. Its versatility has also led to the possibility of producing particulate-filled composites. The incorporation of fillers such as talc, mica, kaolin,

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calcium carbonate etc into thermoplastics is a common practice in the plastics industry, because it reduces the production costs of molded products. Fillers are also used to improve the mechanical, micromechanical and thermal properties of thermoplastics (Khunova et al., 1999).

Talc (derived from the Persian via Arabic *talq*) is a hydrated magnesium sheet silicate mineral (Fig.1) with the chemical formula, $Mg_3Si_4O_{10}(OH)_2$. Talc is practically insoluble in water, weak acids and alkalis. It is neither explosive nor flammable and has very little chemical reactivity. Talc finds use as a cosmetic (talcum powder), a lubricant, and a filler in paper manufacture. Talc is used in astringent powder, stoves, sinks, electrical switchboards. Talc is also used as food additive or in pharmaceutical products. Talc is widely used in the ceramics industry in both bodies and glazes (Ceiflon, 1980).

Isotactic polypropylene (iPP) is a plastic of, chemical formula $(C_3H_6)_n$ and is chemically similar to polyethylene (PE) but have somewhat better physical strength at a lower density. iPP i**s** manufactured from monomer propylene, which may be obtained by cracking butane. The chemical structure of isotactic polypropylene is as follows:

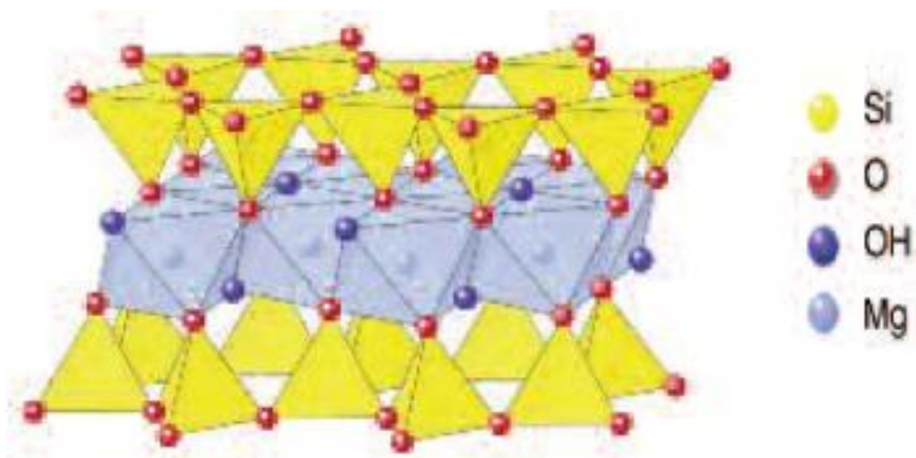
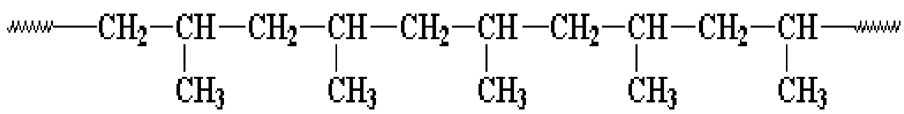


Fig. 1. Chemical structure of talc

iPP is most commonly used for plastic moldings at relatively low cost and high volume. Recently it has been produced in sheet form and this has been widely used for the production of stationary folders, packaging and storage boxes. This light weight, durable and colorful plastic makes it an ideal medium for the creation of light shades and a number of designs have been developed using interlocking sections to create elaborate designs. iPP sheets are a popular choice for trading card collectors; these come with pockets (nine for standard size cards) for the cards to be inserted and are used to protect their condition and are meant to be stored in a binder. iPP has been used in hernia repair operations to protect the body from new hernias in the same location (Wang et al., 2007).



isotactic polypropylene

Composite materials can be defined as substances consisting of two or more physically distinct and mechanically separable materials. Composites are composed of resins, reinforcements, fillers and additives. Each of these constituent materials or ingredients plays an important role in the processing and final performance of the end product.

