

Morphological and Mechanical Properties of Nanoclay Coated Fabric

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Abstract: In this paper we report the morphological and mechanical characteristics of textile fabric coated with nanoclay composites. There has been an increasing consideration in nanotechnology during the present decade due to its enormous potential in applying and creating novel materials for enhanced properties and applications. Many studies were carried out in improving the textiles and clothing properties and performances by applying nanocomposites. In this work, nanocomposites were prepared from mixtures of resin/clay with various percentages of clay. The obtained coatings were then deposited on a cotton fabric. Morphology and properties of nanocomposites' coated fabric were measured by DRX, scanning electron microscopy (SEM) and mechanical tests. The results showed that when observing the multilayers on SEM images, it can be deduced that nanocomposites using classical clay could be synthesized if they are added to PU and PAC resins. Also, the mechanical performances of fabric is globally increased versus the amount of clay for the two used resins. The maximum clay percentage to enhance the mechanical performance of a fabric is between 4 percent and 5 percent. As a matter of fact, the use of important amounts superior to 5 percent does not bring any better results.

Keywords: Nanoclay, Coating, Mechanical, Fabric

1. Introduction

The history and growth in synthesis, characterization, and understanding of microscopic structures has given rise to a new field, the nanotechnology [1].

In its most basic form, nanotechnology refers to the manipulation of materials at the atomic or molecular level. The name derives from the nanometer, a scientific measurement unit representing one billionth of a meter.

Nanotechnology gives scientists the ability to create new materials containing fine layered atomic clusters, quantum dots ...etc, that exhibit mechanical, electrical and optical properties different from the same materials in the bulk form. This difference is attributed to the observed increase in reactivity level due to the large surface to volume ratio that depends on size, shape, and lattice structure [2-3].

The unique and new properties of nanotechnology have attracted scientists and researchers of the textile industry and hence the use of nanotechnology in the textile field has increased rapidly. The textile fabrics provide best suitable substrates where a large surface area is present for a given weight or a given volume of fabric. The synergy between

nanotechnology and textile industry uses this property of large interfacial area and a drastic change in energetic is experienced by various macromolecules or super molecules in the vicinity of a fibre when changing from wet state to a dry state [4-5].

Recent studies are mainly focused on applying nanomaterials on producing nanostructures during manufacturing, finishing and coating process [6]. The application of nanotechnology in textile produced multifunctional or special functions, such as antibacterial [7], superhydrophobic [8], and fire retardant [9] products. In conventional methods, such as dip coating, nano colloidal has been used in coating process [10], while the wide ranges of coating methods have been promoted [11].

Nanomaterials such as layered silicate clays, carbon nanofibre, nanotubes, nanosilica, nano TiO_2 have been incorporated in the base polymeric coating to enhance the performance of coated textiles to achieve these properties on fabrics [12]. Superhydrophobic surfaces mimicking nano protrusions have drawn researcher's attention [13] to mimic this on fabric surface to develop oil water repellent garments and for specific applications like sails or shelter fabrics.

Another process for preparation of super-hydrophobic leaving a nano-roughened surface [14]. Super-hydrophobic cotton surfaces have been prepared by sol-gel method based on silica nanoparticles and perfluoro-octylated quaternary ammonium silane (PFSC) coupling agent [15].

In another study, nanocomposite coating of silica nanoparticle in perfluoroacrylate based water repellent agent produces super-hydrophobic cotton fabrics [16]. The nano-roughening imparted by silica nanoparticles are not durable as silica cannot bind to cotton surface [17].

Nanoclay particles in textile coating are one of those modern technologies which bring revolutionary changes in textile finishing. Clay particle is commonly any of group of important hydrous aluminum silicates with a layer structure and very small size, as for example montmorillonite, which are often organically modified to render them organophilic and to enable their dispersion into a polymer. The result of such dispersion is a nanocomposite comprised of nanoscale clay particles and a surrounding polymer [18]. Here in figure 1, it is seen that nanoclay particle incorporated with hyper branched polymer applied on textile substrate [19].

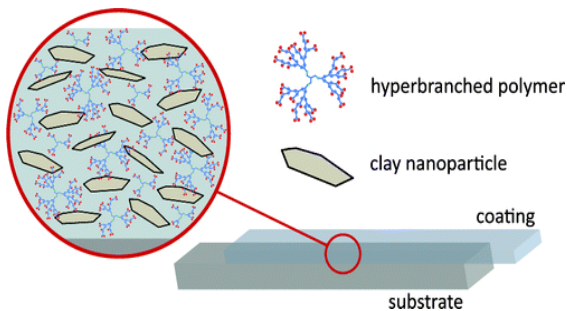


Fig. 1. Nanoclay particle incorporated with polymer in coating process [20]

One of the most important polymer-nanoclay composite is Nylon-6/clay nanocomposites since 1990. In 1990 Toyota research institute prepared a true nylon-6/clay nanocomposite and they were so successful that they started using in their automobiles since then [21].

