

## Effect of Nanoparticles in Polyester Matrix & Physical, Mechanical, Thermal and Rheological Properties for the Textile Application

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### Abstract

**This paper aims to study the influence of addition of Nanotalc on polyester polymer matrix. The effect of Nanotalc on polyester is studied by comparing properties such as Tensile Strength, Elongation, Moisture regain, Gloss, Dyeability(k/s value), Thermal Stability(DSC), Rheological properties of the filament produced by Polyester/Nanotalc nanocomposites yarn with the filament produced from conventional base polymer matrix of Polyester. This comparative study will help in concluding the effect of Nanotalc on polyester. The object of this paper is study the effect of addition of Nanotalc at different concentration on the mechanical, physical, thermal, and rheological properties of polyester. In this firstly, a normal polyester filament is produced from PET/ Nanotalc by adding 0.5%, 1%, 1.5% Nanotalc by weight of polyester chips in the polymer matrix and extruding the fibres through the spinneret. Finally the mechanical, physical thermal and rheological properties of untreated and treated polyester are compared.**

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**Keywords— Buckyballs, Nanotalc, Nanofillers, Nanocomposites.**

### I. INTRODUCTION

Nanotechnology is one of the rapidly growing scientific disciplines due to its enormous potential in creating novel materials that have advanced applications. This technology has tremendously impacted many different science and engineering disciplines, such as Electronics, material sciences and polymeric engineering. This technology has its impact over Textiles. Nanotechnology, the science of small, refers to area of science in which the crucial particle size is less than one micron. "Nano" means one millionth of a millimeter ( $10^{-6}$ ) or ( $10^{-9}$  of a meter). The common definition is the precise manipulation of individual atoms and molecules to create layer structures. First, what is Nano Textiles? It is nothing but the nanotechnology applied in Textiles. Nanotechnology in textile field will enable an entire new generation of products that are clearer, stronger lighter and more precise. This technology of small has been implemented in various sectors in Textile industry, and has produced variety of products like nanofibres, nanocomposite, etc., by which a high range of fabrics are produced. The recent application of nanotechnology in producing fabrics with peculiar properties such as shirt having the property to stop bullets, military uniforms that can change color, water proof, germ proof and various other properties. Nanotechnology is a bottom up science, which enable us to understand the process that makes macro molecules from their building blocks and their properties at atomic levels. Nanotechnology is the study and development of materials at nano levels. When referring to fibers, "Nano" refers to the diameter of the fiber which is less than micron and cannot be seen without visual amplification. While nanofibres have diameter between 50 and 300 nanometers. The concept of nanotechnology is not new; it was started over forty years ago. According to the National Nanotechnology Initiative (NNI), nanotechnology is defined as the utilization of structures with at least one dimension of nanometer size for the construction of materials, devices or systems with novel or significantly improved properties due to their nano-size. Nanotechnology not only produces small structures, but is also an anticipated manufacturing technology which can give thorough, inexpensive control of the structure of matter. Nanotechnology can best be described as activities at the atomic and molecular level that have applications in the real world. Nano-particles, commonly used in commercial products are in the range of 1 to 100 nm. Nanotechnology is increasingly attracting worldwide attention because it is widely perceived as offering huge potential in a wide range of end uses. The unique and new properties of nonmaterial have attracted not only scientists and researchers but also businesses, due to their huge economical potential. [1]

Nanotechnology also has real commercial potential for the textile industry. This is mainly due to the fact that conventional methods used to impart different properties to fabrics often do not lead to permanent effects, and will lose their functions after laundering or wearing. Nanotechnology can provide high durability for fabrics, because nano-particles have a large surface area-to-volume ratio and high surface energy, thus presenting better

affinity for fabrics and leading to an increase in durability of the function. In addition, a coating of nano-particles on fabrics will not affect their breathability or hand feel. Therefore, the interest in using nanotechnologies in the textile industry is increasing. This technology is not only useful for the polyester filament but Polypropylene, Nylon also shows the enhance properties like tensile strength (5). The first work on nanotechnology in textiles was undertaken by Nano-Tex, a subsidiary of the US-based Burlington Industries. Later, more and more textile companies began to invest in the development of nanotechnologies. Coating is a common technique used to apply nano-particles onto textiles. The coating compositions that can modify the surface of textiles are usually composed of nano-particles, a surfactant, ingredients, and a carrier medium. Several methods can apply coating onto fabrics, including spraying, transfer printing, washing, rinsing, and padding. Of these methods, padding is the most commonly used. The nano-particles are attached to the fabrics with the use of a padder adjusted to suitable pressure and speed, followed by drying and curing. The properties imparted to textiles using nanotechnology include water repellence, soil resistance, wrinkle resistance, anti-bacteria, anti-static, and UV-protection, flame retardation, improvement of dyeability and so on. As there are various potential applications of nanotechnology in the textile industry, only some of the well-known properties imparted by nano-treatment are critically highlighted here.

