# EFFECT OF TALC ON MECHANICAL PROPERTIES OF POLYPROPYLENE

# ẢNH HƯỞNG CỦA BỘT TALC ĐẾN CƠ TÍNH CỦA POLYPROPYLENE

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## ABSTRACT

*The extensive range of fillers used nowadays indicated the major significance of filler in the plastic industry. Although their original purpose was to lower the cost of the molding compounds; prime importance is now attached to selective modification of the properties of a specific plastic. With the aim of identifying the effect of Talc filler on mechanical properties of PP, the Talc powder which combined with PP at different portions of 10%, 20%, 30% by weight was studied in this paper. The tensile strength, flexural strength and hardness of samples were determined according to ASTM D638, ASTM D790 and ASTM D2240. The results show the decrease in the tensile strength, flexural strength comparing to those of pure PP; with the presence of 30% talc, the tensile strength decreased from 30.73 MPa of pure PP to 23.29 MPa, the flexural strength decreased from 49.31MPa to 47.62MPa. On the contrary, the hardness experienced an increase. The composites with 30% of talc had the highest hardness of 83.8HD, higher than the pure PP. In this study, the PP/Talc composites achieved the best comprehensive properties in presence of 10% Talc.*

***Keywords:*** *Polypropylene; Talc; Tensile strength; Flexural Strength; Hardness.*

## TÓM TẮT

*Phạm vi sử dụng rộng lớn của các chất độn hiện nay đã thể hiện tầm quan trọng của nó trong ngành công nghiệp nhựa. Mặc dù mục đích ban đầu của chất độn để giảm chi phí của các vật liệu ép khuôn, tuy nhiên lợi ích hàng đầu hiện nay gắn liền với sự điều chỉnh có tính chọn lọc các tính chất của các loại chất dẻo cụ thể. Với mục tiêu xác định ảnh hưởng của bột talc tới cơ tính của PP, bột Talc được đưa vào PP với các tỉ lệ khác nhau lần lượt là 10%, 20%, 30% (theo tỉ lệ khối lượng) đã được nghiên cứu trong bài báo này. Độ bền kéo, độ bền uốn và độ cứng của mẫu được xác định dựa trên tiêu chuẩn ASTM D638, ASTM D790 và ASTM 2240. Kết quả cho thấy độ bền kéo, độ bền uốn giảm dần khi so sánh với PP nguyên sinh. Với hàm lượng 30% bột talc, độ bền kéo giảm từ 30.73MPa xuống 23.29 MPa, độ bền uốn cũng giảm từ 49.31MPa xuống 47.62MPa. Ngược lại, kết quả đo độ cứng lại có xu hướng tăng lên. Hỗn hợp với 30% chất độn có độ cứng cao nhất với 83.8 HD, cao hơn mẫu nguyên sinh. Như vậy, trong nghiên cứu này composites PP/Talc đạt được tính chất toàn diện nhất với hàm lượng 10% bột talc tăng cường.*

***Từ khóa****: Polypropylene; Talc; độ bền kéo; độ bền uốn; độ cứng.*

## 1. INTRODUCTION

Polypropylene (PP) was widely used in a number of industries and fields, including construction, automobile and medical applications [1, 2]. Though PP has low density, good electrical insulation, chemical stability, excellent mechanical properties and good transparency and many other advantages [3, 4], the disadvantages of low strength, poor heat resistance and creep resistance also greatly limit the application as

high performance engineering plastic [5]. In order to overcome these limitations, numerous studies have been carried out to improve the toughness, stiffness, and strength balance; PP has been modified by many fillers and elastomers [6]. In the last decade, PP and its blends have been found to be interesting matrices for filled materials, due to their combination of remarkable properties and low cost [7,8].