The aim of this study is to analyse the morphology and the nanostructure of Tunisian clay nanocomposites when used as a coating on a Cotton fabric. The impact of nanoclay particles on the mechanical behaviour of coated fabrics is studied to check if the nanocomposite enhances the mechanical properties of fabrics when used as coating material.

2. Experimental Part

Nanoclay particles are obtained from Tunisian natural clay. The former was extracted from the soil, crushed, and dried during 48h in an oven (60°C). Then, Impurities were removed from the clay. Finally, the clay was filtered (on a fine riddle) three times in order to obtain very fine particles.

In order to have a good dispersion of clay particles, we mixed 10g of Tunisian clay with 100 ml of methylene chloride, then the mixture were ultrasonicated for 2h at 25°C (freq.=28KHz). After that, the prepared clay solution was added very gradually to the resin with low percentages of clay (from 1 to 5%). In fact, the commercially available resins are micro-emulsion with water that may cause problems when mixed with clay which is very hydrophilic.

Nanoclay particles has been mixed up with two kinds of resins: Polyurethane (PU) and Polyacrylate (PAC).

The various composites resin/clay were put on a 100% cotton fabric (200g/m²) with the use of a 40 mesh printing flat frame. These coatings have been polymerised at a temperature of 150 ° C for 5 minutes after which the drying step was crowned by the evaporation of chloride methylene and water.

SEM observation of the coatings showed the formation of nanocomposites. Indeed, specific standards of measurements have been put into practice (AFNOR: NF G07 148, NF G07 119, NF G07 149, ASTM D4966) to measure the tear, tensile, breakout and abrasion strength, and consequently, to figure out the mechanical characteristics of the coated fabrics.

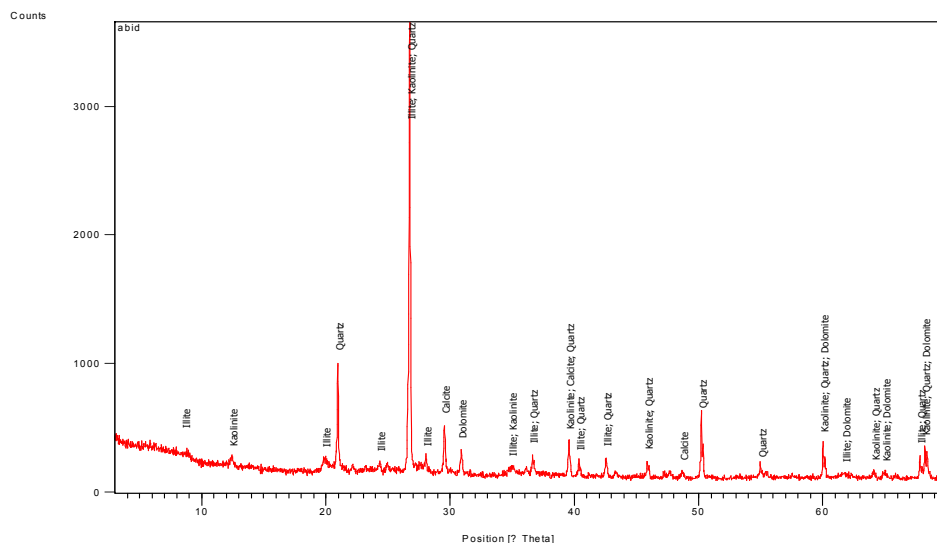


Fig. 2. Diffractogram of used clay.

3. Results and Discussion

3.1. Morphological Analysis of Nanoclay Particles

The mineral composition of the used clay has been demonstrated in the DRX diagram (Figure 2). As seen on the diffractogram, there are five types of clay (Illite, Kaolinite, Quartz, Dolomite, and Calcite), which provide distinguished

characteristics to Tunisian clay.

SEM images of the obtained nanocomposites resin/clay demonstrated in figures 3 and 4 respectively prove that clay is well penetrated in the organic matrix, to the extent that it forms a homogenous structure of a new material. Dark zones show the organic matrix and the bright ones represent the mineral charge (clay) which is well- mixed up by the organic matrix.

