CHAPTER 6

THERMAL PROPERTIES OF UNMODIFIED AND MODIFIED HDPE/PP BLEND - NYLON MAT COMPOSITES

6.1 INTRODUCTION

Thermogravimetric Analysis or TGA is a type of testing that is performed on samples to determine changes in weight in relation to change in temperature. TGA is commonly employed in research and testing to determine characteristics of materials such as polymers, blends and their composites in order to determine degradation temperatures, absorbed moisture content of materials, the level of inorganic and organic components in materials and solvent residues. The loss in weight over specific temperature ranges provides an indication of the composition of the sample, including volatiles and inert filler, as well as indications of thermal stability. It also indicates the number of stages of thermal breakdown, weight loss at each stage, onset temperature etc [1]. Many fillers have been incorporated into polymer matrix for cost reduction and it was later discovered that they improved the stiffness and mechanical properties [2 – 8]. Both TGA and DTG provide information about the nature and extent of degradation of the material.

Dynamic Mechanical Analyser measures the stiffness and damping properties of a material. The stiffness depends on the mechanical properties of the material and its dimensions. It is frequently converted to a modulus to enable sample inter-comparisons. Damping is expressed in
terms of Tan $\delta$ values and is related to the amount of energy a material can store. DMA is the most sensitive technique for monitoring relaxation events, such as glass transitions, as the mechanical properties change dramatically when relaxation behaviour is observed.

### 6.2 EXPERIMENTAL

HDPE and PP granules are placed in an air oven set at 100°C for 4 hours to remove any moisture present and allowed to cool to room temperature in a desiccator. Two blend compositions are selected namely 80% HDPE/20% PP and 20% HDPE/80% PP and the granules are weighed out. The individual polymers as well as the two blends are melted in a Thermo Haake Rheomix 600P blender set at 180°C at a rotor speed of 30 rpm. The blends as well as the pure polymers are modified with 0.3phr DCP as well as 5phr maleic anhydride in presence of 0.3phr DCP. The molten polymers are pressed into sheets in a hydraulic press. Three grades of nylon mats namely A, B and C with fibre diameter 0.2, 0.4 and 0.6mm respectively are sandwiched between two polymer sheets and compression moulded in a hydraulic press at 180°C and allowed to cool in a cold press. The composites so prepared are subjected to dynamic mechanical analysis and thermo gravimetric analysis.

TGA studies of HDPE, PP and their blend matrix and composites are conducted with a TGA Q50 equipment of TA Instruments. The samples in the range of 5 to 10 mg are heated in a nitrogen atmosphere. The heating is done at a rate of 20°C per minute to a maximum temperature of 800°C. The temperature of onset of decomposition, the temperature at which 50% material had decomposed and residue left over
are noted from weight loss profiles and derivative weight loss curves obtained.

The dynamic mechanical measurements of HDPE, PP and their blend matrix and composites are performed on a DMA Q800 machine of TA Instruments. Bars of dimension 35 mm x 12 mm x 2 mm are cut from the composites prepared. The bars are subjected to dual cantilever bending test at a frequency of 1 hertz and amplitude of 15 µm. The ramp temperature is set to increase at 3°C per minute to a maximum of 160°C.

6.3. RESULTS AND DISCUSSION

6.3.1. DYNAMIC MECHANICAL ANALYSIS

6.3.1.1. HDPE COMPOSITES

(a) Storage modulus

The matrix as well as the composites show a decreasing trend in storage modulus with increase in temperature. The composites have higher storage modulus than the matrix at all temperatures studied. A similar trend is observed when HDPE is modified with DCP as well as maleic anhydride grafted to HDPE (Fig 6.1 A – C).
The storage modulus of the composites with HDPE as matrix with nylon mat reinforcement is higher than the matrix at almost all temperatures at which studies are conducted. The highest storage modulus is observed in the case of composite with nylon mat B as reinforcement.
The matrix as well as composites show a declining trend in storage modulus with increase in temperature. At 50°C, the composites show an increase in storage modulus by 4, 42 and 18% for nylon mats A, B and C as reinforcements over the matrix which increase to 10, 92 and 24% at 70°C and 18, 170 and 30% at 90°C. The composite with nylon mat C as reinforcement show lower storage modulus than the matrix at 110° and 130°C while the composite with mat A as reinforcement shows lower value at 130°C.

The storage modulus of DCP modified HDPE matrix as well as the composites show a trend similar with unmodified HDPE matrix and composites. The storage modulus decrease with increase in temperature except for nylon mat C reinforcement which shows a higher value at 130°C than at 110°C. The storage modulus is higher by 14, 12 and 5% than the matrix for nylon mats A, B and C as reinforcements at 50°C and 9, 13 and 2% at 70°C. At 90°C, the composites with nylon mats A and B as reinforcement show increments of 2 and 14% while mat C composite shows a decline of 1.5%. The maximum increments shown are 51 and 80% at 110°C for nylon mat A and B as reinforcements.

The storage modulus of maleic anhydride grafted HDPE matrix and composites also show a decreasing trend on increasing the temperature. Here the composites with nylon mat C as reinforcement has the highest storage modulus at all temperatures. The increments over the matrix are 7, 8 and 47% at 50° and 70°C while at 90°C are 23, 11 and 45% for nylon mats A, B and C respectively. The storage modulus of mat A and C composites at 110°C are nearly equal, 67 and 69% higher than the matrix while mat B composite recorded an increment of 27% only. At
130°C, composites of mat A and B show 100% higher storage modulus than the matrix while mat C composite a 250% increment over the matrix.

Overall comparison between HDPE and its modifications as matrix for composites, it is found that HDPE matrix has the highest storage modulus compared to its modifications at 50°C. The highest storage modulus is shown by the composite with nylon mat B as reinforcement to DCP modified HDPE matrix.

(b) Loss modulus

The loss modulus of the matrix decreases to a minimum and increase as temperature is increased. A regular decreasing trend is observed for the composites. The composites have higher loss modulus than the matrix at most temperatures. A regular decreasing trend is shown by the DCP modified HDPE, but when maleic anhydride is grafted to HDPE, the loss modulus show an increase at higher temperatures for certain composites (Fig 6.2 [A – C]).

The loss modulus of the HDPE matrix and its composites decreases with increase in temperature. The composites have higher loss modulus than the matrix. The increments for the composites are 4, 43 and 16% for nylon mats A, B and C respectively at 50°C. The values show increments of 4, 75 and 20% over the matrix at 70°C while at 90°C, it is 6, 124 and 23% for nylon mats A, B and C respectively. Composites with nylon mats A and C had lower loss modulus than the matrix at 110° and 130°C.
Figure 6.2: [A – C] Loss modulus of HDPE matrix and its composites with nylon mats.

The loss modulus of the matrix and the composites show decrements when HDPE is modified with DCP. The matrix shows a decrement of 6%. The composites have higher loss modulus than the matrix at all temperatures except in the case of composite with nylon mat C as reinforcement at 50°C and nylon mat A at 130°C. The composites
with nylon mats A and B as reinforcement show an increment of 5 and 7% while nylon mat C as reinforcement shows a decrement of 3% over the matrix at 50°C. The increments at 70°C are 9, 12 & 3% while at 90°C is 8, 13 & 7% for nylon mats A, B and C respectively. The highest loss modulus is 143 MPa shown by nylon mat B composite at 49.8°C.

