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Study on Functional Behavior of Polypropylene/nanoclay Nonwoven Composites

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ABSTRACT

Polypropylene / nanoclay nonwoven composites were prepared by spun bond technology on laboratory model spunbonding machine. Nanoclay was inserted into the polymer matrix in different proportions and the prepared nonwoven composites were evaluated for its functional properties like air permeability, moisture management and UV resistance. The structural, thermal and mechanical analysis of the prepared composites is already carried out and published.

This paper only deals with the functional behavior of the product. It was observed that air permeability increases with increase in nano clay percentage, where as the composite becomes hygroscopic against the hydrophobic nature of pure PP. The resistance to UV rays also increases with increase in clay content compared to the nonwoven prepared without the addition of nanoclay.

Keywords: Polypropylene (PP); Nanoclay; Nonwoven; Ultra violet (UV).

I.INTRODUCTION

In the past decade, polymer nanocomposites have emerged as a new class of materials and attracted considerable interest. This is largely due to their new and often much improved mechanical, thermal, electrical and optical properties as compared to their macro and micro-counterparts. Nanocomposites are a new class of composites, for which at least one dimensions of the added particles, is in the nanometer range **[1]**. Nanocomposites are generally organic polymer composites with inorganic nanoscale dispersed particles which leads to a dramatic increase in interfacial area as compared with traditional composites. They combine the advantages of the inorganic material (e.g., rigidity, thermal stability) and the organic polymer (e.g., flexibility, dielectric, ductility, and processability). In general, polymer nanocomposites are made by inorganic and organic nanofillers into either a thermoplastic or thermoset polymer.

Recently reports are available on inclusion of clay particles enhance the thermal stability of polymers by acting as thermal insulator [**2**] and mass transport barrier [**3**] to the volatile products generated during decomposition. However, it is very difficult for the hydrophilic clay (montmorrilonite) to be exfoliated and well-dispersed in a hydrophobic polymer matrix. Therefore, organically modified clay (nanoclay) is generally used with objective to expand the interlayer space of the clay and allowing large polymer molecules to enter into the interlayer space. By use of organically modified clay (nanoclay), interaction between the clay particles and the polymer matrix has been enhanced [**4, 5**]. Polypropylene being a commodity polymer, is widely used in range of products namely; automotive textile, agro textiles and in packaging material.

In order to develop high performance inorganic-polymer composite nonwoven textile material for industrial application, nanoclay particles were incorporated as filler inside a polypropylene matrix. In this study, nonwoven

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fabric of PP and PP/nanoclay composite were prepared by spun bond technique on lab model spunbonding machine. The composites were characterized by SEM, EDX and XRD for analyzing the incorporation of nano particles into the polymer matrix and same has been published [**6**]. Functional behavior of the prepared composite was analysed by air permeability, moisture behavior and its effect by exposing to UV rays were measured using standard methods.

II. MATERIALS AND EXPERIMENTAL

Fibre grade PP chips of 35 MFI were procured from Reliance Industries for the manufacturing of nonwoven fabric.

2.1 Preparation of Polypropylene/Nanoclay Composite Nonwoven

Polypropylene granules were thoroughly mixed with nanoclay particles with different concentration, as given in table 1. Precise weight of nanoclay was obtained using electronic balance having accuracy of 0.0001 gms. For proper evaluation of the parameters, through mixing of the clay particles in with PP granules is necessary. To achieve this, twin screw extruder was used. Material in different proportion was added to twin screw extruder and homogeneous mixed granules of PP contained nanoclay were obtained. These chips were further fed into the hopper of laboratory model melt spun nonwoven machine, to get samples with fabric weight of about 160 GSM. Extrusion was performed within the temperature range 170−235°C at a through put of 0.09gms/hole/min. All the samples were produced under same laboratory condition and were analysed.

