

Study of Physical, Chemical and Thermo-Mechanical Properties of Talc Filled Polyester Resin Composite Using Styrene Monomer

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Abstract

Fiber Reinforced Thermoplastic (FRTP) composites are emerging as potential materials in many engineering fields. In this research, the compression-molding process was used as the fabrication technique for producing talc-filled reinforced polyester composite. The weight percentage of these composites was varied, like 30 wt%, 40 wt%, 45 wt%, and 50 wt% talc, respectively. Besides, different percentages of styrene monomer, such as 0 wt%, 20 wt%, and 30 wt%, were also used in this study. Different types of physical, chemical, mechanical, and thermal properties were investigated. The water absorption percentage is increased for composites having a higher percentage of talc filler, while the elasticity of the composites shows a decreasing nature with the increase of talc content. Compressive strength is increased with higher talc content. After a certain limit, with the increase of talc content, it decreases and remains more or less constant. The flexural properties (flexural strength, tangent modulus, and flexural strain) of polyester-talc composites are higher initially, and as the percentage of talc increases, the flexural properties decrease or remain constant. The rate of water absorption is very low with the increase in soaking time. The thermal analysis of polyester-talc composites shows that the thermal stability of the composites is better than that of polyester.

Keywords

Talc, Composite Material, Polyester-Resin, Thermal Conductivity, TGA, DTA

1. Introduction

Minerals are being used as fillers in plastic compounds to reduce material costs by replacing a portion of the polymer with less expensive material. However, nowadays many functional fillers or minerals modifiers are required to modify processing characteristics or finished part properties. Many of them are also being used to reduce the level of more expensive additives such as pigments, flame-retardants and impact modifiers [1]. A wide variety of minerals are employed as plastics additives, including graphite, calcium carbonate (CaCO_3), talc, alumina hydrate, silica, mica, kaolin, diatomite, dolomite and wollastonite [2]. Since 1980, demand for these additives has increased on average by 7% a year in volume terms, compared to an annual increase in the US demand for plastics of only 4% - 5%. In 1980, 9% of all plastic compounds were incorporated with minerals but this percentage had grown to 15% by 2002 [3] [4] [5].

The use of composites in all products—from sporting goods to bridges to satellites is increasing also outside of the profession, though, many people would be hard-pressed to identify a composite, and this article presents a simple definition of composite materials. Composite materials consist of two or more materials combined in such a way that the individual materials are easily distinguishable. A common example of a composite is concrete which consists of a binder and reinforcement [4] [5] [6]. Adding reinforcement transforms concrete into a three-phase composite. The individual materials that make up composites are called constituents; most composites have two constituent materials: a binder or matrix, and a dispersed phase for reinforcement. The reinforcement is usually much stronger and stiffer than the matrix [7] [8] [9] [10] [11], and gives the composite a good property. The matrix holds the reinforcements in an orderly pattern, because the reinforcements are usually discontinuous, the matrix also helps to transfer load among the reinforcements. Basically, reinforcements come in three forms: particulate, discontinuous fiber, and continuous fiber [12] [13]. Gravel, micro balloons and resin powder are examples of particulate reinforcements.

A polymer is a versatile material [14] [15] [16] which is the most promising and comprehensive field in the present era of science. The development of polymer is a continuous process for achieving it in a specific application under certain environmental condition. The polymer materials that are biodegradable are now enjoying considerable popularity, especially from the standpoint of environmental protection [17].

Many of our modern technologies require materials with unusual combinations of properties that cannot be met by conventional metal alloys, ceramics, and polymeric materials. This is especially true for materials that are needed for aerospace, underwater, and transportation applications. For example aircraft engineers are increasingly searching for structural materials that have low densities, are strong, and abrasion and impact resistant, and are not easily corroded. Frequently, strong materials are relatively dense; also increasing the strength or stiffness generally results in a decrease in impact strength [18] [19] [20]. Com-

posite materials [21] represent nothing but a giant step in the ever-constant endeavor of optimization in materials. Exactly speaking, the idea of the composite is not a new or recent one; nature is full of examples wherein the idea of composite is worn [22] [23] [24] [25].

Besides naturally occurring composites, there are many other engineering materials that are composites in a very natural way. Among the modern structural materials, the history of fiber-reinforced composites is only three decades old. However, in this period of time, there are an incredible progression in the science and technology of the new classes of materials. The low density, high strength, high stiffness-to-weight ratio, excellent durability, and design flexibility of fiber reinforced polymers [26] are primary reasons for their use in many structural components in the aircraft, automotive, marine and other industries.

Composite technology utilizes the high stiffness and strength of filamentary material one common example includes straw-reinforced clay bricks from biblical times and today's steel (fiber) braced radical tier [27] [28] [29]. The advantages of these materials lie in the high specific stiffness, which can be achieved, for example, carbon fibers by molecular and crystal orientation along their fiber length, such that the chemical carry a higher proportion of the load. Since the population of Griffith flaws controls the strength of a material [30], it follows that a fine filament will have a lower density of critical (strength reducing) flaws.

Polyester resin is an attractive candidate for many engineering applications because of its excellent chemical resistance, acceptable range of tensile strength and modulus, good impact strength and process ability, and low price. It is a versatile polymer that has many qualities like excellent chemical resistance, good mechanical properties, and low cost which making it the polymer of choice for various applications. There are many ways in which the mechanical properties of polyester resin can be modified to suit a wide variety of end-use applications. Various reinforcements, such as talc, graphite, and mica, are typical ingredients that are added to polyester to attain cost effective mechanical properties [31]. Fibrous materials tend to increase both mechanical and thermal properties, such as tensile and flexural strength, flexural modulus, heat deflection temperature, creep resistance, and even impact strength. Fillers, such as talc, are often used as extenders, thus reducing the final material cost [32].

Talc is water repellent and very soft in fact it is the softest material according to Mohs. Hardness scale, it can resist temperature up to 900°C and unaffected by chemicals and will not harm living tissue [33]. Talc can be utilized as a medium filler of average whiteness in thermosetting as well as thermoplastic resins where improvements in electrical insulation, heat, and moisture resistance, chemical inertness and good machine ability are needed. Talc has low absorption rate and because of its plate-like structure, certain grades can improve flexural properties of moldings [34] [35]. In this study, the effect of styrene monomer on chemical, thermo-mechanical, physical, and water absorption behavior of talc-polyester resin composites is studied.

2. Materials and Methods

2.1. Raw Materials

The raw materials used for the preparation of the sample are talc, unsaturated polyester, methyl ethyl ketone peroxide (MEEK), and styrene monomer. Talc is supplied by Tekcast Industries, Inc. USA. Unsaturated polyester resin and styrene monomer were collected from the local market of Bangladesh.