## 2. REVIEW OF LITERATURE

### 2.1. History & production of nano fiber

Polymers are used in different form for a wide range of application. Synthetic and regenerated polymers that have found application in not only textile and apparel sector but also in numerous industrial usages like tire cords, reinforcing, food and packaging industry, automotive parts etc. The processes of making fibers from polymers generally involve spinning in which the polymer is extruded through spinneret to form a fiber under suitable shear rates and temperature.

In the second half of 20<sup>th</sup> century, the use of polymers in our daily life has grown tremendously. Drawing generally follows the conventional fiber formation process; it involves the plastic stretching of the fiber as spun material to increase its strength and modulus. Depending on whether the polymer is in molten state or in solution, the process is termed as melt spinning or solution spinning respectively. Typical diameters obtained by this conventional spinning method are about 10 mm and higher.

Over the last ten years, a novel technique has been re- explored to generate polymeric fibers in submicron range. This technique is termed as electrospinning, produced filaments that are in diameter range one or two orders of magnitude smaller than those obtained from the conventional melt spinning and solution spinning. A number of processing technique such as drawing, template synthesis, phase separation, self assembly, electrospinning, etc. has been used to prepare the polymer nano fibers in recent years. Electrospinning offers the opportunity for control over thickness and composition of nanofibers along with the porosity of the nanofiber meshes using a simple experimental set up. Electrospinning is the process that produced polymer through the action of external electric field imposed on polymer solution or melt. This technique produces strong electric field between the polymeric melt within the extrude and metallic collecting devices.

Electrospinning provides a straightforward way to produce the long polymer fibers with the diameter in the range of 40-2000nm. Another technique to produce the nanofibers has recently been introduced by Nanofiber technology Inc. of Aberdeen, NC. In this method nanofibers are created by melt blowing fibers with modular die. The fibers produced are the mixture of micron and submicron size. Other technique can be used to produced nanofiber is spinning biocomponent fibers that split or dissolve.

The electrospinning process is not a new technology. The phenomenon that a spherical drop of water on a dry surface was drawn into a cone when a piece of electrically charged amber is held at a suitable distance above it, it was pointed out about 370 years ago by William Gilbert. This was the beginning of electrospinning and electrostatic spraying.

The technology of electrospinning was first established 1745 where Bose created an aerosol spray by applying high potential to liquid at the end of glass capillary tube. In the late 1800, Lord Rayleigh investigated the hydrodynamic stability of a liquid jet, with and without an applied electric field. In 1882 he studied the condition of instability occurring in the electrically charged liquid droplets. He showed that when electrostatic force overcomes the surface tension force, which acts in the opposite direction of the electrostatic force, liquid is thrown

out in fine jets. He modified Boses' idea to calculate maximum amount of charge which a drop of liquid can hold before the electrical force overcomes the surface tension of the drop.

Zeleny explored Electrospinning in detail in 1917. In 1934, Forhmhals was issued a patent for a process capable of producing micron level monofilament fibers using the electrostatic forces generated in the electrical field for a variety of polymer solution. In 1960 Taylor analyzed the condition at the point of droplet that was deform by electric field in a conical geometry. He identified the critical electrical potential for an electrostatic formation of a cone liquid now known as Taylor cone at the end of capillary tube. By examining a range of low molecular weight fluids, Taylor concluded that the conical interface between air and the fluid was stable at the semi angle conical angle of  $49.3^\circ$ . Conductivity and viscosity both play an important role in the electrostatic atomization process.

Baumgartner described the electrostatic spinning of acrylic micro fibers in 1971. In his experiment solution with viscosities ranging from 1.7-215 were used. Fibers with diameters ranging from 500-1100nm were produced. In 1981, Larrondoand Manely published work describing the production of fibers from a solution of polyethylene in paraffin and perhaps more importantly, molten polypropylene. The fibers that obtained were 50 micrometers in diameter and the size was attributed to viscosity. It was noted that by increasing the temperature of the melt and the voltage used, the fiber diameter become smaller and certain degree of control could be obtained. Buchko was able to obtained moderate alignment in nylon nanofibers with a misorientation angle of 17 degree. Shrinivasan and Renekar produced the fibers as small as 40 nanometers using both positive and negative polarity. Kaiser explained that when a solution was capable of being electrospun using either negative or positive polarity, dielectrophoretic forces were present as a result of high non- uniform field acting on an uncharged fluid.

In 1994, Renekar, Doshi characterized electrospinning process by using aqueous solution of polyethylene oxide (PEO). Many electrospun fibers were also produced from water-soluble polymers, biopolymers and liquid crystalline polymer. They electrospun a liquid crystal system, poly (p – phenyleneterephthalamide) had a circular cross section, were brief regent and stable at temperature above  $400^\circ\text{C}$ .

In 1995, Renekar and Chun electrospun nanofibers from several polymer solution such as poly(ethylene terephthalate), poly (amic acid) and poly acrylonitrile.

In 1996, G.J. Vansco and coworkers electrospun poly ethylene oxide fibers and characterized with scanning prob microscopy. From 1996 to 2010, there have been more than hundred polymers electrospun to produce the nano fiber.