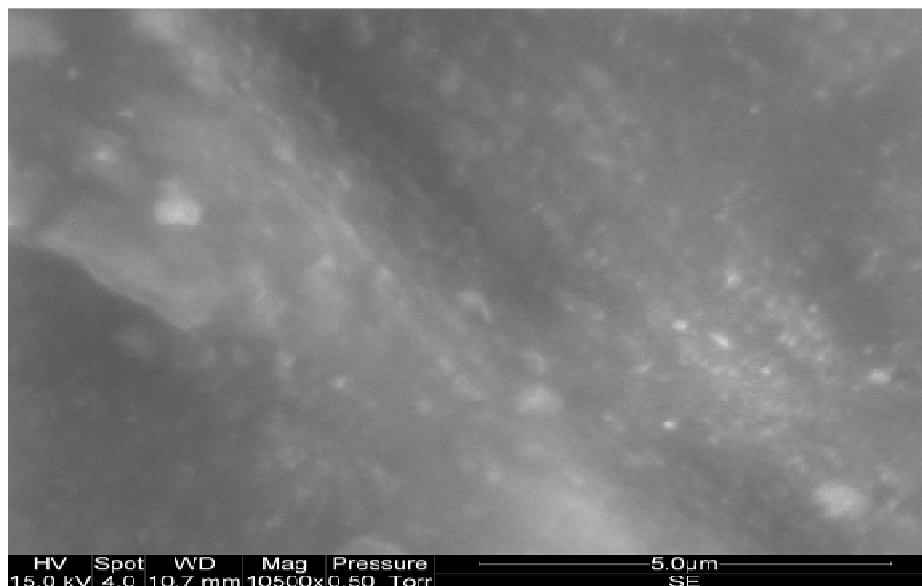


Fig. 3. SEM image of nanocomposite PAC/clay.

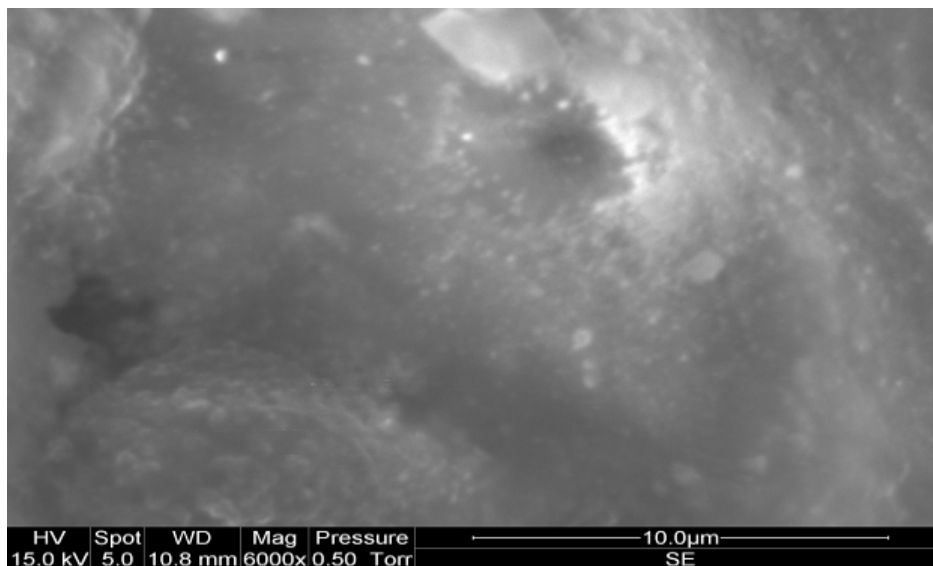


Fig. 4. SEM image of nanocomposite PU/clay.

The estimated size of a few clay nanoparticles is approximately 0.005 to 0.12 μm.

SEM images which are done on some nanometers proved that the nanocomposite is of a layered structure often called the multilayers periodicity.

Furthermore, several clay elements (Mg, K, AL, Si) proved to be present in the chemical composition inside the dark zone already fixed on the screen.

3.2. DRX Analysis of Obtained Nanocomposites

The clay presence in both zones (Figures 5a and 5b) which is confirmed to be inside the structure of the organic matrix affirms the formation of nanocomposites since the composition of the organic resins can only be composed of C, H, O. The same procedure has been followed for the bright

zone to prove the presence of the resin components (C, H, O) in the bright zones (mineral zone).