Researchers around the world work to develop both new composite materials and also improve existing ones. A large number of research works has been dedicated to improve the properties and quality of composite materials to meet engineering requirements. Lubomir et al. (2008) studied the effect of microsize/nanosize talc filler on the physicochemical and mechanical properties of filled iPP composite matrices. Increasing filler content lead to an increase in the mechanical strength of the composite material with a simultaneous decrease in the fracture toughness. The observed increase in tensile strength ranged from 15 to 25% (the maximum tensile strength at break was found to be 22 MPa). The increase in mechanical strength simultaneously led to a higher brittleness, which was reflected in a decrease in the mean impact strength from the initial 18 kJ/m^2 to 14 kJ/m^2 that is a 23% decrease. Wang et al. (2007) analyzed an alternative method to modify talc for use in the fabrication of composites of iPP and talc. Grinding pulverization is employed to prepare talc fillers (referred to hereafter as p-talc). The morphology of iPP/p-talc composites illustrates particle orientation and a uniform dispersion of pulverized talc in the iPP matrix. Tjong and Li (1997) investigated mechanical properties and impact toughness of talc filled β-crystalline phase iPP composites. The X-ray diffraction analysis showed that the talc filler suppresses the formation of β-form iPP dramatically. As a result, the β-iPP composites containing talc content ≥ 20 wt% consisted mainly of the α-form iPP phase. The tensile test showed that the addition of talc filler up to 40 wt% leads to an increase in Young's modulus whereas little effect is observed on the yield strength of composites with the addition of talc up to 30%. Wulin et al. (2000) reported the effect of silane-grafted PP (PP-g-Si) on the mechanical properties and crystallization behaviors of talc/PP composites. Effect of PP-g-Si on the mechanical properties, crystallization, and melting behavior of PP composites was investigated. Compared with the uncoupled composites, the mechanical properties of talc/pp composites coupled with a small amount of PP-g-Si were increased to some extent. PP-g-Si can promote crystallization rate and increase crystallization temperature of iPP in the composites. Effects of filler treatments on the mechanical, flow, thermal, and morphological properties of talc and calcium carbonate filled iPP hybrid composites were studied by (Leong et al. 2004). The silane and titanate treatments dramatically increased the elongation at break for both the single-filler and hybrid-filler composites, whereas stearic acid did not. There was also a moderate improvement in the impact strength of the composites. The hybrid composites, through the synergistic coalescence of positive characteristics from talc and $CaCO_3$, had exceptionally good impact properties, more so with the aid of the coupling agents. Further investigations of the thermal and morphological properties were also conducted to facilitate the determination of the coupling mechanisms and their interesting effects on the hybrid composites.

The commonly used fillers in iPP are calcium carbonate and talc, whose effects in different properties of the composites were described in the literature. Properties of injection molded iPP/talc composites were investigated by some researchers. The aim of this research work is to prepared iPP/talc composites by extrusion cum compression molding technique and investigate the mechanical and micromechanical properties of these composites with a view to find its suitability in various industrial and scientific application.

Materials and Methods

In this work, composites were prepared from iPP and talc. Commercial grade iPP was purchased from BASF, Germany. The density of iPP is 0.91 g/cc and its melting temperature is 438 K. Talc was collected from local market having in the form of powder. The density of talc is 0.56g/cc and melting temperature 1073 K. Several equipment was used for preparation of samples. The main equipments are as follows-

1. Extrusion machine**:** The extrusion machine was set up in the laboratory of BUET, Dhaka (Fig. 2a)

2. Paul-Otto Weber-press machine (shown in Fig. 2b) was set up at BCSIR, Dhaka.

At first, five different composites were prepared by iPP and talc powder according to the ratio (10-X) PP: X talc, where X =1, 2, 3, 4, 5. Besides these, one pure iPP sample was also prepared. The mixtures were kept in separate pot and then mixed uniformly as much as possible. The different mixtures were melted by an extrusion machine. Three heaters of extrusion machine were switched 'ON' for about one hour. The barrel was heated for about one hour at 513 K. After heating for one hour the mixture was put into the feed hopper. The motor was then switched on to feed the batch from the feed hopper into the barrel. The molten composite material was then collected through the die in the form of rod. These were cooled in a water bath during collection. The rods were then cut with a hexsaw. For converting the rod shape samples into dumbbell disc shape sample 450 kN Weber-Press machine were used. The heating temperature and initial pressure were set at 180 °C and 50 kN, respectively. After reaching the set temperature, the pressure was increased up to 100 kN and the heating system was stopped.