Many parameters can influence the transformation of polymer solution into nanofibers through electrospinning these parameters include solution properties such as viscosity, elasticity, conductivity and surface tension. Nanofibers have extremely high specific surface area due to their small diameter and nanofiber mats can be highly porous with excellent pore interconnection. These unique characteristics plus the functionalities from the polymers themselves impart nanofibers with many desirable properties for advance application. [2]

Applications

Medical application

Tissue engineering scaffold

Filtration

Optical communication and sensor

Wound healing

Sensors

## 2.2 Talc

### 2.2.1 Production Methods

Talc is a natural mineral found worldwide and is the major constituent of rocks known as soapstone or steatite. Montana ores have 85–95% talc, while New York, Vermont, and Canada ores contain 35–60% talc, with the remainder of the ore being magnesium carbonate. The purest of talcs are found in Montana, while the whitest come from California; however, the latter are more abrasive because of asbestos related hard contaminants. Vermont talcs contain higher percentages of magnesium and iron. Talcs can be gray, green, blue, pink, and even black.

Talc is mined in open-pit (for the majority of talc deposits) or underground operations. There are seven to eight steps to talc production. The first step involves overburden removal. This involves the removal of waste rock

covering the talc vein by giant shovels (which can shift up to 1500 tons of rock an hour). Second, the exposed talc is extracted using shovels, and different ore types are sorted; this step is known as the talc extraction step. Third, the crude ore is crushed with rollers or jaw crushers to a size of 10–15 cm and sorted according to content and brightness with techniques such as hand sorting or state-of-the-art laser image analysis technology.

The type of further processing depends on the purity of the ore (dry versus wet processing). Pure Montana talc can be dry processed. The fourth and fifth steps in talc manufacturing involve grinding and classification. It is in these areas that most advances have been made in the past 25 years as consumers have realized the effectiveness of fine particles (large surface area) over coarser ones. Only for more demanding applications such as in the pharmaceutical industry is further purification necessary. The size of the crushed ore can be further reduced using roller mills or cone crushers. The requirements of the talc–plastic composite determine the fineness of the talc. A standard grinder roller produces 50 mm particles, finer grades are between 10 and 40 mm, and the finest grades are between 3 and 10 mm. Roller-milled products are used in low impact strength polymer-filled parts, such as fans in automotive under-the-hood applications. Fine micronization (1–12 mm) is carried out in hammer mills, tube mills, pebble mills, fluid-energy mills, and now by using a new delaminating process. Ball or rod milling with steel media can discolor the talc, so ceramic grinding media are used instead. Acceptable grinding rates can be achieved. Grind is measured in the plant by top size, loose bulk density, and/or median particle size. Most suppliers report the last measurement. The median particle size can be measured using laser light scattering technique or using Stokes law settling rates. It has only been possible to obtain submicron products since the advent of improved classification methods. Classification is usually carried out by air methods. To obtain the desired grades, the choice of process conditions and type of equipment are critical.

High-purity talc (97–98%) is obtained by means of wet methods. Manufacturers use techniques such as froth flotation, sedimentation, spray drying, magnetic separation, centrifugation, and hydrocycloning. After techniques such as flotation have been applied, the material is filtered, dried, and milled by jet mill micronization or in an impact mills. Bleaching agents are used where brightness is a major concern.

The sixth and seventh steps involve treatment of certain talcs. Some talc grades are silane surface-treated for the rubber industry. Others are treated with glycol stearate to improve dispersibility and processing. Amine-coated talcs are used for fertilizer sand cationic talcs for pitch control in papermaking. The surface treatment also helps with compatibilization reactions of certain components of polymer blends.

The last step in the production of talc involves delivery of the powdered mineral in bags, semi bulk bags, or bulk. Talc can also be delivered in pellet form or as slurry. A major talc producer in Montana has achieved a 26% reduction in greenhouse gas emissions at one of its mills by increasing operational efficiency and equipment upgrades using robotics. Decreases of 26 and 15% in natural gas and water, respectively, have also been achieved by using a dry compacting process for densification. [3]

### 2.2.2 Structure and Properties

Pure talc is a hydrated magnesium silicate with the chemical formula  $Mg_3Si_4O_{10}(OH)_2$  that belongs to the group of phyllosilicates. The center brucite plane is chemically bonded by bridging oxygen atoms to two tetrahedral silica planes (Fig. 2.2.1). Talc, unless heated at above 800 °C, has a plate-like structure. The planar surfaces of the individual platelets are held together by weak van der Waals force, which means that talc can be delaminated at low shearing forces. This makes the mineral easily dispersible and accounts for its slippery feel. The greasy feel is also due to its very low hardness (Mohs hardness 1) and density of 2.7–2.8 g/cm<sup>3</sup>. In contrast, ionic forces hold the layers in mica together, whereas in kaolin hydrogen bonding forces hold aluminosilicate layers together. The size of an individual talc platelet can vary from 1 to >100 nm, depending on the deposit. The platelet size determines the talc lamellarity. Highly lamellar talc has large individual platelets, whereas compact (microcrystalline) talc has smaller platelets. Talc is accompanied by the mineral chlorite in which Mg<sup>2+</sup> ions have been substituted by Al<sup>3+</sup> or Fe<sup>3+</sup>. Other mineral contaminants are magnesium carbonate, mica, quartz, sericite, and often tremolite, a type of amphibole asbestos. The composition of talc depends on the source and presence of tremolite. The US Montana talcs are considered to be free of asbestos and tremolite. California platy talcs contain minor amounts (<3%) of tremolite. Hard talcs contain 5–25% tremolite. Industrial talcs mined in New York contain 25–50% tremolite and other asbestiform minerals. Certain talc compounds have odor issues depending on

the source. The odor is believed to result from interaction of the talc with stabilizers added to the polymer-based formulation.