A similar trend is observed when maleic anhydride is grafted on HDPE. The composites had higher loss modulus than the matrix at all temperatures. The increments at 50°C are 10, 13 & 21%; at 70°C are 13.6, 13.5 & 32%; at 90°C are 26, 15 & 38%; at 110°C are 54, 26 & 63% and at 130°C are 86, 97 & 191% for nylon mats A, B and C respectively. The highest loss modulus is observed is 158 MPa for the composite with nylon mat C as reinforcement.

Comparing the loss modulus of both unmodified and modified HDPE matrix and composites, the loss modulus is found to increase slightly and then decrease with increase in temperature. The highest loss modulus of 207.3 MPa is observed for HDPE - nylon mat B composite.

(c) Tan δ values

Tan δ values of HDPE as well as the composites with HDPE as matrix increased with increase in temperature. The composites had lower tan δ values than the matrix under experimental conditions. A similar trend is observed in the DCP modified HDPE as well as maleic anhydride grafted HDPE used as matrix (Fig 6.3 [A – C]).

The tan δ values shows an increasing trend with increase in temperature in the case of all matrix and composites of HDPE and its modifications. The tan δ values of HDPE matrix and its composites are
nearly equal at 50°C and then increased with increase in temperature. The increase is not regular in all cases. The highest tan δ value is observed in the case of HDPE - nylon mat A composite being 0.3077 at 130°C. The peak value is 0.3066 at 130°C for the matrix, 0.2955 at 131°C for nylon mat B composite and 0.3014 at 124°C for nylon mat C composite.

The tan δ values of DCP modified HDPE matrix as well as its composites increased with increase in temperature. The highest tan δ value of 0.3678 is observed for nylon mat A composite at 128°C. The peak value for the matrix is 0.3409 at 130°C, nylon mat B composite had 0.3377 at 130°C and nylon mat C composite had 0.264 at 106°C.

The studies on maleic anhydride grafted HDPE matrix and composites show similar results. The highest value of 0.3732 is observed in the case of the matrix at 128 °C. The composites had peak tan δ of 0.3271 at 130°C for nylon mat A composite, 0.3231 at the same temperature for nylon mat B composite and 0.3208 at 133°C for nylon mat C composite.

The comparison of tan δ values indicated the value to increase with temperature to reach a peak value and then a decline slightly. This trend is observed in almost all cases of HDPE matrix and composites.
Figure 6.3: [A – C] Tan Delta values of HDPE matrix and its composites with nylon mats.
6.3.1.2. PP COMPOSITES

(a) Storage modulus

The storage modulus of PP matrix as well as its composites decreased with increase in temperature. The composites with nylon mat A as reinforcement had higher storage modulus than the matrix up to 110°C whereas nylon mat B as reinforcement had lower storage modulus at all temperatures. A similar decreasing trend with increase in temperature is shown by the DCP modification as well as maleic anhydride grafted version of PP used as matrix (Fig 6.4 [A – C]).

The storage modulus of PP matrix as well as the composites decreased with increase in temperature. The composite with nylon mat A as reinforcement had higher storage modulus than the matrix up to 110°C and then became lesser than the matrix. The composite nylon mat B as reinforcement had lower storage modulus than the matrix at all temperatures. The storage modulus of nylon mat A composite is 8.5, 15, 15 and 5% higher than the matrix at 50°C, 70°C, 90°C & 110°C respectively. At the same time the increments are 13, 16, 12 & 4% at the same temperatures. At 130°C, the decrements are 75 and 13% for nylon mat A and B composites.
The modification of the matrix with 0.3phr DCP is found to lower the storage modulus of the matrix by 23% than pure PP. All its composites had higher storage modulus than the matrix up to 90°C and...
then decreased. The composite with nylon mat A as reinforcement shows increments of 22, 13 & 4% at 50°, 70° and 90°C respectively where as the composite with nylon mat B as reinforcement had 27, 18 and 8% as increments at the same temperatures while the nylon mat C composite shows increments of 58, 43 and 33%. Slight decrements are shown by all composites at higher temperatures when compared with the matrix.

Grafting of PP with maleic anhydride improved the storage modulus of the matrix. The values are higher than those for unmodified matrix up to 110°C and then a decrement is observed. The composites with nylon mats A and B as reinforcement had lower storage modulus than the matrix up to 110°C. Increments are observed in the case of composites at higher temperatures. The decrements observed are 32, 34, 33 & 22% for mat A as reinforcement and 14, 22, 23 & 3% for mat B reinforcement at 50°, 70°, 90° and 110°C respectively. Large increments are observed in the case of mat B reinforcement at higher temperatures.

(b) Loss modulus

The loss modulus of PP matrix as well as the composites show a slight increasing trend up to 70°C and then decreased with increase in temperature. On DCP modification, the matrix as well as the composite with nylon mat C as reinforcement show a regular decrease in value with increase in temperature while the composites with nylon mat A & B as reinforcement show a trend similar to that of unmodified PP. The composites had a slightly higher loss modulus than the DCP modified matrix. Grafting of maleic anhydride into PP produced a result similar to unmodified PP matrix (Fig 6.5 [A – C]).
The loss modulus of PP matrix as well as its composites show an increase followed by decrease with increase in temperature. The maximum values are observed at 70°C. The matrix had higher values than the composites except at 130° & 150°C for composites with nylon mat B as reinforcement. The loss modulus of composites with nylon mat A as reinforcement are lower by 4, 3, 4, 0.1, 12 & 13% at 50°, 70°, 90°, 110°, 130° & 150°C respectively. The decrements in the case of composites with nylon mat B as reinforcement are 9, 9, 7 and 3% at 50°, 70°, 90° & 110°C respectively while increments of 10 & 3% are observed at 130° & 150°C.

The loss modulus of DCP modified PP matrix and the composite with nylon mat C as reinforcement decreases with increase in temperature where as an initial increase followed by decrease is observed for composites with nylon mats A & B as reinforcement. All composites exhibited higher loss modulus than the matrix at all temperatures except composites with nylon mats A & B as reinforcement at 50°C. The highest loss modulus is observed for composite with nylon mat C as reinforcement at 50°C. Nylon mat A & B as reinforcement for composites show decrements of 16 & 8% at 50°C while composite with nylon mat C as reinforcement show an increment of 3% at the same temperature. At all other temperatures the matrix had higher loss modulus than composites, the decrements being 4, 6, 4, 5 & 4% for mat A composite, 10, 14, 11, 5 & 22% for mat B composite and 8, 15, 31, 48 & 48% for mat C composite at 50°, 70°, 90°, 110°, 130° & 150°C respectively.
Loss modulus of maleic anhydride grafted PP matrix as well as its composites is found to show an increase initially and further decrease with increase in temperature. The peak values are observed around 70°C. In most cases the loss modulus of composites are lower than that of
matrix except at 130° and 150°C for composite with nylon mat A reinforcement and 110°, 130° & 150°C for mat B composite. The highest value is observed for mat B composite at 70°C. The composite with nylon mat A as reinforcement shows decrement of 28, 24, 19 & 9% at 50°, 70°, 90° & 110°C while composite with nylon mat B as reinforcement shows decrements of 3, 1.5 & 1% at 50°, 70° & 90°C respectively. Increments of 14 & 22% are observed at 130° & 150°C for composite with nylon mat A as reinforcement while 13, 53 & 79% are observed at 110°, 130° & 150°C for composite with nylon mat B as reinforcement.