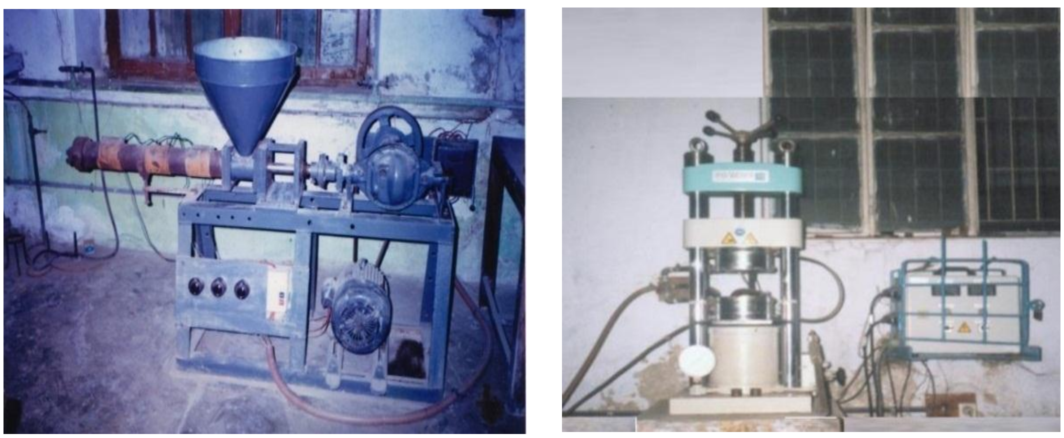


Fig. 2. (a) The Extrusion machine **(b)** Paul-Otto Weber Press machine

Fig. 3. Shimadzu micro hardness tester

A Software controlled vicker's square-based diamond indenter (Shimadzu, Japan) as shown in Fig. 3 was employed to measure the microhardness (H) from the residual impression on the sample surface after an indentation time of 15s. Loads of 0.245, 0.490 and 0.980 N were used to derive a load independent value of H in MPa by the following relation:

$H=K\ P/\ d^2$ where d (m) is the indentation diagonal, P (N) is the applied load and K a geometrical factor equal to1.854. For this measurement, samples with flat and smooth surface was preferred. 5 indentations were taken on the sample surface for each load and the H was evaluated from the average value of all impressions (Balta and Fakirov, 2000).

For the mechanical testing of the samples a universal testing machine (Hounsfield UTM 10KN) shown in Fig. 4 was used. Tensile specimen was prepared according to (ASTM D-638M-91) and the tensile measurements were performed at a crosshead speed of 1 mm/min. The specimen dimension was (80m×10m×3m) and support span was 64 mm. At each composition at least five samples were tested and the average results are reported.