The theoretical chemical composition of pure talc by weight is 19.2% magnesium, 29.6% silicon, 50.7% oxygen, and 0.5% hydrogen. In terms of metal oxides, it is 31.7% MgO and 63.5% SiO<sub>2</sub> with the remaining 4.8% being H<sub>2</sub>O. Other elements found in impure talcs in variable amounts are Ca, Al, and Fe. Trace elements include Pb, As, Zn, Ba, and Sb.

Talc-filled composites have low gas permeability and high resistivity because of the plate-like nature of the impermeable talc particles and the resulting tortuous, complicated diffusion path. Talc is also unique in its ability to easily delaminate and can be used as a lubricant. Talc is the softest mineral on the Mohs hardness scale and is used as a standard. Commercial grades are, however, usually somewhat harder as a result of impurities. In general, as the mineral is soft it is also less abrasive. This is advantageous as there is reduced wear on processing equipment (such as extruders). The surface of talc is hydrophobic, which has been explained in terms of the high ionic character of the central magnesium plane, uniform polarity, and symmetry of structure and neutrality of the layers. The hydrophobic nature of talc allows it to be more compatible with polymer resins. Hydrophobicity can be further increased through coating with zinc stearate.

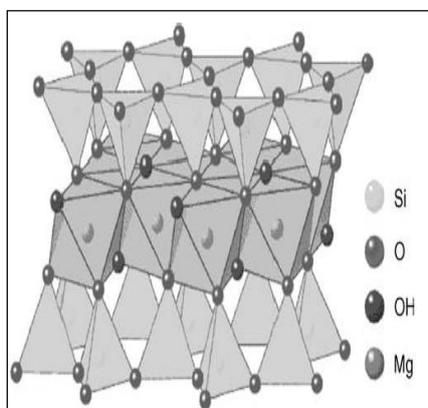


Figure 2.2.1. Molecular structure of talc. Magnesium has octahedral coordination

Particle size and shape are very critical with regard to the final mechanical properties of the composite. For a medium porosity particle material, the specific surface area is in the range 3–20 m<sup>2</sup>/g. Coarser products have an average size of about 10–20 μm and top size of up to 75 μm.[3]

### 2.2.3 Environmental/Toxicity Considerations

Safety issues regarding talc have been controversial. The debate revolves around asbestos-type impurities, particularly tremolite. Most commercial talc grades contain no asbestos, and those that do, contain only trace amounts. The Occupational Safety and Health Administration (OSHA) and Mine Safety and Health Administration (MSHA) have an 8 h time weighted exposure limit for non-asbestos containing talc dust of  $3 \times 10^{-6}$  kg/m<sup>3</sup>. For personal product industries, more rigorous controls are instituted and set by the American Industrial Hygiene Association (AIHA) and the Cosmetic Toiletry and Fragrance Association (CTFA). The US Food and Drug Administration (FDA) approve talc for use in polymeric compounds in contact with food. There are minimal concerns with skin contact, other than dryness with continuous exposure. Eye contact causes a mild mechanical irritation, while ingestion is of no concern. Approved dust masks should be worn when the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV) of  $2 \times 10^{-6}$  kg/m<sup>3</sup> is exceeded according to the National Institute of Occupational Safety and Health (NIOSH) and now also OSHA. Studies by Porro et al., Siegal et al., McLaughton et al., and Kleinfeld et al. have shown that long-term inhalation can lead to mild scarring of the lungs (pneumoconiosis symptoms: wheezing, chronic cough, and shortness of breath). Pneumoconiosis was found to be caused by fibrous varieties of talc, and the particle length, rather than the composition of the talc, seemed important. Other adverse health effects are associated with covering of the lungs (pleural thickening) [3]

## 2.2.4 Applications

### 2.2.4.1 General

Talc is an important reinforcing filler for plastics, in particular polypropylene (PP). Primary reasons for using talc include improvements in mechanical properties such as heat deflection temperature (HDT), rigidity, creep resistance and sometimes impact resistance, and lower shrinkage. Additional secondary benefits, because of the flaky nature of talc, include improvements in dimensional stability (as it orients along flow lines during molding) and lower permeability; other benefits include reduced coefficient of linear thermal expansion (CLTE), increased brightness, reduction of injection molding cycle due to nucleation and its use as an antiblock additive. Adverse effects include reduction in toughness and elongation at break in certain polymers, reduced weld line strength, and for certain polymer/stabilizer package combinations reduction in long-term thermal aging and UV resistance. In the rubber industry, talc is used to increase stiffness and processability.

