Understand, Assess, and Control

Dynamic Loads in Climbing and Rigging

presented at the
Kletterforum Augsburg 2014

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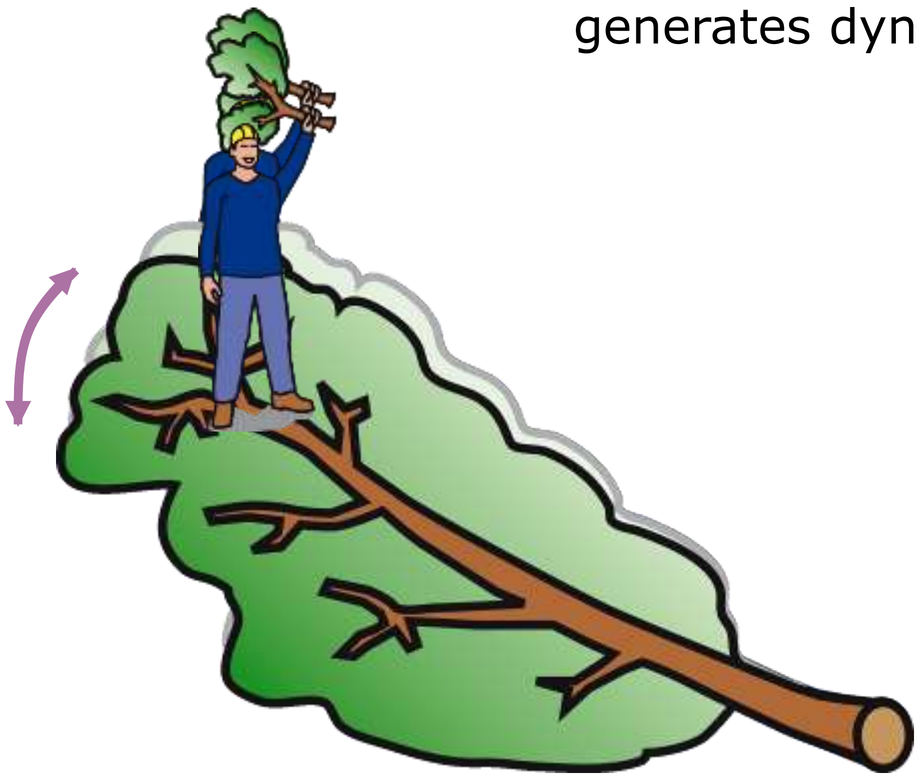
Static vs. Dynamic

Load causes deflection

Any suddenly imposed load generates dynamic conditions.



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Static vs. Dynamic

Load causes deflection

Any suddenly imposed load generates dynamic conditions.

Dynamic Conditions

Rate of Load Application

quasi-static: very slow, over several minutes/hours

dynamic: fast, within seconds

shock: rapid, within small fractions of a second

harmonic: in tune with the rhythm of the structure

Dynamic Conditions

Rate of Load Application

quasi-static: **snow/ice accumulating on a branch**

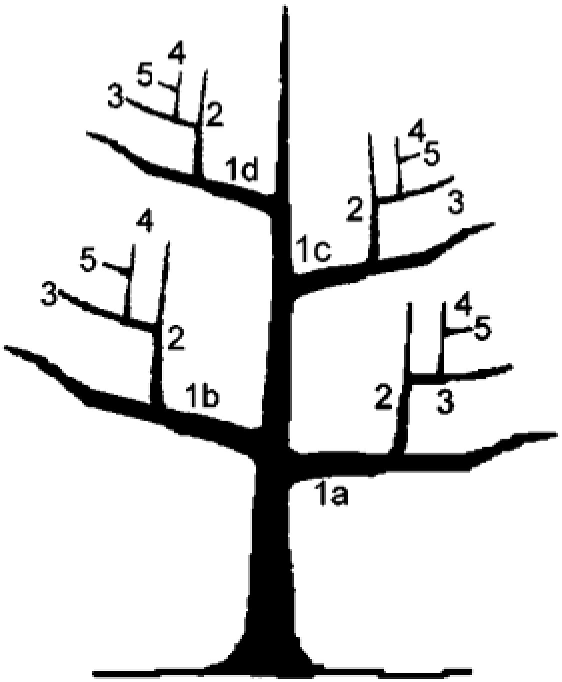
dynamic: **wind, climbing, „letting the log run"**

shock: **snubbed-off rigging, fall arrest**

harmonic: **oscillation test, resonance**

Resonance

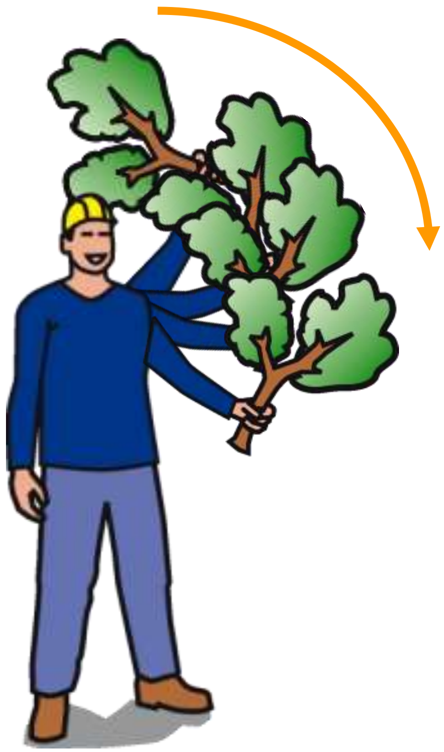
Oscillation and damping



James (2006)

