Mechanical Behavior of Nylon Composites Containing Talc and Kaolin

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ABSTRACT: Particulate reinforced thermoplastic composites are designed to improve the properties and to lower the overall cost of engineering plastics. In this study, the influence of adding talc and kaolin fillers on the mechanical properties of nylon 6 was investigated. Fillers, either singly or mixed by various weight ratios between 10 and 30 wt %, were added to nylon 6. Test samples of the composite material were prepared by the injection-molding process. Uniaxial tensile and Izod impact tests were carried out. Tensile strength, elongation at break, modulus of elasticity, and impact energy were obtained. The results showed that the tensile strength and modulus of elasticity of nylon 6 composite increased with the increase in filler ratio, whereas the impact strength and maximum elongation decreased with the increase in filler ratio. The optimal nylon composite was determined with the addition of a 10 to 15 wt % filler ratio.
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Key words: talc; kaolin; mechanical properties; nylon; thermoplastics

INTRODUCTION

Particulate reinforced thermoplastic composites have received considerable attention for many years. Great efforts have been taken to design composites with unique properties and low cost.[1,2] Particle-filled polymer composites have become attractive because of their wide application and low cost and widespread applications in household, automobile, and electrical industries.[3,4] Incorporating inorganic mineral fillers and/or organic fibers into plastic resin improves various physical properties of the materials, such as mechanical strength, modulus, and heat deflection temperature. Furthermore, replacing the volume of expensive resins with less costly filler results in lower costs.[3] In general, the mechanical properties of particulate-filled polymer composites depend strongly on the size, shape, and distribution of filler particles in the matrix polymer and good adhesion at the interface surface.[5,6] Nylons are one of the most widely used engineering thermoplastics, such as in automobile, electrical/electronic, packaging, textiles, and consumer applications, because of their excellent mechanical properties.[3,7–9] However, limitations in mechanical properties, the low heat deflection temperature, high water absorption, and dimensional instability of pure nylons have prevented their applications to structural components. Hence, numerous efforts have been undertaken to use nylons as matrix resins for composites by adding inorganic fillers such as aluminatrihydrate, clays, talc, silica, montmorillonite, wollastonite, and kaolin.[10] In this investigation, kaolin and talc fillers, either singly or mixed by weight ratios, were added to nylon 6 polymer. Influences of the addition of these fillers on the tensile strength, modulus of elasticity, elongation at break, and impact strength properties of nylon 6 were examined. Finally, we sought to determine the optimal filler by weight ratio.

EXPERIMENTAL

Matrix material nylon 6 (density, 1.14 g/cm^3; relative viscosity, 2.7) was obtained from Domopolymers (Belgium). Filler additives and talc and kaolin fillers were added separately or in combination to nylon with 10, 15, and 20 wt % ratios (Table 1). The composite granules were prepared by use of an NR II-75 twin-screw extruder. Tensile and Izod impact samples (according to ISO 527 and ISO 180/1A standards, respectively) were prepared using an injection-molding machine with a barrel temperature of 220–250°C. Uniaxial tensile tests were carried out using a Zwick Z020 type test machine at a crosshead speed of 5 mm/min. The impact test was carried out at room temperature using a Zwick tester. Tensile strength, elastic modulus, elongation at break, and impact energy were obtained and recorded. To observe the morphology of the tensile

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TABLE I
Properties of the Material Used in This Study

Material	Supplier	Shape	Size (μm)	Density (g/cm³)
Nylon 6	Domopolymers	—	—	1.14
Kaolin	Dorfner	Flake	1.7	2.6
Talc	Omya Mining	Flake	6–9	2.7

fracture surface of the specimens, a scanning electron microscope (SEM; Model Camscan S4) was used. The specimens were coated with gold before observation. The acceleration voltage was 15 kV.

RESULTS AND DISCUSSION

Mechanical properties

Figure 1 shows the variation of tensile strength with filler by weight percentages. It is clear from this figure that the strength increases with the increase in the filler percentage. In the case of kaolin filler, the influence is noticeably significant for a 10 wt % filler addition. Above 10 wt % the influence of increasing filler ratio is not observed. In the case of talc, the strength follows an increasing and a decreasing profile with the increasing filler ratio. The increase is about 17 and 11% for kaolin and talc, respectively. Figure 2 presents the variation of the tensile strength with a mix combination of the two fillers with an overall 30 wt % ratio. The highest value is with 20 wt % kaolin + 10 wt % talc fillers ratio, respectively. This is almost equivalent to the influence that resulted from the single kaolin filler addition.