Table 1 Sample code and their composition for nonwoven

Sr.	Sample code	PP granules (Wt in gms)	Nanoclay (Wt in gms)	% Concentration
1	NW-S	250	---	0
2	NW-S1	250	0.25	0.1
3	NW-S2	250	1	0.4
4	NW-S3	250	1.75	0.7
5	NW-S4	250	2.5	1
6	NW-S5	250	4	1.6

2.2 Testing and Analysis

The air permeability of polypropylene pure and composite nonwoven fabrics was measured on Metefem air permeability tester. The testing was carried out as per ASTM D 737 test method. The result of the test measured in m3/h/m2 to three significant digits. Moisture management tester is an instrument which specifically designed to know the water management of performance fabrics. It works on AATCC TM195-2009 standards for Liquid Moisture Management Properties of Textile Fabrics. It measures the whole liquid transfer process in the textile material, dynamically, in 3 Dimensions. The UV transmittance of nonwoven fabric was measured by using Labsphere UV-2000F ultraviolet transmittance analyzer. It satisfies all the requirements of following standards viz., AS/NZ 4399:19961, EN 13758-1:2001, AATCC TM 183-2000 and GB/T18830.

III. RESULTS AND DISCUSSION

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Polypropylene / clay nanocomposite nano woven fabric was prepared with addition of nanoclay particles in different proportions. The difficulties came across during the preparation are discussed here as observation:

3.1 Observations

It is evident **[7]** from studies that viscosity of samples with the nano additives is higher than that of the control. The main effect of these viscosity differences was on the processability, where the pressure in the spin pack increases with increase in viscosity. To avoid it may require the use of higher melt temperature for proper processing, however, in this study, the melt temperatures were kept same. Processing was almost without any major problem up to 1% addition nano clay particles but was not very good for more than 1% addition of nanoclay particles. With higher level (1.6% in this case) of clay, there was increase in back pressure. To avoid any further problem, at this stage the metering pump rpm was increased to 5, which increased the through put value from 0.09 gms / hole / min to 0.11 gms / hole / min. For maintaining the GSM, minor increase in take-up speed was done. Since the run was only carried out for short duration, we did not observe any possible buildup on spinneret face. However there were droppings and good quality fabrics could not be collected especially with higher % of nanoclay samples. Actual photographs of the samples prepared are shown in Figure 1.