(c) Tan δ values

The tan δ value of PP matrix increased with increase in temperature to a maximum and then decreased. The composites show a regular increase in tan δ values. The composite with nylon mat A as reinforcement had lower tan δ value than the matrix while nylon mat B reinforcement had higher values. The tan δ values of the DCP modified PP matrix as well as its composites show an increasing trend with temperature. The matrix had higher tan δ value at low temperatures while the composites had higher value at high temperatures. Maleic anhydride grafted PP matrix shows a steady increase in tan δ with increase in temperature. The composites show a maximum at 110°C (Fig 6.6 [A – C]).

The tan δ values of PP matrix is found to increase with increase in temperature, reached a peak value at 110°C and then declined. The composite with nylon mat A as reinforcement is found to show an increasing trend while composite with nylon mat B as reinforcement behaved similar to the matrix.
Figure 6.6: [A – C] Tan Delta values of PP matrix and its composites with nylon mats.

The composites had higher tan δ values than the matrix at 50°C. At 70°, 90° & 110°C, composite with nylon mat A as reinforcement had lower tan δ values while composite with nylon mat B as reinforcement had higher values. At 130° and 150°C, the composite with nylon mat A as
reinforcement had the highest tan δ values. The composite with nylon mat B as reinforcement had higher values than the matrix at all temperatures, the increments being 5, 9, 7, 12 & 18% at 50°, 70°, 90°, 110°, 130° & 150°C respectively. The highest tan δ value is observed for PP – nylon mat A composite at 150°C.

An increasing trend is observed in the tan δ values of DCP modified PP as well as its composites on increasing the temperature. The matrix had higher tan δ values than the composites at 50° & 70°C. At higher temperatures, the composites had higher tan δ values. Composites with nylon mat A as reinforcement had increments of 2, 6, 9 & 12% while that with mat B as reinforcement had 6, 11, 17 & 2% increments over the matrix at 90°, 110°, 130° & 150°C respectively. The composite with nylon mat C as reinforcement show a decrement of 14% at 90°C and increments of 7, 40 & 54% at 110°, 130° & 150°C respectively.

The tan δ value of the matrix of maleic anhydride grafted PP had an increasing trend with increase in temperature. The composites had a peak value at 110°C which decreased at higher temperatures. The composites had higher tan δ values than the matrix up to 110°C and then became lower. The composite with nylon mat A as reinforcement exhibited increments of 5, 17, 21 & 18%: mat B as reinforcement exhibited 13, 26, 28 & 17% increments at 50°, 70°, 90° & 110°C respectively. The decrements observed are 1 & 9% for mat A as reinforcement and 5 & 7% for mat B as reinforcement at 130° & 150°C.
6.3.1.3 80% HDPE/20% PP BLEND AND COMPOSITES

(a) Storage modulus

The storage modulus of the blend matrix as well as the composites show a decreasing trend as temperature increased. The matrix had higher storage modulus than the composites at most temperatures studied. A similar trend is shown by the DCP modification of the blend. When maleic anhydride is grafted in, the composites had higher storage modulus than the matrix (Fig 6.7 [A – C]).

A regular decrement is observed in the case of the storage modulus of the 80% HDPE + 20% PP blend matrix as well as the composites with increase in temperature. The composite with nylon mat A as reinforcement had lower storage modulus than the matrix at all temperatures studied. The decrements are 10, 13, 26, 52 & 64% at 50°, 70°, 90°, 110° & 130°C respectively when compared with the matrix. The composite with nylon mat B as reinforcement shows values lesser by 18, 22 & 4% at 50°, 70° & 90°C respectively while 11 & 4% increments are observed at 110° & 130°C respectively. Composite with nylon mat C as reinforcement shows greater storage modulus by 11 & 8% at 50° & 70°C but at higher temperatures the storage modulus is lowered to large extents.
Figure 6.7: [A – C] Storage modulus of 80% HDPE + 20% PP blend matrix and its composites with nylon mats.

The storage modulus of the blend modified with 0.3phr DCP shows a trend similar to the unmodified blend. The storage modulus of the matrix as well as the composites decreased with increase in temperature. The DCP modified matrix is observed to possess greater storage modulus than the composites except for composite with nylon mat A as...
reinforcement at 50° & 70°C, the increments being 8 & 4% respectively. The composite with nylon mat A as reinforcement shows decrements of 14, 34 & 32% over the matrix at 90°, 110° & 130°C respectively. Decrements of 4, 10, 24 & 14% are observed at 50°, 70°, 90° & 110°C respectively while an increment of 2% is observed at 130°C for the composite with nylon mat B as reinforcement. The composite with nylon mat C as reinforcement shows decrements of 2, 7, 24, 48 & 33% at 50°, 70°, 90°, 110° & 130°C respectively.

Introduction of maleic anhydride into the blend did not change the decreasing trend of storage modulus with increase in temperature. The composites had greater storage modulus than the matrix up to 90°C which then decreased. The increments are 25, 33 & 26% for nylon mat A; 43, 61 & 67% for nylon mat B and 30, 45 & 49% for nylon mat C reinforcement at 50°, 70° & 90°C respectively. The decrements observed are 35 & 30% for nylon mat A and 18 & 60% for nylon mat C reinforcements at 110° & 130°C respectively. The composite with nylon mat B shows an increment of 3% at 110°C while at 130°C, a decrement of 21% is observed.

(b) Loss modulus

The loss modulus of the blend matrix as well as its composites decreased with increase in temperature. A similar trend is observed when the DCP modification and maleic anhydride grafted blend are used to prepare the composites. In most cases, the matrix had higher loss modulus than the composites (Fig 6.8 [A – C]).

A decreasing trend is observed in the loss modulus of the blend as matrix and as well as composites with increase in temperature. A higher
loss modulus is observed in the case of the matrix except for nylon mat B as reinforcement at 110° & 130°C and for nylon mat C as reinforcement at 50° & 70°C. The composite with nylon mat A as reinforcement shows decrements of 10, 13, 26, 52 & 64% at 50°, 70°, 90°, 110°& 130°C respectively while composite with nylon mat B as reinforcement shows decrements of 18, 22 & 4% at 50°, 70° & 90°C and increments of 11 & 4% at 110°& 130°C. At the same time composite with nylon mat C as reinforcement shows increments of 11 & 8% at 50° & 70°C while decrements of 10, 40 & 68% are observed at 90°, 110° & 130°C respectively.

DCP modification of the blend also shows the loss modulus of the matrix to be higher than the composites prepared except for nylon mat A as reinforcement at 50°C and nylon mat B as reinforcement at 130°C. The nylon mat A as reinforcement shows higher loss modulus by 3% at 50°C while nylon mat B as reinforcement shows an increase by 5% at 130°C. The decrements observed are 2, 14, 29 & 28% at 70°, 90°, 110° & 130°C respectively for composite with nylon mat A as reinforcement; 1, 4, 15 & 9% at 50°, 70°, 90° & 110°C respectively for composite with nylon mat B as reinforcement and 8, 12, 25, 42 & 31% at 50°, 70°, 90°, 110° & 130°C respectively for composite with nylon mat C as reinforcement.
Figure 6.8: [A – C] Loss modulus of 80% HDPE + 20% PP blend matrix and its composites with nylon mats.