2.2. Machines Used for Fabrication and Testing of Composites

Several pieces of equipment were used in the fabrication of polymeric matrix composites. The main equipment and accessories were simple balance, press, molds, etc. A number of machines and equipment were used in the testing of polymeric matrix composites. The main equipment included universal testing machine, thermal analyzer, etc.

Molds: In this research work, mold which has the upper half and lower half but no cavity in any half of the mold were used. These two halves are completely plane with smooth surface platens which also act as a heater and cooler simultaneously. A ring with inside diameter of 146 mm and outside diameter of 158 mm, and two disc or plates of 7.5 mm thickness on each side were used as a die.

Hydraulic hot press machine: A Hot press (PW40, P/W/weber, Germany), was used for compression molding. In compression molding, the polymeric materials and the fiber are subjected to heat and pressure in a single stroke. This is accomplished by using a hydraulic press with heated platens, molding temperature and pressure can be as high as 300°C and 450 KN, respectively.

Universal testing machine: Various mechanical properties such as tensile strength, elongation at break, tensile modulus, bending strength and bending modulus, etc. can be determined by using universal testing machine (H10KS, Hounsefield, UK).

TGA/DT Analyzer: The thermal properties (TGA and DTA) of the sample were accessed by thermal analyzer, TGDTA (EXSTAR 6300, Seiko Instrument Inc., Japan). A computer-controlled (Seiko Instrument Inc., Japan) machine was used in the present research at a heating rate of 20°K/min and gas flow of 100 mL/min.

2.3. Preparation of the Composite

Talc was dried at 100°C for 24 hours in a preheated oven. Different percentage of talc and polyester resin with styrene monomer was taken to prepare composite. Talc was taken from 30 to 50 wt% and unsaturated polyester resin was taken according to **Table 1**. The amount of styrene content was kept constant. The following table shows different percentages of samples.

A bowl was taken to mix up the raw materials of the composite. Definite amount of various percentages of talc, polyester resin and styrene monomer was weighed in the bowl and mixed very carefully with a stirrer for about half a hour. Ethyl Methyl Ketone Peroxide (MEKP) was used as initiator, as an amount of 1.5 wt% of polyester resin and styrene weight. The mixer was then poured into the

mold and kept it 4 - 5 hours for setting. After setting up the composite is released from the mold by applying low load. Millot paper was used as separator up the sides of the composite. Another set of composite was prepared taking various percentage of styrene monomer as shown in **Table 2**.

2.4. Properties of the Composites

2.4.1. Water Absorption

Water absorption specimen was prepared according to ASTM designation: C 67 - 91. Specimen dimension 25 mm × 7 mm × 8 mm accordingly. A protective gel coat (araldite) was applied on the cut sides to prevent penetration of water from cut sides. The water absorption was calculated by the following equation-

$$\% \text{Wa} = 100(W_f - W_i)/W_i$$

W_f = final weight after water absorption.

W_i = initial weight before immersion.

2.4.2. Compressive Properties

Compressive strength: Compression sample was prepared according to ASTM D638. Then the sample was subjected to compression testing. The sample was 10 × 10 × (6 - 8) mm. The compression strength and strain are defined as:

$$\sigma_e = \frac{F}{A_0}$$

A_0 = Original cross sectional area [m²].

$$\epsilon_e = \frac{l - l_0}{l_0}$$

where, l = specimen length [m] and l_0 = original specimen length [m].

2.4.3. Flexural Properties

Flexural strength: Flexural specimen was prepared according to ASTM D790M,

Table 1. Talc-Polyester resin composite with constant wt% of styrene monomer.

Talc %	Polyester resin (with 20% styrene monomer) %
50	50
40	60
45	55
30	70

Table 2. Talc-polyester resin composite with variable percentage of styrene with polyester.

Talc %	50% polyester resin containing styrene, wt%
50	20
50	30
50	0

3 point loading. The specimen dimension was $125 \times 10 \times (6 - 8)$ mm and support span was 96 mm. The test speed was taken as 2.6 mm/min.

The strength and strain is calculated by means of the following equations

$$S = 3PL/2bd^2$$

$$\varepsilon_f = 6bd/L^2$$

where, S = Stress in the outer fibers at mid-span, MPa, P = Load at a given point on the load – deflection curve, N , L = Support span, mm, b = Width of specimen tested, mm, D = Depth of tested specimen, mm.

3. Results and Discussion

Various properties such as physical and mechanical properties of polyester-talc composite using styrene monomer were observed. The results of these properties are discussed below.

3.1. Physical Properties

The effect of soaking time on water absorption of polyester-talc composites prepared with different wt% (30 wt%, 40 wt%, 45 wt%, and 50 wt%) of talc is shown in **Figure 1**. It reveals that the water absorption depends on talc addition and immersion time. It can be seen that the percentage of water absorption for all percent of talc content increases with time as it is a diffusion phenomenon. The rate of water absorption is high initially; after that, it decreases with the increase of soaking time. The hydrophilic nature of talc fiber and the hydrophobic nature of polyester control the absorption of composites. For this reason, there is a very low amount of water intake in the composites.

The water absorption of these composites was measured by soaking the composites in water contained in a static bath for different period of time.

Figure 2 shows that water absorption is decreased with the addition of styrene

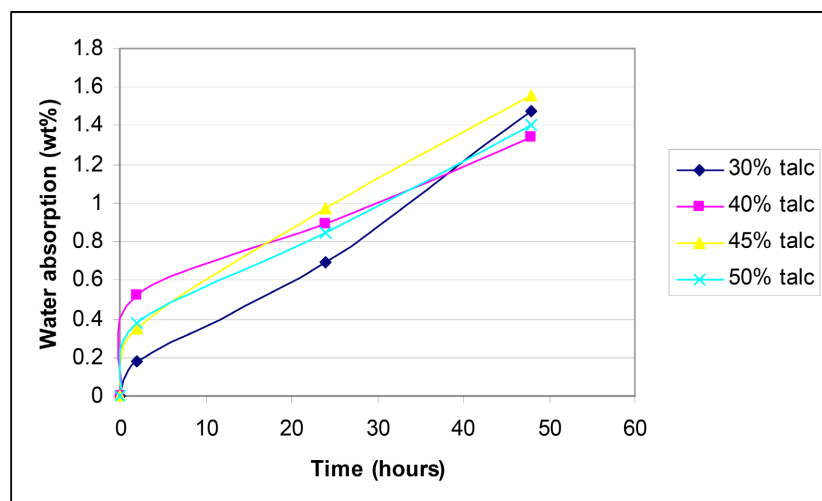


Figure 1. Effect of soaking time on water absorption of polyester-talc composites for different wt% of talc.

percentage. The figure shows that the percentage of water intake increases slowly initially with the increase of time due to slow absorption of polystyrene.