Figures 3 and 4 display the variation of modulus of elasticity with talc and kaolin fillers as single and as mixed compounds, respectively. The results show that the modulus of elasticity increases linearly with the

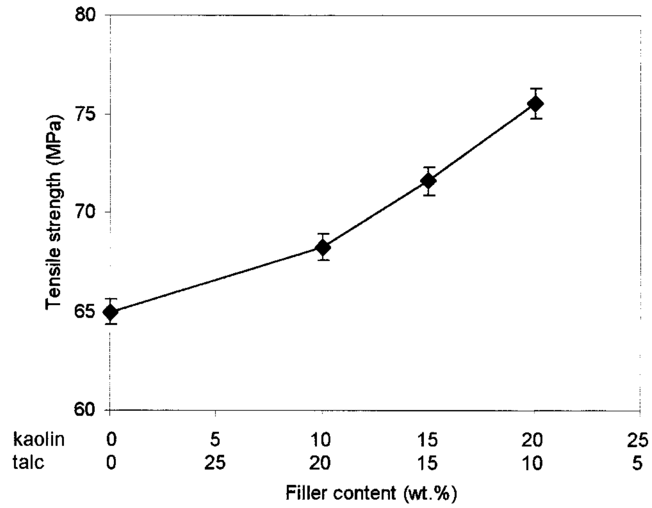

Figure 2 Variation of the tensile strength of nylon 6 with overall 30 wt % of mixed kaolin and talc fillers.

increase in filler ratio. For 20 wt % filler ratio, the increase was 104 and 72% for talc and kaolin fillers as single additions, respectively, and 104% for talc and kaolin fillers as a mixed-compound addition. The increase in modulus of elasticity is explained by the percolation theory described by He and Jiang,[11] which states that a matrix zone around each particle is affected by a stress concentration. Therefore, if the distance between particles is small enough, these zones join together and form a percolation network, which increases the modulus. Figures 5 and 6 illustrate the variation of impact strength with kaolin and talc as single and as mixed compound additions, respectively. It is clear from these figures that for single additions the impact strength decreases linearly with the increase in filler ratio. For 20 wt % filler ratio, the decrease is 23.5% for talc and kaolin fillers. In the case

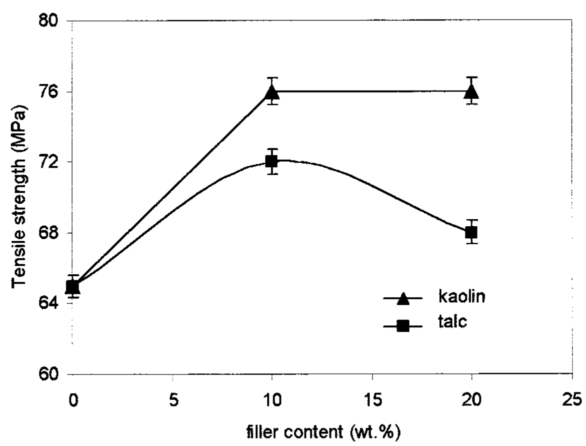

Figure 1 Variation of the tensile strength of nylon 6 with wt % of filler content.

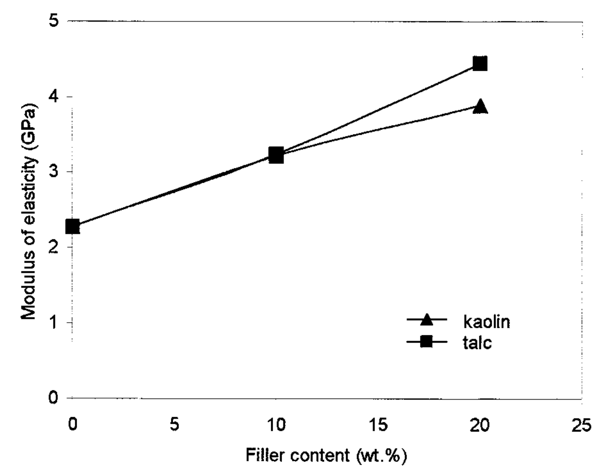

Figure 3 Variation of the modulus of elasticity of nylon 6 with wt % of filler content.