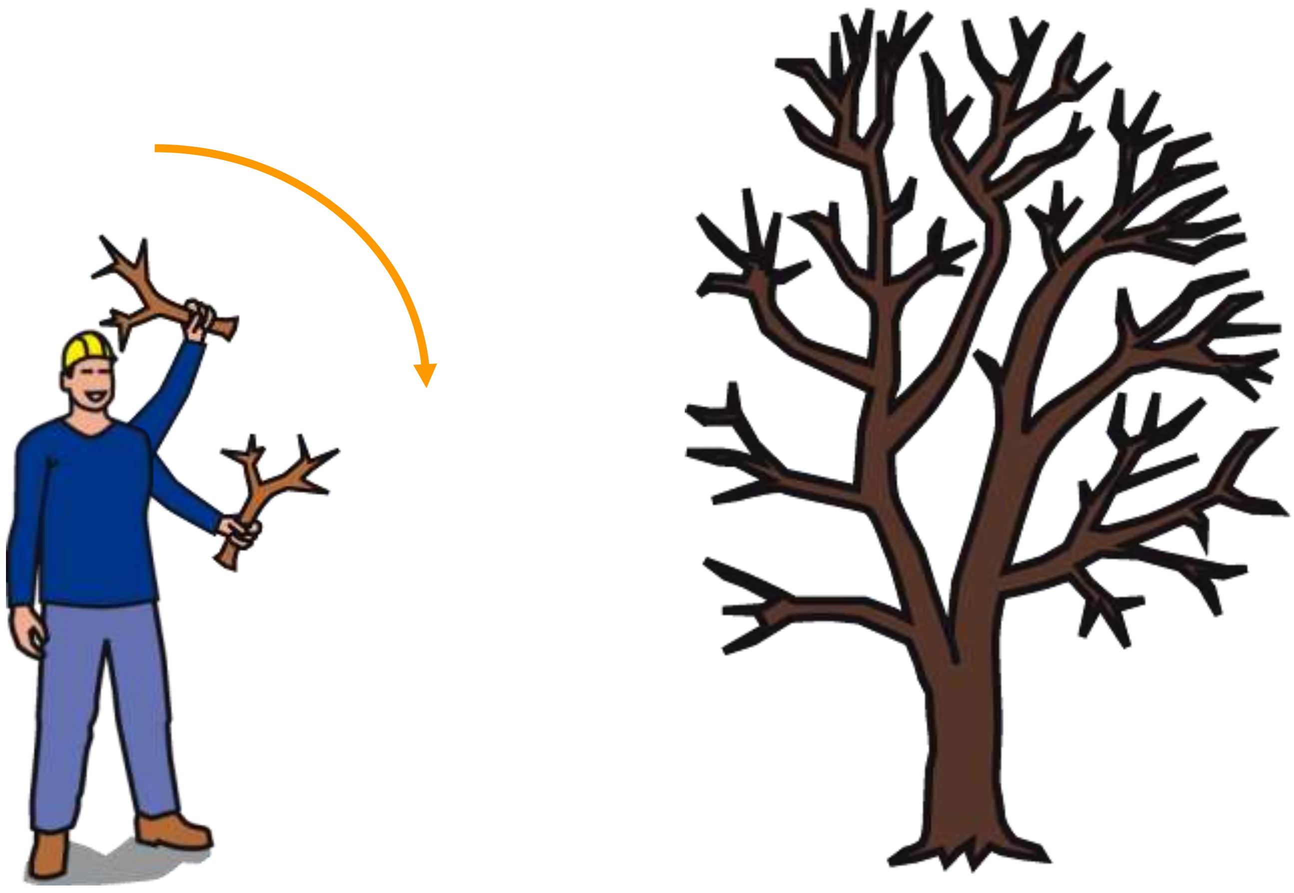
Tree Dynamics

The effect of leaves



Tree Dynamics

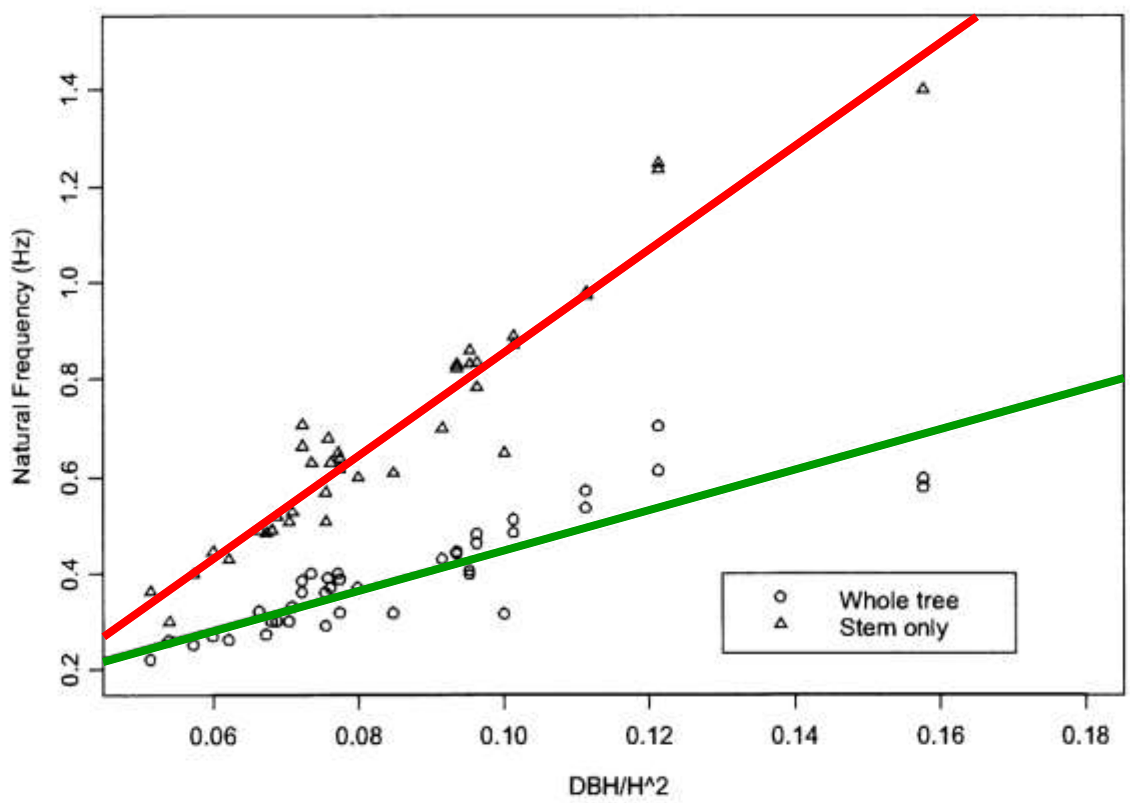
The effect of leaves



Tree Dynamics

The significance of branches

Natural frequency



Moore & Maguire (2004)