3.2. Mechanical Properties

The performance and durability of composites are dependent on the mechanical properties. Mechanical properties of the composites were measured in terms of compressive strength (CS), E-modulus, flexural strength, flexural strain, and tangent modulus.

Compressive strength for polyester-talc composites is shown in **Figure 3**. It can be seen that the maximum value of the compressive strength of the polyester-talc composite was found at a percentage of 40 wt% talc, but for a further increase in the percentage of talc, the compressive strength decreases. The compressive strength of the composite was very well; it was higher than brick [36].

The changes in compressive strength of the polyester-talc composites with the addition of different percentages of styrene monomer are shown in **Figure 4**. The CS increases with the increase of styrene addition and reaches maximum, then

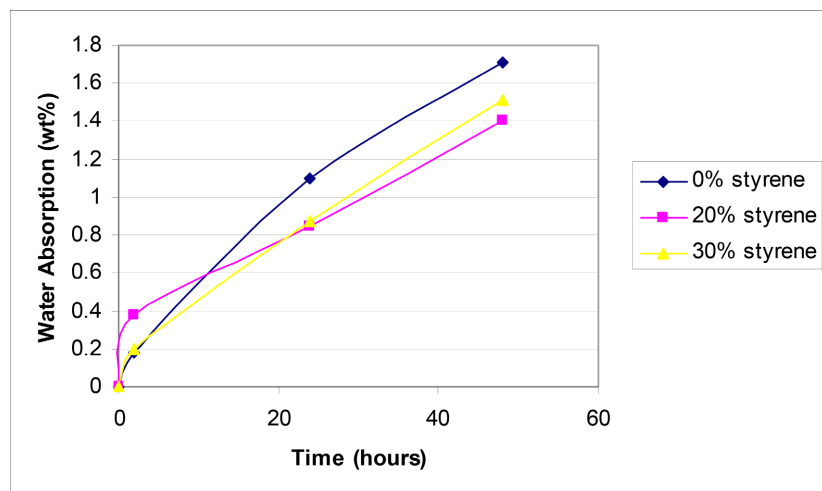


Figure 2. Effect of soaking time on water absorption of polyester-talc composite for different concentration of styrene wt%.

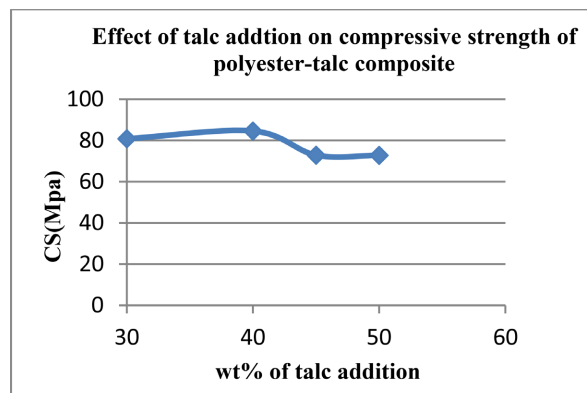


Figure 3. Effect of talc addition to the change in compressive strength at polyester-talc composites.

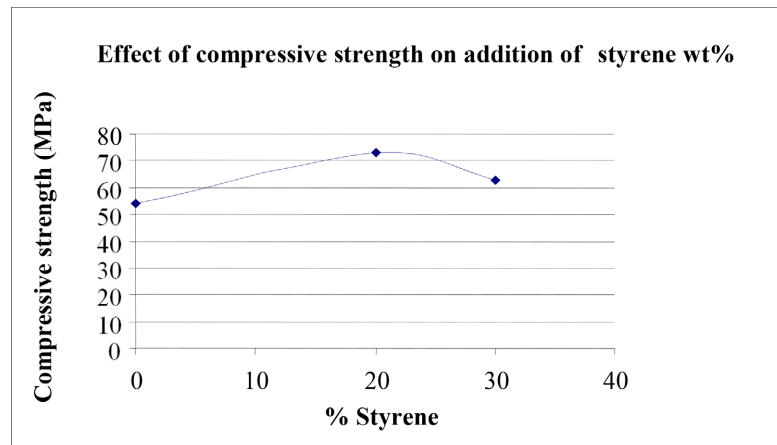


Figure 4. Effect of the addition of different % of styrene monomer on change of compressive strength for polyester-talc composites.

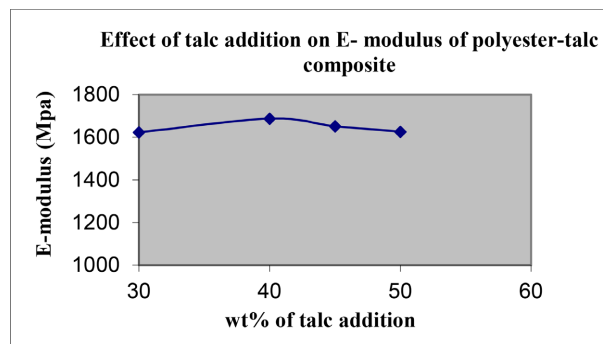


Figure 5. E-modulus of polyester-talc composites by addition of different talc percentages.

decreases. The maximum compressive strength was found at the percentage of 20 wt% styrene monomer content [36].

Figure 5 shows E-modulus of talc reinforced composites of different wt% of talc. It reveals that the E-modulus increases with increase in addition of talc from 30 wt% to more. It shows the maximum value at 40 wt% talc content, for more addition of talc like 45 wt%, 50 wt% E-modulus decreases. The E-modulus is a measure of stiffness of a material. Thus, the stiffness of polyester-talc composites increases with increase of talc addition initially and then decreases with increases percentage [37].

The following figure shows the variation of E-modulus with change of percentage of talc:

Figure 6 shows the effect of E-modulus of talc reinforced composites of different percentage of styrene. It reveals that E-modulus increases with increase of styrene percentage, reaches maximum and then remains more or less constant [37].

Flexural strength for polyester-talc composites is shown in **Figure 7**. It shows flexural strength decreases with the increase of talc addition [37].