Among the mineral fillers for PP, calcium carbonate was often used [9, 10]. Hamid Essabir studied a comparison between bio- and mineral $CaCO_3$ on the properties of PP composites. The samples (SS/PP and $CaCO_3$/PP) were compounded by extrusion with various filler content (5, 10, 15, 20, 25 and 30% wt.) The results showed that $CaCO_3$ composites (at 20% wt.) improved the thermal stability of PP by $27.5^0$C. Also, the tensile modulus of composites PP/$CaCO_3$ showed 97% improvement at 30% [10]. A.L.N Da Silva studied mechanical and rheological properties of composites based on polyolefin and mineral additives. In this paper, results of rheological and mechanical analysis on PP composites prepared with talc and $CaCO_3$ were reported. The addition of fillers provoked an increase in modulus of elasticity, stress at break and yield stress. It was also verified that melt viscosity increases with the addition of filler. The results are more significant with talc/PP blends and archive the highest result with the presentation of 15% talc [11]. Y. W. Leong studied the mechanical and thermal properties of talc and $CaCO_3$ filled PP hybrid composites, the polymer composite was fabricated by mixing polymer blend with different filler weight ratios of Talc/$CaCO_3$ (0:30, 5:25,10:20, 15:15, 20:10, 25:5, 30:0) wt.%, In present study, it was found that, talc dominant hybrid composites had higher tensile and flexural strength and modulus, whereas $CaCO_3$ dominant hybrids were tougher and more deformable. A hybridization effect was seen when 50% of talc was replaced with $CaCO_3$, as there was a more significant increase in the flexural and impact strength than in other hybrid compositions [9]. The reports showed that composite with talc performed higher mechanical properties than composites PP/$CaCO_3$.

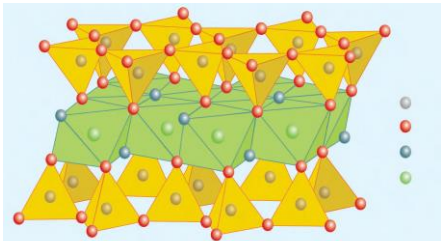


***Fig.1**. Crystal structure of Talcum [16]*

Besides $CaCO_3$, talc is one of the most common filler to reinforced PP because of its low cost and high aspect ratio [12~14] Talc nucleates PP and so reduces cycle time in moulding applications [15]. Pure talc, the softest of all minerals, was an organophilic, water repellent and chemically inert mineral. It was characterized as a hydrated magnesium sheet silicate with the formula $Mg_3Si_4O_{10}$ $(OH)_2$ [10]. Talc consists of a layer or sheet of brucite ($Mg(OH)_2$) sandwiched between two sheets of silica ($SiO_2$).The crystal structure of the Talc was shown in Fig.1 [16].

Many research works have been reported on talc fillers reinforced thermoplastic composites. Shri Kant studied of talc filled PP. The Talc/PP samples were compounded by extrusion with various filler content (10, 20, 30, 40 and 50% wt.) The tensile strength from results showed a decreased with filler % increases, flexural modulus increases with increases filler but it shows good result for 30~50 % talc filled PP in case of stiffness, modulus, HDT [3]. Wei Pan studied with various concentration of talc from 5 to 25phr, the result of mechanical properties were reported, when talc was added with a large amount, talc as rigid inorganic fillers can make the strengthening and toughening effects on PP/talc composites. The appropriate dosage of talc was 10phr, at which point the notched charpy impact strength and tensile strength achieved the maximum value. The

bending strength increased gradually with the increasing dosage of talc, but the elongation at break decreased dramatically [17]. M. Ali Khan found that on increasing the concentration of talcum powder from 10% to 20% in PP leads to increased modulus of elasticity because of increased brittleness in talc-PP matrix due to increased talc concentration as talc act as a strong reinforcing filler in PP-talc composites [5].

On the contrary, A. M. Zihlif shown that the yield stress decreased with the talc content, while the stiffness of the material increased [18]. R. J. Clark studied of talc filled PP, the mechanical properties of composites PP/talc (tensile strength, flexural strength...) were found to decreased with filler particle size [19,20]. Based on our literature search, there is no unified information on the mechanical properties of PP/talc composites. For these reasons, the main objective in this work is to study the effect of filler content on the properties of PP. To do so, blends based on PP were made with three different concentrations, which was 10, 20, 30% by weight.

## 2. EXPERIMENTAL SECTION

### 2.1 Material

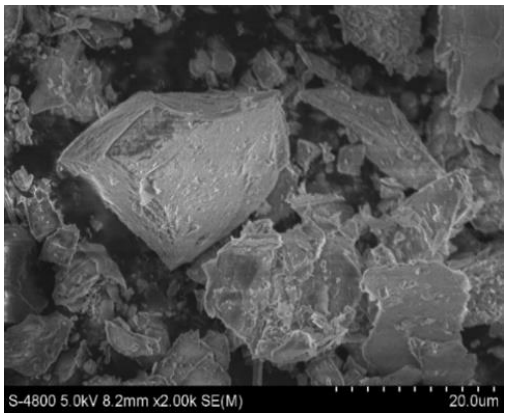



***Fig.2.*** *SEM Photomicrographs of Talc*

PP (Moplen HP500N) was supplied from Lyondell Basell Industries (Saudi Arabia). Talc (TMD) particle size was from 28 to 44 µm, whiteness ranged from 88-95%, chemical composition comprises $Fe_2O_3$ 2-3%, MgO 25-27%, CaO < 0.6%, $SiO_2$ 52-54%. Microstructure of talc was shown in Fig.2.