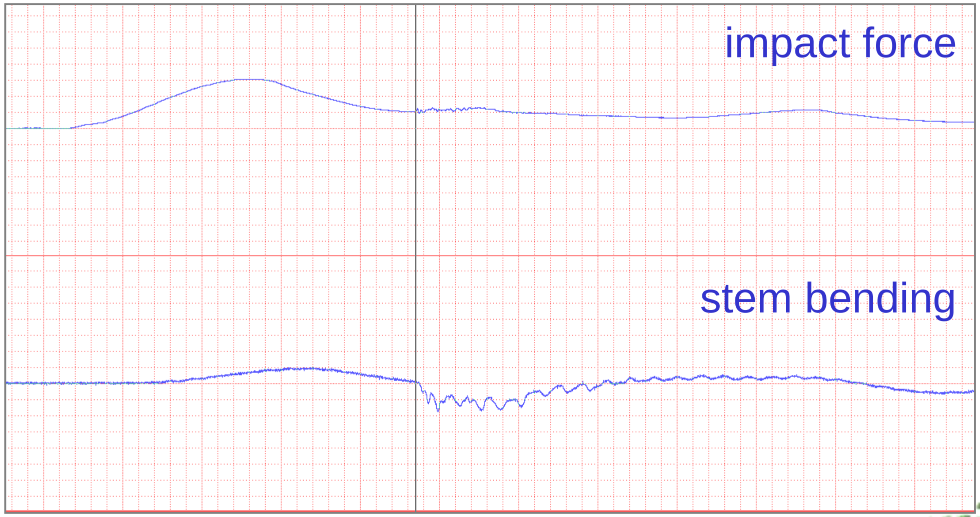
Tree Dynamics

The significance of branches

Tree Dynamics

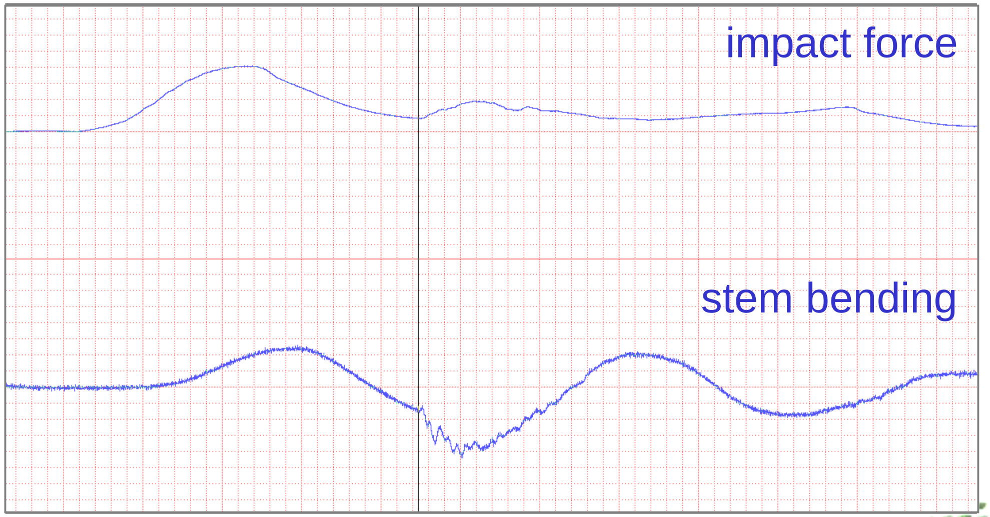
Peak force and stem reaction

Results of field tests on
Beech and Sycamore



Tree Dynamics
Peak force and stem reaction

Results of field tests on
Beech and Sycamore



Tree Dynamics
Peak force and stem reaction

Results of field tests on
Beech and Sycamore

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Dynamic Conditions

Damping properties

Low: bulk mass, bluff body

medium: mass unilaterally concentrated, porous structure

high: well distributed mass, rough surface

critical: no dynamic response

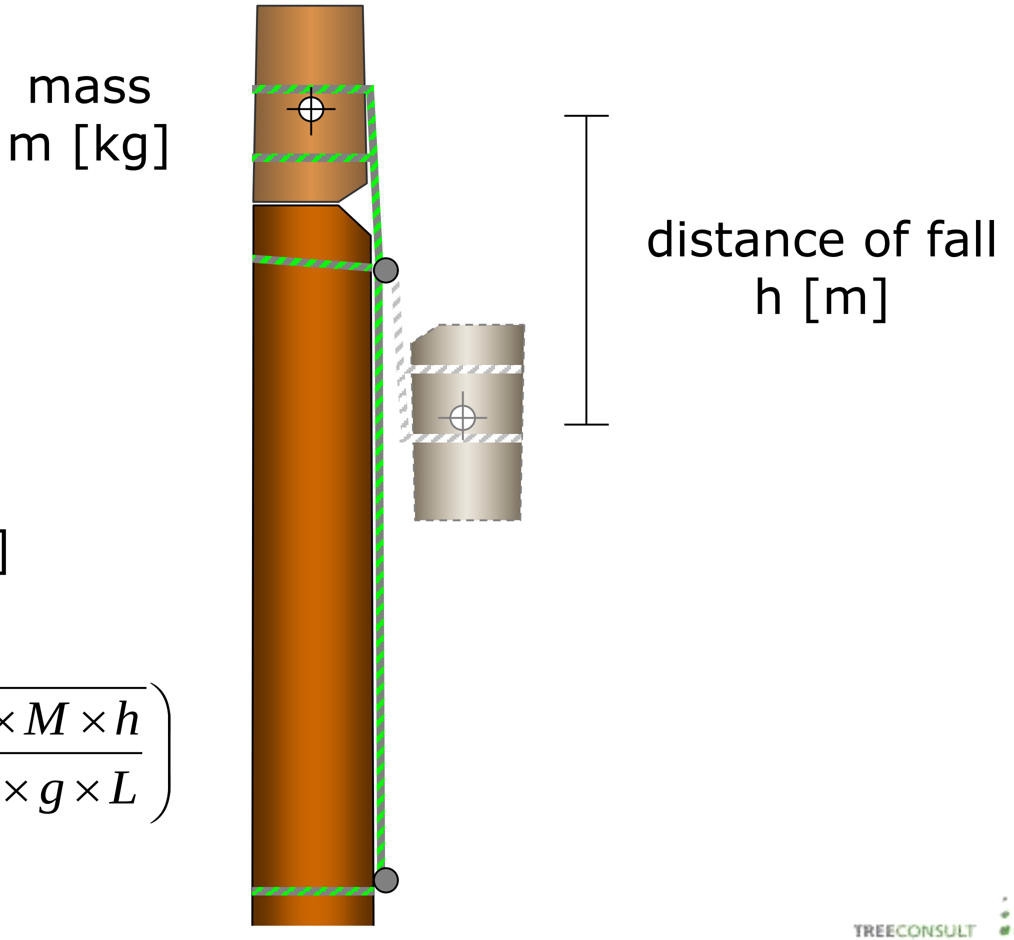
Dynamic Conditions

Damping properties

Low:	**big diameter stem without crown**
medium:	**forest conifers with small live crown ratio**
high:	**broad-leaved tree with full crown**
critical:	**sponge, shock absorber**

Energy Input - Excitation

Potential energy in a fall-arrest scenario



$$E_{pot} = m \times g \times h \text{ [Nm]}$$

$$F_{peak} = m \times g \times \left(1 + \sqrt{1 + \frac{2 \times M \times h}{m \times g \times L}}\right)$$

Kinematics of a „Snubbed-off“ Scenario

Results of a laboratory study

Drop tests carried out in the lab
recorded at 250 frames/sec
in Motion Capture Technique

Spruce Ø 35 cm ~ 1 ft 2 inches

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Kinematics of a „Snubbed-off“ Scenario

Results of a laboratory study

Drop tests carried c
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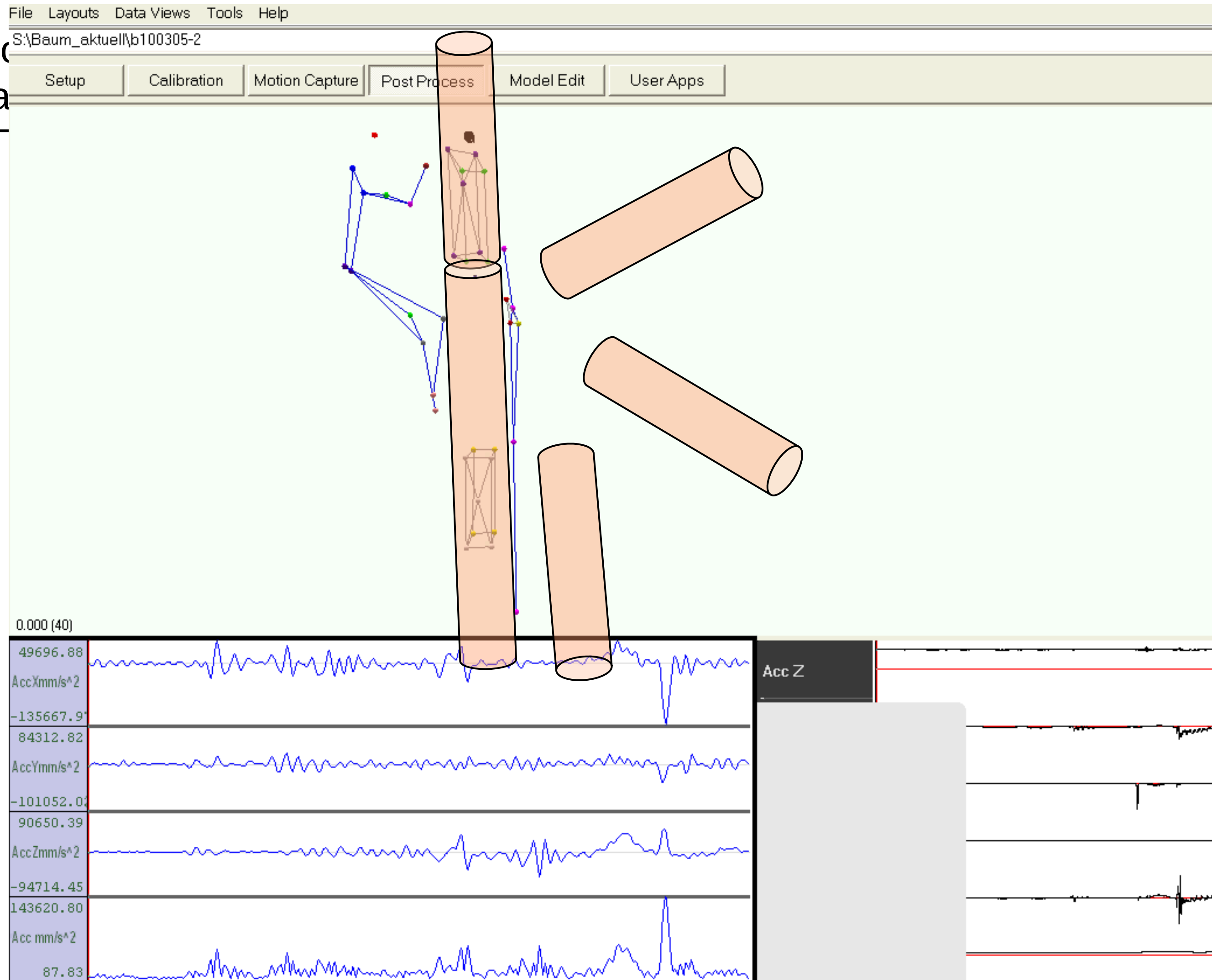
Spruce Ø 35 cm ~