Grafting of maleic anhydride onto the blend did not change the trend in loss modulus of the matrix and composites prepared. The composites exhibited greater loss modulus than the matrix except at 110°C for nylon mat A & C as reinforcement and at 130°C for all composites. The increments for composite with nylon mat A as
reinforcement are 23, 30 & 20% at 50°, 70° & 90°C while decrements of 20 & 15% are observed at 110° & 130°C. Nylon mat B as reinforcement brought out increments of 27, 43, 44 & 8% at 50°, 70°, 90° & 110°C respectively while a slight decrement of 0.2% is observed at 130°C. The composite with nylon mat C as reinforcement is found to possess increment in loss modulus by 28, 35 & 31% at 50°, 70° & 90°C respectively and decrements of 12 & 46% at 110° & 130°C over the matrix.

(c) Tan δ values

The tan δ values of the blend as well as its composites show an increasing trend with increase in temperature. The matrix had lower values than the composites. A similar trend is observed when the DCP modification and maleic anhydride grafted blend (Fig 6.9 [A - C]).

The tan δ values of the matrix as well as the composites of the blend as well as its modifications exhibited an increasing trend with increase in temperature. All composites of the unmodified blend had higher tan δ values than the matrix at all temperatures. The increments observed are 10, 8, 7, 18 & 33% for nylon mat A as reinforcement, 22, 23, 9, 1 & 4% for nylon mat B as reinforcement and 9, 5, 2, 9 & 40% for nylon mat C as reinforcement at 50°, 70°, 90°, 110° & 130°C respectively.
Figure 6.9: [A – C] Tan Delta values of 80% HDPE + 20% PP blend matrix and its composites with nylon mats.

The composite with DCP modified blend and nylon mat B as reinforcement exhibited higher tan δ values than the matrix at all temperatures, the increments being 3, 6, 11, 7 & 2% at 50°, 70°, 90°, 110° & 130°C respectively. Decrements of 5, 5 & 1% are observed for nylon
mat A as reinforcement at 50°, 70° & 90°C where as the composites with nylon mat C as reinforcement had decrements of 6, 5 & 1% at the same temperatures.Increments of 8 & 5% for nylon mat A as reinforcement and 13 & 5% for nylon mat A as reinforcement are observed at 110° & 130°C respectively.

The composites with maleic anhydride grafted blend as matrix exhibited lower tan δ values than the matrix at 50°, 70° & 90°C respectively. The decrements are 2, 3 & 4% for nylon mat A as reinforcement, 11, 12 & 14% for nylon mat B as reinforcement and 2, 7 & 12% for nylon mat C as reinforcement. All composites had higher tan δ values than the matrix at 110° & 130°C, the increments being 23 & 22% for nylon mat A as reinforcement, 5 & 26% for nylon mat B as reinforcement and 7 & 34% for nylon mat C as reinforcement.

6.3.1.4 20% HDPE/80% PP BLEND AND COMPOSITES

(a) Storage modulus

The storage modulus of the blend matrix as well as composites decreased when temperature increased. The matrix had higher values than the composites prepared. The storage modulus of the DCP modified blend matrix show a regular decreasing trend with increase in temperature but the composites show a minimum value which then increase. The storage modulus of maleic anhydride grafted blend matrix decreased to a minimum and then increased with increase in temperature. The composites prepared show a regular decrease in storage modulus (Fig 6.10).
The storage modulus of the blend matrix and composites exhibited a decreasing trend with increase in temperature. The matrix possessed higher storage modulus than the composites except for nylon mat A as reinforcement at 110° & 130°C and for nylon mat B as reinforcement at 130°C. The composite with nylon mat A as reinforcement exhibited decrements of 28, 31 & 23% at 50°, 70° & 90°C respectively while at 110°C it shows an increment of 6%. The composite with nylon mat B as reinforcement exhibits decrements of 28, 31, 30 & 24% at 50°, 70°, 90° & 110°C respectively while at 130°C, it shows an increment of 74%. In fact the storage modulus at 130°C is greater than at 110°C by 11%. The composites with nylon mat C as reinforcement exhibits decrements of 42, 41, 38, 35 & 30% over the matrix at 50°, 70°, 90°, 110° & 130°C respectively.
Figure 6.10: [A – C] Storage modulus of 20% HDPE + 80% PP blend matrix and its composites with nylon mats.

Modification of the blend with 0.3phr DCP shows the matrix to behave in the same pattern as the unmodified blend. The composites exhibit a decreasing trend, reaching a minimum at 90°C for nylon mat A & C as reinforcements and 110°C for nylon mat B as reinforcement. Composites with nylon mat A as reinforcement possess lower storage
modulus than the matrix at 50°, 70° & 90°C, the decrements being 27, 25 & 12% and at higher temperatures, the composite has larger storage modulus by 25 & 90% at 110° & 130°C respectively. Composites with nylon mat B & C as reinforcement possess higher storage modulus than the matrix, the increments being 11, 18, 10, 7 & 58% at 50°, 70°, 90°, 110° & 130°C respectively for nylon mat B as reinforcement and 12, 23, 54, 120 & 240% at 50°, 70°, 90°, 110° & 130°C respectively for nylon mat C as reinforcement.

Grafting the blend with maleic anhydride along with DCP, storage modulus of the matrix decreases to a minimum at 110°C and then increases slightly with increase in temperature. The composites with nylon mat A & C as reinforcement exhibit a decreasing trend with increase in temperature while composite with nylon mat B as reinforcement shows a trend similar to the matrix. The matrix possess higher storage modulus than the composites at all temperatures except for composites with nylon mat A & C as reinforcement at 70°C, the increments being 2 & 3% respectively for the composites. The composite with nylon mat A as reinforcement exhibits decrements of 2, 18, 56 & 67% at 50°, 90°, 110° & 130°C respectively while composite with nylon mat C as reinforcement exhibit decrements of 5, 12, 49 & 68% at the same temperatures. The decrements observed for nylon mat B as reinforcement are 1, 1, 12, 22 & 19% at 50°, 70°, 90°, 110° & 130°C respectively.
(b) Loss modulus

The loss modulus of the blend as well as the composites decreases with increase in temperature. The matrix has higher loss modulus than the composites prepared. DCP modified blend matrix shows a similar trend while the composites show a minimum followed by increase. Similar trend is shown by maleic anhydride grafted blend (Fig 6.11 [A – C]).

The loss modulus of the blend matrix and composites exhibit a trend similar to its storage modulus. The loss modulus decreases with increase in temperature. The matrix has higher loss modulus than the composites except at 130°C for nylon mat A & B as reinforcements. The decrements found are 20, 16, 12 & 1% for nylon mat A as reinforcement and 20, 18, 19 & 18% for nylon mat B as reinforcement at 50°, 70°, 90° & 110°C respectively. The composites with nylon mat C as reinforcement exhibits decrements of 3, 18, 27, 34 & 33% at 50°, 70°, 90°, 110° & 130°C respectively.
Figure 6.11: [A – C] Loss modulus of 20% HDPE + 80% PP blend matrix and its composites with nylon mats.

The loss modulus of DCP modified blend decreases with increase in temperature, but for composites, it reaches a minimum and then increase. All composites have lower loss modulus than the matrix except for composite with nylon mat C as reinforcement at 110° & 130°C. The depreciations are 54, 47, 36, 28 & 19% for nylon mat A as reinforcement,
41, 35, 28, 33 & 8% for nylon mat B as reinforcement at 50°, 70°, 90°, 110° & 130°C respectively. The composites with nylon mat C as reinforcement exhibit decrements of 45, 37 & 19% at 50°, 70° & 90°C respectively while increments of 4 & 44% are observed at 110° & 130°C.