The change of flexural strength due to the addition of different percentage of styrene for the polyester-talc composites is shown in **Figure 8**. From the figure it

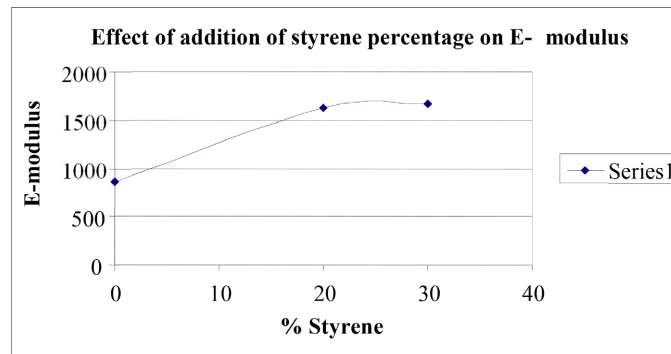


Figure 6. Effect of addition of styrene monomer into polyester-talc composite on tensile E-modulus.

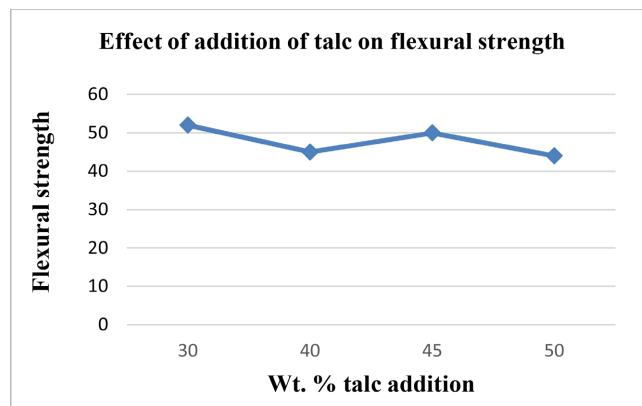


Figure 7. Effects of addition of talc on the change of flexural strength of polyester-talc composites.

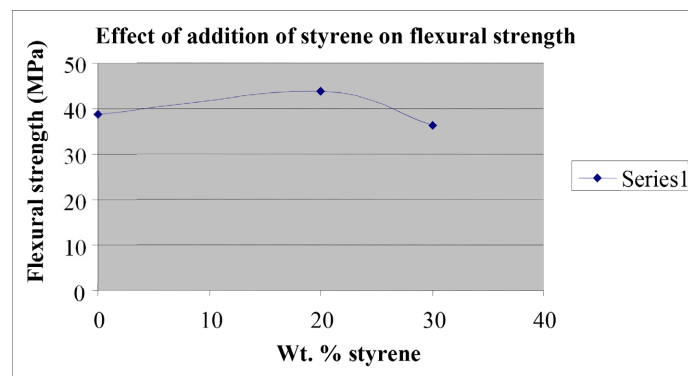


Figure 8. Effects on flexural strength of polyester-talc composite with addition of different percentage of styrene.

is shown that the highest value of flexural strength is obtained at 20 wt% Styrene, increasing from this value the flexural property is decreased [37] [38].

Figure 9 shows flexural E-modulus of talc reinforced composites of different wt% of talc. It reveals that the E-modulus increase with increase of talc addition. The E-modulus is a measure of stiffness of a material. Thus, the stiffness of polyester-talc composites increases with increase of talc addition initially and then decreases [39].

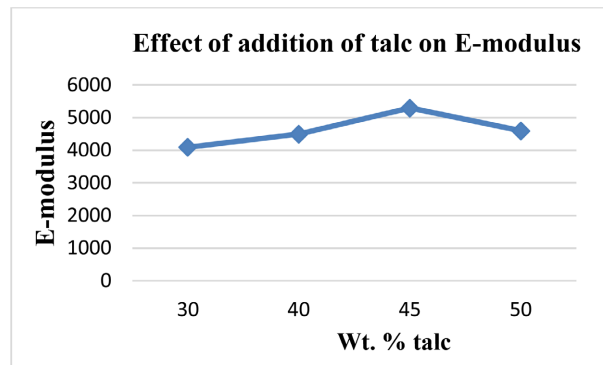


Figure 9. Effects of talc addition on E-modulus of polyester-talc composites.

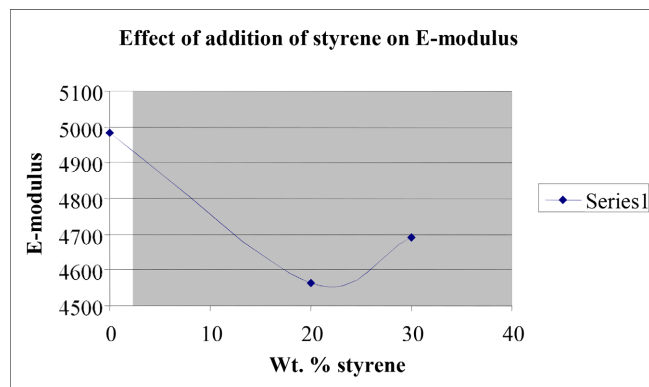


Figure 10. Flexural E-modulus of polyester-talc composite by addition of different wt% of styrene.

Figure 9 shows that E-modulus of talc reinforced composites of different percentage of talc. It reveals that E-modulus increases with increase of conc. of talc due to increase E-modulus of the talc and the polyester are well distributed. After 45 wt% of styrene monomer the value of E-modulus decreases [39].

Figure 10 shows the effect of the styrene addition on flexural modulus of composites. It reveals that modulus decreases with the increase styrene addition. It decreases to minimum value, then increases [40].

3.3. Thermal Analysis

Figure 11 shows the TG curves of talc, polyester and composite. The top one is for talc, bottom one is for polyester and middle one is for composite. The figure reveals that the TG of composites is the average of the two curves of talc and polyester. The figure shows that major degradation occurs for both the polyester and talc at a single stage, but it occurs at two for the composite. The initial stage/1st stage is related to talc, whereas the second stage is related to polyester [37].

Figure 12 and **Figure 13** show the DTG and DTA curves for talc, polyester and composite. In **Figure 12**, the above black curve is for polyester, the bottom one is for talc and the middle one is for composite. As usual, the value of DTG of composite is in between the raw materials [40].