***Table 1****. Compositions of the samples (%wt.)*

| Components (%wt.) | | | | |
|---|---|---|---|---|
| **Material** | **Samples** | | | |
| | **$A_1$** | **$A_2$** | **$A_3$** | **$A_4$** |
| PP | 100 | 90 | 80 | 70 |
| Talc | 0 | 10 | 20 | 30 |

The samples were made by mixing and molding based on the rate given in Table 1 using computer systems mixing and extrusion Polylab research OS - Haake (Germany), which has the basic parameters of the system such as mixing chamber contained 120 $cm^3$, to study the plastic and rubber mixed with additives or other polymer processing conditions for the optimization (save time, temperature, speed, etc.), twin screw extrusion equipment L/D = 25, D = 16 mm to study the master batch mixture, based on the thermoplastic composite. Single screw extrusion equipment connected to: blown film system (blown film) and sheet extrusion system (0.2 to 1.2 mm x 100mm). Mixed samples were melt-blended during the period from 6-7 minutes with the temperature of the extruder zones was 180$^o$C. After extruding, the resulting pellets were dried at 80°C for 4h and then molded using injection molding machine into plates. The mold-temperature profiles was set at 180$^o$C. Molding process was carried out in 5 minutes and then cooled for 20 minutes. The size of plate samples after molding were 145x145mm and 2mm thickness.

### 2.2 Mechanical properties testing

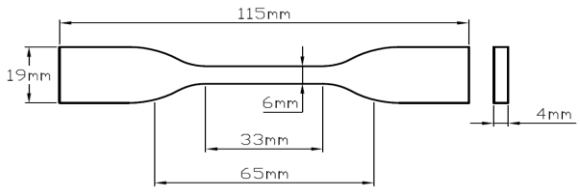



***Fig.3.*** *Specimen for Tensile strength test*

Tensile property was defined by method ASTM D638-02 experiments with the conditions required (Fig.3). Testing samples

must be cleaned of oil, grease and other impurities, then put into the environmental conditions of 23 ± 2 ° C direct heat, humidity 50 ± 5%, for 40 hours prior to the test. The experiments were conducted by Universal testing machine Shimadzu Autograph AG-X Plus 20kN (Japan).

***Fig.4.*** *Placing sample for Tensile Strength Test*

Bending property was defined by method ASTM D790 experiments. Samples were a composite material beam of rectangular cross section placed 3-point bending under load. The sample size was shown in Fig.5. The experiments were conducted by Universal testing machine Shimadzu Autograph AG-X Plus 20kN.

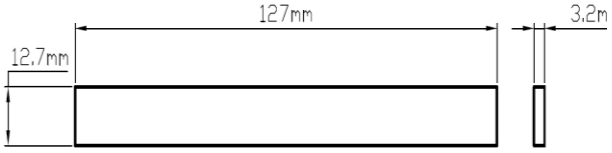



***Fig.5.*** *Sample for flexural strength test*

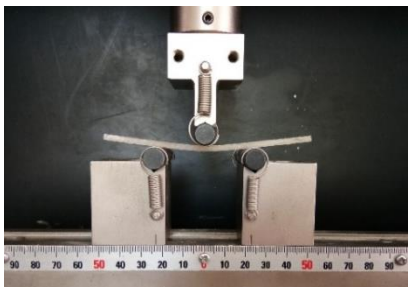


***Fig.6.*** *Placing sample for flexural strength test*

The hardness of the sample was measured through SHORE hardness measurement methods, using the tester SHORE D Durometer DESIK. The durometer measures hardness by determining the depth of penetration into the material under test. The dial was graduated from 0-100 with a pointer sweep of 265$^{o}$.

The Fracture surface of each specimen in bending strength test was observed by scanning electron microscope HITACHI S -high resolution - 4800 (SEM), with acceleration 5.0 kV. The surface of the samples used for SEM all were platinum-sputtered with a conductive layer before observation.