Grafting of maleic anhydride with the blend shows the loss modulus of the matrix to decrease to a minimum at 90°C and then increase with increase in temperature. A similar trend is observed in the case of the composite with nylon mat B as reinforcement. Other composites exhibit a regular decrease in loss modulus with increase in temperature. The matrix has greater loss modulus than the composites except that with nylon mat B as reinforcement at 50°& 70°C. The composites with nylon mat A as reinforcement exhibit decrements of 3, 2, 20, 46 & 57% while composite with nylon mat C as reinforcement show 17, 15, 31, 48 & 58% decrements at 50°, 70°, 90°, 110° & 130°C respectively. The composite with nylon mat B as reinforcement showed increments of 4 & 5% at 50° & 70°C while decrements of 7, 14 & 13% are observed at 90°, 110° & 130°C respectively over the grafted matrix.

(c) Tan δ values

The tan δ values of the blend matrix as well as its composites increases with increase in temperature. The composites have higher value than the matrix. Similar trend is observed in the case of DCP modified blend and its composites. Maleic anhydride grafting of the blend shows the values to increase to a maximum and then decrease as temperature is increased (Fig 6.12 [A - C]).

The tan δ values of the blend matrix increases with increase in temperature. A similar trend is observed in the case of composites with
nylon mat B & C as reinforcements. All composites have higher tan δ values than the matrix except at 130°C. The composite with nylon mat A as reinforcement exhibits an increasing trend, reach a peak value at 110°C and then decrease. The composite with nylon mat A as reinforcement exhibits higher tan δ values by 11, 21 & 15% at 50°, 70° & 90°C respectively over the matrix and decrements of 6 & 30% at 110° & 130°C. The composite with nylon mat B as reinforcement exhibits increments of 12, 20, 18 & 9% at 50°, 70°, 90° & 110°C respectively while at 130°C it shows a lower value by 17%. The composite with nylon mat C as reinforcement has higher tan δ values by 66, 40, 17 & 2% at 50°, 70°, 90° & 110°C respectively while at 130°C the composite exhibits a decrement of 17% over the matrix.

An increasing trend is observed in the case of DCP modified matrix and the composite with nylon mat C as reinforcement. When nylon mat A is used as reinforcement, tan δ values reach a maximum at 90°C and then decrease. In the case of nylon mat B as reinforcement, the maximum is observed at 110°C. All composites have lower tan δ values than the matrix at all temperatures. The decrements are 37, 31, 27, 43 & 58% for nylon mat A as reinforcement; 47, 45, 34, 28 & 42% for nylon mat B as reinforcement and 51, 49, 47, 52 & 58% for nylon mat C as reinforcement at 50°, 70°, 90°, 110° & 130°C respectively.
Figure 6.12: [A – C] Tan Delta values of 20% HDPE + 80% PP blend matrix and its composites with nylon mats.

Grafting of maleic anhydride along with DCP with the blend shows tan δ values to increase with temperature, reach a maximum at 90°C and then decrease for the matrix as well as composites with nylon mat A & B as reinforcements. The composite with nylon mat C as
reinforcement exhibited an increasing trend with temperature. The nylon mat B composite as reinforcement have increments of 6, 3, 5, 10 & 9% over the matrix at 50°, 70°, 90°, 110° & 130°C respectively. The composites with nylon mat A & C as reinforcements have lower tan δ values than the matrix at 50°, 70° & 90°C. The decrements are 1, 7 & 3% for mat A and 12, 23 & 22% for nylon mat C as reinforcement at 50°, 70° & 90°C respectively. At 110° & 130°C, mat A reinforced composites show increments of 23 & 31% while mat C reinforced had 2 & 32% increments.

DMA studies have been conducted at a constant frequency and in a wide temperature region on epoxy glass fibre composites. The tensile testing are conducted at three different strain rates at different temperatures in order to study the strain rate as well as the temperature effect. The strong material dependence on temperature and strain rate which is mainly attributed to the inelastic response of the polymer matrix is modeled with empirical scaling rules for material elastic constants, valid in viscoelasticity. They also observed a satisfactory agreement between simulated and experimental results for different temperatures and strain rates and various types of off-axis specimens using the same set of parameter values.

It was observed the storage modulus of the composite decrease with increase in temperature in all cases studied. The tan δ values showed a maxima and then diminished with increase in temperature [9]. The dependence of the thermo mechanical behaviour of the composite on the distribution of fibers in the cross section of a unidirectional composite has been investigated by Bulsara et.al. The importance of non – Uniformity
of fiber spatial distribution with regard to the transverse failure of composites was highlighted. It was observed that by the use of an actual radial distribution function obtained for a ceramic matrix composite by quantitative stereology in conjunction with a simulation technique. The RVE size is investigated with respect to the initiation of debonding and radial matrix cracking. Tensile loading transverse to the fiber and residual stresses induced by thermal cool down are considered separately as loading modes for transverse failures [10 -13].

6.3.2 THERMOGRAVIMETRIC ANALYSIS

6.3.2.1 HDPE COMPOSITES

The TGA studies of the matrix and composites of HDPE with nylon mat reinforcements show the following observations. The decomposition started around 400°C for the matrix as well as the composites with nylon mats A and B as reinforcement. The onset temperature is only 360°C for the composite with nylon mat C as reinforcement. 50% of the material decompose around 475°C for the matrix as well as composites with nylon mats A and B while it is 468°C for composite with mat C. The residue left over is less than 0.5% indicating the volatile nature of the polymer used (Fig 6.12).

Modification of HDPE with 0.3phr DCP lowers the onset temperature of the matrix as well as the composites prepared. Composites with mat C as reinforcement has the lowest onset temperature of 340°C. 50% of the material decomposed around 475°C for the matrix and composites with nylon mats A and B as reinforcements while mat C composite has 461°C for 50% decomposition. The residue left over is around 0.35%.
Grafting of maleic anhydride onto HDPE increases the onset temperature of the matrix as well as its composites over the DCP modification. The lowest onset temperature is for the composite with nylon mat C as reinforcement. The temperature at which 50% decomposition takes place is lowest for the composite. The residue left over is around 0.5%.

Figure 6.12: TGA curve of HDPE - Nylon C composite.

The TGA analysis of HDPE matrix and the composites indicate less than 0.35% weight loss at 300°C. This indicates the presence of very low quantity of volatile matter involved in the composites. The weight loss is around 1.5% at 400°C for all composites while at 450°C, the matrix and composites with nylon mats A & B as reinforcements recorded a weight loss of around 10% while composite with mat C recorded a weight loss of 16%. These results indicate the thermal stability of the matrix and composites.
The onset temperature for the decomposition of the matrix and composites with nylon mats A & B as reinforcements are nearly same at around 400°C while the composite with nylon mat C as reinforcement recorded a lower value of 360°C. The temperature for 50% decomposition is around 476°C for the matrix and composites with nylon mats A & B as reinforcements while the composite with nylon mat C as reinforcements has a lower value. The residue left over is below 0.5% indicating the volatile nature of the composites (Table 6.1).