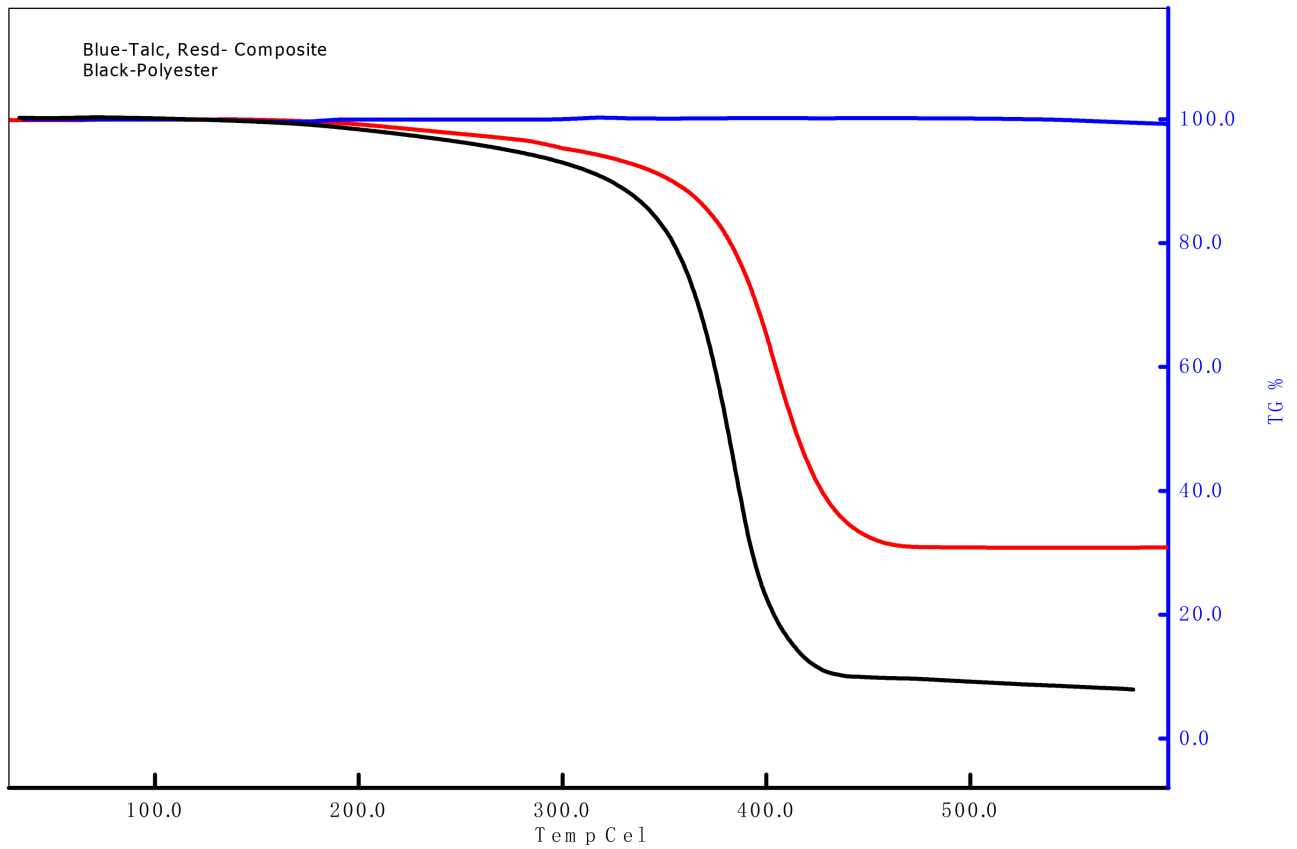


Figure 11. TG for talc, polyester resin and composite.

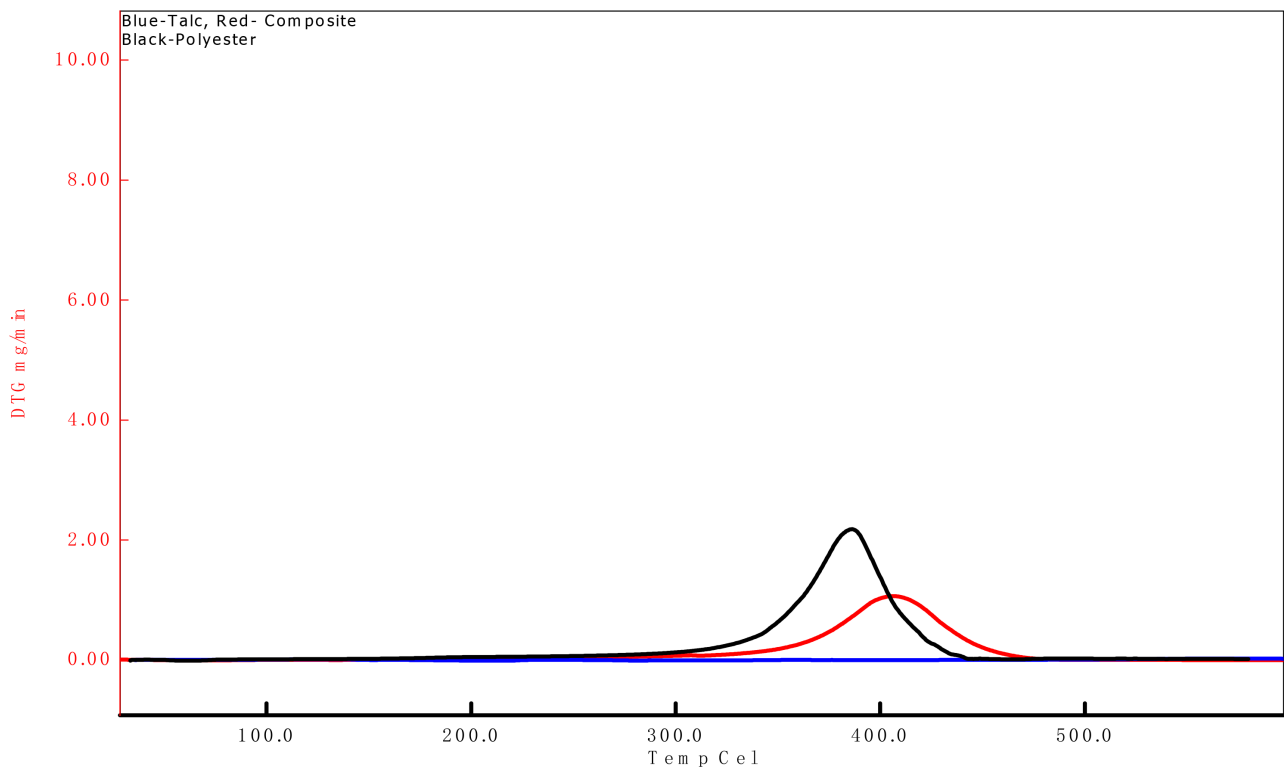


Figure 12. DTG for talc, polyester and composite.