## 3. RESULT AND DISCUSSION

### 3.1 Tensile strength

It can be seen from Fig.7 that the tensile strength decreased obviously when compared to A1, from 30.73MPa to 25.91MPa for A2 sample, and reduced to 23.68MPa for A3 and the lowest 23:29 MPa of A4. Fig.8 shows the stress-strain behavior of A1, A2, A3, A4 samples, the elongation at break of the A2 was 3.14%, lower than A1 (6.08%). The elongation of the A3 was 1.83%, lower than A1. The elongation of the A4 was 2.98%, lower than A1. In closing, the elongation at break of A1 was the highest and A3 was the lowest.

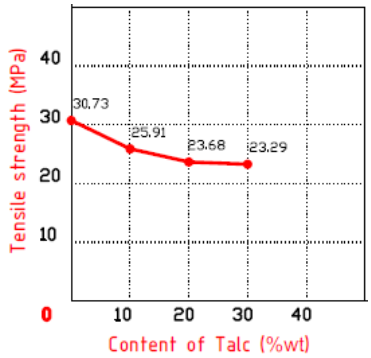



***Fig.7.*** *Tensile Strength of Sample*

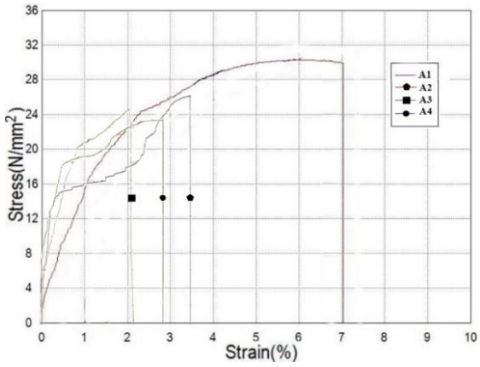



***Fig.8.*** *Stress/Strain behavior of samples*

This result may be due to the function of talc, when mixing talc into the PP, the aggregation of talc affects the crystallization process whereby talc acting as a nucleating agent uniformly distributed in the matrix resin PP and filling the matrix. However, an uneven talc particle size (Fig.2) and furthermore was an excessive incorporation of filler may lead to filler agglomeration (weak bonding) in the polymer matrix leading to formation of micro-filler due to the difficulties in achieving a homogeneous dispersion of fillers. Which leading to weak interfacial bonding with the PP matrix and to some voids and defected structure of the composites and consequent reduction in tensile strength.

### 3.2 Flexural strength

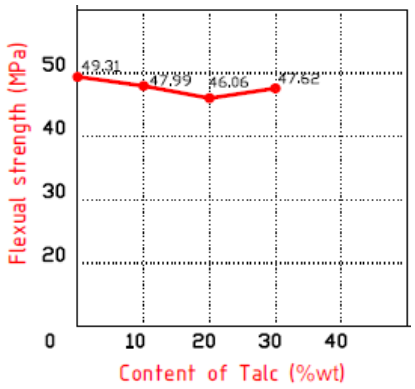



***Fig.9.*** *Flexural Strength of samples*

It can be seen from Fig.9 that the filled samples had lower flexural strength than pure sample, flexural strength tends to fall while the filler content was increased to 20% filler content. The flexural strength was decreased from 49.31MPa for A1 to 47.99MPa for A2, and reduced to 46.06MPa continuously for A3 but slightly increased to 47.62MPa for A4. To summarize, the flexural strength of A1 was the highest and A3 was the lowest.

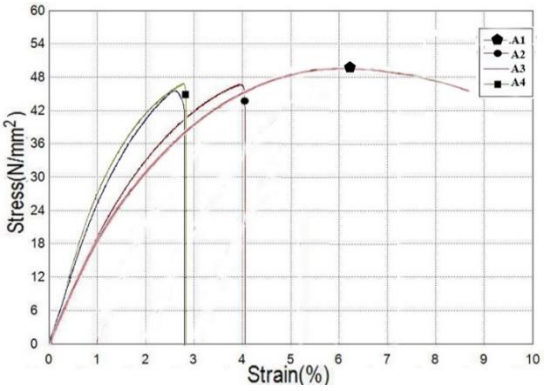
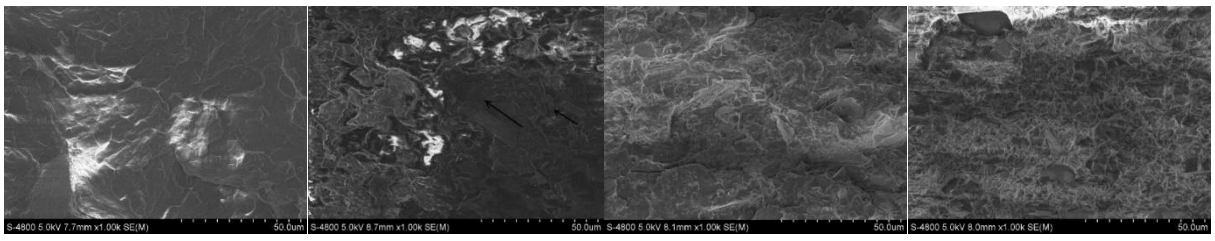