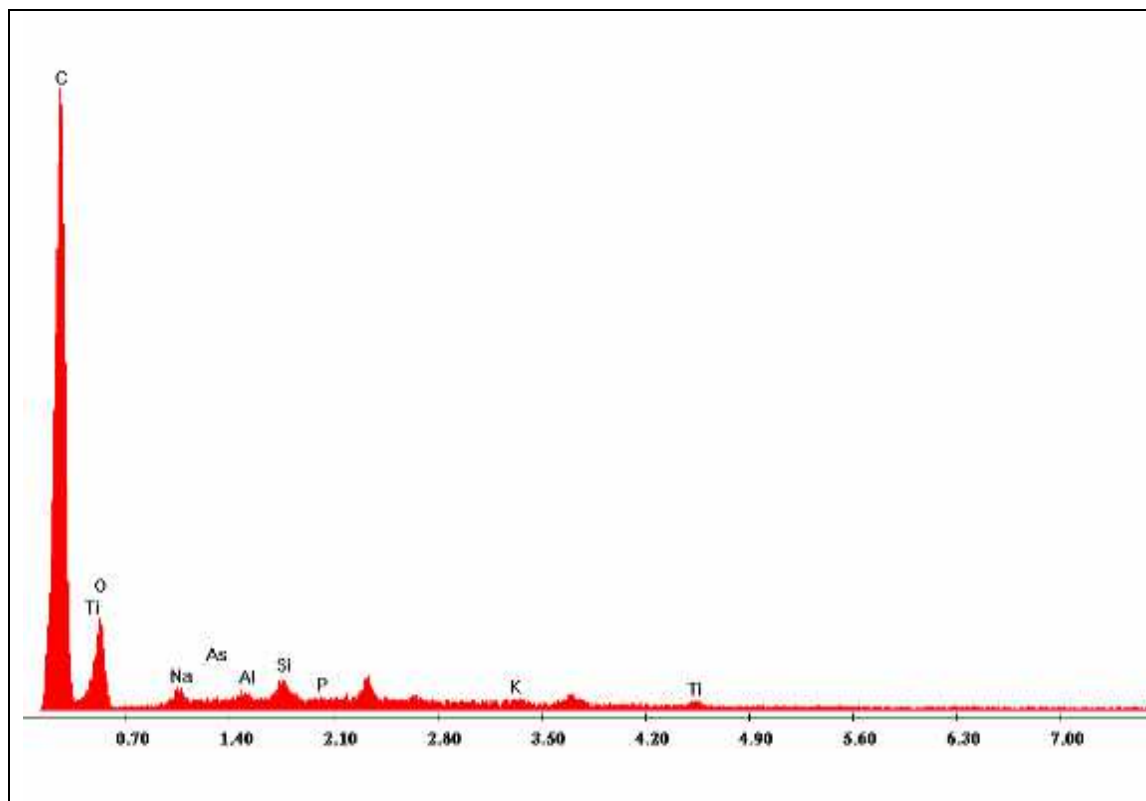


Fig. 5a. Composition analysis of nanocomposite PAC/clay in the bright zone.

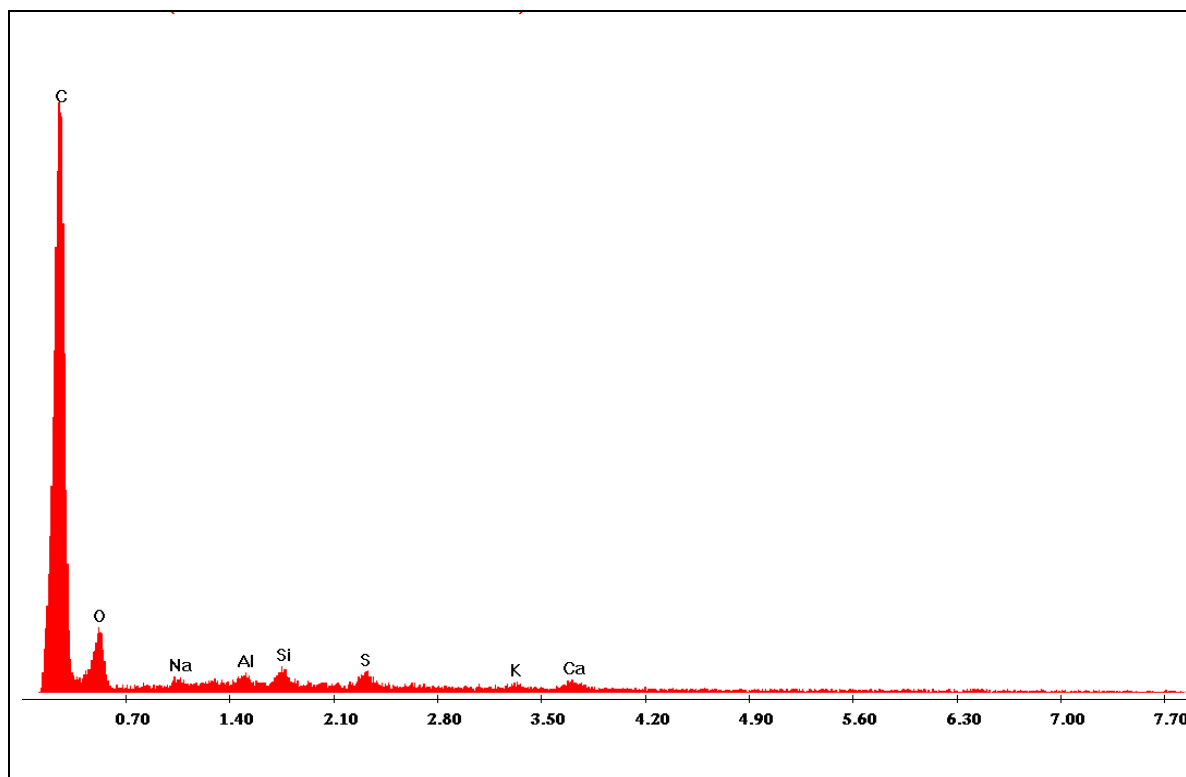


Fig. 5b. Composition analysis of nanocomposite PAC/clay in the dark zone.

