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Tensile Behaviour of Spandex

Abstract

Spandex is extensively used in woven and knitted fabrics. Spandex is mostly used in combination with other fibres in low percentage. To study properties of yarn and fabric in detail, it is necessary to study properties of constituent's fibres first. Spandex elongation can go upto 700%. It is necessary to study tensile behaviour of spandex. An attempt has been made to evolve a suitable method to get tensile behavior of spandex which can be done easily and quickly. Tensile behavior of spandex was studied and explained on the basis of the structure of spandex. The stepwise rise of the stress was observed in the stress-strain curve of the spandex filament. The spandex filament contains long segments of soft, flexible nature and short segments of hard nature alternately. Spandex can be stretched and then it can recover to original shape. Elastic behavior is due to soft and rubbery segments containing polyester or polyether polyols which allow the fibre to stretch upto 600 % and recover to it's original shape. Tensile strength of spandex is due to hard segments which restrain plastic flow are usually urethanes or urethane-ureas. When stretching force is removed, local Brownian motion encourages the flexible segment to resume their folded configuration so that fibre will contract rapidly. As the stress in the spandex increases, it breaks the bonds present in the soft segment gradually which is reflected from the stepwise rise in the stress-strain curve of the spandex filament.

Keywords: Spandex, Elastane, Tensile behavior, Elastomers

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Introduction

Spandex fibres are entirely manmade. They are chemical fibres whose major ingredients is a polyurethane is an elastomer. Fibres containing at least 85 % of segmented polyurethane have been given the generic name of Spandex and typical examples are Lycra and Spanzelle. This term was coiled by reversing syllables in the word expand so as to convey the elastic properties of the fibre. Spandex is used in combination with other fibres and it's percentage is less in the fabrics.It's percentage may range from about 2-5 % of fabrics weight in stretch fabrics and may go upto 20-25 % and occasionally higher in skinfit garments.

Fibres which have an extension at break higher than 200 % and also have the property of rapid recovery when tension is released are known as elastomers. Elastane has been adopted as the British generic name for elastomeric fibres and is defined as long chain synthetic polymer composed of at least 85% of segmented polyurethane. The word elastomeric was coined from elastic and monomer, to imply an elastic fibre.

Chemically the elastomeric are polyurethane based fibres, whose polymers are characterized by urethane groups (-NH—COO—). Polyurethane is synthesized from urea. Elastomerics are man-made, synthetic polymer based, segmented polyurethane filaments. They are seldom manufactured as staple fibres. Elastomerics are produced by coalescing numerous filaments yarns. On a world-wide basis nearly 80 % of the spandex produced is by solution dry spinning process.

The initial emphasis which led to the investigation and application of the polyurethane was the desire to create a fibre which would be of nylon type. Perhaps elastomeric polymer is the most complex textile fibre polymer that has been synthesized. Two types of elastomeric polymers are synthesized. Each is extruded into filaments with excellent elastic properties but differing in their resistance to alkalis. First is polyether type and composed of segments of polyurethane in the form of block copolymers. The presence of ether group greatly contributes to making of this type of elastomeric polymer, resistant to alkalis. Second is very complex and most relevant part of this type of elastomeric polymer are ester group.

