MUSINGS ON ROPES

PMS 19/3/84 (1 of 5)

Copies: SGR
: Bill H.
: Roo W.

DR. PHILIP SARGENT
MICROCIRCUIT
ENGINEERING
GROUP
CUED CAMBRIDGE CB2 1PZ
(0223) 66466 ex 371

SH07

dimensions of length.

$$x = A \sin(\omega t + \alpha) + B$$

$$v = \omega A \cos(\omega t + \alpha)$$

$$a = -\omega^2 (x + B)$$

does this mean that deceleration reaches a peak at $x = x_{max}$ then? OK. But why is it dependent on Rope length ($B = s.l$). ??? Seems wrong to me.

length, pure number

$$A = l\sqrt{2s\eta + s^2}$$

$$B = sl$$

length

derivation of which I suppose I could work out - but I'm lazy. [The Roberts Eqns.]

l, m, x

$m = 0 \rightarrow x = 0, s = 0$

$m = m_1 \text{ kg} \quad x = s_1 l, \; s = s_1$

for mass m_1, it stretches by $s_1 \cdot l$

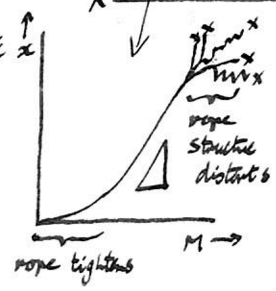
the intrinsic rope property is s/m_1, in <u>% per kg.</u>

plot is a guess.

η is a pure number

the 's' you use is <u>for a particular mass m</u>, I think.

static test:



Self weight of rope is ignored throughout. OK, but 300 m of wet rope is a significant weight.....

peak tension in rope due to selfweight is at <u>belay</u> $T = l \times \rho \times g$

l = length in m
ρ = mass in kg m^{-1}
$g = 9.81 \text{ m s}^{-2}$

T is the tension (force) which has to be added directly to any peak load you calculate.

<u>ESTIMATE</u>: 300m of superbraidline weighs c. ~~30~~ 15kg dry, 30kg wet :→

on a 100m pitch: $T = 100 \times \frac{30}{300} \times 9.81 \Rightarrow 98\text{ N}$ or 10kg, but this has to be added to the mass of the <u>caver</u> strictly speaking. So this introduces an "end effect", Fall factors are now NOT independent of the length of the rope, the weight of the rope becomes significant for long pitches (I weigh 60kg) so need extra 20% safety factor approx. ?!

Effect of varying your 'standard mass' – which I presume you take as the UIAA standard (for fall-factors) of 80kg. on an SRT (2%) rope.

hmm – re Bridle article. If strength of bolt is 1000kg, then overload must be < 12.5 for an 80kg bloke, or bolts – even good ones – start popping. New rope would just pop a bolt – the Xitu Marlow sounds as if it wouldn't bend a paperclip.

	s	
	1%	2%
FF = 1	11 ×	7.4 ×

O.K. so suppose I only weigh 40kg, suddenly the rope is less stretchy, it only stretches 1% whereas under 80kg it stretched 2%. I then fall on it and experience a peak tension of 11.0 × 40kg → 440kg.f. My heavier friend also lobs off at the same time, on the same kind of rope, and experiences a peak tension of

7.4 × 80kg → 592 kg.f.

This is not what I expect – I would have thought, intuitively, that the peak loads & accelerations should be the same for the 2 cases so I think your eqns. do not mean what they say and that there is a normalisation missing somewhere?! But I'm willing to be convinced otherwise.

I do like your 'interesting cases' Steve.

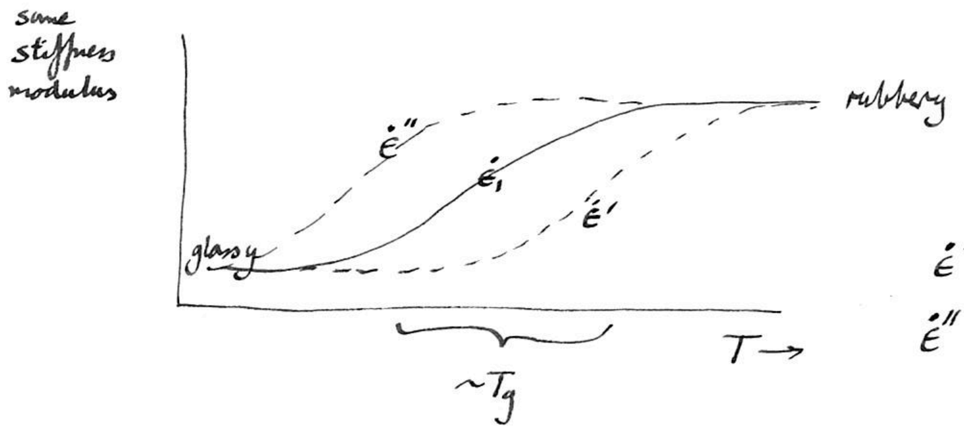
s = function{number of falls, FF for each fall}