Talc-filled masterbatches are available up to 75 wt% loadings. Talcs densified through zero force compaction/densification technology have shown better mechanical properties and higher throughput rates during processing than regular talcs using compressive forces of pelletization. Dark talc is used where color is not important, such as in certain exterior and interior automotive applications, and when the reinforcing properties are not as critical. White talcs are used in applications involving washers and dryers and garden furniture. Lower flexural modulus composites are based on talcs containing more granular minerals such as quartz and magnesite. Higher flexural strength and modulus composites are based on talc grades that are more homogeneous in particle size distribution and contain higher percentage of coarser particles [3]

### 2.2.4.2 Applications by Polymer Matrix

**Polyolefins** Owing to its platy nature, talc is used in linear low-density polyethylene (LLDPE) as an antiblocking agent preventing two or more contacting film layers from sticking together and as a nucleating agent. Recently, talc has found some new applications, such as reducing the necessary dosage of fluorocarbon elastomer polymer processing aids (PPAs) and enhancing the moisture barrier in packaging films. Because of its non-polar nature, a major application of talc in high density polyethylene (HDPE) (where a 2–10 wt% concentration leads to a 15–80% increase in tensile strength) is in wire and cable. Grades coated with zinc stearate are used in cross-linked low-density polyethylene (XLPE) wire coatings as flame retardancy aids. These talc grades increase char build up and also act as thixotropic agents and reduce dripping. Talc is mostly used with PP (over 200000 tons each year) with typical loadings in the range 10–40 wt%. It provides benefits such as stiffness, dimensional stability, enhanced thermoforming, opacity, whiteness, and high temperature heat resistance for automotive (fan shrouds and blades) and appliance (washer tubs, pump housings, and spin baskets) applications. [3]

## 3. MATERIAL & METHOD

### 3.1 Melt Spinning Process

Melt spinning process is used for the polymeric fibers or the polymers that can be melted. The polymer is melted and then pumped through a spinneret. The cooled and solidified molten fibers get collected on a take-up wheel. The fibers, when stretched in both, the molten and solid states, facilitate orientation of the polymer chains along the fiber axis. Melt spun fibers can be forced through the spinneret in different cross-sectional shapes such as round, trilobal, pentagonal, octagonal among others. Trilobal-shaped fibers are capable of reflecting more light which give a sparkle to the fabrics. Pentagonal-shaped and hollow fibers are soil and dirt resistant and as such are used for making carpets and rugs. Octagonal-shaped fibers offer glitter-free effects whereas hollow fibers trap air, creating insulation. Polymers like polyethylene terephthalate and nylon 6, 6 are melting spun in high volumes. Nylon fiber, olefin fiber, polyester fiber, etc. are also manufactured through melt spinning. Fiber has to go through the process of drawing /stretching. It is the process by which the yarn/fiber is elongated by passing it through a series of pair of rollers, each pair moving faster than the previous one is called drawing. The objects of the process are to increase strength, reduce creep properties, increase orientation and crystallinity and to remove brittleness. In this experiment four different types of polyester filament yarn are produced on melt spinning machine in Reliance Industries Ltd. Polyester chips used are of SDPET type i.e. semi dull type which contain 0.3% TiO<sub>2</sub> as

delustring agent. FDY produced in this experiment is of 75 denier. Spinning conditions remain same for all the sample i.e. for 100% polyester sample and sample containing 0.5%, 1%, 1.5% nano talc.

### 3.2 Material description

SD PET chips are used along with Nano Talc

Table 1

Properties of Nano talc-ESC-2	
Property	Value
Particle size distribution (PSD, Sedigraph)	d (10) = 0.30 $\mu\text{m}$ d (50) = 0.307 $\mu\text{m}$ d (90) = 2.67 $\mu\text{m}$ Below 2 $\mu\text{m}$ = 82.7%
Specific Surface area (BET)	76.94 m <sup>2</sup> /g
Specific Gravity	2.56 g/cc
Color Value	L = 93.46 a= -0.35 b= 0.33
Brightness	86.66%
Whiteness	85.07
Yellowness	0.46
X-ray Diffraction 2 $\theta$ d value intensity Major Content	9.27 9.53 100 Talc (90% crystalline)
Loss of Ignition (LOI)	5.0%
Chemical Analysis (XRF) MgO SiO <sub>2</sub> CaO Fe <sub>2</sub> O <sub>3</sub> BaO CuO	63.16% 29.38% 0.95% 0.85 % 0.60% 0.052%
Zeta Sizer Zeta Potential Conductivity Mobility	-18.2 mV 0.0152 mS/cm -1.426 $\mu\text{mcm/Vs}$

### 3.3 Spinning conditions for experiment

Table 2

Specification	Value
<b>Machine make</b>	Hills pilot melt spinning machine.