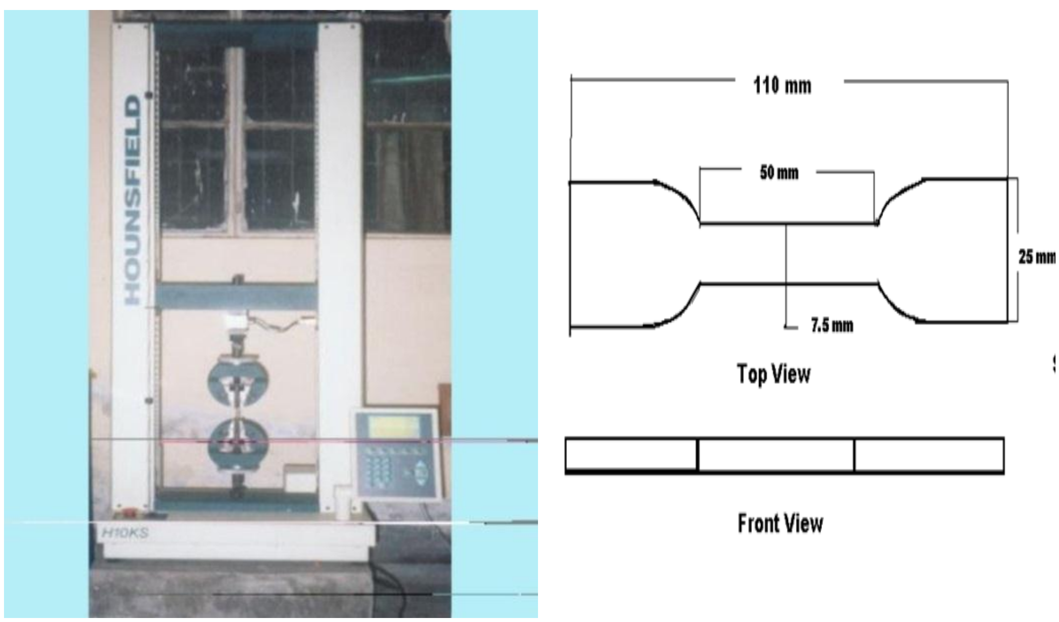


Fig. 4. (a) UTM Machine (Hounsfield test equipment) (b) Different views of the tensile test sample

Results and Discussion

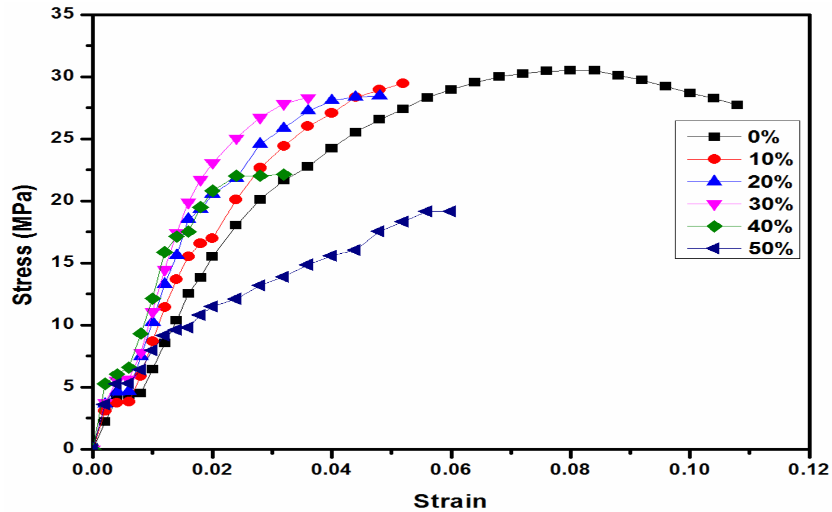


Fig. 5. Effect of talc addition on stress – strain curve of iPP and iPP-talc composites

In Fig. 5 it can be observed that stress-strain relationship of iPP and iPP-talc composites is non linear. Each curve shows the maximum stress; after this point, stress decreases steadily with strain until fracture occurs in case of iPP but other than iPP, composites show increases of stress to the maximum after which falls due to fracture of the samples. From this Fig. it is also observed that tensile stress and strain are maximum for iPP.