<u>N.B.</u> Bill found that the stretch factor for a particular rope DECREASED ~~was~~ after a fall on it. So immediately became <u>more dangerous</u>, even if it's <u>static</u> strength was then <u>unchanged</u> (or even <u>increased slightly!</u>)

<u>Safety Cords & Cowstails</u> For use with SRT, ∃ a strong argument that they should be made of shock-cord, not climbing rope. Also – the case for the Rubber TROLL anchor!!

Polymers in the vicinity of the glass transition only

[not relevant for ropes unless you are abseiling into hell.]



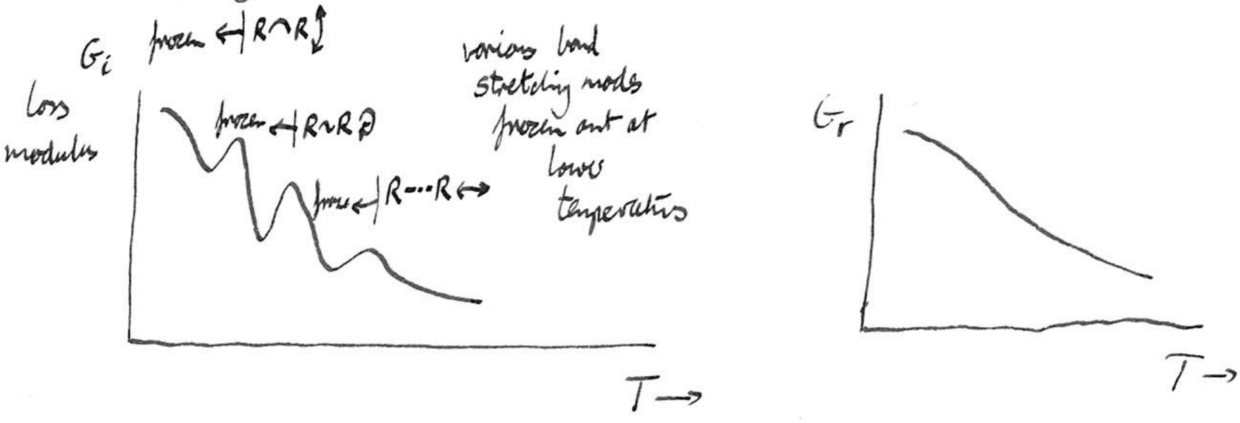
$\dot{\varepsilon}' > \dot{\varepsilon}_1$

$\dot{\varepsilon}'' < \dot{\varepsilon}_1$

(N.B. moduli in glasses are due to enthalpy, those in rubbers are determined by ENTROPY)

[This is more relevant - & more worrying.]

crystalline polymers (like hard-drawn nylon, PE etc)

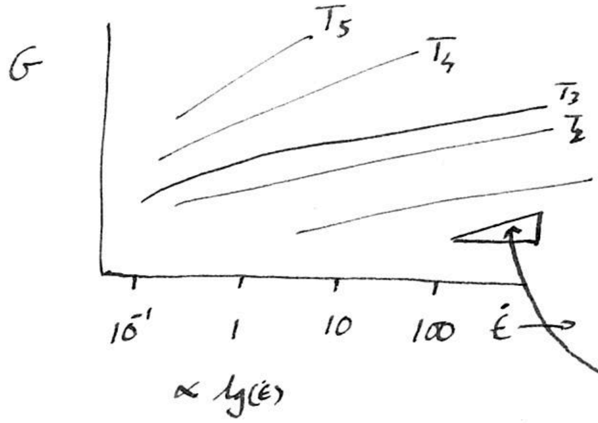


loss modulus is the imaginary part of the complex modulus:

$$G^* = G_r + i.G_i$$

and on a complete cycle it is proportional to the damping and the hysteresis loss. The real component probably changes monotonically(?). So we get a monotonic variation of peak decceleration but a complex variation of heat dissipation in the rope. Whoops!

Effect of strain-rate on crystalline fibres is probably monotonic (but not linear) as a function of $\dot{\varepsilon}$ (strainrate) at any particular temperature.



some sort of fairly gentle curve I would guess. probably approximate as linear: i.e.