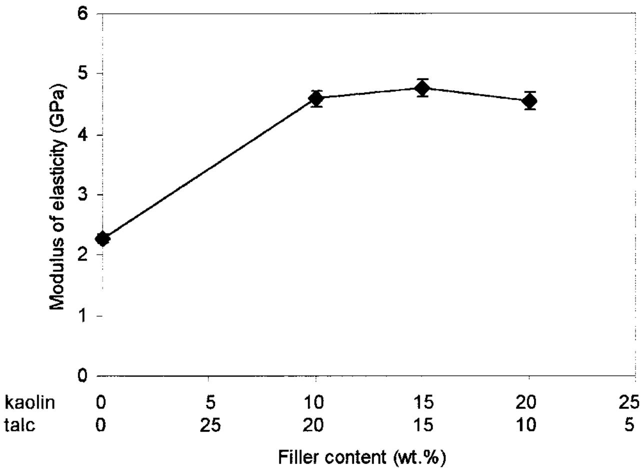

Figure 4 Variation of the modulus of elasticity of nylon 6 with overall 30 wt % of mixed kaolin and talc fillers.

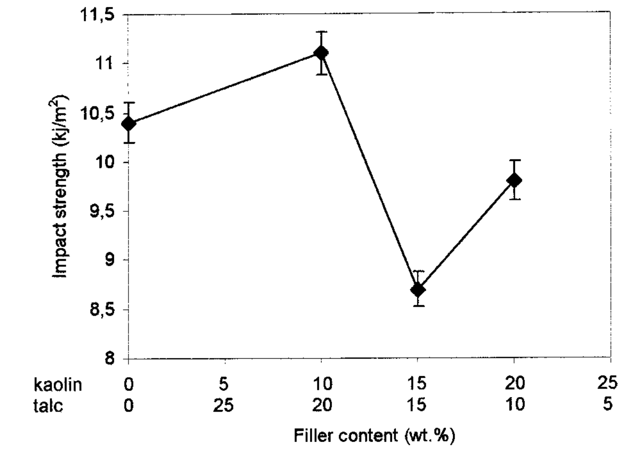

Figure 6 Variation of the impact strength of nylon 6 with overall 30 wt % of mixed kaolin and talc fillers.

of mixed-compound additions, there is a 7.6% increase in impact strength for 10% kaolin + 20% talc mix and there is a decrease of 17.3% for 20% kaolin + 10% talc mix. This suggests the lower degradation in impact strength by the addition of mixed fillers. The degradation in impact properties can be attributed to the immobilization of the macromolecular chains by the filler, which limits their ability to deform freely and makes the material less ductile.[12]

Figures 7 and 8 present the variation of the elongation at break with kaolin and talc fillers as single and as mixed-compound additions, respectively. The results show that the elongation at break decreases linearly with the increase in filler ratio. For 20 wt % filler ratio, the decrease is 88 and 97% for kaolin and talc fillers as single additions, respectively. In the case of 30% mixed-filler compound, the decrease in ductility is 92%. This shows the almost equal influence of the addition of these fillers as single and as mixed state. This is explained by immobilization of the macromolecular chains by the filler, which increases the brittleness of the polymer. For the filler materials and with the weight ratios used in this investigation, the superposition of all the results indicates that, apart from impact property, the addition of kaolin and talc with 20 wt % ratio as single ratio was optimal. In the case of mixed-compound addition, the optimal ratio was 10 wt % kaolin + 20 wt % talc.

Morphology

The SEM observation, often called a fractograph, is useful for clarifying the fracture mechanism.[13] The fracture surfaces of the specimens were examined and photographed by SEM subsequent to the mechanical testing. Micrographs of the nylon 6/kaolin/talc com-

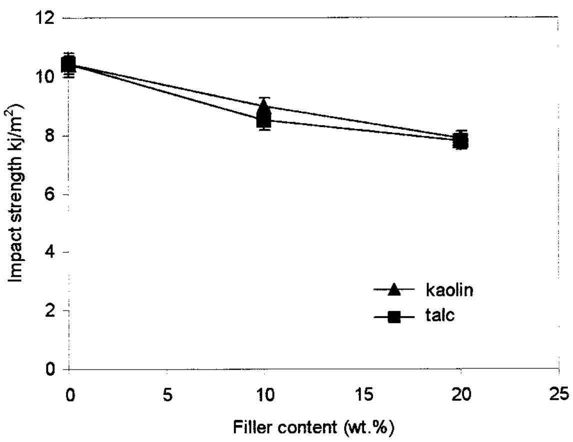

Figure 5 Variation of the impact strength of nylon 6 with wt % of filler content.

