

## EFFECTS OF ALCOHOL CONCENTRATION ON THE MECHANICAL PROPERTIES OF POLYESTER FIBRE

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### Abstract:

unsaturated polyester fibre commonly referred to as polyethylene terephthalate (PET) were treated in 3 various alcoholic solvents: ethanol (ETH), propanol (PRP) and Isopropanol (ISP) isothermally at a constant time of 1800 s for various concentrations of 0.1M, 0.3M and 0.5M to confer structural modifications on the PET fibres. The effects of these treatments in an isothermal condition on the tensile properties of the treated PET fibres for initial (Young's) modulus (MPa), tenacity (MPa), energy (J) and extension at break (mm) were determined. A decline in the initial modulus was observed in the treated fibres which may be due to increase in segmental mobility of the polymers amorphous region. The increase in extension at break and tenacity values experienced as a solvent treatment can be related to the convolution of the polymers chain folds and increase of segmental mobility. Isopropanol (ISP) was found to give the highest extension at break value amongst solvents. Ethanol (ETH) has a moderate extension at break value and the highest tenacity value which makes it more stable when compared to other solvent's tenacity value as concentration increases. The steady increase in tenacity and extension at break of ethanol treated sample as concentration increases indicates its usefulness in textile materials that would resist deformation during processing and dry cleaning operations.

**Keywords:** Polyester, alcohol, modifications, tenacity, modulus, extension at break, ethanol.

### Introduction

Polyester is a category of polymer containing at least one ester linking group per repeating unit (Rogers, 2013). Depending on their chemical structure, they can be classified either as thermoplastic or thermosetting (Chan C. H et al., 2012). Polyesters are majorly produced by reacting ethylene glycol with either terephthalic acid or dimethyl terephthalate (Cook, J. G., 1968). Polyester is hydrophobic in nature and quickly dry. The lack of polarity and the very crystalline structure resists the entry of water molecules into the polymer system (Shristi P., 2016).

Polyester is one of the world's largest industrially produced polymer, it was estimated that the production will exceed 50 million tons by the year 2015 (Chan C. H. et al., 2012). It has several properties ensuring its ever growing production. The range of its application in several manufacturing industries such as – textile, pharmaceuticals, automobile etc is solely dependent on chemical and physical properties. Polyester fibres applications also includes, tire cord filaments, industrial fibers and fabric for industrial filtration. The polymer is also used for making blow molded bottles for soft drinks, beers, spirits, other food-products and pharmaceuticals, which is as a result of the outstanding barrier properties of poly(ethylene terephthalate) fibre.

However, modifications are needed to ensure the wide range of its application in terms of the polymers appearance, strength, tenacity, elasticity, melting point, glass transition temperature.

The presence of benzene rings in the polymeric chain of polyester causes chain stiffness which prevents the easy deformation of its disordered regions denying easy flexibility and segmental mobility of its molecules (Popoola et al., 2014). Heat and liquid treatments of polyesters have been reported to produce desirable tensile properties by structural modifications (Popoola, A.V. and Peters, R.H., 1998). Several workers have reportedly investigated various methods to improve the surface characteristics of polyester fibre (Ugbolue, S.C.O. and Popoola, A.V., 1989; Muralidharan, B. et al., 2004; Samanta, A.K. et al., 2003). Modification of polyester yielding higher crystallinity and molecular orientation leads to higher tensile strength and initial modulus vice versa.

## **2. Materials and method**

### **2.1. Materials**

Unsaturated polyester yarn was obtained from United Nigeria Textile, Plc, Ikorodu, Lagos. All chemicals used were Analytical grade products: Ethanol (97% v/v) (Sigma Aldrich Alchemy Germany), Propanol (97% v/v) (Sigma Aldrich Alchemy Germany), Isopropanol and Trixton x a non-ionic surfactant (Sigma Aldrich Alchemy Germany).

### **2.2. Polyester scouring process**

Unsaturated polyester yarn samples used were first subjected to Soxhlet extraction with petroleum ether to remove traces of oils and waxes and then dried for 17 hrs in the oven. It was followed by aqueous surfactant washing with 1g/L Trixton X (a surfactant) in a material to liquor ratio of 1:20 it was first cold rinse and then warm rinsing before being dried to bone mass.

### **2.3. Alcoholic carrier treatment procedures**

0.5g polyester yarn fibres were treated isothermally at boil with ethanol, propanol and isopropanol respectively via reflux with a material liquor ratio of 1:30. The concentrations of the solvent treatment were varied while temperature and treatment time was kept constant. Treated polyester fibres were dried at minimal temperature of both solvents so as to retain as much solvent as possible.

Mechanical properties of treated the polyester yarn was evaluated by the Instron machine (British Standard 3411: 1972; 1978) at Engineering materials development institute (EMDI), Akure, Nigeria.

## **3.0 Results and discussion**

### **3.1 Mechanical properties**

The wide range use of polyester is solely dependent on its mechanical properties. Desired modification can be achieved to improve or reduce some of its properties so as to serve specific purposes. Heat treatment of polyester have been studied over the years and proven to help reduce its glass transition temperature ( $T_g$ ). The tensile properties of polyester fibre such as energy at break, modulus, specific stress and extension were all affected. Tensile properties of the polyester fibre were affected consequentially by solvent treatment as a function of time and concentration.

#### **3.1.1 Extension at break**

From the tables above, a general increase in extension at break values of treated polyester fibre was observed when compared to the control's value (11.4448 mm) across all concentrations. The result can be explained as the reconfiguration of treated fibre chain molecules into chain folds that are not present in the control fibre.