Review of Literature

Research in the field of spandex is widespread and may be divided into many parts like production methods of spandex, properties of spandex filament, production of core- spun yarn, optimization of pre-draft in spinning, yarn properties, properties of woven fabric, knitted fabrics, sportswear, skin-fit fashion wear and other fields like bandage, etc. Yongrong W. et al [1] have studied elastic fabrics as compression products. They have studied behavior of compression fabrics in relation to physical and mechanical properties such as tensile, shearing and bending properties. Yin Yunjie et al [2] have studied removal of spandex from nylon/spandex blended fabrics by selective polymer degradation. As the use of fabrics containing spandex for apparel applications is expanding, developing eco-friendly technologies to recycle the industrial as well as post-consumer waste for spandex blended fabrics becomes increasingly important. In this study, spandex may be removed from blended fabrics by dissolving it in solvents such as N, N-dimethylformamide, but the use of such solvents is undesirable for economical and environmental reasons. The main focus of this study was to develop an alternative process for removing the spandex component in a nylon/spandex blended fabric by selective degradation so that the nylon component can be recovered for recycling. Merati A.A. et al [3] has produced elastic core/cotton spun yarns in a friction spinning system and then investigated the effect of spandex filament draw ratio on the physical and mechanical properties of produced yarns. First, a positive feed device was designed and developed to adjust the spandex draw ratio and then mounted on the friction spinning machine. The theoretical and experimental results indicate that the tenacity of elastic core spun yarn increases as the spandex draw ratio increases. Ortlek G. H. [4] in his research focused on the effects of spandex and yarn count parameters on the properties of elastic core-spun vortex yarns. The experiment and test results indicated that the various properties of elastic core-spun vortex yarns were significantly affected by spandex and yarn count. Coarser yarns showed lower unevenness, imperfection and breaking elongation values than finer yarns. Core-spun vortex yarns containing spandex showed lower tenacity and higher breaking elongation values than vortex spun yarns. Das A. and Chakraborty R. [5] have studied elastane-cotton spun stretch yarns and fabrics. They have reported the interaction effect of elastane stretch, properties of elastane core and twist multiplier on physical and mechanical properties of stretchable elastane-cotton core-spun yarn. Gupta D. et al [6] have studied comfort properties of pressure garments in extended state. In this study air-permeability, water vapour transmission rate and thermal behavior of elastic fabrics in extended condition have been studied so as to simulate the condition during wear. Comparison was done by using textured nylon filaments and spandex yarn covered with nylon for producing circular knitted single jersey fabrics. Senthilkumar M. [7] has described Elastane fabrics as a tool for stretch applications in sports. This paper reports the elastane fibre characteristics, elastane yarn production method, new attempts in yarn production, commercial ways of fabric manufacturing techniques, fabric properties, new testing methods to test elastic products and it's application. Herath N. C.[8] has studied dimensional stability of core spun cotton/spandex single jersey structures with high, medium and low tightness factors. Experiments were done under dry, wet and full relaxation conditions. From the study, it was confirmed that yarns with elastomeric components increase tightness factors, which have a significant effect on dimensional behaviors, giving better dimensional stability to single jersey fabrics.Lou C.W.[9] studied production of polyester core-spun yarn with spandex using a multi-section drawing frame and a ring spinning frame. In this study a polyester core-spun yarn containing spandex fibers was made using a self-designed, multi-section drawing frame and a ring spinning frame. The mechanical properties of the core-spun elastic yarns were examined in various processing conditions. The analytical results show that when the main drawing ratio of the spandex fibers was either 2.2 or 2.7, the maximum breaking tenacity and elongation of the core-spun elastic yarns exceeded those in any other of the main drawing ratio conditions. Cuden P.A.[10] has reported that development of knitted fabrics with incorporated elastane has increased in recent decades. Knitting with these elasticized yarns usually results in a very compact structure. Loop length is considered to be the primary parameter for knitted structures. Consequently, knowledge of all factors influencing loop length is vital for planning yarn consumption, comfort fit, quality, performance and aesthetic properties of knitted fabrics made from elasticized yarns. The objective of this research was to study the impact of material, knitted structure and relaxation process parameters on loop length. In addition, the objective was to examine the differences in loop length of single weft knitted fabrics, produced from different types of elasticized and non-elasticized yarns. For both groups of knitted fabrics, elasticized and non-elasticized, knitted fabric density and relaxation process influence the loop length most of all. Loop length decreases during the process of consolidation, but this decrease is not substantial. Addition of elastane does not significantly influence the loop length.

Gohl E.P.G.[11] and Morton W.E. [12] have studied properties of spandex and put forward theories to explain elastic nature of spandex. Iyer S.B.[13,14] have studied properties of polyurethane in detail.Reisch Marc [15] has explained that elastic properties of spandex are due to segmented polyurethane. Yarn tensile testing is done by using method mentioned in ASTM book[16].