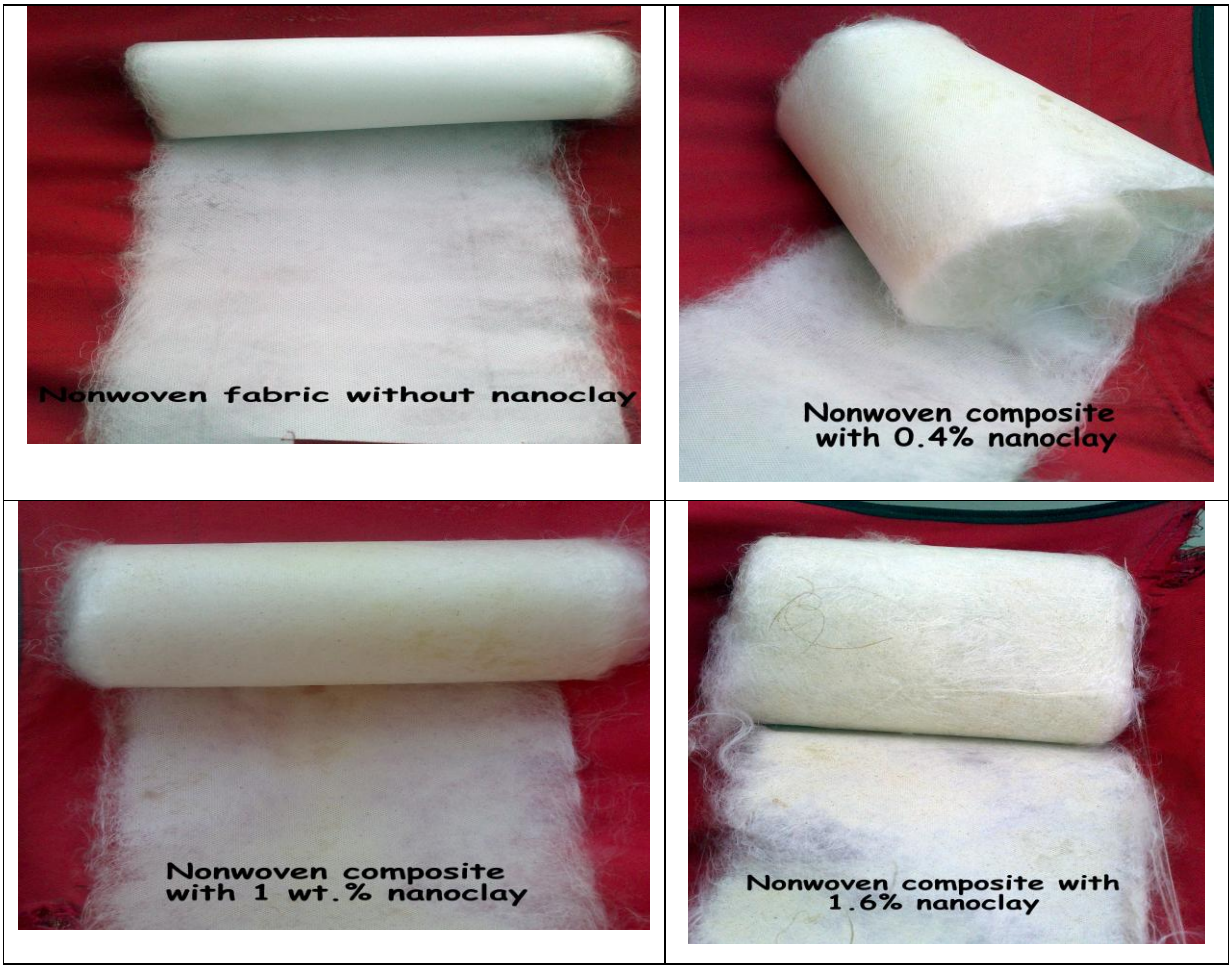

Figure 1 Photographs of pure polypropylene and polypropylene / nanoclay composite nonwoven fabric

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3.2 Effect on Air permeability

The addition of inorganic compound as filler does not allow to bond. The bonding is done at around 145°C with the help of calendar rollers, nanoclay particles present in the material does not allow the material to bond properly which results in an open structure of nonwoven fabric.

Table 2 Air permeability of pure polypropylene and polypropylene / nanoclay composite nonwoven fabric

Sample code	Sample	Air permeability (m3/m2/min) at 100 Pa
NW1	Pure PP nonwoven fabric	280
NW2	PP + 0.1 wt.% Nanoclay	306.67
NW3	PP + 0.4 wt.% Nanoclay	313.33
NW4	PP + 0.7 wt.% Nanoclay	348.13
NW5	PP + 1.0 wt.% Nanoclay	393.33
NW6	PP + 1.6 wt.% Nanoclay	393.33

From the Table 2 it can be seen that air permeability of the fabric increases with increase in the addition of nanoclay particles. As the quantity of filler material the structure becomes more and more open, which results in increase of air permeability. It was also observed that this increase in air permeability is only up to certain level i.e.1 weight % nanoclay incorporation, further addition of nanoclay particles, does not change the air permeability value.

3.3 Effect on Moisture Behaviour

The prepared nonwoven nanoclay composite fabric was tested for its moisture behaviour on moisture management tester from SDL. It is evident from the results as shown in Table 3and Figure 4.51 that one way moisture transport capability of the control fabric (NW1) i.e. without addition of nanoclay particles is negative (-493.33) and percentage absorption rate is also 49.49% per sec, which means that the fabric is not supporting the flow of water and it comes under the category of water proof fabric.