<b>Hopper capacity</b>	100 kg
Gear pump rpm	15 rpm.
No of holes in spinneret	<b>36</b>
Quench air temperature	20 <sup>0</sup> c
Godget 1 Rpm temperature	1429 90 <sup>0</sup> c
Godget 2 Rpm temperature	<b>4000</b> 145 <sup>0</sup> c.
Winding roller rpm	4000rpm
<b>Draw ratio</b>	2.8
<b>Machine throughput speed</b>	8 kg/ hour

#### 4. TESTING TABLES & FIGURES

##### 4.1. Moisture Regain

In this test moisture regain of four FDY sample has been calculated by using  $R = 100 W / D$  formula. R represents moisture regain of sample where W is weight of water and D is oven dry weight of FDY.

TABLE 3

Sample	Initial weight (gm)	Oven dry weight (gm)	Weight of water (gm)	Moisture Regain (%)
100% Polyester	4.533	4.514	0.019	0.4
0.5% Nanotalc	4.536	4.510	0.026	0.6
0.1% Nanotalc	4.551	4.527	0.024	0.55
1.5% Nanotalc	4.651	4.627	0.024	0.5

##### Result

Moisture regain of polyester yarn increases by adding nanotalc in it as compared to 100% polyester yarn sample. By adding 0.5% nanotalc in polyester matrix moisture regain increases by 50% as compare to 100% polyester yarn sample.

##### 4.2. Thermal Stability (DSC)

Differential scanning calorimeter (DSC) is widely used to characterize the thermophysical properties of polymers. DSC can measure important thermoplastic properties including like melting temperature, heat of melting, percent crystallinity, T<sub>g</sub> or softening, crystallization, plasticizers, polymer blends ( presence,

composition, compatibility). Most DSC experiments on polymers are conducted by heating from ambient conditions to above the melting temperature. But, for some thermoplastics, which do exhibit differences during processing, standard heating DSC may not show any significant differences. A more sensitive test, for detecting subtle, but important differences between different batches of a given thermoplastic, is the DSC isothermal crystallization test.

TABLE 4

Sample	Onset Melting Temp (0°)	Peak Melting Temp (0°)	End Melting Temp (0°)	Enthalpy for Transition (J/gm)
100% Polyester	243	255.9	262.9	41
0.5% Nanotalc	245.7	251.3	263.2	35.4
1 % Nanotalc	236	248	259	50.2
1.5% Nanotalc	238	254	260	42

#### Result

Onset, Peak & End melting temperature of 0.5%, 1%, and 1.5% nanotalc added polyester yarn is almost similar to 100 % polyester yarn sample which indicates that addition of talc does not degrade the polyester.

#### 4.3. Rheology

To test rheology machine used is Anton Paar Physica MCR 101. Its sensor is PP35 having diameter 35mm. Temperature during the test was 260<sup>0</sup>c. Gap between sensor and material was 0.5 mm.

TABLE 5 (100% POLYESTER)

Meas. Pts.	Shear Rate [1/s]	Shear Stress [Pa]	Viscosity [Pa·s]	Speed [1/min]	Torque [μNm]
1	0.000656	4.64	7,060	0.000179	38.9
2	0.00164	15.6	9,480	0.000449	131
3	0.00446	30.5	6,840	0.00122	256
4	0.0126	49.1	3,890	0.00344	412
5	0.027	69.4	2,570	0.00736	582
6	0.0491	91.1	1,850	0.0134	764
7	0.079	116	1,470	0.0216	972
8	0.123	146	1,190	0.0336	1,230
9	0.187	184	983	0.0512	1,550
10	0.283	234	826	0.0773	1,960
11	0.424	299	706	0.116	2,510
12	0.638	383	601	0.174	3,220
13	0.95	491	517	0.26	4,120
14	1.42	631	444	0.388	5,290

15	2.11	814	386	0.576	6,830
16	3.14	1,040	330	0.858	8,710
17	4.64	1,310	282	1.27	11,000
18	7	1,660	237	1.91	13,900
19	10.4	1,630	156	2.85	13,700
20	15.2	1,900	125	4.16	16,000
21	21.7	2,340	108	5.93	19,700
22	31.7	2,740	86.4	8.67	23,000
23	47.1	3,330	70.6	12.9	27,900
24	69.2	3,520	51	18.9	29,600
25	101	3,420	34	27.5	28,700

Table 6 (0.5% Nanotalc)