Elastane is used in combination with different yarns. Keeping in view very high elongation of elastane, guage length of Tensile Tester should be reduced and then stress strain curve of spandex filament should be taken.

Aim of the Study

If we want to use spandex judiciously in any application, it is necessary to study tensile behavior of spandex first. The aim of the study is as follow

1. To find out tenacity of spandex on tensile testing machine.
2. To find out elongation at break of spandex on tensile testing machine.
3. To obtain stress-strain curve of spandex.
4. To explain tensile behavior of spandex in accordance with molecular arrangement.

Materials and Methods

40 dtex (36 denier) spandex having 5 coalesced filaments, was used for this study. The samples were conditioned for 48 hr in the standard atmosphere of 65% R. H. and 27^0C and then tested after some modification in the standard procedure. Standard testing methods are available for tensile testing of yarns. In most of the cases 500 mm guage length is used.

It is not possible to take stress strain curve of spandex filament at normal guage length of 500 mm as it is having an elongation more than 600%. To study tensile behavior of spandex it is necessary to elongate upto full elongation of 700 %. Hence a guage length of 100 mm was taken on Instron Tensile Tester and the stress strain curve of spandex filament was taken. Rest of the procedure was same.

Result and Discussion

The properties of the spandex filament used in this study are shown in Table 1.

Table 1

Properties of Spandex Filament

	Spandex Filament
Tenacity (g/den)	0.76
Elongation (%)	650
Fineness (den)	36

Spandex is elastomeric yarn with high stretch and recovery power. Spandex composes of soft and hard segments. Elastic recovery is due to presence of soft and hard segments. Fibres with 0% soft segment will have hard segment as continuous phase. Fibre with 70% soft segment concentration will have soft segment as continuous phase. Below 60% soft segment concentration the elastic recovery of fibres decreases rapidly. Only those fibres with a high soft segment concentration show the properties characteristics of good elastomeric fibre. We used spandex which has a soft segment concentration of about 83%. The essential feature of elastomeric fibres is their glass transition temperature is below zero degree centigrade, so that soft segments have a considerable degree of movement at room temperature and above. The stress-strain curve of spandex is shown in Fig. 1.

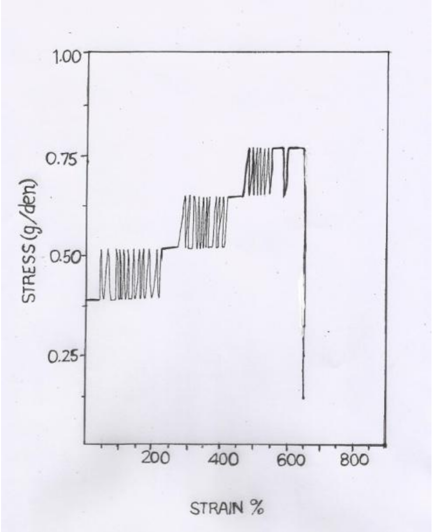

Fig. 1- Stress-Strain Curve of Spandex.

The stress in the specimen is not increasing gradually but stepwise rise is observed. The stepwise rise of the stress is distinguishing feature in the stress-strain curve of the spandex filament. To understand this kind of behaviour, we will have to understand arrangement of soft, hard segments and elastic nature of spandex fibres.