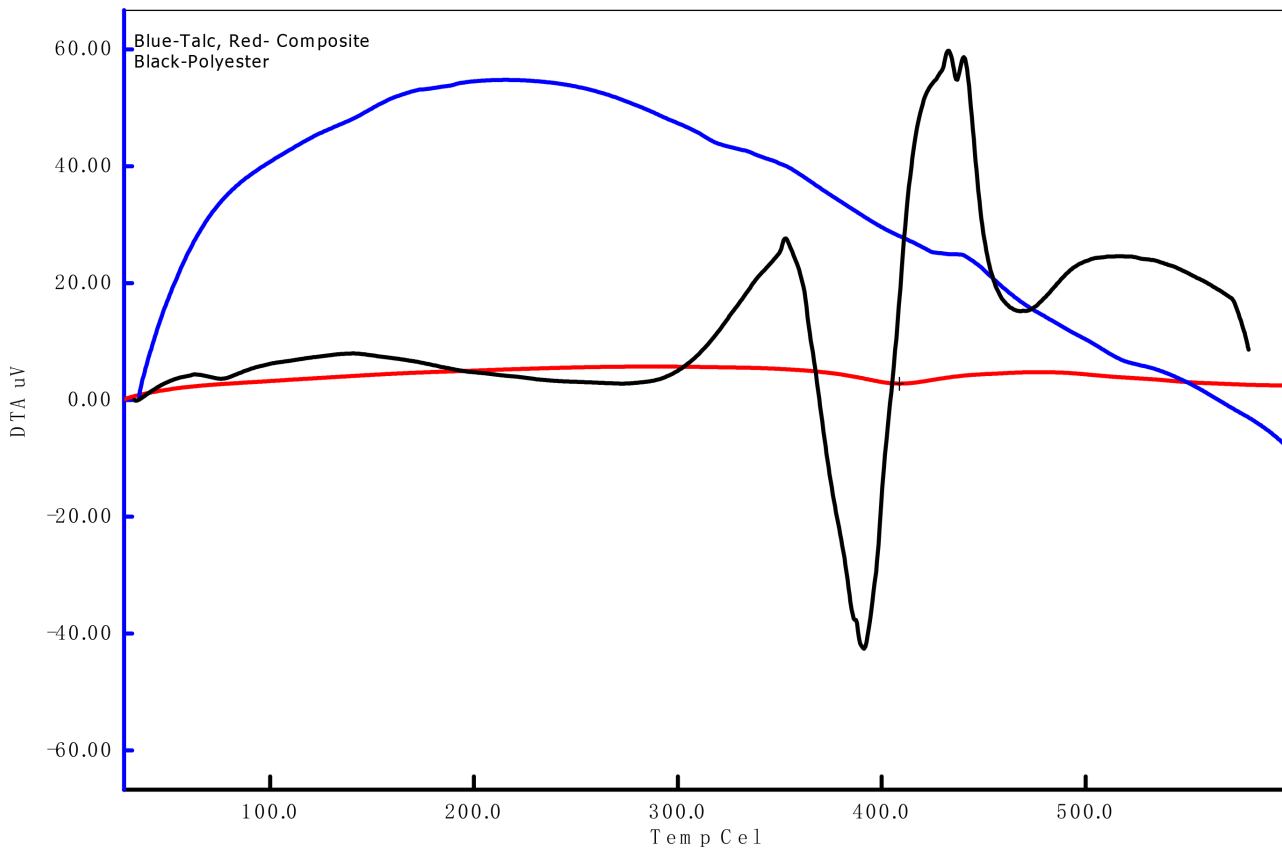


Figure 13. DTA for talc, polyester and composite.

From **Figure 14** and **Figure 15**, the graph shows that TG/DTA value decreases if the percentage of talc decreases. For 30 wt% talc addition TG/DTA of the composite is lower than for 50 wt% talc addition.

Figure 16 and **Figure 17** of the following shows the variation of TG/DTA of the composite due to the addition of 30 wt% styrene monomer and without adding styrene monomer. Addition of styrene shows degradation of the TG value. The highest slope is at 412.7°C which is for 30 wt% styrene monomer addition and the highest slope for the sample without styrene is at 406.7°C.

3.4. Chemical Attack

The composite was subjected to 97% sulfuric acid. At the lower concentration, the composite was merely attacked by the acid but when the composite was kept in concentrated sulfuric acid for about several hours it was badly attacked by the acid. The raw material of the composite such as talc, polyester resin and styrene monomer reacts with concentrated sulfuric acid and the composite becomes soft and also the color of the composite degraded.

4. Conclusions

The results of the present study revealed that composites with good strength could be successfully developed using talc as the reinforcing agent. According to