Two resins with and without clay have been used to make ten samples to be analysed by DRX in order to study the

development of its behaviour in terms of the X-ray and conclude if there is any modification of the d-spacings

(figures 6a and 6b):

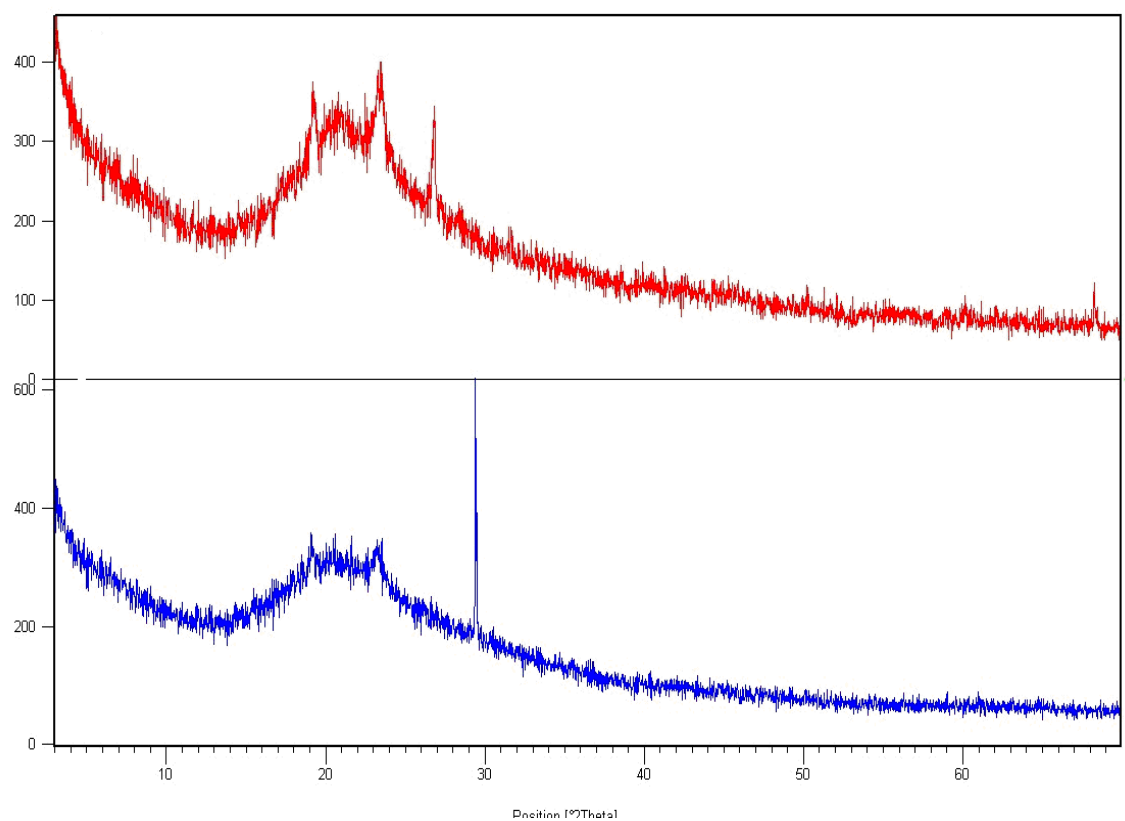


Fig. 6a. DRX patterns: pure PU (down) and PU/clay (up).