**Table 6.1: Comparison of TGA scans of HDPE matrix composites**

<table>
<thead>
<tr>
<th>Material studied</th>
<th>Weight Loss at 300°C</th>
<th>Weight Loss at 400°C</th>
<th>Weight Loss at 450°C</th>
<th>50% Decomposition temperature</th>
<th>Onset Decomposition temperature</th>
<th>Residue %</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDPE</td>
<td>0.24%</td>
<td>1.05%</td>
<td>9.14%</td>
<td>476.18°C</td>
<td>398.49</td>
<td>0.38%</td>
</tr>
<tr>
<td>NYLON A</td>
<td>0.34%</td>
<td>1.11%</td>
<td>8.83%</td>
<td>475.73°C</td>
<td>399.50</td>
<td>0.16%</td>
</tr>
<tr>
<td>NYLON B</td>
<td>0.08%</td>
<td>0.96%</td>
<td>8.42%</td>
<td>476.20°C</td>
<td>392.43</td>
<td>0.43%</td>
</tr>
<tr>
<td>NYLON C</td>
<td>0.16%</td>
<td>1.51%</td>
<td>15.96%</td>
<td>468.02°C</td>
<td>360</td>
<td>0.17%</td>
</tr>
<tr>
<td>HDPE/DCP</td>
<td>0.2%</td>
<td>0.98%</td>
<td>10.42%</td>
<td>473.72°C</td>
<td>380.32</td>
<td>0.18%</td>
</tr>
<tr>
<td>NYLON A</td>
<td>0.33%</td>
<td>1.2%</td>
<td>9.72%</td>
<td>475°C</td>
<td>377.78</td>
<td>0.001%</td>
</tr>
<tr>
<td>NYLON B</td>
<td>0.37%</td>
<td>0.93%</td>
<td>7.35%</td>
<td>477.05°C</td>
<td>384.13</td>
<td>0.18%</td>
</tr>
<tr>
<td>NYLON C</td>
<td>0.11%</td>
<td>4.88%</td>
<td>29.15%</td>
<td>461.1°C</td>
<td>339.69</td>
<td>0.04%</td>
</tr>
<tr>
<td>HDPE/MA</td>
<td>1.82%</td>
<td>6.41%</td>
<td>43.04%</td>
<td>454.26°C</td>
<td>391.42</td>
<td>0.37%</td>
</tr>
<tr>
<td>NYLON A</td>
<td>1.6%</td>
<td>2.83%</td>
<td>11.15%</td>
<td>477.78°C</td>
<td>399.50</td>
<td>0.34%</td>
</tr>
<tr>
<td>NYLON B</td>
<td>1.42%</td>
<td>2.50%</td>
<td>10.02%</td>
<td>477.45°C</td>
<td>391.42</td>
<td>0.04%</td>
</tr>
<tr>
<td>NYLON C</td>
<td>1.38%</td>
<td>8.41%</td>
<td>34.70%</td>
<td>461.63°C</td>
<td>384.4</td>
<td>0.40%</td>
</tr>
</tbody>
</table>

A similar trend is observed in the DCP as well as maleic anhydride modifications of HDPE used as matrix. The weight loss at
300°C is below 0.5%, around 1% at 400°C and 10% at 450°C. The nylon mat C reinforced composites showed higher weight loss, 5% at 400°C and 29% at 450°C. The onset temperature of DCP modified HDPE composites are around 377 - 385°C which is lower than that for unmodified composites. The composite with nylon mat C reinforcement had onset temperature of 340°C. The temperature for 50% decomposition is 473 - 477°C while the composite with nylon mat C reinforcement recorded 454°C. The residue left over is below 0.2%.

6.3.2.2 PP COMPOSITES

Introduction of nylon mats as reinforcements to PP matrix lowers the onset temperature as well as the temperature for 50% decomposition. The matrix has an onset temperature of 366.2°C. The lowest onset temperature is for the composite with nylon mat B as reinforcement. Residue left over is nearly 0.6% (Fig 6.13).

*Figure 6.13: TGA curve of PP matrix.*
The onset temperature of DCP modified PP is higher than that of unmodified PP, all composites having lower onset temperatures than the matrix. The temperature for 50% decomposition is nearly constant at 455°C for the matrix as well as the composites. The residue left over is around 0.5%.

*Table 6.2: Comparison of TGA scans of PP matrix composites.*

<table>
<thead>
<tr>
<th>Material studied</th>
<th>Weight Loss at 300°C</th>
<th>Weight Loss at 400°C</th>
<th>Weight Loss at 450°C</th>
<th>50% Decomposition at</th>
<th>Onset Temperature °C</th>
<th>Residue %</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP</td>
<td>0.40%</td>
<td>3.83%</td>
<td>35.45%</td>
<td>456.05°C</td>
<td>366.20</td>
<td>0.04%</td>
</tr>
<tr>
<td>NYLON A</td>
<td>0.33%</td>
<td>3.99%</td>
<td>36.05%</td>
<td>455.78°C</td>
<td>365.18</td>
<td>0.34%</td>
</tr>
<tr>
<td>NYLON B</td>
<td>0.20%</td>
<td>17.72%</td>
<td>64.27%</td>
<td>441.28°C</td>
<td>329.41</td>
<td>0.66%</td>
</tr>
<tr>
<td>NYLON C</td>
<td>0.42%</td>
<td>4.56%</td>
<td>38.34%</td>
<td>453.86°C</td>
<td>353.45</td>
<td>0.36%</td>
</tr>
<tr>
<td>PP/DCP</td>
<td>0.39%</td>
<td>4.94%</td>
<td>37.82%</td>
<td>455.28°C</td>
<td>372.7</td>
<td>0.41%</td>
</tr>
<tr>
<td>NYLON A</td>
<td>0.31%</td>
<td>4.28%</td>
<td>37.03%</td>
<td>455.32°C</td>
<td>361.27</td>
<td>0.50%</td>
</tr>
<tr>
<td>NYLON B</td>
<td>0.38%</td>
<td>4.66%</td>
<td>37.27%</td>
<td>455.55°C</td>
<td>365.08</td>
<td>0.32%</td>
</tr>
<tr>
<td>NYLON C</td>
<td>0.71%</td>
<td>13.36%</td>
<td>46.66%</td>
<td>452.80°C</td>
<td>327.85</td>
<td>0.31%</td>
</tr>
<tr>
<td>PP/MA</td>
<td>2.22%</td>
<td>6.01%</td>
<td>37.21%</td>
<td>455.92°C</td>
<td>286.36</td>
<td>0.42%</td>
</tr>
<tr>
<td>NYLON A</td>
<td>2.01%</td>
<td>5.32%</td>
<td>30.45%</td>
<td>460.37°C</td>
<td>301.23</td>
<td>0.32%</td>
</tr>
<tr>
<td>NYLON B</td>
<td>1.38%</td>
<td>4.0%</td>
<td>21.95%</td>
<td>466.26°C</td>
<td>316.84</td>
<td>0.20%</td>
</tr>
<tr>
<td>NYLON C</td>
<td>2.06%</td>
<td>4.98%</td>
<td>24.27%</td>
<td>464.62°C</td>
<td>359.13</td>
<td>0.04%</td>
</tr>
</tbody>
</table>

Grafting maleic anhydride onto PP lowers the onset temperature to 286.4°C for the matrix. All composites show comparatively lower values than the composites of PP or DCP modified PP matrix. The temperature
for 50% decomposition is highest in the case of composites of ma-g-PP matrix.

Comparison of TGA data of PP – nylon mat composites indicate very low percentage of volatile matter to be present in the composites. The weight loss is below 0.5% at 300°C, 4% at 400°C and around 35 – 40% at 450°C. The weight loss for nylon mat C reinforced composites are 18% at 400°C and 64% at 450 °C. The composites had lower onset temperatures than the matrix and the same trend is followed for the temperature for 50% decomposition. The thermal stability of the composites are lower than that of the composites (Table 6.2).