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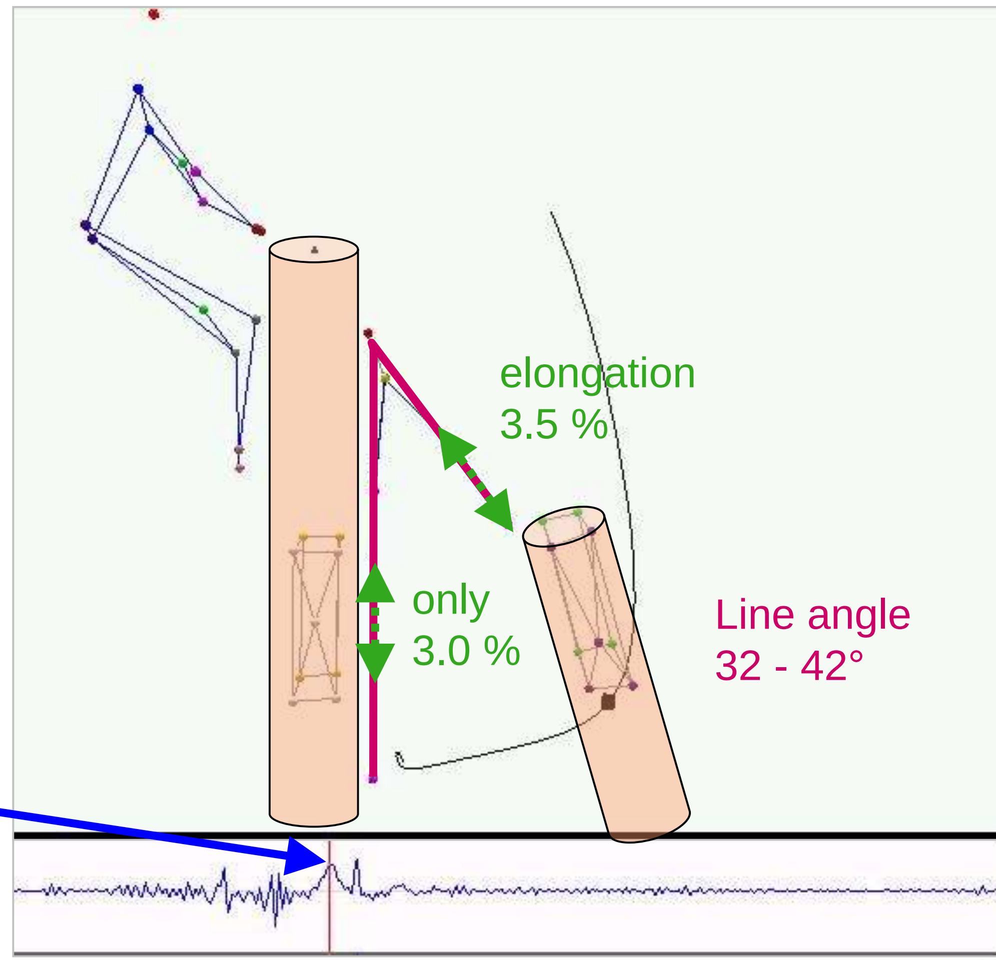
Kinematics of a „Snubbed-off“ Scenario

Results of a laboratory study



Peak deceleration of log

Maximum rope stretch

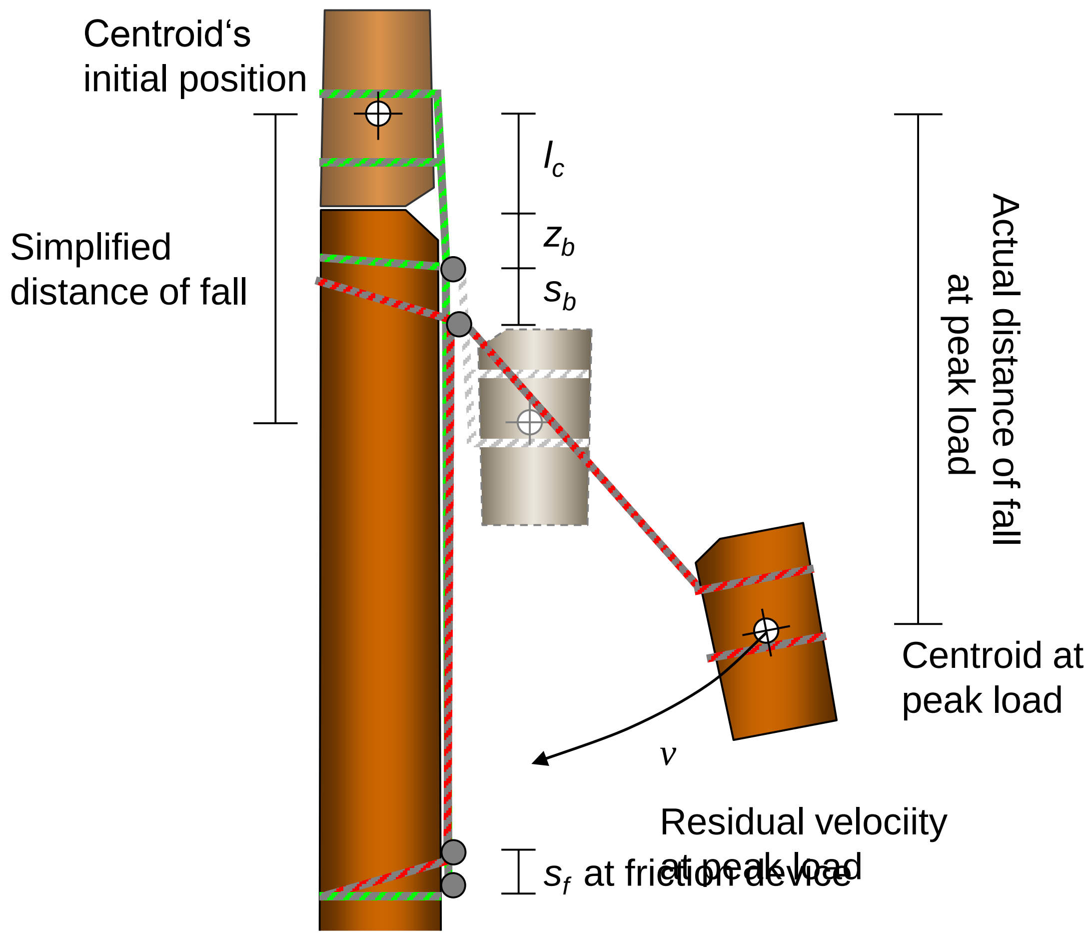
Kinematics of a „Snubbed-off“ Scenario

Studying a real rigging operation

Field tests on Maple

Kinematics of a „Snubbed-off“ Scenario

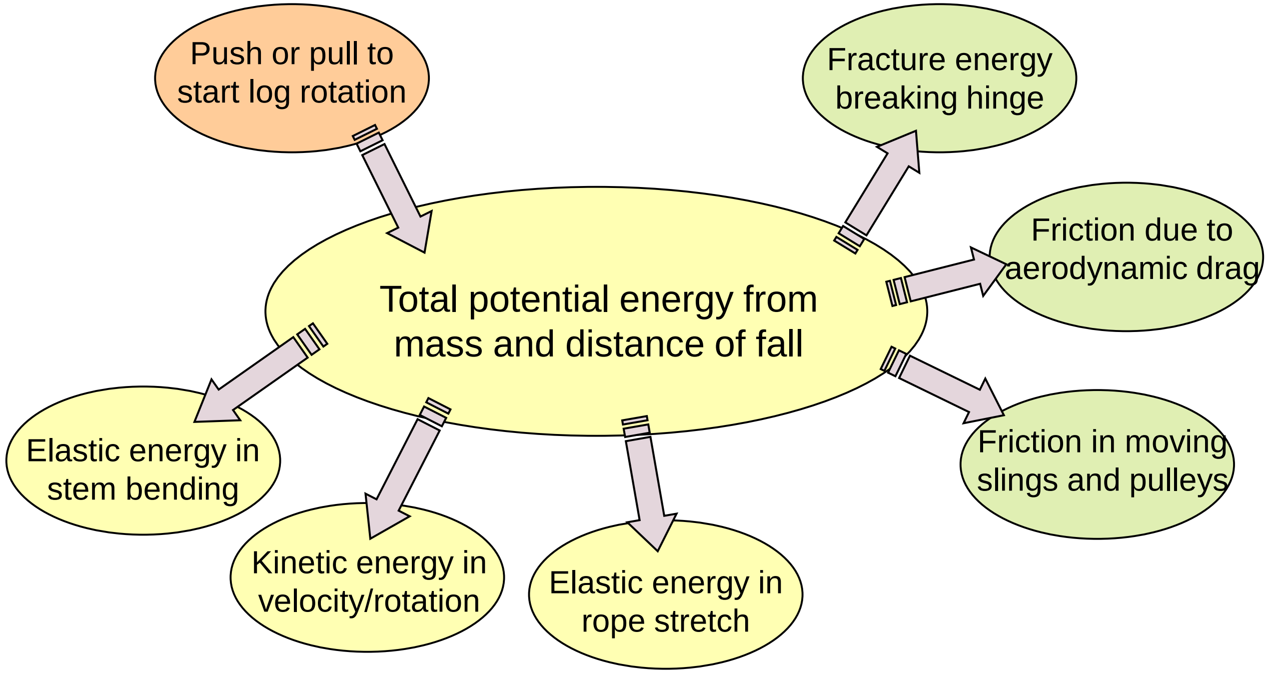
Components of a more complex model for energy dissipation