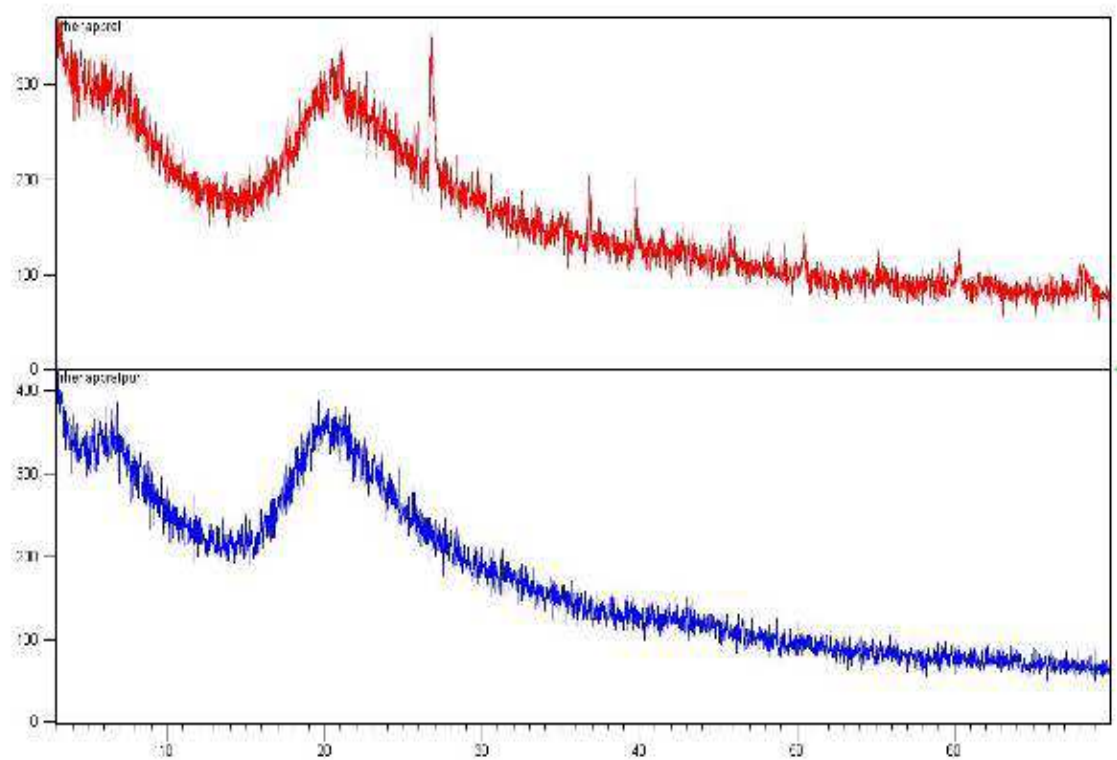


Fig. 6b. DRX patterns: pure PAC (down) and PAC/clay (up).

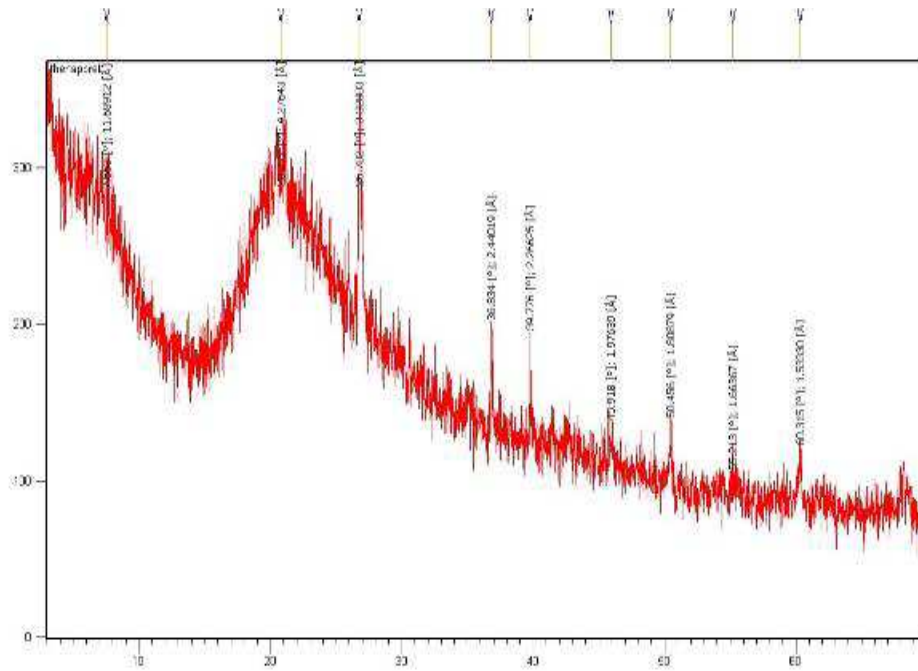


Fig. 6c. DRX pattern of nanocomposite PAC/clay showing 2θ angle and the d-spacings.

A comparison between the pure resin spectrum and the nanocomposites spectrums reveals that they are quite different. Indeed, other peaks compared to the pure resin appear in the above charts due to clay. Also, the 2θ of new characteristic peaks are almost between the corresponding clay and resin peaks (Fig 6c). So, there is much adherence between resin and clay and consequently new crystalline units come out.

Table I. d-spacing of clay

Clay peaks	2θ	d(Å)
Illite	20, 24, 27, 28, 35, 37, 41, 43, 62, 68°	4.43, 3.7, 3.3, 3.2, 2.6, 2.43, 2.2, 2.1, 1.5, 1.375Å
Kaolinite	12.5, 35, 40, 46, 60, 64, 65, 68°	7.06, 3.3, 2.6, 2.25, 1.9, 1.54, 1.4, 1.39, 1.375 Å
Dolomite	31, 60, 62, 65, 68°	2.8, 1.54, 1.5, 1.39, 1.375 Å
Calcite	30, 40, 49°	3, 2.2, 1.833Å
Quartz	21, 37, 40, 41, 43, 46, 50, 55, 60, 64, 68°	4.23, 3.3, 2.43, 2.25, 2.2, 2.1, 1.9, 1.8, 1.7, 1.54, 1.4

From 2θ values in figure 6c for, new d-spacings could be calculated when referring to the previous peaks. The results are given in table. II :

Table II. d-spacing of nanocomposite PAC/clay versus 2θ .