Meas. Pts.	Shear Rate	Shear Stress	Viscosity	Speed	Torque
	[1/s]	[Pa]	[Pa·s]	[1/min]	[ $\mu$ Nm]
1	0.0083	2.15	249	0.0026	18.1
2	0.0137	3.92	287	0.0033	32.9
3	0.0201	6.15	306	0.0055	51.6
4	0.0302	9.39	311	0.0084	78.8
5	0.0443	13.7	309	0.0121	115
6	0.0644	19.7	306	0.0176	165
7	0.0965	28.6	296	0.0264	240
8	0.143	39.6	278	0.0389	333
9	0.211	54.8	259	0.0577	460
10	0.314	74	236	0.0857	621
11	0.463	98.4	213	0.126	826
12	0.692	126	183	0.189	1,060
13	1	160	160	0.274	1,340
14	1.48	204	138	0.403	1,710
15	2.07	339	163	0.567	2,840
16	2.98	407	137	0.813	3,410
17	4.54	684	151	1.24	5,740
18	7.01	905	129	1.91	7,590
19	10.1	1,100	109	2.75	9,200
20	14.6	381	26	4	3,200
21	22.3	497	22.4	6.08	4,170
22	32.1	506	15.8	8.78	4,250
23	46.7	352	7.54	12.8	2,960
24	64.3	1,020	15.8	17.6	8,530
25	101	2,050	20.4	27.5	17,200

Table 7 (1% Nanotalc)

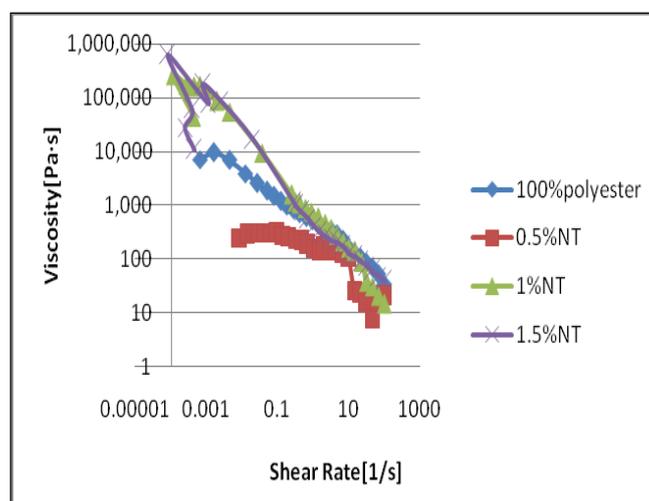
Meas. Pts.	Shear Rate	Shear Stress	Viscosity	Speed	Torque
	[1/s]	[Pa]	[Pa·s]	[1/min]	[ $\mu$ Nm]
1	0.000423	18.3	43,200	0.000116	154
2	0.000115	30	260,000	0.0000315	252

3	0.000275	47.4	172,000	0.0000752	398
4	0.000455	72.8	160,000	0.000124	611
5	0.000649	110	170,000	0.000177	923
6	0.00192	164	85,700	0.000523	1,380
7	0.00453	243	53,500	0.00124	2,040
8	0.0379	350	9,230	0.0104	2,940
9	0.25	394	1,580	0.0683	3,310
10	0.331	385	1,160	0.0904	3,230
11	0.409	439	1,070	0.112	3,690
12	0.621	542	873	0.169	4,550
13	0.917	676	737	0.25	5,670
14	1.43	833	582	0.391	7,000
15	2.18	974	447	0.596	8,180
16	3.21	1,140	354	0.877	9,540
17	4.78	1,310	275	1.31	11,000
18	7.07	1,490	210	1.93	12,500
19	10.2	1,610	158	2.78	13,500
20	15.1	2,060	137	4.12	17,300
21	23.6	2,060	87.5	6.45	17,300
22	31.3	1,160	37	8.55	9,720
23	46.1	1,410	30.6	12.6	11,800
24	67.9	1,380	20.4	18.5	11,600
25	99.6	1,450	14.6	27.2	12,200

Table 8 (1.5 % Nanotalc)

Meas. Pts.	Shear Rate	Shear Stress	Viscosity	Speed	Torque
	[1/s]	[Pa]	[Pa·s]	[1/min]	[μNm]
1	0.00046	-4.96	10,800	-0.000126	-41.7
2	0.000247	6.97	28,200	0.0000675	58.5
3	0.000394	24.3	61,700	0.000108	204
4	0.0000807	49.7	615,000	0.000022	417
5	0.00108	86.8	80,100	0.000296	728
6	0.000793	141	178,000	0.000217	1,180
7	0.00248	220	88,900	0.000677	1,850
8	0.0196	335	17,000	0.00537	2,810
9	0.291	330	1,130	0.0796	2,770
10	0.319	317	994	0.0871	2,660
11	0.461	349	757	0.126	2,930
12	0.703	397	564	0.192	3,330
13	1.05	423	403	0.287	3,550
14	1.5	471	313	0.411	3,960
15	2.17	577	266	0.592	4,840
16	3.17	717	226	0.867	6,020
17	4.64	943	203	1.27	7,910
18	6.99	1,190	171	1.91	10,000
19	10.3	1,290	126	2.81	10,900
20	15	1,660	111	4.09	14,000

21	21.4	1,950	91	5.85	16,400
22	32.3	2,380	73.6	8.81	19,900
23	46.8	2,850	61	12.8	23,900
24	69.2	3,320	48	18.9	27,900
25	102	3,950	38.9	27.8	33,200



#### Result

As we add 1% & 1.5% nanotalc in polyester matrix viscosity of material increases as compared to 100% polyester sample. When we add 0.5% nanotalc in polyester matrix viscosity of polyester decreases as compared to 100% polyester sample which indicates that by adding 0.5% nanotalc in polyester matrix proper mixing and melting of material takes place and it results in uniform filament formation.