from the HSE Rigging Report 2008

Energy Dissipation

In a „snubbed-off“scenario



from the HSE Rigging Report 2008

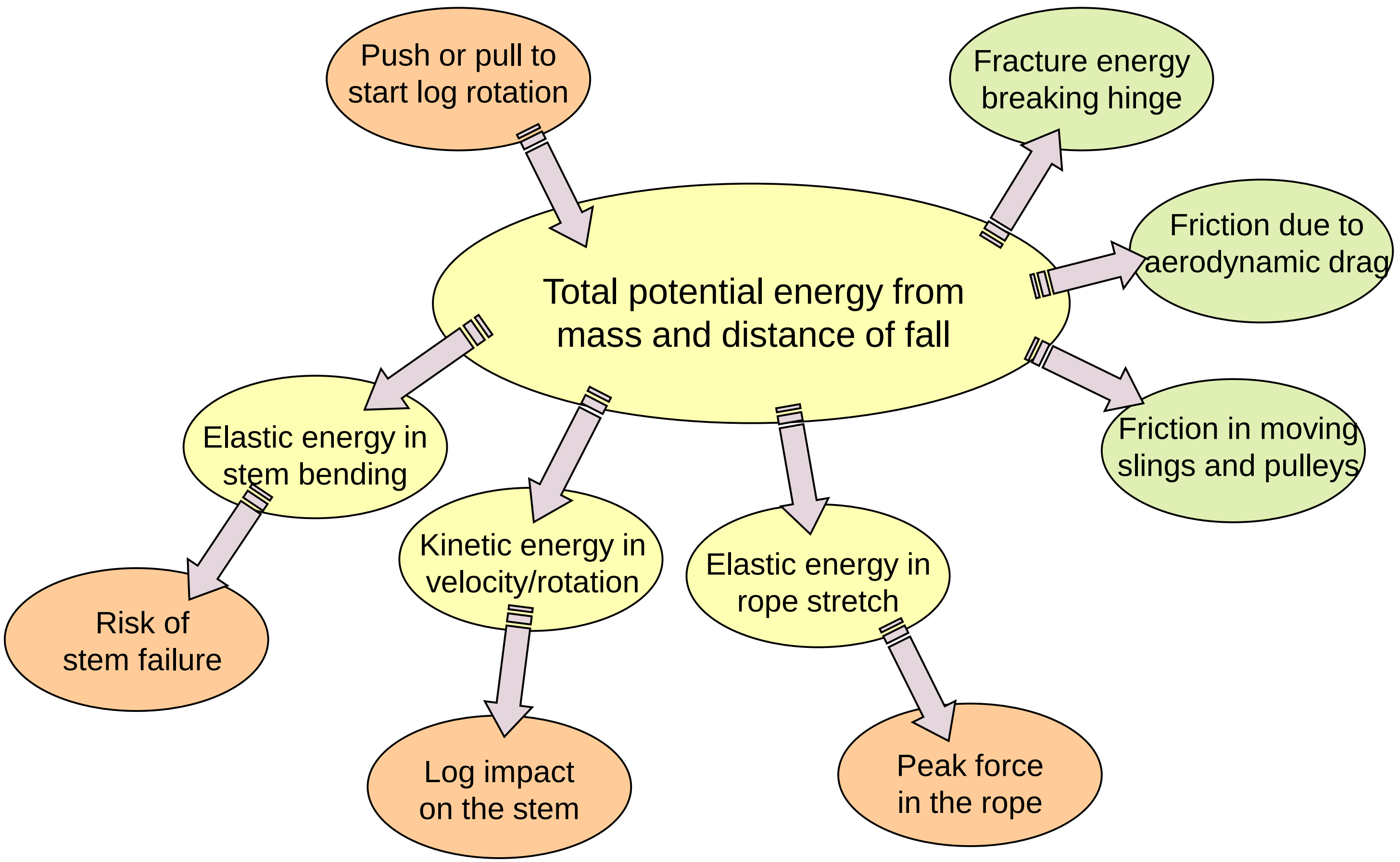
Kinematics of a Rigging Operation

Topping down a tree top

Field tests on Beech

Energy Dissipation

In a „snubbed-off“scenario

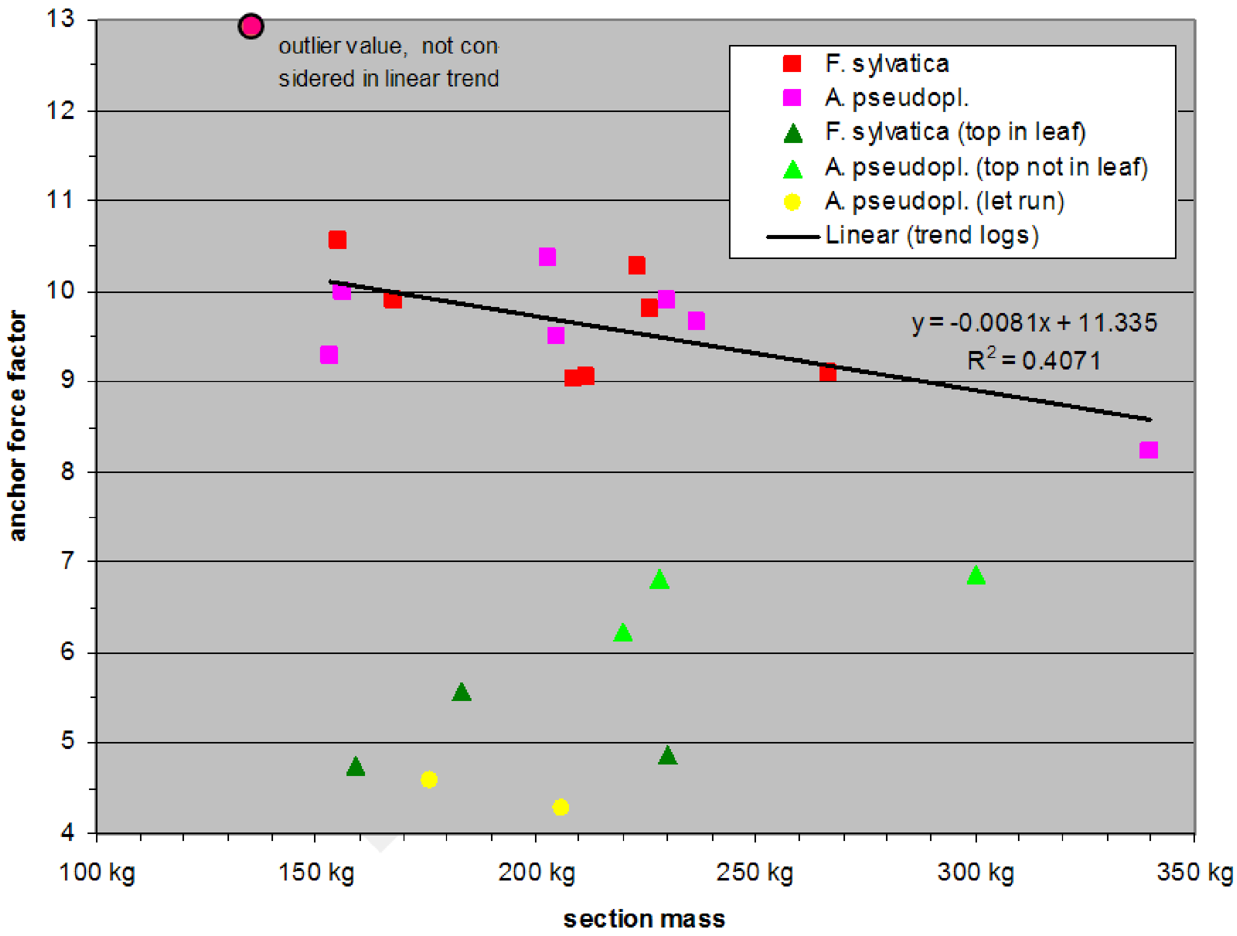


from the HSE Rigging Report 2008

Forces Generated from Rigging Operations

Results from field tests

22 drop tests on Beech and Sycamore, 14 mm doublebraid rope