Clay peaks	2θ	d(Å)
Kaolinite	7.6°	11.68912Å
Illite	20.7°	4.27643 Å
Dolomite, Calcite	26.8°	3.32883Å
Illite, Quartz, Calcite	36.8°	2.44019Å
Kaolinite, quartz	39.8°	2.26625Å
Quartz, Calcite	45.9°	1.97639Å
Quartz	50.5°	1.80879Å
Illite, Kaolinite, quartz, Dolomite	55.2°	1.66367Å
Illite, Kaolinite, quartz, Dolomite	60.3°	1.53333Å

As shown in tables I and II, we can deduce that the D-

spacing of clay was between 7,06 Å and 1,375 Å whereas ; it was between 11,68 Å and 1,5 Å for the nanocomposite. So, it is obvious that there is an increase by almost 4 Å for the little scanning X-ray angles, which correspond to a retreat to the left of the spectrum. Consequently, 2θ decrease about 5° on the left and 8° on the right of the spectrum.

The DRX diagrams are quite similar to each other as well as to the polymer, and this is a proof that clay nanocomposites have kept their crystalline structure. According to MEB images, there are no delamination traces.

3.3. Mechanical Characteristics of Coated Materials

As shown below in figures 7 until 10, we can conclude that the tensile strength of the coatings varies in terms of the amount of clay used. For example, when adding 5 percent of clay to the resin, the tensile strength has increased by 15 to 20 percent.

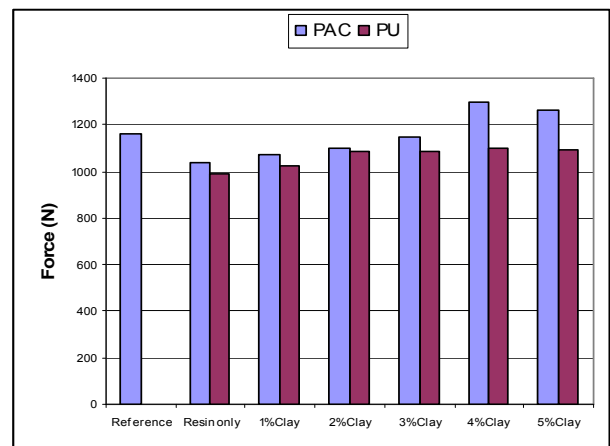


Fig. 7. Warp tensile resistance of coated fabric.

The addition of clay in all resins boosts the tear and tensile strength of the fabric, and this is, of course, proportional to the amount of clay added and no matter which kind of resin is used. However, pure resins diminish the tensile strength of the fabric. Besides, it can be noticed that PAC tensile resistance is the most sensitive to the added clay and this is quite obvious from 1 percent on, but the PU resin proves to have the most regular increase of the tensile resistance in terms of the amount of clay added to resin.

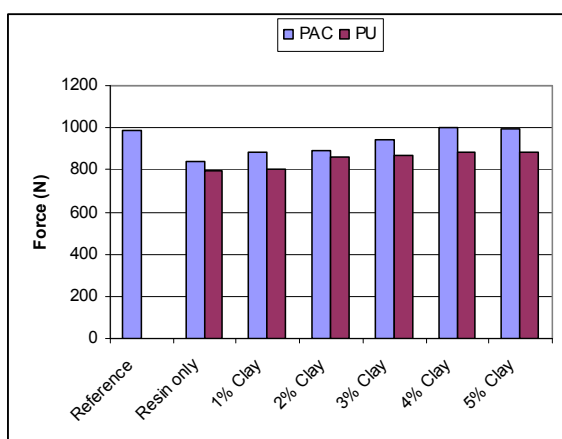


Fig. 8. Weft tensile resistance of coated fabric.