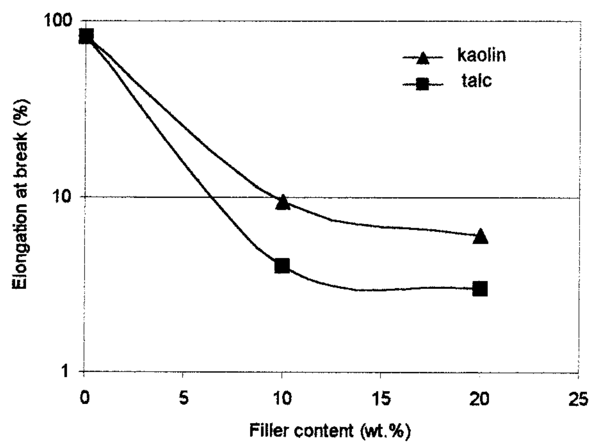

Figure 7 Variation of the elongation at break of nylon 6 with wt % of filler content.

posites at different ratios obtained from the injection-molded samples are shown in Figure 9(a), (b). Figure 9(a) shows the SEM micrograph of nylon 6 with 10 wt % kaolin + 20 wt % talc filler. In this figure the micrographs reveal the existence of aggregates. This is clearer for higher percentage contents of kaolin in composites [Fig. 9(b)]. In general the kaolin particles are more strongly inclined to agglomerate than the talc because of the nature of their surface. According to Griffith's theory,[14] a large aggregate is a weak point that lowers the stress required for the composite fracture. In this figure a large aggregate can be clearly distinguished in the micrograph of the fracture surface and it is also clear that the crack was propagated through it.

CONCLUSIONS

- The addition of kaolin and talc filler to nylon 6 improves the tensile strength and elastic modulus but weakens the impact strength and the ductility of the polymer.
- For a single filler, it is apparent that kaolin is optimal for improving both tensile strength and elastic modulus. Furthermore, the most suitable content of kaolin in nylon is at a 20 wt % ratio.
- The better improvement in properties of nylon 6 is reached either with kaolin filler or with 10 wt % kaolin + 20 wt % talc mixed fillers.
- In all cases the addition of the fillers dramatically decreases the ductility of the polymer.
- The addition of cheaper fillers has the advantage of low overall cost.

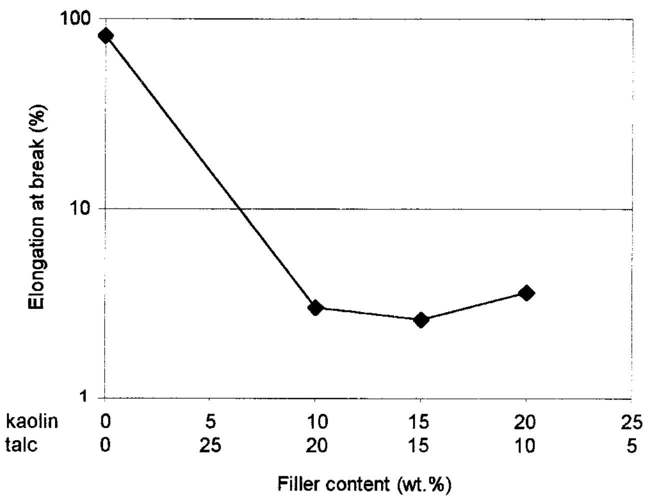

Figure 8 Variation of the elongation at break of nylon 6 with overall 30 wt % of mixed kaolin and talc fillers.

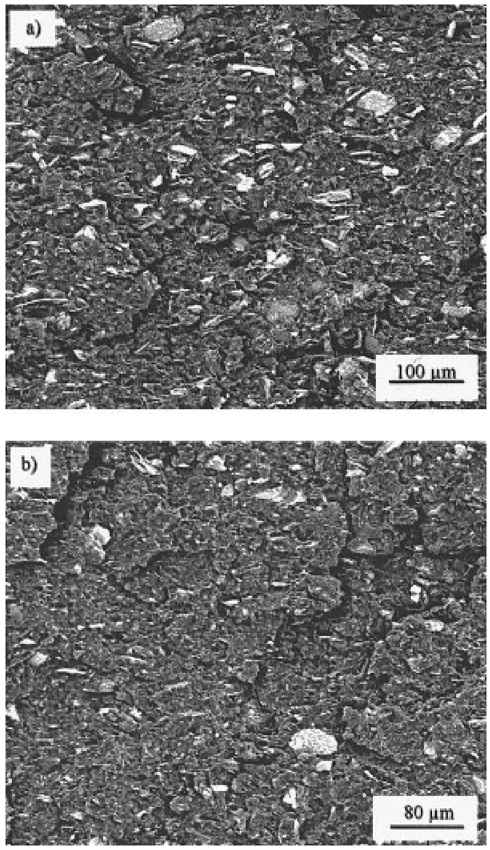

Figure 9 Scanning electron micrograph of tensile fracture cross section for the nylon with (a) 10 wt % kaolin + 20 wt % talc; (b) 20 wt % kaolin + 10 wt % talc.

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