from the HSE Rigging Report 2008

Dynamic Conditions

Energy dissipation

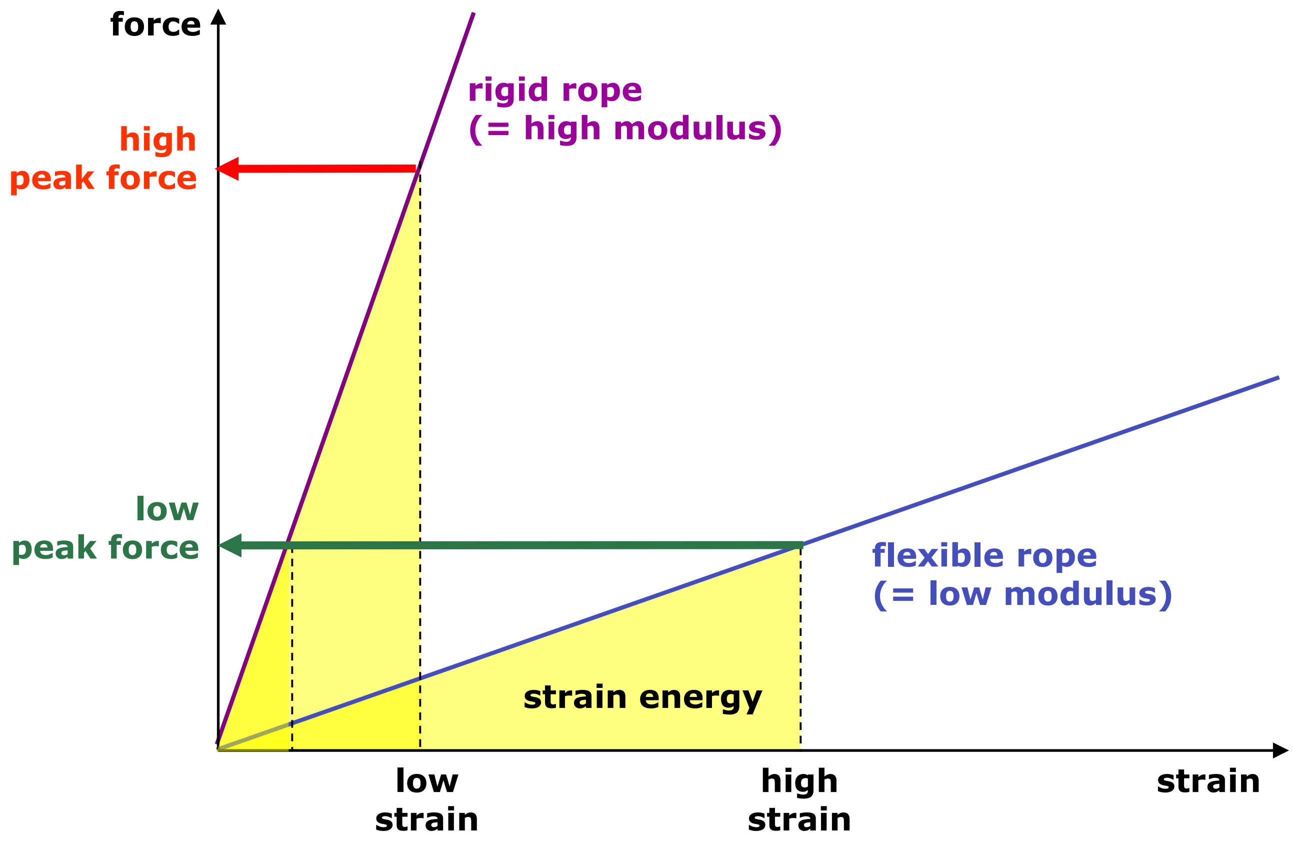
Potential energy: **weight x distance of fall**

Kinetic energy: **½ mass x velocity^2**

Strain energy: **½ force x elongation**

Forces Generated from Fall Arrest

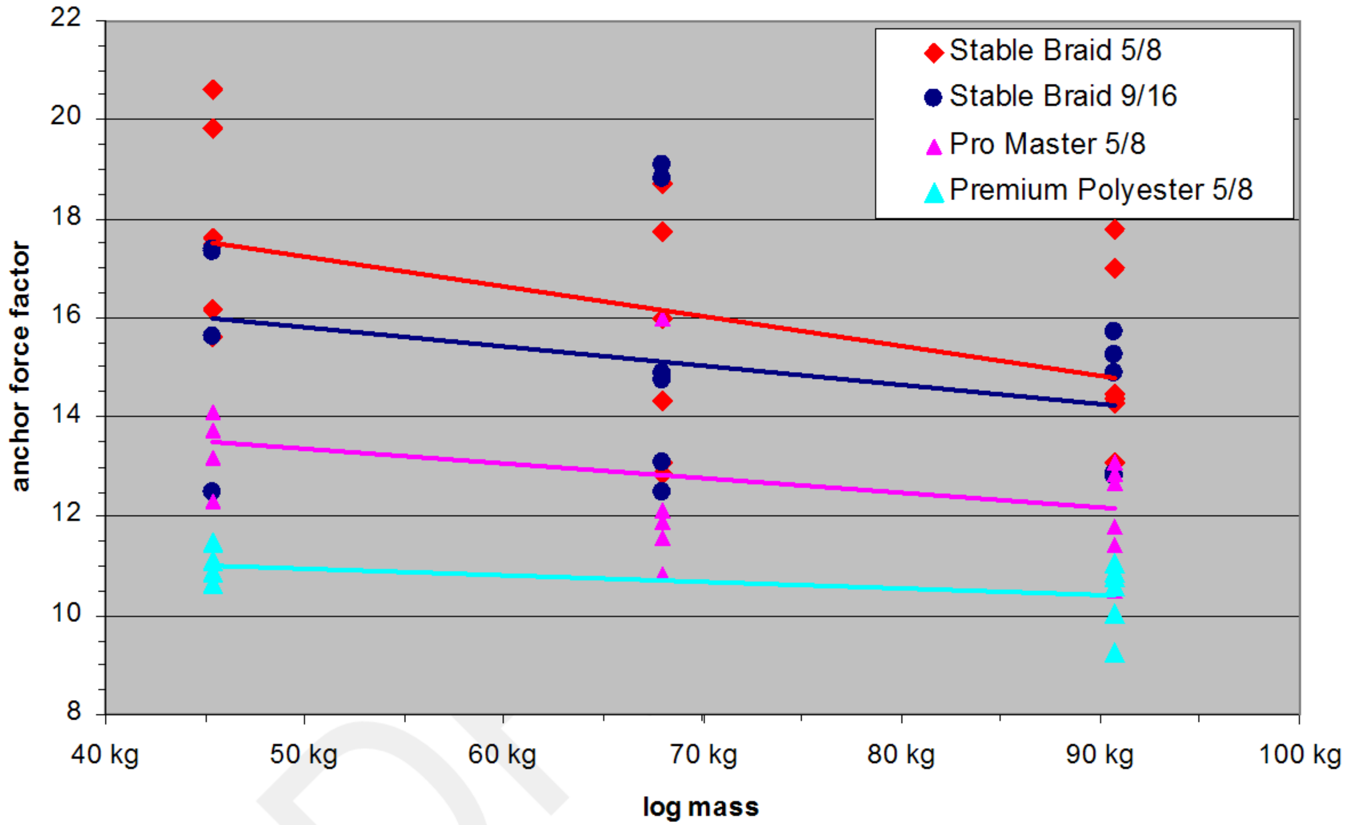
The effect of rope modulus



Forces Generated from Fall Arrest

The effect of rope modulus

Peter Donzelli's field tests from 2001
in cooperation with ArborMaster Inc.