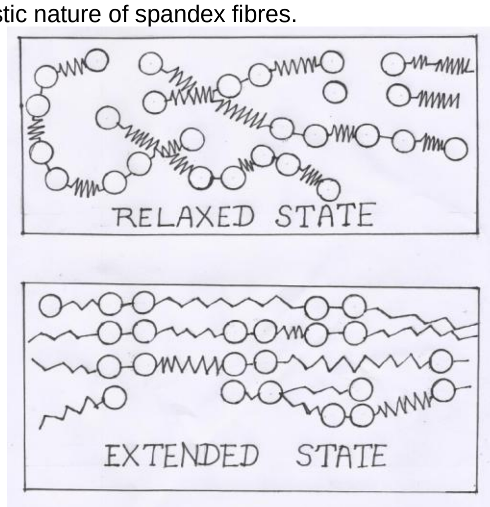

Fig. 2- Diagrammatic Arrangement for Spandex Molecules in Relaxed and Extended State. Zigzags Represent Coiled or Folded Chains of Polyol Circles Represents Isocyanate Groups

Elasticity of spandex can be explained on the basis of arrangement of molecular chains in spandex as shown in Fig.2. The essential feature of snap back fibres is in the molecular chain, which is an alteration of soft and hard segments. Elastomeric polymers are linear and composed of alternatively hard and soft segments. The spandex filament contains long segments of flexible nature and short segments of hard nature alternately. Spandex can be stretched and then it can recover to original shape. This is due to soft and rubbery segments of polyester or polyether polyols which allow the fibre to stretch upto 600 % and recover to it's original shape as shown in Fig.3.

When stretching force is removed, local Brownian motion encourages the flexible segment to resume their folded configuration so that fibre will contract rapidly. Main factor that resists stretch of spandex is interaction of more and more crystalline segments as the spandex elongates. Attraction between isocynanate groups is hydrogen bonding and chemical cross linking that exists between molecules. Hence upto a certain limit, recovery is observed but as the stress in the spandex increases, it breaks the bonds present in the soft segments gradually which is reflected from the stepwise rise in the stress-strain curve of the spandex filament.

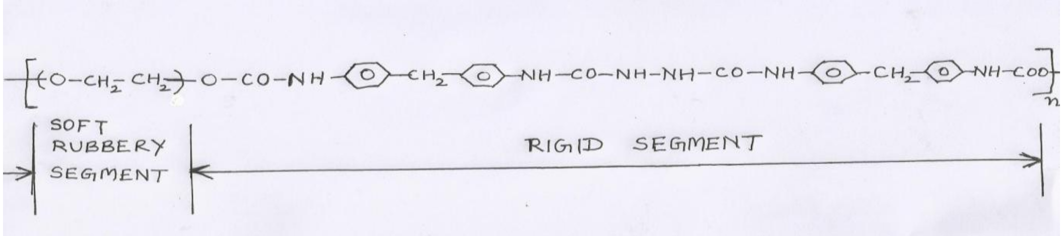

Fig.3- Structure of Lycra Polymer

Tensile strength of spandex is due to hard segments which restrain plastic flow, are usually urethanes or urethane-ureas. Spandex contains isocyanate segments (polyester or polyether) which are coiled or folded on themselves in a regular or random manner. When the fibre is stretched or folded or coiled portion of flexible segment are extended as shown in the Fig. 2 and upon removal of force they recover to this coiled or folded state. During extension isocyanate segments are shown close together so that they attract each other as a crystallite lattice and further stretching which results in increased orientation and crytallinity. In the relaxed state, very little orientation or crytallinity is there.

Conclusion

The results for tensile testing of spandex filament are

1. The tenacity of spandex is 0.76 g/ denier.
2. Elongation at break of spandex is 650%.
3. The stepwise rise is visible in the stress-strain curve of spandex filament. Spandex filament contains long segments of flexible nature and short segments of hard nature.
4. Long segments are of a very flexible nature, rubbery and non crystalline. These are known as soft segments often of polyester. These soft segments are easily deformed so that low stresses produce high extensions. When stretching force is removed, local Brownian motion encourages the flexible segment to resume their folded configuration so that fibre will contract rapidly.
5. Short segments of chain having strong inter-chain force which don't give and are known as hard segments and are usually cross linked and crystalline and polar. These hard segments are built up through isocynates addition. These hard segments are not deformed during the stretch.
6. When the folded or coiled portions of flexible segments are extended they are able to recover. Hard segments restrain plastic flow and are responsible for tensile strength of filament.

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