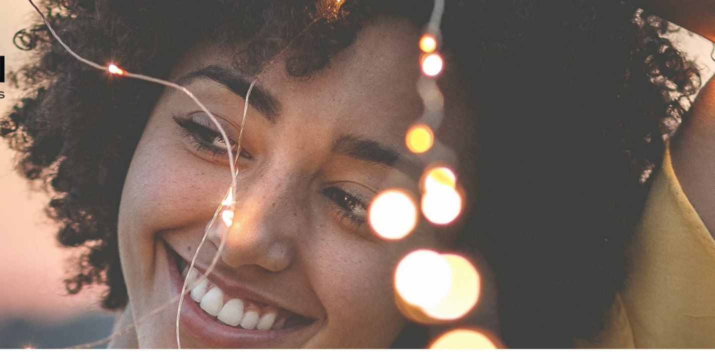


DIA–STRON
DELIVERING MEASUREMENT SOLUTIONS

Single fibre testing on high curl type hair

Introduction

This application note outlines two methods of mechanical testing of single hair fibres, illustrating the advantages/complimentary nature of each method and the data that can be determined.

Tensile studies on high curl type hair

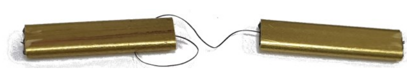
The tensile behaviour of hair fibres is dominated by the cortex. It is well documented that water has the ability to significantly alter the mechanical properties of keratin fibres[1,2]. In hydrated hair, the intermediate filaments, which are located within the cortical cells are relatively unaffected by the presence of water, and therefore dominate the tensile stiffness. However, the presence of water within the matrix proteins disrupts hydrogen bonds, causing a weakening of the fibre.

Tensile studies can be conducted on both wet and dry hair fibres, to investigate and assess the performance of ingredients, treatments and products that penetrate into the hair cortex or regulate/control the moisture of the hair. This data can be used to substantiate claims such as "strength", "damage protection", and "damage repair".

Methodology

Studies were conducted on hair of African origin with a curl type of 6/7[3] using the Dia-Stron Fibre Dimensional Analysis System (FDAS770) and Miniature Tensile Tester (MTT690).

Two hair tresses were used, one untreated (virgin) and one relaxed twice using a commercially available no-lye relaxer treatment[4]. 50 fibres were randomly selected from each tress and mounted between two brass crimps using the Dia-Stron Automated Assembly System (AAS1600).



Single high curl type hair fibre mounted between two brass crimps

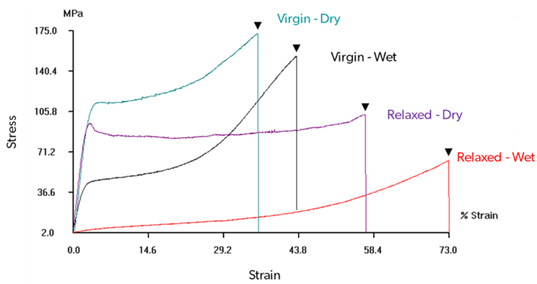
Dimensional and tensile measurements were recorded using the FDAS770 and MTT690 respectively. For wet measurements, the fibres were immersed in deionised water for 1 hour prior to testing, with all measurements conducted under controlled environmental conditions.

Data was analysed with Dia-Stron UvWin software, using the single-phase and three-phase analysis to obtain the elastic modulus, the break stress and the break strain:

Elastic Modulus – the ratio of stress/strain is a measure of the stiffness, expressed in GPa. A higher modulus indicates a stiffer fibre.

Break Strain – the % a fibre has stretched before it breaks, expressed as percentage compared to the initial length of the fibre (30mm).

Break Stress – the force per unit area required to break the hair fibre, expressed in MPa. The break stress represents the tensile strength of a fibre, with a lower break stress indicating a weaker fibre.



Results

Following treatment with a relaxer, a decrease in the elastic modulus is seen compared to the virgin hair. The hair has become less stiff and more flexible as a result of applying the relaxer treatment, particularly in the wet state.

The relaxer also reduces the stress and increases the strain required to break the fibre. This results in weaker fibres extending further before breaking, but breaking at a lower force.

Single fibre testing on high curl type hair

Fatigue studies on high curl type hair

During daily grooming practises and routines, hair fibres are exposed to differing amounts of stresses at levels much lower than what is required to break the hair. Over time, this leads to an accumulation of stress and eventual failure of the fibre originating at microscopic cracks and flaws propagating within the hair fibre substructures.

Hair breakage is a major concern for consumers, particularly for those with high curl types or who use aggressive grooming regimes. These individual fibres are highly curled and kinked, with an elliptical cross section and significant variation along the length of the fibre. Premature breakage of high curl type fibres, occurring exclusively in the dry state at extensions often of less than 20%, is attributed to the inherent structural flaws in the twist of the fibre or flaws produced by grooming procedures.

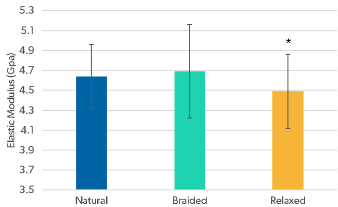
To study this, a repeated stress or strain can be applied to single fibres until they break, which is known as fatigue analysis. As well as cycles to break, the elastic modulus can be measured, and the data used in isolation or alongside the complementary quasi-static tensile data to support "strength", "damage protection" and "repair" claims.

Methodology

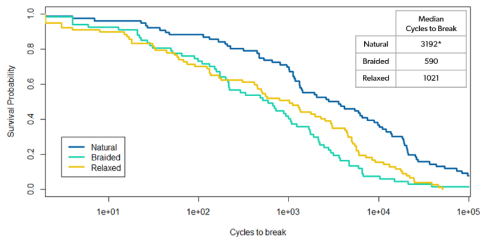
Studies were conducted on hair of South African origin with a curl type of 6/7[3] using the Dia-Stron Fibre Dimensional Analysis System (FDAS770) and Cyclic Module (CYC802)[5].

Tests were conducted on hair in either its natural form, relaxed or post-braiding. Hair was relaxed using a commercially available no-lye relaxer system. A small bundle of hair fibres were tightly braided, left for 1 week and carefully unwound. This was to ascertain how the additional torsional stresses caused by braiding impact the fatigue survivability compared to a chemical treatment.

Results



The tensile elastic modulus, recorded on the first loading cycle of the cyclic fatigue test, demonstrates that the application of the relaxer has significantly (*) reduced the elastic modulus compared to the natural hair. However, the physical process of braiding does not appear to significantly impact the elastic modulus compared to the natural hair.



Using a Kaplan-Meier estimator, the number of cycles to break can be plotted against the fibre survival probability. The data shows the natural hair statistically survives for a higher number of cycles than both of the damaged hair groups (*). A likely cause of these results is the chemical damage from the highly alkaline relaxer and structural damage from the tight inter-weaving of the braided fibres.

This study illustrates the complementary nature of quasi-static tensile and cyclic fatigue testing, with the fatigue experiments highlighting differences unseen in quasi-static testing.

References:
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