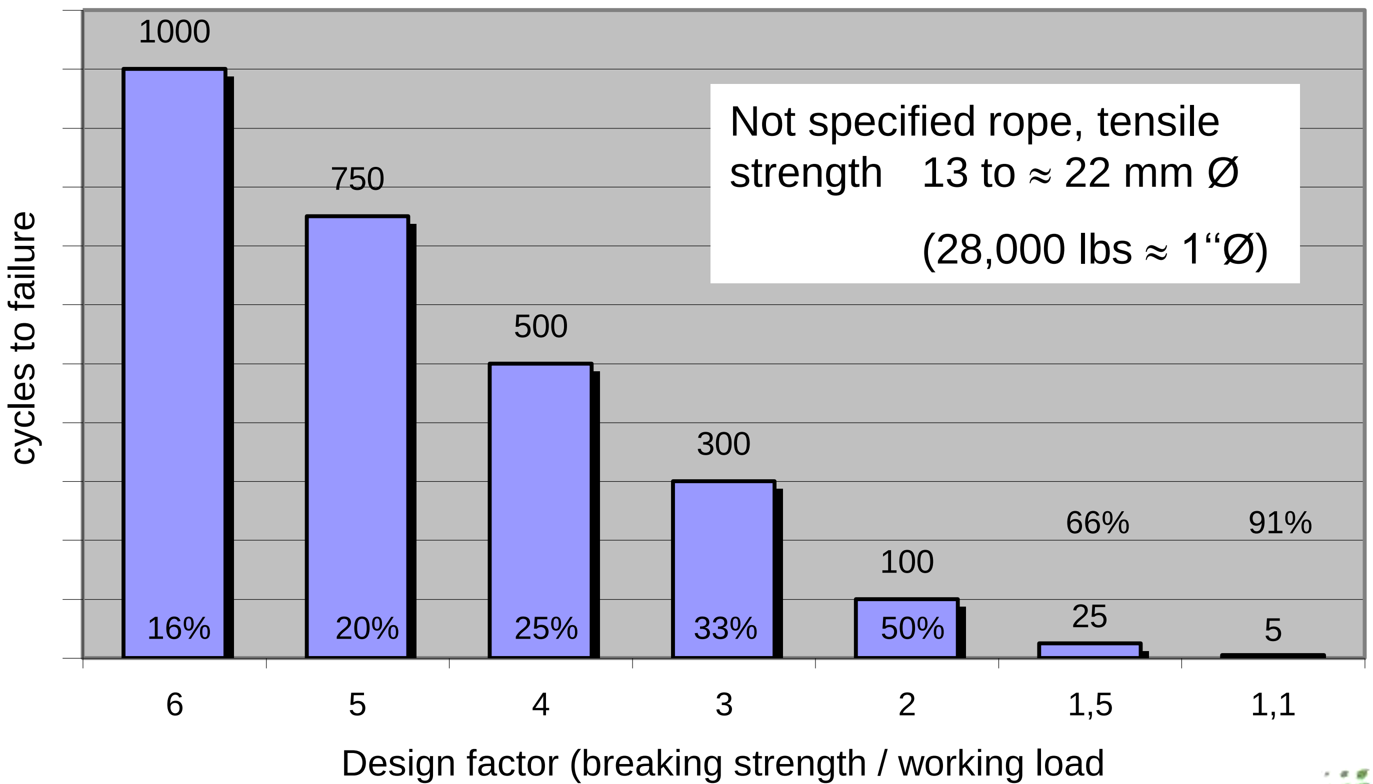
from the HSE Rigging Report 2008

Fatigue

due to cycling with quasi-static loads

Cycling reduces the strength of ropes.

source: D. Blair & Samson
Rope Technologies



Fatigue
due to shock loads

Test series carried out by Treemagineers with Teufelberger Ropes

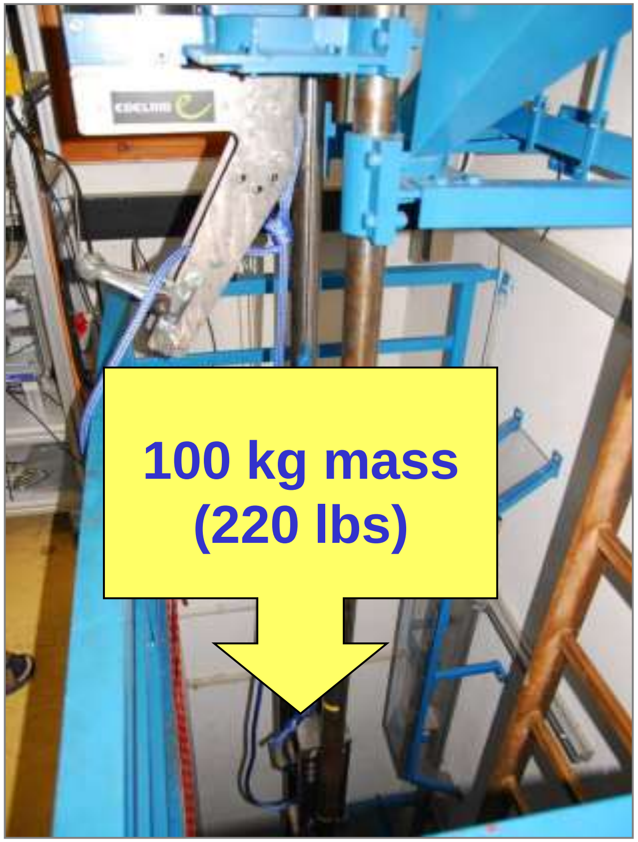
Static rope 14 mm (9/16‘‘)

Test in a drop tower

mass 100 kg

Distance of fall 2 m

Rope length 3,5 m



Fatigue
due to shock loads

Test series carried out by Treemagineers with Teufelberger Ropes

Static rope 14 mm (9/16“)

Test in a drop tower

mass 100 kg

Distance of fall 2 m

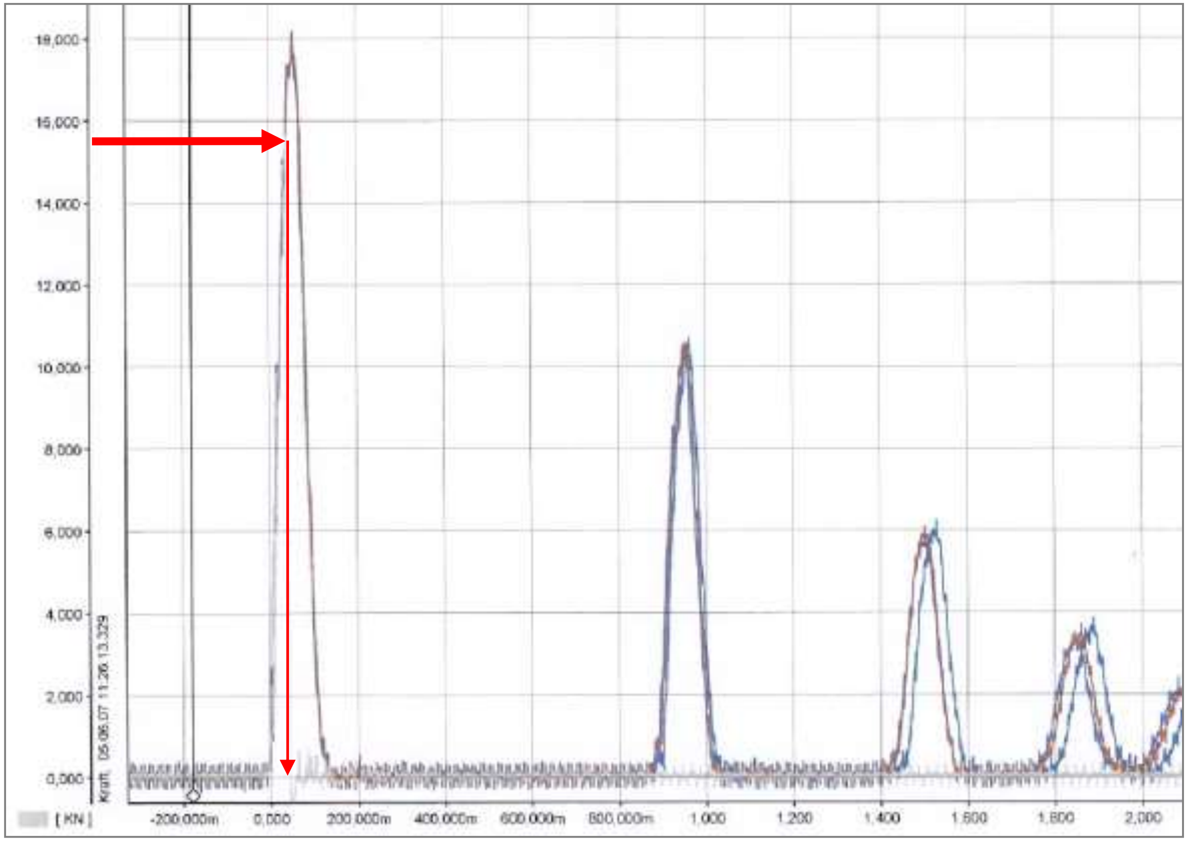
Rope length 3,5 m

Peak load

13 drops at 25 - 37% BS

during the 14th drop

failure at 16 kN (33% BS)



