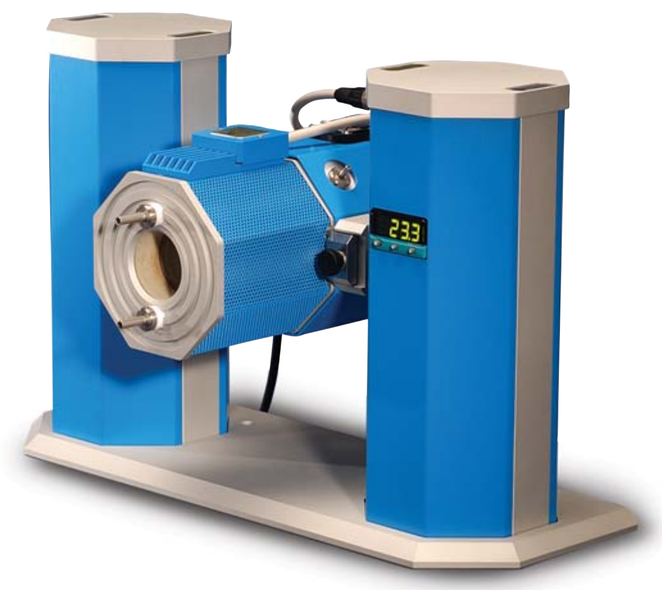
Nylon 6 – Influence of Water on Mechanical Properties and Tg



Summary

Most fishing lines used by anglers are made from polyamides, often more commonly known as Nylon. One of these, Nylon 6, can absorb a surprising amount of water, either by immersion or simple exposure to high humidity. The effect on the glass transition and mechanical properties is an important consideration in the use and suitability of the material for specific applications. After characterizing and identifying the glass transition temperature of a well dried sample, the material was exposed to immersion in water.

Introduction

Dynamic Mechanical Analysis (DMA) is one of the most appropriate methods to study viscoelastic behavior and relaxations in polymeric materials. The glass transition (Tg) is a key process in most polymers and influences use and processibility of the material, possibly more than any other factor. This technique provides very revealing information about these relaxations through the tan δ vs temperature data. The same experiment also yields the stiffness (modulus) of the material vs temperature.

An oscillating force is applied to a sample of material and the resultant displacement of the sample is measured. From this, the stiffness can be determined and the modulus and tan δ can be calculated. Tan δ is the ratio of the loss modulus to the storage modulus. By measuring the phase lag in the displacement compared to the applied force it is possible to determine the damping properties of the material.

The Tensile Strength of dry nylon 6 at 20 °C is typically 76 – 97 MN m^{-2}. The properties are highly dependent on water content. Water will behave as a plasticizer, i.e. the glass transition process moves to a lower temperature upon exposure to moisture. The effect of plasticization is easily shown with nylons by immersion of dry material in water. Within a very short time scale, this material can absorb between 6 and 9% by weight of water and this will lower the glass transition to about 20 °C.

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Experimental

1. **DMA temperature scan of dry and humidified nylon.**
   The sample was mounted in the tension clamps and the experiment started. The dry sample was run with no conditioning. The humidified sample was run with some water in the bottom of the furnace to create a near saturated atmosphere during the test.
2. **DMA immersion study of nylon**
   This experiment was performed immersing the nylon in water at 65 °C. The Fluid Bath accessory was used for this experiment.

Equipment	Experimental Conditions	
DMA 8000 Fluid Bath	Sample:	22lbs 0.48mm Nylon Fishing Line
Circulator	Geometry:	Tension
1L Dewar	Temperature:	0 °C to 100 °C at 5 °C/min
	Dimensions:	8.88 (l) x 0.16 (d) mm
	Frequency:	1.0 Hz

Results and conclusion

The glass transition temperature of a dry and a humidified sample of Nylon are shown in Figure 1. The Tg of both samples is shown as a peak in the tan δ. It is clear that humidity acts to plasticize the material and hence reduce the glass transition temperature significantly. A decrease in Tg of nearly 40 °C is observed.

When the sample is immersed in water, at 65 °C, both modulus and tan δ drop rapidly (shown in Figure 2). The modulus falls to around 0.6 GPa after approximately 1.5 hrs. This effectively shows that the fishing line has plasticized dramatically when immersed in water. The whole glass transition process has moved to a lower temperature.

The implication of this work is that the material is not ideal for the use it is being put to. Once a polymer is at or above its glass transition temperature, it will tend to creep when any applied load occurs. In fishing, the issue is self evident. After only a few catches and after being used for only moderate amounts of time, this material will tend to elongate. It is worth noting the effect on the modulus of this material when it is above the glassy region. It can drop to as low as 0.6 Gpa. This clearly will affect the breaking strength declared on the product for the dry material.

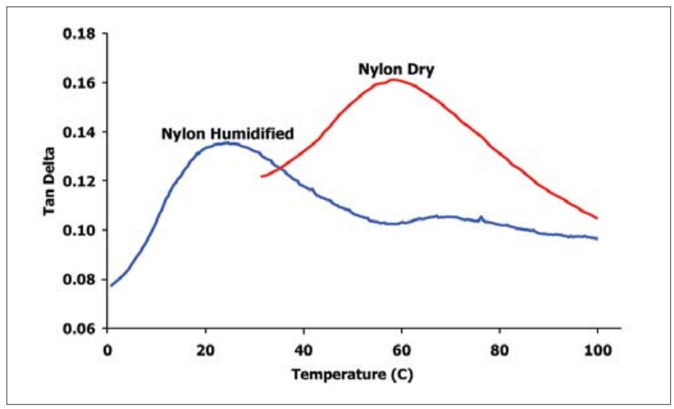

Figure 1. Glass transition of dry and humidified nylon.

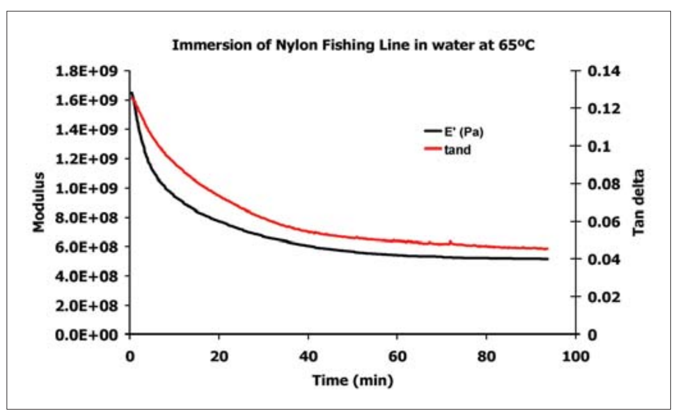

Figure 2. Glass transition of a nylon sample immersed in water.

PerkinElmer Life and Analytical Sciences
710 Bridgeport Avenue
Shelton, CT 06484-4794 USA
Phone: (800) 762-4000 or
(+1) 203-925-4602
www.perkinelmer.com

For a complete listing of our global offices, visit www.perkinelmer.com/lasoffices

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