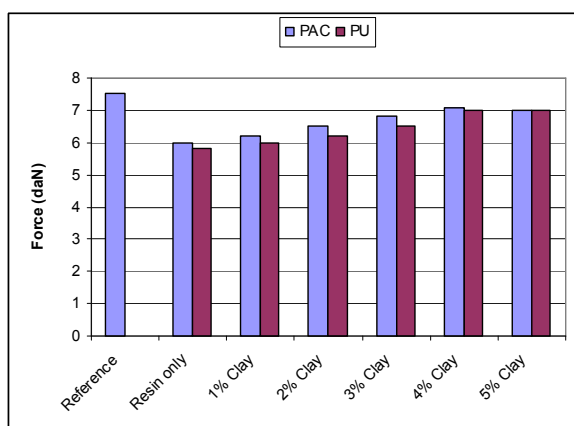


Fig. 9. Warp tear resistance of coated cotton fabric

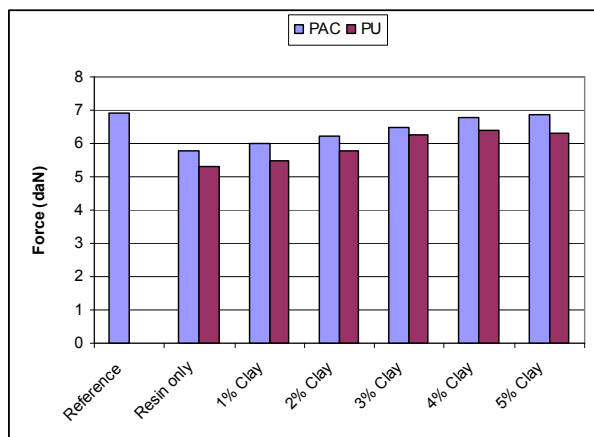


Fig. 10. Weft tear resistance of coated cotton fabric.

Concerning the abrasion test (figures 11 and 12) the tear laps of these samples increased in terms of the quantity of clay regardless of the used resin, except if the amount of clay is superior to 4 percent. Added to that, the resistance of the reference is better just because of the absence of clay.

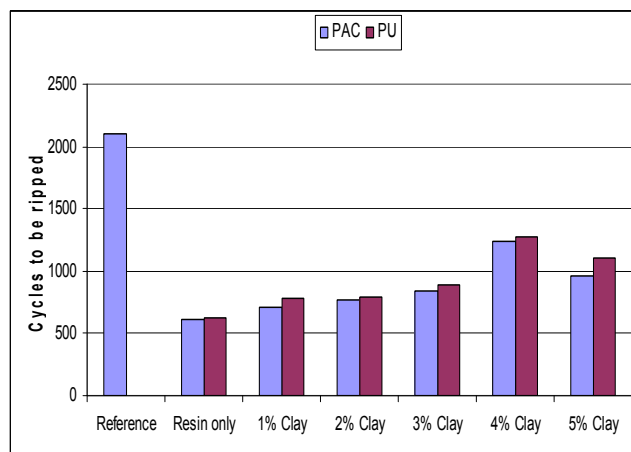


Fig. 11. Number of laps "ripped after" of coated cotton fabric.

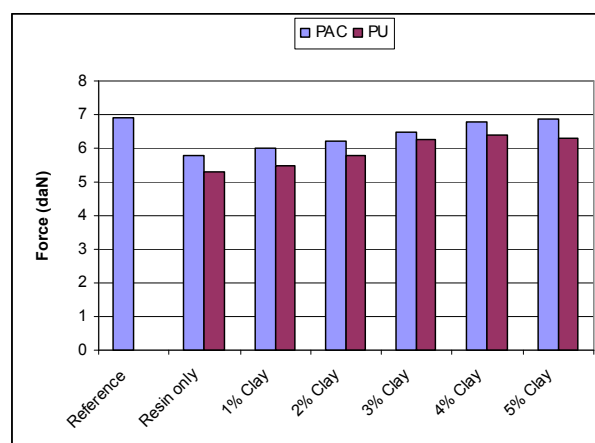


Fig. 12. Weight loss cause of abrasion of samples coated with several resins on a cotton fabric.

When the fabric is coated with pure resin it loses about 20 percent of its weight after 615 laps, whereas; any other sample without coating loses just 3 percent of its weight. So, this is a proof that the mechanical characteristics of fabric decrease due to coating. The added clay in the resin could be a solution for this decrease, especially if the quantity of clay equals 4 percent (figure 12).

Therefore, the samples coated with resins have the same weight loss, and this deserves a more detailed work about the chemical reactions between resins and fabric.

That's why, we can guarantee that 20 percent of lost cellulose is the product of reactions between cellulose and resins. In addition, the loss of weight is more important than the reference and the coated samples with nanocomposites weight loss, and this proves once again that clay addition can enhance the ability of fabric to recuperate its mechanical characteristics after the decrease caused by the application of resin.

4. Conclusion

The application of nanocomposites as coatings will automatically enhance the mechanical characteristics of the fabric which is measured in terms of tear, abrasion and tensile strength. In return, this enhancement remains proportional to the percentage of clay used in the coating.

So, it sounds that the increase in the tear strength of a fabric is tightly related to the quantity of clay for all resins.

As for the abrasion test, it can be noticed that the loss of weight and even the number of laps" ripped after" are significantly boosted in comparison to the samples which are coated just with resin or with the reference.

As far as the tensile tests are concerned, weft and wrap strength is remarkably improved depending on low clay percentage as it decreases for great clay quantities.

Consequently, the maximum clay percentage to enhance the mechanical performance of a fabric is between 4 percent and 5 percent. As a matter of fact, the use of important amounts superior to 5 percent does not bring any better results, in contrast; it hinders its application.

At last, despite of the improvement of the mechanical performance of fabrics, it has been noticed that the use of clay on coated material has an important side- effect because of its yellow colour most of the time for light shades. That's why, this parameter has to be taken into consideration for appropriate use.

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