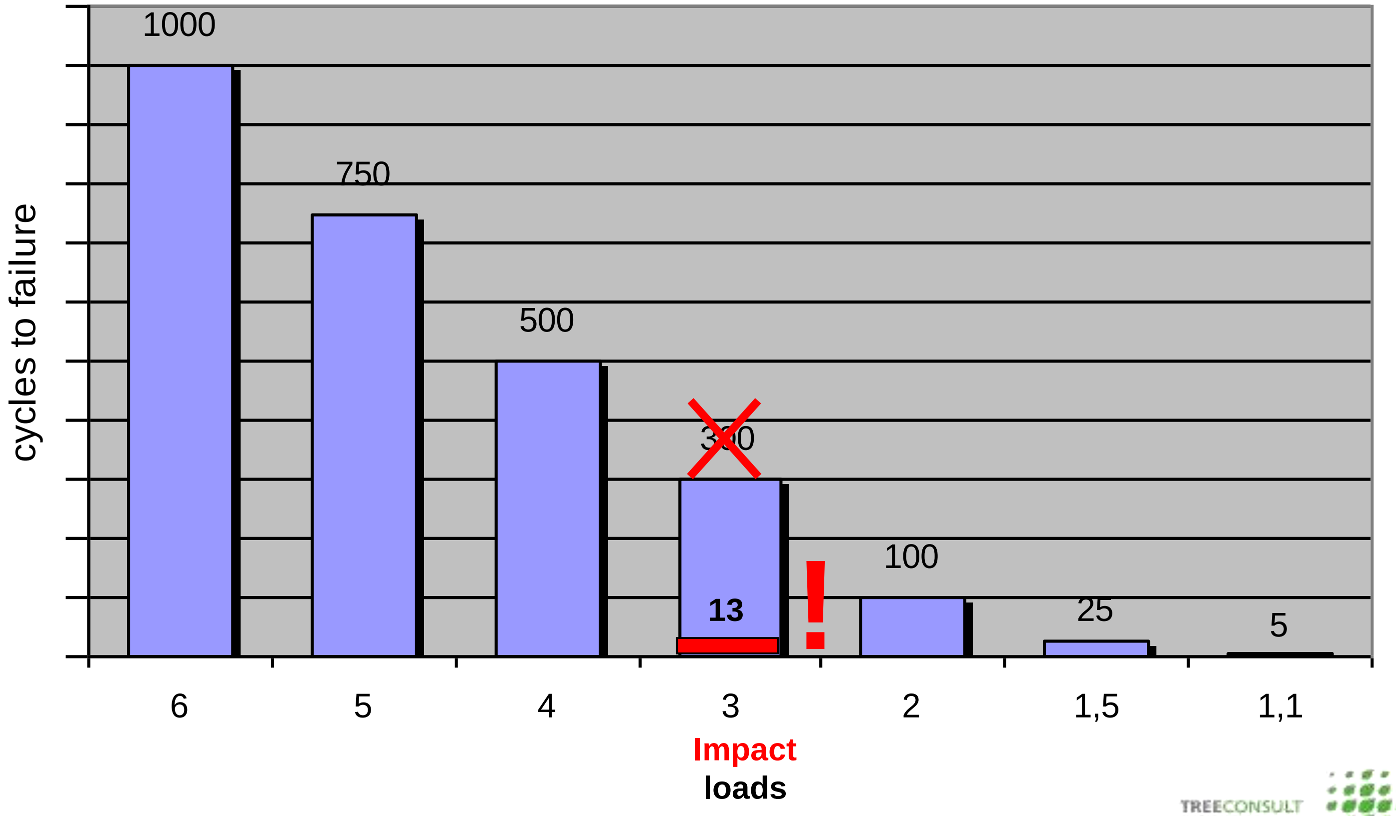
Shock loading will reduce the rope strength!

Fatigue

due to shock loads

Shock loads will reduce the number of cycles to failure!

Quelle: D. Blair & Samson
Rope Technologies



Dynamic Conditions

Energy dissipation

Potential energy: weight x distance of fall

Kinetic energy: ½ mass x velocity^2

Strain energy: ½ force x elongation

‚loss‛ of energy: friction - rope on block/bollard,
rope in knots, slings on the stem
aerodynamic drag
fracture – hinge/branches

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Dynamic Conditions

Control Dynamic Conditions:

The rate of load application:

Decelerate slowly, avoid shock loads

Damping properties:

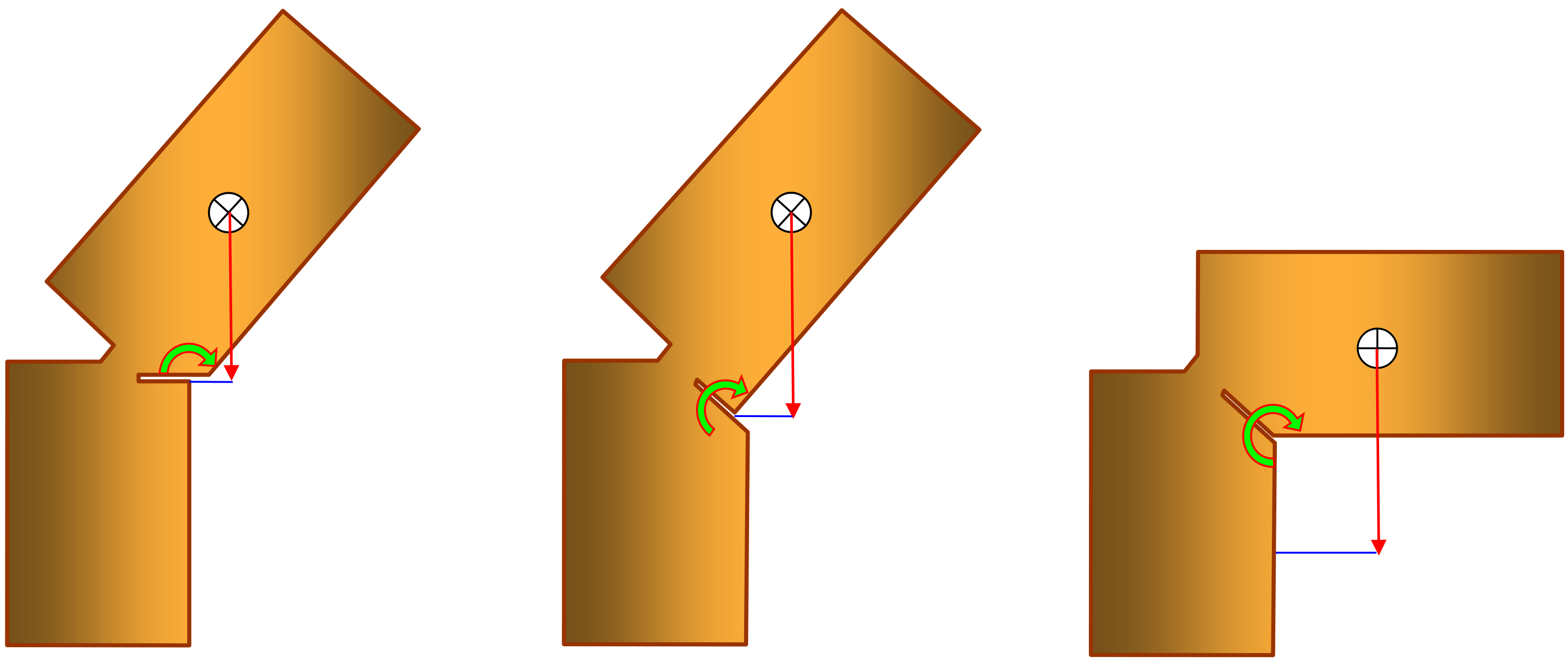
Retain mass, flexibility and aerodynamic resistance

Energy dissipation:

**Cut smaller logs, reduce distance of (free) fall,
avoid rigid ropes, reduce velocity by friction devices**

Distance of Fall

The form of the notch:



conventional

inverted (Humbolt)

open face

from the HSE Rigging Report 2008

Thank you
for your attention!

Thanks to my co-workers & friends

Chris Cowell

Paul Howard

Oriol Campana!

Please check www.tree-consult.org for more info

and www.treecalc.com for a new online-tool!