#### 4.4. Tenacity & Elongation

To test tenacity machine used is Texttechno Statimat. Gauge length was 250 mm. Principle used to test the sample is CRE with the speed 300 mm/min.

Table 9

Nano Talc On Yarn %	Nil	0.5	1	1.5
Base Polymer	SDPET	SDPET	SDPET	SDPET
Den / Fil	75/36	75/36	75/36	75/36
Process	FDY	FDY	FDY	FDY
Tenacity (gpd)	4.1	2.9	2.4	1.8
Elongation (%)	23	12	10.5	10

#### Result

As we increase the nano talc percentage in the polyester matrix tenacity & elongation decreases.

#### 4.5. Gloss Testing

For gloss testing machine used is Minigloss tester. In this test light is inserted on the fabric at an angle of 45°

Table 10

Fabric Sample	1 <sup>st</sup> Reading	2 <sup>nd</sup> Reading
100 % Polyester	2.5	2.5
0.5% Nanotalc	1.6	1.8
1 % Nanotalc	2.4	2.5
1.5% Nanotalc	1.8	2

#### Result

As we add nanotalc in polyester matrix gloss of the polyester decreases as compared to 100 % polyester sample.

#### 4.6. Dyeability (K/S)

HTHP dyeing machine has been used to dye the fabric sample. Weight of sample was 11.4 gm. Shade description is as follows; Yellow brown ( 0.250 % , concentration 0.5), Red F3BS ( 0.115 % , concentration 0.1), Navy S ( 0.2 % , concentration 0.5) .Disperse stock solution taken as 0.1 % . MLR ratio taken as 1:10

To test spectral reflectance value spectrophotometer is used. Spectrophotometer 7000A, Gretag Macbeth is used for testing. 100 % polyester sample is taken as standard.

$$K/S = (1 - 0.01 R)^2 / 2 (0.01 R)$$

R indicates Spectral reflectance (R in %) of the sample

K indicates Absorption

S indicates Scattering

Table 9

Sample	% Strength	Shade	sR i.e. R%	K/S
0.5% Nanotalc	94.53	Lighter	53.33	0.840
1 % Nanotalc	90.44	Lighter	55.66	0.801
1.5% Nanotalc	88.62	Lighter	56.33	0.790

#### Result

As we increase nanotalc percentage in polyester matrix k/s value of the sample decrease which indicates that by increasing nanotalc percentage in matrix shade become lighter.

## 5. CONCLUSION

The modified polyesters are prepared to overcome some drawbacks such as low moisture regain, static electricity and soiling problems, these three drawbacks are interrelated and associated with hydrophobicity of the polyester. By making hydrophilic these drawbacks can be overcome. Thus, a hydrophilic fiber will have a higher moisture regain. The garments made up of hydrophilic fibre will absorb perspiration and will be comfortable. The advantages of above properties are good comfortable while in wearing, easy to dyeing, so it provides cost

reduction and very good appearance of the polyester garment. In the project, a polyester filament yarn (FDY) was spun successfully with nanotalc at different proportions. The physical, mechanical, thermal, rheological properties of the filament were studied. The moisture regain of polyester filament has increased by 50% after addition of 0.5% nanotalc as compared to the untreated polyester. Rheology test shows that the viscosity of polyester decrease by addition of 0.5% nanotalc in the matrix as compared to untreated polyester which indicates that by adding 0.5% nanotalc in polyester matrix proper mixing and melting of material takes place and it results in uniform filament formation. DSC properties also show that filaments produced by addition of nanotalc are thermally stable and it does not degrade the polyester. Thus the threshold value of addition of nanotalc lies at 0.5%.

Many other properties like dyeing, tenacity, elongation, gloss can be increased by adding some additives in it so further research is required to improved these properties. Super hydrophilicity is imparted in the filament can be studied by further preparation of fabric. Moisture regain of polyester (FDY) increases by adding nanotalc in it as compared to 100% polyester (FDY) sample. By adding 0.5% nanotalc in polyester matrix moisture regain increases by 50% as compare to 100% polyester sample. Onset, Peak & End melting temperature of 0.5%,1%,1.5% nanotalc added polyester is almost similar to 100 % polyester sample which indicates that addition of talc does not degrade the polyester. As we add 1% & 1.5% nanotalc in polyester matrix viscosity of material increases as compared to 100% polyester sample. When we add 0.5% nanotalc in polyester matrix viscosity of polyester decreases as compared to 100% polyester sample which indicates that by adding 0.5% nanotalc in polyester matrix proper mixing and melting of material takes place and it results in uniform filament formation. As we increase the nanotalc percentage in the polyester matrix tenacity & elongation decreases. As we add nanotalc in polyester matrix gloss of the polyester decreases as compared to 100 % polyester sample. As we increase nanotalc percentage in polyester matrix k/s value of the sample decrease which indicates that by increasing nanotalc percentage in matrix shade become lighter.

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