Table 1: Tensile properties of ethanol treated fibre

| <b>concentration</b>  | <b>Extension at Break (mm)</b> | <b>Tenacity (MPa)</b> | <b>Energy (J)</b> | <b>Modulus (MPa)</b> |
|-----------------------|--------------------------------|-----------------------|-------------------|----------------------|
| 0.1 M                 | 13.7000                        | 5.9160                | 0.0475            | 214.9615             |
| 0.3M                  | 13.4359                        | 5.4695                | 0.0497            | 213.3225             |
| 0.5M                  | 15.4913                        | 9.4120                | 0.0531            | 220.4699             |
| <b>Control sample</b> | <b>11.4448</b>                 | <b>2.1759</b>         | <b>0.0561</b>     | <b>263.9019</b>      |

Table 2: Tensile properties of propanol treated fibre

| <b>concentration</b>  | <b>Extension at Break (mm)</b> | <b>Tenacity (MPa)</b> | <b>Energy (J)</b> | <b>Modulus (MPa)</b> |
|-----------------------|--------------------------------|-----------------------|-------------------|----------------------|
| 0.1 M                 | 15.2500                        | 2.2434                | 0.0367            | 207.0935             |
| 0.3M                  | 15.6170                        | 3.1726                | 0.0677            | 194.3381             |
| 0.5M                  | 16.0500                        | 1.1008                | 0.0658            | 231.3996             |
| <b>Control sample</b> | <b>11.4448</b>                 | <b>2.1759</b>         | <b>0.0561</b>     | <b>263.9019</b>      |

Table 3: Tensile properties of Isopropanol treated fibre

| <b>concentration</b>  | <b>Extension at Break (mm)</b> | <b>Tenacity (MPa)</b> | <b>Energy (J)</b> | <b>Modulus (MPa)</b> |
|-----------------------|--------------------------------|-----------------------|-------------------|----------------------|
| 0.1 M                 | 15.6500                        | 1.9840                | 0.0527            | 201.6786             |
| 0.3M                  | 16.2170                        | 2.2005                | 0.0687            | 223.4308             |
| 0.5M                  | 16.8500                        | 2.1876                | 0.0654            | 199.1419             |
| <b>Control sample</b> | <b>11.4448</b>                 | <b>2.1759</b>         | <b>0.0561</b>     | <b>263.9019</b>      |

The increase in extension at break values observed showed a steady increase as the concentration of each solvent increases. This implies that quantity of solvent present facilitates the reconfiguration of fibre chain molecules and lateral forces (Vander waals, covalent bonds and hydrogen bonds) that hold them within the fibres amorphous region. Since the high concentration signals the higher number of moles present. Increase in extension at break was also reported by Samanta A.K. et al., 2003, to be as result of shrinkage during and solvent induced chain relaxation treatment.

The increase in quantity with increase in concentration shows a higher value for ETH treated fibre, followed by PRP and ISP respectively which is related to their solubility. Table 4, shows the interacting efficiency of each solvent’s solubility parameter on the polymer and indicates that the average extension at break values for the treated polyester fibres increases as the solubility parameter increases: ETH < PRP < ISP.

Table 4:Solubility parameters of the four chlorinated solvents

| Solvents    | Solubility parameter $\delta$ [MPa <sup>1/2</sup> ] |
|-------------|---|
| Ethanol     | 26.5  |
| Propanol    | 24.6  |
| Isopropanol | 23.8  |
| Polyester   | 21.9  |

### 3.1.2 Tenacity (MPa)

The results obtained in tables 1- 3, showed that the treated fibres have higher values than the control fibre. The achieved result is as a result of greater stability conferred on the treated fibres by solvent treatment. The increase in strength and stability experienced by treated polyester is due to the polymer matrix’s improved structure. The gradual increase in tenacity as the concentration of solvent treatment increases was also observed by Samanta A.K. et al., 2003, using organic solvents.

### 3.1.3 Energy at break (J)

The force required to break the inter microfibrillar bonds present within the polymer is related to the segmental structure of the polymers matrix. Tables 1-3 showed that the treated fibres at lower concentrations when compared to the control’s value. The result showed that all the solvent has no negative effect on the polyester fibre strength’s.

### 3.1.4 Initial Modulus (MPa)

The quantity of initial deformation of a polymer as a result of load bearing (force) is a vital property of the polymer. It determines the application and uses of the polymer as a measure of fibres stiffness and rigidity. The initial modulus of a fibre is a measure of such initial deformation. The decrease of this quantity in this present study is mainly ascribed to the effect of solvent treatment and high temperature. The result observed was similar to reports by Barella et al., 1990; Rajendran, S. and Mishra, S.P. 2007; Popoola et al., 2014. Table 1-3, showed a lower value for all treated fibre samples when compared to the controls value of 198.3440 MPa. Similar result obtained by Popoola et al., 2014 was attributed the fact that small solvent molecule can penetrate the fibres crystalline region at room temperature. The implication of this result is that the treatment of polyester with low molecular weight alcoholic solvent reduces the textural rigidity and stiffness. However, further studies should be carried out at higher concentrations and treatment time. The decrease in the initial modulus values of the treated samples obtained is due to the level of plasticization effect conferred by the presence of residual liquid within the polymer’s matrix causing segmental mobility in the amorphous regions.

#### **4.0 Conclusion**

The three alcohol involved in treatment has shown to modify the polyester fibre tenacity, extension at break and energy. Ethanol as a solvent imparted more stable quality in terms of fibre tenacity, extension at break and energy at low concentrations within this research's framework.

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