Addition of nanoclay particles even in small proportion makes drastic changes in the moisture behaviour of the fabric. It has been observed that moisture behaviour of the fabric becomes better and one way moisture transport capability of the fabric improves, the values become positive viz; 316.60, 443.68, 471.06, 480.91 and 479.05 respectively.

Table 3 Moisture behaviour analysis of pure and composite nonwoven fabric

Sample code	Wetting time (sec)	Absorption rate (% / sec)	Spreading speed (mm/sec)	One way transport capability	Overall rating
NW1	6.83	49.49	0.71	-493.33	WF
NW2	9.92	329.03	0.49	316.60	WP
NW3	10.10	416.28	0.48	443.68	WP
NW4	13.10	417.24	0.37	471.06	WP
NW5	11.04	410.49	0.44	480.91	WP
NW6	11.04	425.69	0.44	479.05	WP

Note : WF = Water proof fabric; WP = Water penetrating fabric

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Along with it the absorption rate and wetting time is also increased as we increase the percentage nanoclay addition. The composite fabric thus produced supports the flow of water and it comes under water penetrating fabric category. This can be attributed to, as the nanoclay particles are incorporated inside the polymer structure; it makes the polypropylene more absorbent. This may also increase the dyeing capability of the polypropylene

It was also observed that the difference in one way transport capacity and wetting tine in the case of 1% and 1.6% nanoclay addition is negligible or it's almost constant. Thus one can say that by little addition of nanoclay the polymer structure has become more porous and further increase in nanoclay addition does not support the at the same time seen from table, the value of one way water transport becomes almost constant from 1% addition and thereafter. Thus, with the addition of negligible percentage of nanoclay particle, the most hydrophobic material PP can be converted to hygroscopic material

3.4 Effect on Ultraviolet Rays

As seen from the Table 4, the UPF rating of the samples increases with the increase in addition of nanoclay particles. As the UV rays transmits through the space between yarns and also through the fibers. The UPF is affected mainly by the thickness and density of textiles, as well as by dyes, pigments and other compounds in fibers and textiles, such as pectin, wax, water, etc.132. For the samples prepared, it is evident that UPF rating of the pure PP nonwoven is 5, which is very low whereas increment in the percentage nanoclay addition increases the UPF factor to 6, 9, 10, 10 and 17. It has been observed that 1.6% nanoclay addition gives best results and comes under "Good" protection category. This may have happened as nanoclay particles embedded inside the polymer matrix would have scattered / absorbed the radiations and reduced the transmittance. This has designated this material as high UV blocking material which can be used as an industrial product

Table 4 UPF ratings of pure and composite nonwoven fabric

Sample code	UPF rating	T(UVA) in %	T(UVB) in %
NW1	05	17.69	15.12
NW2	06	13.14	7.10
NW3	09	14.6	6.77
NW4	10	10.77	4.46
NW5	10	13.35	6.26
NW6	17	9.41	3.74

III. CONCLUSION

- PP/nanoclay nonwoven nanocomposites fabric was successfully prepared by spun bond technique.
- As the structure of the prepared nonwoven fabric becomes open, as seen from SEM, and number of bond points decreases, air permeability of the fabric increases with addition of nanoclay up to 1 wt% loading and becomes stead thereafter.
- Incorporation of nanoclay particles inside the structure of the polymer, has also changed the moisture properties of PP which is remarkable. By addition of nanoclay, the fabric becomes "water penetrating fabric" from "water proof fabric". This can lead to major breakthrough in industry.
- There is increase in UPF rating of the fabric, which increases the durability of the fabric in sun, as PP is most used in agrotextile for green house effect.

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- The application of such nonwoven composite fabric can be at various fields like food packaging, medical and biological applications. This also can be very useful product for automobile industry.
- By combining the attractive functionalities of nanoclay and different polymeric components, resultant nanocomposites material could potentially be applied in various areas such as automotive, aerospace, opto-electronics, medicinal etc. owing to their engineered structural and mechanical properties

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