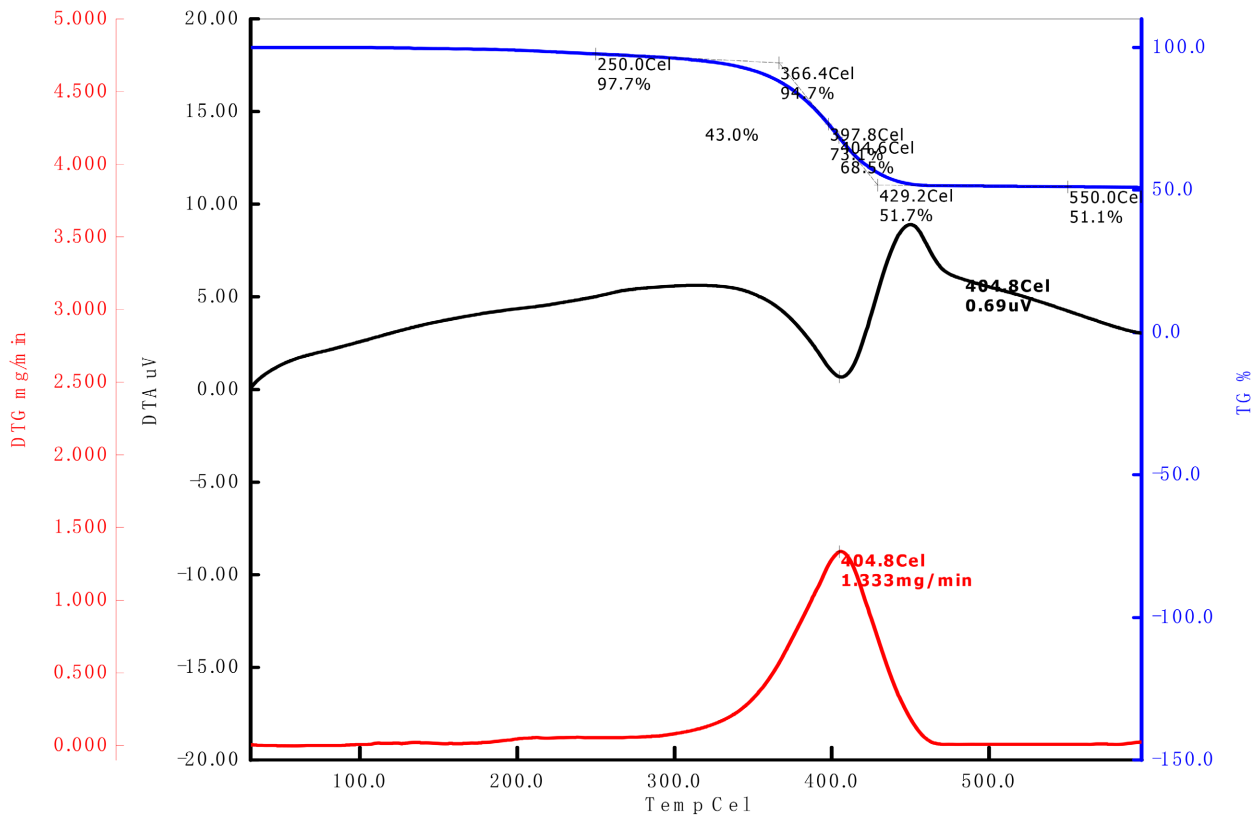


Figure 14. TG/DTA for polyester-talc composite on addition of 50 wt% talc.

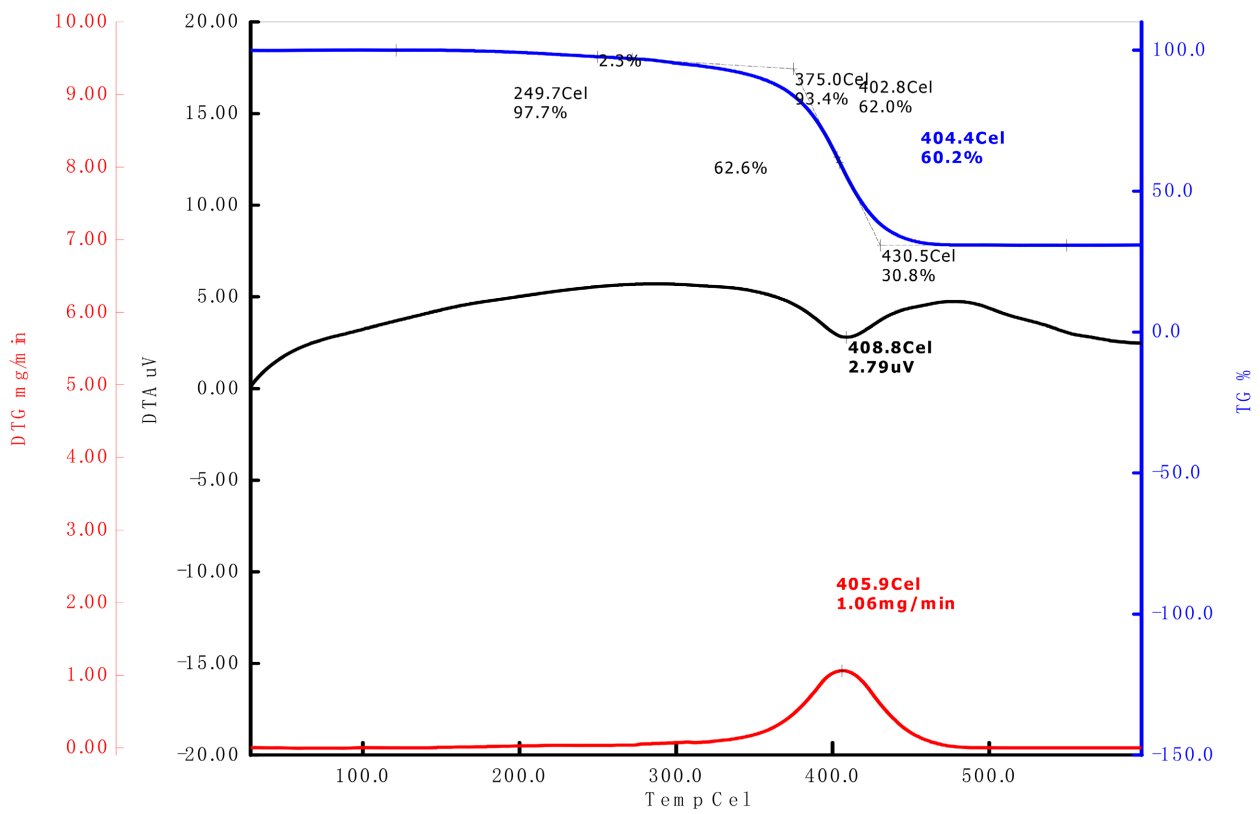


Figure 15. TG/DTA for polyester-talc composite on addition of 30% talc.