DCP modified PP matrix and composites lose around 1% weight at 300°C, 5% at 400°C and 37% at 450°C. The weight loss for nylon mat C reinforced composites are 13% at 400°C and 46% at 450°C. All composites have lower onset temperatures than the matrix. The temperature for 50% decomposition is nearly steady at around 455°C and residue left over is below 0.5%. These results do not indicate a higher thermal stability for the composites with DCP modified PP matrix.

The weight loss recorded for maleic anhydride modified PP matrix are 2% at 300°C, 4 – 6% at 400°C and around 20 – 37% at 450°C. The weight loss for nylon mats B & C reinforced composites are 22 & 24% as compared to 30% for nylon mat A composite and 37% for the matrix. This indicates greater thermal stability for the composites over the matrix. The onset temperatures and temperature for 50% decomposition are greater for the composites than the matrix which substantiates their greater thermal stability.
6.3.2.3 80% HDPE/20% PP BLEND AND COMPOSITES

Studies on 80% HDPE/20% PP blend as matrix showed all composites to have higher onset temperature than the matrix. The onset temperature of the matrix is 370.7°C. The temperature for 50% decomposition is also lowest for the matrix. The residue left over is around 0.4% (Fig 6.14).

Modification of the blend using DCP improved the onset temperature of the matrix. The matrix has an onset temperature of 381.3°C where as the composites have higher values. The temperature for 50% decomposition of the matrix shows improvement but the temperatures for composites are nearly same as for composites of unmodified blend, the values being lesser than that for the matrix. The residue left over is around 0.15%.

Grafting maleic anhydride on to the blend improved the onset temperature of the matrix to 478.8°C. The composite with nylon mat C had a slightly higher onset temperature than the matrix, the other composites showing lesser values. The temperature for 50% decomposition is lesser than that of the unmodified blend, the composites showing greater values. The residue left over is around 0.3%.
The weight loss recorded for the composites are below 0.4% at 300°C, 1 – 2% at 400°C and around 8 – 12% at 450°C. The weight loss for the matrix is higher at 0.55% at 300°C, 13% at 400°C and 49% at 450°C. The onset temperature and temperature for 50% decomposition are higher for the composites than the matrix and the residue left over is around 0.4%. These observations indicate the composite to have greater thermal stability than the blend matrix (Table 6.3).

The DCP modified blend matrix and composites recorded weight loss of below 0.4% at 300°C, below 1.7% at 400°C and 13% at 450°C. The weight loss in the case of nylon mats A reinforced composites are 3.5% at 400°C and 25% at 450°C. All composites had higher onset temperatures as well as temperature for 50% decomposition over the matrix indicating greater thermal stability for the composites.
<table>
<thead>
<tr>
<th>Material studied</th>
<th>Weight Loss at 300°C</th>
<th>400°C</th>
<th>450°C</th>
<th>50% Decomposition Ion at °C</th>
<th>Onset Temperature °C</th>
<th>Residue %</th>
</tr>
</thead>
<tbody>
<tr>
<td>BLEND(80PE)</td>
<td>0.55</td>
<td>13.31</td>
<td>48.58</td>
<td>451.31</td>
<td>370.7</td>
<td>0.32</td>
</tr>
<tr>
<td>NYLON A</td>
<td>0.35</td>
<td>2.14</td>
<td>11.46</td>
<td>479.75</td>
<td>375.24</td>
<td>0.04</td>
</tr>
<tr>
<td>NYLON B</td>
<td>0.25</td>
<td>1.28</td>
<td>8.13</td>
<td>480.45</td>
<td>383.35</td>
<td>0.17</td>
</tr>
<tr>
<td>NYLON C</td>
<td>0.28</td>
<td>2.01</td>
<td>12.03</td>
<td>474.62</td>
<td>373.26</td>
<td>0.10</td>
</tr>
<tr>
<td>BLEND/DCP</td>
<td>0.28</td>
<td>1.28</td>
<td>9.38</td>
<td>479.91</td>
<td>381.30</td>
<td>0.19</td>
</tr>
<tr>
<td>NYLON A</td>
<td>0.31</td>
<td>3.43</td>
<td>25.39</td>
<td>474.93</td>
<td>384.13</td>
<td>0.27</td>
</tr>
<tr>
<td>NYLON B</td>
<td>0.30</td>
<td>1.39</td>
<td>9.61</td>
<td>479.78</td>
<td>396.83</td>
<td>0.02</td>
</tr>
<tr>
<td>NYLON C</td>
<td>0.38</td>
<td>1.69</td>
<td>13.0</td>
<td>474.05</td>
<td>381.32</td>
<td>0.11</td>
</tr>
<tr>
<td>BLEND/MA</td>
<td>1.85</td>
<td>3.10</td>
<td>9.86</td>
<td>478.77</td>
<td>426.03</td>
<td>0.07</td>
</tr>
<tr>
<td>NYLON A</td>
<td>3.47</td>
<td>8.73</td>
<td>32.23</td>
<td>466.68</td>
<td>386.11</td>
<td>0.04</td>
</tr>
<tr>
<td>NYLON B</td>
<td>2.84</td>
<td>9.73</td>
<td>33.26</td>
<td>467.33</td>
<td>389.69</td>
<td>0.01</td>
</tr>
<tr>
<td>NYLON C</td>
<td>2.73</td>
<td>3.95</td>
<td>11.09</td>
<td>478.39</td>
<td>395.56</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Comparison of TGA data of composites with maleic anhydride modified blend as matrix show lower thermal stability for the composites. The weight loss at 300°C is 1.8% for the matrix while the composites loose around 2.7 – 3.5%. At 400°C, the weight loss is 3% for the matrix while the composites loose about 10%. The weight loss for nylon mat C reinforced composites is around 4%. The matrix and composites with nylon mat C as reinforcements lose around 10% at 450°C while the other two composites loose around 32%. All composites have lower onset temperatures and temperature for 50% decomposition than the matrix.
6.3.2.4. 20% HDPE/80% PP BLEND AND COMPOSITES

The studies conducted on 20% HDPE/80% PP as matrix for composites show the composite with nylon mat B as reinforcement to have the highest temperature for 50% decomposition. The onset temperature for nylon mat A as reinforcement is lesser than the matrix while that for nylon mat B as reinforcement is higher. The residue left over is around 0.05% (Fig 6.15).

![Figure 6.15: TGA curve of 20% HDPE/80% PP blend matrix](image)

Modification of the blend with DCP lowered the onset temperature of the matrix and the composites to have lower onset temperature than the unmodified blend and composites. The temperature for 50% decomposition is also lowered in the same manner. The residue left over is slightly greater than that for the unmodified blend.

Introduction of maleic anhydride into the blend further lowers the onset temperature of the blend. The composites have higher onset temperatures than the matrix. The composites have higher temperature at
which 50% decomposition took place. The residue left over is slightly higher for the matrix and composite with nylon mat A as reinforcement (Table 6.4).

Table 6.4: Comparison of TGA scans of 20% HDPE/80% PP blend matrix composites.

