CREEP AND DAMAGE IN RAT TAIL TENDONS

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Introduction

Damage following repetitive, overuse loading contributes to painful and debilitating tendon rupture and tendinopathy [Magnusson, 2010]. Tendon-related complaints are the second most common reason for a GP visit, healing takes months and current treatments have poor outcomes [Chaudhury, 2010].

Tendon mechanical behaviour under fatigue loading is identified in two [Wang 1995] or three [Fung 2009] phases. However understanding is lacking of the microstructural deformation mechanisms taking place in each phase. Previous work has identified processes with two different activation energies [Cohen, 1976] but this work has not been independently confirmed.

The aim of this study was to determine the temperature dependence of creep in rat tail tendons, and hence estimate the activation energies throughout creep deformation. The study tested the hypothesis that creep behaviour could be described by processes with two different activation energies.

Methods

Creep loading a polymer at range of temperatures enables activation energies to be estimated through the Arrhenius equation:

$$\textit{process rate} = A \exp(-E_A / k\,T) \quad (1)$$

where A is an arbitrary constant, E_A is activation energy, k is the Boltzmann constant and T is the absolute temperature.

Tendon fascicles, carefully dissected from mature Sprague-Dawley rat tails, killed as part of unrelated experiments, were equilibrated in PBS at room temperature before testing. The diameter of the fascicle was measured at 6 points using an optical micrometer (Keyence Milton Keynes, UK; precision 1×10^{-5} mm) immediately before testing in a custom temperature controlled (± 0.5 °C) PBS bath using a 20 N frame (Bose Electroforce) under a creep stress of 10 MPa at 25 °C, 30 °C, 37 °C and 42 °C, with N=9 specimens per group.

Viscoelastic and constant rate plus exponential damage models were least squares fitted to the creep curves.

Results

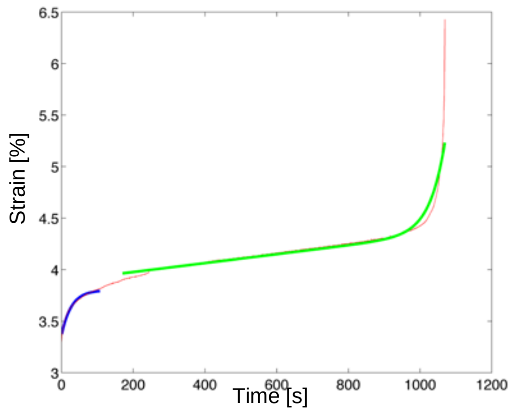

Figure 1: Typical creep curve (red) fitted with viscoelastic (blue) and damage (green) models.

°C	25	30	37	42
τ_{visc}	2.9 ± 1.95	0.9 ± 0.89	1.4 ± 0.60	1 ± 0.64
τ_{dam}	109.5 ± 48.2	6.4 ± 4.5	5.3 ± 8.4	1 ±0.79

Table 1: Time constant, τ_{visc} and τ_{dam} variation with temperature normalised to 42 °C.

Significant variations with temperature were found only for the time constants for the viscoelastic and damage model. Least square fitting an Arrhenius relationship gave $E_{A\ visc}$ = 6.3 kcal/mol and $E_{A\ dam}$ = 45 kcal/mol.

Discussion

Our hypothesis is confirmed and the estimated E_A are similar to those reported previously. The viscoelastic process is similar to hyaluronic acid gel 5 – 10 kcal/mol, and the damage process to semi-crystalline polymers 30 – 60 kcal/mol (Cohen 1976). Further temperature data points will increase confidence in our estimates and will give new insight into the damage and failure of tendon.

References

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