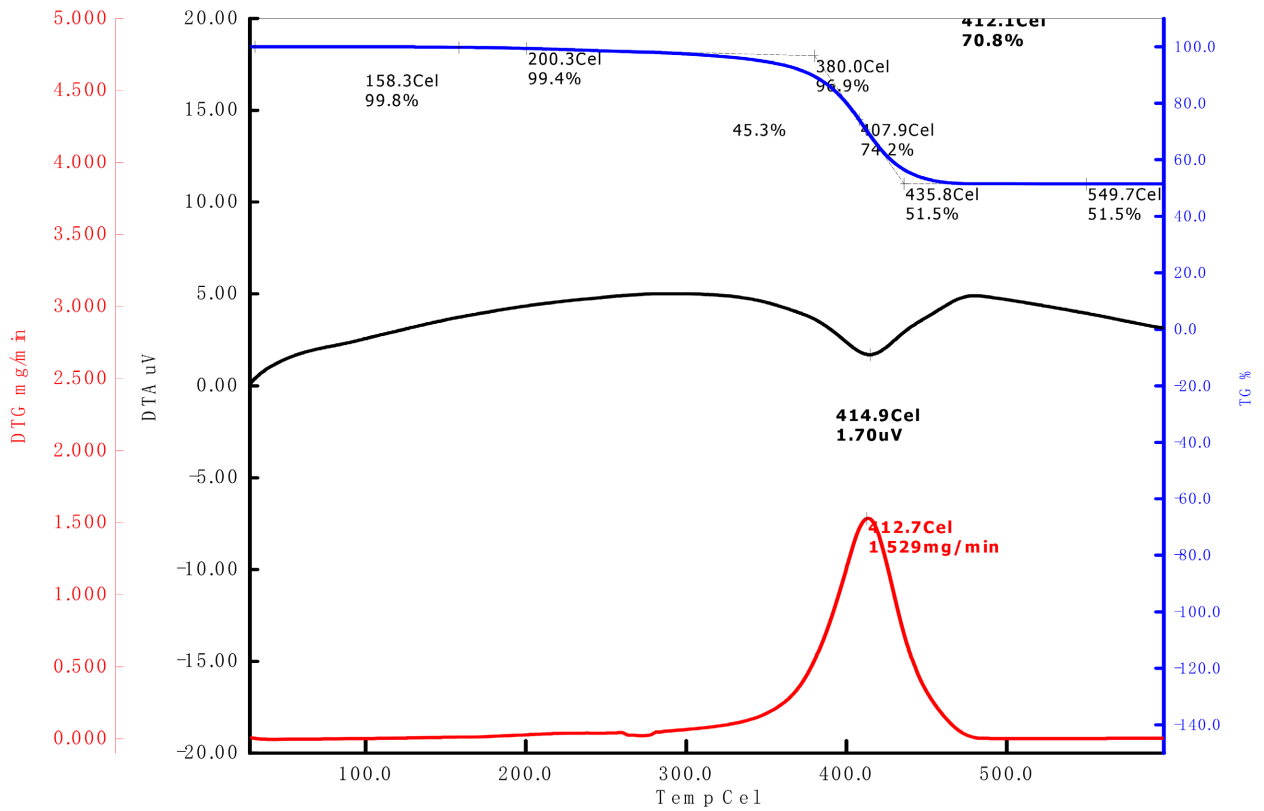


Figure 16. TG/DTA for polyester-talc composite on addition of 30 wt% styrene.

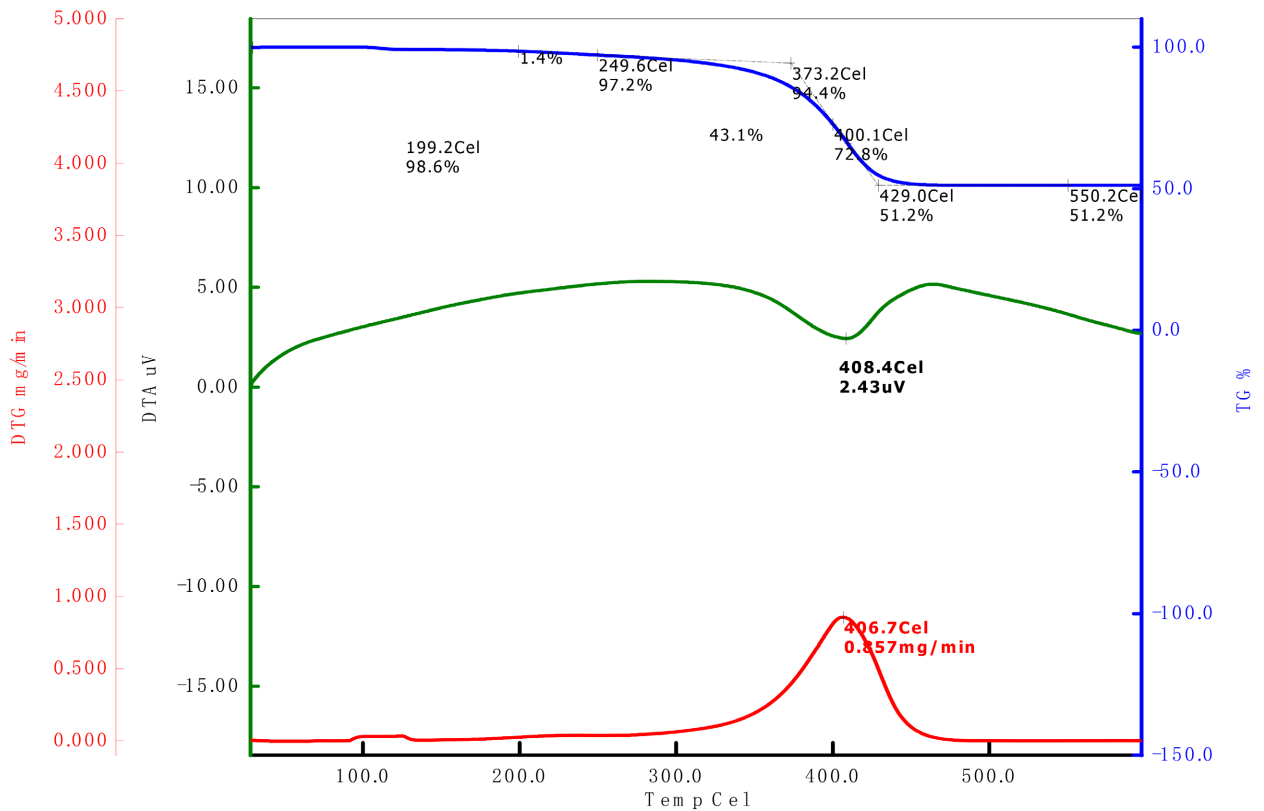


Figure 17. TG/DTA for polyester-talc composite without styrene monomer.

the present work on the development of the mineral filler reinforced polymer composite the following conclusions can be made.

Varying amount of matrix and talc filler is the most important parameter of this fabricated process. A percentage of talc (30 wt%, 40 wt%, 45 wt% and 50 wt%) and styrene monomer (0 wt%, 20 wt% and 30 wt%) have been taken for fabrication of the composite. The water absorption increases with increase in soaking time because the mineral fillers obey this behavior and the absorption of water was highest at 45 wt% talc then decreased.

Compressive strength of the composite was found very high and it was increased for addition of talc percentage from 30 wt% to 40 wt%, furthermore increase in the percentage of talc caused decrease in compressive strength. Flexural strength of the composite found to be highest at 30 wt% talc content, which decreased for 40 wt% talc addition, and it is again increased at 45 wt% talc content and at 50 wt% talc decreased again. At 20 wt% of styrene monomer, the compressive strength and flexural strength are highest and the values decrease with increasing the percentage of styrene monomer. It is found that TG, DTG and DTA curves of the composites were the average of the filler and the polyester. The degradation of composites was occurring in only one stage due to the polymer. The thermal stability of polyester-talc filler composites was higher than polyester. Chemical analysis showed that the composite was attacked by concentrated acid solution. The composite corroded in acid but did not dissolve in it. A good morphology presented by the studied samples was observed.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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