$T_5 > T_1$

$\left\{\frac{\partial G}{\partial lg(\dot{\epsilon})}\right\}$ is gradient

This is a guess based on physical reasoning:

most energy activated processes become more important at higher T so I am guessing that $\frac{\partial G}{\partial \cdot lg(\dot{\epsilon})} \simeq f(T)$ only, & monotonic too

and that $\frac{\partial}{\partial T}\left\{\frac{\partial G}{\partial lg(\dot{\epsilon})}\right\}$ is always +ve (or poss. zero)

but remember, the absolute value of G will still be wiggling about as a function of temperature.

(eqns. looking more impressive now, I wonder if C&C typesetters can handle partial differentials)

This is all just considering the effects of T and $\dot{\epsilon}$ on individual polymer fibres, ignoring weaving, core-tightening & friction effects – which, as far as dependence on $\dot{\epsilon}$ and T go, I guess will be of SECONDARY importance.

The different dependence on T & $\dot{\epsilon}$ will depend largely on the fibre, so we can expect large differences between various nylons, PET (Marlow) etc. The draw-ratio of the fibre will affect this too, even for chemically identical fibres. Cardrosin – write to ICI, Courtaulds etc. for technical data sheets on their fibres eg. Mr. C. Butcher, Courtaulds, Coventry ...!! Steve K. would know too, possibly, or Ian H.

Energy Dissipation

d/mm	8	9	10.5	11
V'/$m^3 m^{-1}$	5.03×10^{-5}	6.36×10^{-5}	8.66×10^{-5}	9.50×10^{-5}

80 kg weight. SRT: 2% rope

FF ①: $U = M.x.g$

dissipation per unit length $= K \; Jm^{-1}$

total energy dissipation $= U = K.\ell = Mxg = M.s.\ell.g$

$\therefore K = Msg = 80 \times 9.81 \times 0.02 \; Jm^{-1}$

$K = 15.7 \; Jm^{-1}$

not a lot.

if density is $3 \times 10^3 \, kg\,m^{-3}$
diameter is 10.5 mm
area $\sim 9 \times 10^{-5} \, m^2$
V' in 1m $= 9 \times 10^{-5} \, m^3$
$\rightarrow 0.26 \, kg \, m^{-1}$
if $C_v \sim 0.3 \, J \, cm^{-3} K^{-1}$
$\sim 0.3 \times 10^{+6} \, J m^{-3} K^{-1}$
$\Delta T = \frac{K}{C_v . V'}$
$\Delta T \sim 0.6K$

> In fact, energy is mostly stored, not dissipated, except when it breaks when all the stored energy is liberated <u>locally</u>

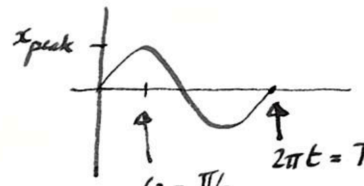
This assumes all energy is dissipated as heat and there is no elastically stored energy – i.e. that the situation is perfectly damped.

In fact, we need to integrate the mass × the rope tension between $x = 0$ and $x = $ peak to get the total heat:

$V' = \left(\frac{\text{diameter/mm}}{2}\right)^2 \times \pi \times 10^{-6}$ (in m^3 per m.)

$K \approx Mg.x$ (FF∅)

$$U = \ell \times K = Mg \int_{x=0}^{x=\text{peak}} A \sin(\omega t + \alpha) + B \; . \, dx$$



same as

$$K = Mg . \int_0^{\pi/2} \frac{A}{\ell} \sin(\omega t + \alpha) . d\omega \; + \; Mg . \frac{s\ell}{\ell}$$

$\alpha = 0$ I believe...

need A/ℓ to make dimensions correct... fiddled – I've done something inelegant & probably wrong here!

$$K = Mg . \frac{A}{\ell} \Big[-\cos(\omega t) \Big]_0^{\pi/2} + Mg.s.$$

$$K = Mg \left(\frac{A}{\ell}(0 + 1) + s \right) \; = \; M \times (2s\eta + s^2)^{1/2} + M \times s.$$

$$K = M.s. \left[\left(\frac{2\eta}{s} + 1 \right)^{1/2} + 1 \right] \quad Jm^{-1}$$

Temperature increase $= \Delta T = \frac{K}{C_v \cdot V'}$ where V' is volume of 1m of rope, C_v is volume specific heat }

so K <u>increases</u> with s for a particular fall factor. Hmm. Yes, that makes sense, the further it falls, the more energy to get rid of.

Next Week... Fracture Mechanisms!

Why do ropes fail at knots?

Rod's PIN-FAILURES... hmm.