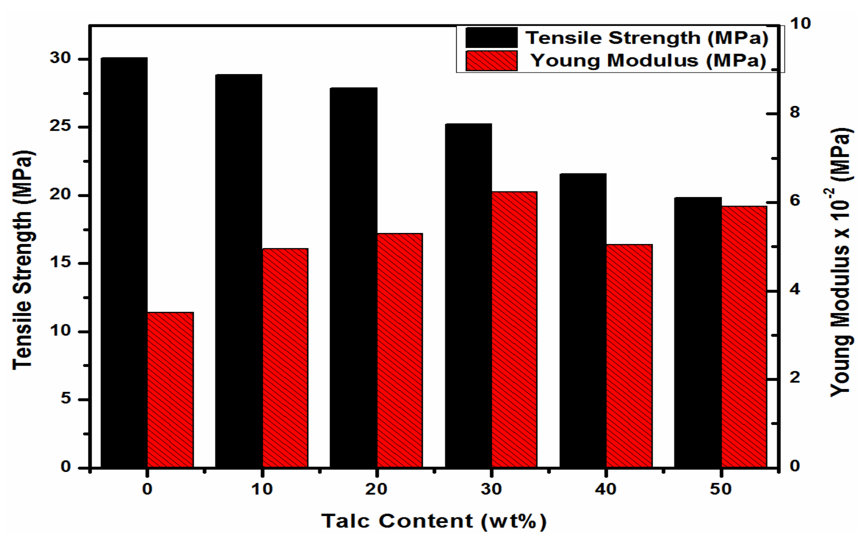


Fig. 6. Effect of talc addition on tensile strength and Young modulus of iPP-talc composites.

From Fig. 6, it is observed that with the increase of talc content the tensile strength (TS) of iPP-talc composites decreases but Young modulus (YM) of the fabricated product increases. YM value is highest for 30% talc. Therefore stiffness of the iPP-talc composites increases with the increase of talc content.

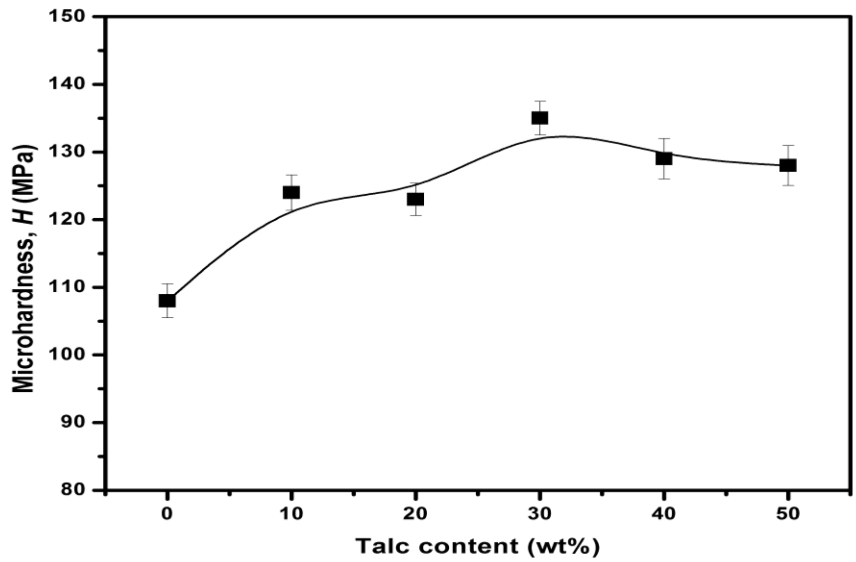


Fig. 7. Effect of talc addition on microhardness of iPP-talc composites.

Fig. 7 shows the effect of talc addition on microhardness (H) of iPP-talc composites. It is seen that with the increase of talc addition the H values increases for iPP- talc composites up to 30 wt% after that it decreases. The maximum value of H is 132 MPa for composites with 30 wt% talc. Reason of increasing H is probably that talc and iPP are well distributed up to 30 wt%. The reason of decreasing H value for 40 and 50 wt% talc is probably due to poor interfacial adhesion between the talc particles and the iPP matrix as well as inhomogeneous distribution of talc in the matrix at higher content of filler.

Conclusions

Tensile and micromechanical properties of compression molded iPP/talc composites have been investigated by this research. It is observed that stress-strain relationship of iPP and iPP-talc composites is non linear. With the increase of talc content the TS of iPP-talc composites decreases but YM of the fabricated product increases. YM value is highest for 30% talc. It is also seen that with the increase of talc addition, the H values increase for iPP- talc composites up to 30 wt% after that it decreases. The maximum value of H is 132 MPa for composites with 30 wt% talc. The mechanical and micromechanical test results suggest that 30 wt% is an optimum talc concentration at which these composites have improved micromechanical properties. So iPP with 30 wt% talc can be used for industrial and scientific application.

Acknowledgments

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