***Fig.10.*** *Stress/Strain behavior of samples*

Fig.10 shown the stress-strain behavior of A1, A2, A3 and A4. The fracture elongation of the A2 was 3.99% was lower than A1 (7.24%). The elongation of A3 was 2.56% lower than A1. The elongation of A4 was 2.73% lower than A1. To sum up, the bending resistance of A1 was the highest and A3 was the lowest. The reducing of the flexural strength may be due to the toughness and hardness increase, which was the result of the uniformly dispersion and distribution of the filler in the polymer matrix, the introduction of rigid particles in a ductile matrix leads to lower elasticity/deformability of the resulting compound. Which explain the reduction in flexural strength.



a) A1 b) A2 c) A3 d) A4

***Fig.11.*** *Fracture surface microstructure of samples*

To know more about the flexural strength of composites PP/Talc, the fracture surface microstructure of samples were analyzed, those fracture surfaces were got form the flexural test. The Fig.11b shows that when there was the presence of Talc, the talc

uniformly dispersion in PP matrix. SEM image also shows the existence of the void between the talc with PP matrix compared to unfilled PP (Fig.11a). When the mineral talc powder was increased to 20%, the uniformly dispersion and the void were observed more clearly (Fig.11c). But when the Talc concentration was 30% dispersed in polymer substrates become more evenly, the substrate surface adhesion polymers fillers as well as the appearance of the openings between the filler and the substrate was reduced (Fig.11d). All these factors contributed to the transfer of stresses from the matrix to the filler leads to reduce the bending properties. Furthermore, it was cleared that the fracture surface of PP matrix was clear and the number of craze was limited, so the fracture was brittle fracture. But the fracture surface of PP/Talc blends were rough, and the number of craze increased with the increasing dosage of talc. So, in this case, the fracture of PP matrix was ductile fracture.

### 3.3 Hardness

The results of hardness of four samples were shown in Fig.12. It can be seen that the hardness increased obviously when compared with A1, from 79.5 HD to 81 HD for sample A2, and continuously increasing to 82.2 HD for A3 and the highest was 83.8 HD of A4. The increasing hardness was due to the structure of the composite and actually happens in most reinforced filler. Talc reinforced polymers due to its platelet-like geometry and has a strong nucleation effect on PP [21]. In case of talc-filled PP, the blend was characterized by good dispersion of longitudinal talc crystals associated with some orientation. When the hardness of the model increases, the material becomes brittle and hard. For this reason, when flexural strength testing, A2, A3 and A4 samples were broken into two pieces while the A1 was just bended.

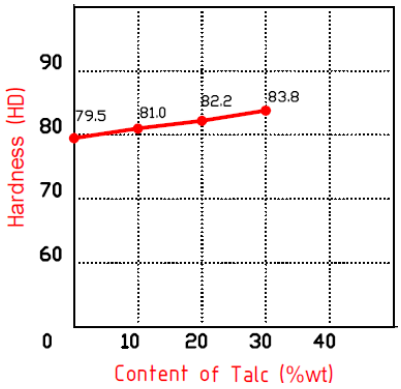



***Fig.12.*** *Hardness of the samples*

## 4. CONCLUSIONS

The effects of talc on the mechanical properties of the composite PP/Talc has been investigated. Tensile strength decreased with the increasing dosages of talc from 30.73MPa to 23.9 MPa. SEM images show that talc can be uniformly dispersed in the PP matrix and fracture mechanism changes from brittle fracture to ductile fracture. When the content of Talc was 10-20-30% wt., the addition of talc obviously improved hardness of the composite. In particular, with the appropriate dosage was 10% wt., mechanical properties such as hardness (81HD), tensile (25.91 MPa) and flexural strength (47.99MPa) of the composite achieved the best comprehensive properties.

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