<table>
<thead>
<tr>
<th>Material studied</th>
<th>Weight Loss at</th>
<th>50% Decompl. At °C</th>
<th>Onset Temp °C</th>
<th>Residue %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>300°C</td>
<td>400°C</td>
<td>450°C</td>
<td></td>
</tr>
<tr>
<td>BLEND(20PE)</td>
<td>0.61</td>
<td>2.05</td>
<td>16.77</td>
<td>468.35</td>
</tr>
<tr>
<td>NYLON A</td>
<td>0.41</td>
<td>15.35</td>
<td>52.94</td>
<td>447.61</td>
</tr>
<tr>
<td>NYLON B</td>
<td>0.39</td>
<td>2.0</td>
<td>13.62</td>
<td>472.72</td>
</tr>
<tr>
<td>NYLON C</td>
<td>0.39</td>
<td>1.36</td>
<td>18.11</td>
<td>466.37</td>
</tr>
<tr>
<td>BLEND/DCP</td>
<td>0.48</td>
<td>3.95</td>
<td>27.27</td>
<td>461.88</td>
</tr>
<tr>
<td>NYLON A</td>
<td>0.60</td>
<td>24.98</td>
<td>62.76</td>
<td>438.19</td>
</tr>
<tr>
<td>NYLON B</td>
<td>0.53</td>
<td>8.58</td>
<td>36.37</td>
<td>458.39</td>
</tr>
<tr>
<td>NYLON C</td>
<td>0.36</td>
<td>4.18</td>
<td>26.63</td>
<td>462.47</td>
</tr>
<tr>
<td>BLEND/MA</td>
<td>2.16</td>
<td>11.81</td>
<td>42.19</td>
<td>456.55</td>
</tr>
<tr>
<td>NYLON A</td>
<td>0.39</td>
<td>5.10</td>
<td>28.34</td>
<td>462.60</td>
</tr>
<tr>
<td>NYLON B</td>
<td>1.43</td>
<td>3.08</td>
<td>18.01</td>
<td>468.69</td>
</tr>
<tr>
<td>NYLON C</td>
<td>2.21</td>
<td>3.93</td>
<td>18.05</td>
<td>468.88</td>
</tr>
</tbody>
</table>

The study of unmodified blend matrix and its composites indicate weight loss of below 1% at 300°C, around 2% at 400°C and 13 – 18% at 450°C. The composite with nylon mats A as reinforcement has greater weight loss of 15% at 400°C and 53% at 450°C. All composites except that of nylon mat B as reinforcement have lower onset temperature than the matrix. Similar is the observation regarding temperature for 50%
decomposition. The residue left over is below 0.05%. These results indicate composites with nylon mat B as reinforcement to have greater thermal stability.

The weight loss recorded for DCP modified blend matrix and its composites are below 0.1% at 300°C, 4% for the matrix and composite with nylon mat C as reinforcement at 400°C and 27% at 450°C for the same. The composites with nylon mats A & B as reinforcements recorded weight loss of 25 & 8% at 400°C and 63 & 36% at 450°C respectively. The composites with nylon mat A & B as reinforcements have lower onset temperature as well as temperature for 50% decomposition than the matrix. The composite with nylon mat C as reinforcement has greater thermal stability than the matrix.

Comparison of TGA data of maleic anhydride modified blend matrix and composites indicate all composites to have greater thermal stability than the matrix. The weight loss recorded by the composites are below 2.2% at 300°C, around 5% at 400°C and around 20% at 450°C. The matrix recorded weight loss of 12% at 400°C and 42% at 450°C while composite with nylon mat A as reinforcements recorded 5 & 28% weight loss at 400°C & 450°C respectively. Residue left over is around 0.5%.

6.4. CONCLUSIONS

1. The storage modulus of unmodified and modified HDPE - Nylon mat composites decreases with increase in temperature for the matrix as well as composites of unmodified and modified HDPE. The storage modulus of composites of unmodified and modified matrix are greater than their matrix at all temperatures. The loss modulus of of composites of unmodified and modified matrix are
greater than their matrix except for nylon mat C reinforcement of DCP modified HDPE. The tan \( \delta \) values of all composites of unmodified and DCP modified HDPE are lesser than the matrix. The tan \( \delta \) values for nylon mat A & B reinforced composites of maleic anhydride modified HDPE are greater than the matrix.

2. The storage modulus of modified PP – Nylon mat nylon mat A reinforced composite is greater than the unmodified matrix. The storage modulus of composites of DCP modified PP are greater than the matrix while the reverse trend is observed in maleic anhydride modification. The loss modulus of nylon mat A reinforced composite is greater than the unmodified matrix. The loss modulus of composites of DCP modified PP are lesser than the matrix. The maleic anhydride modified matrix has greater loss modulus than unmodified PP but composites have lower loss modulus. Composites of unmodified and maleic anhydride modified matrix has higher tan \( \delta \) values than their matrix.

3. The storage modulus of nylon mat A & B reinforced composites of unmodified 80\% HDPE / 20\% PP blend blend are lower than their matrix. The storage modulus of nylon mat B & C reinforced composites of DCP modified blend are lower than their matrix. The storage modulus of all composites of maleic anhydride modified blend are higher than their matrix. The loss modulus of nylon mat B & C reinforced composites of unmodified blend are greater than their matrix. The same trend is observed for DCP modified blend. The loss modulus of all composites of maleic anhydride modified matrix are greater than their matrix. The tan \( \delta \)
values of all composites of unmodified blend are greater than the matrix. When DCP modified, nylon mat B reinforced composite had greater tan δ value than the matrix. The tan δ values of maleic anhydride modified matrix composites are lower than those of the matrix.

4. The storage modulus of all composites of unmodified and maleic anhydride modified 20% HDPE / 80% PP blend are lower than their matrix. The storage modulus of nylon mat B & C reinforced composites of DCP modified blend are higher than their matrix. The loss modulus all composites of unmodified and modified blend are lower than their matrix. The tan δ values of all composites of unmodified blend are greater than the matrix. When DCP modified, reverse trend is observed. The tan δ values of maleic anhydride modified matrix composites are higher than those of the matrix.

5. The onset temperature of decomposition nylon mat A reinforced composites of unmodified HDPE is greater than that of the matrix. Nylon mat B & C reinforced composites have greater temperature for 50% decomposition to be complete. All composites of DCP modified matrix have lower onset temperature of decomposition and temperature for 50% decomposition to be complete. Nylon mat A reinforced composite of maleic anhydride modified HDPE matrix has higher onset temperature of decomposition as well as temperature for 50% decomposition to be complete than the matrix.
6. All composites of unmodified PP and its DCP modification exhibit lower onset temperature of decomposition and temperature for 50% decomposition to be complete. The temperature for 50% decomposition to be complete for DCP modified PP matrix and its composites with nylon mats A & B are nearly the same. The onset temperature of decomposition and temperature for 50% decomposition to be complete for the maleic anhydride modification are found to be higher than the matrix.

7. The onset temperature of decomposition and temperature for 50% decomposition to be complete of all composites of the unmodified 80% HDPE / 20% PP blend are higher than the matrix. On DCP modification, the onset temperature of decomposition has the same trend but the temperature for 50% decomposition to be complete is lowered. The composites of maleic anhydride modified blend had lower onset temperature of decomposition and temperature for 50% decomposition to be complete than their matrix.

8. The onset temperature of decomposition and temperature for 50% decomposition to be complete of nylon mat B reinforced composites of unmodified 20% HDPE/80% PP blend are higher than that of the matrix. The same pattern is observed when nylon mat C is used to reinforce the DCP modified blend matrix. All composites of maleic anhydride modified blend have higher onset temperature of decomposition and temperature for 50% decomposition to be complete than the matrix.
6.5 REFERENCES


