Blocks or Rigging Rings?

An Investigation into the Efficacy of Introducing Friction at the Rigging Point

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Tree removal operations in urban and peri-urban settings often extensively utilize rope-based rigging to control and manage the dismantling of large trees, often over structures or obstacles that must be preserved. For much of the removal operation, the use of an anchor point above the dismantled section allows for the mitigation of significant dynamic forces as the piece loads into the rope. However, once the majority of the removal has been completed, the operation often becomes what is often referred to as a negative rigging scenario, where the anchor point for the cut piece is below its center of mass. This results in dynamic forces being placed on the tree and equipment that far exceed the static load of the weight of the log.

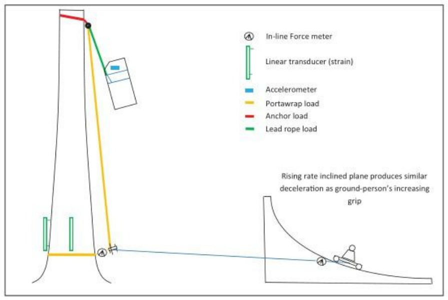

Figure 1. General experiment set-up and definition of terms.

Figure 2. Test site.

A compounding factor for the magnitude of these loads that must be dissipated, in both the upper anchor rigging and the tree itself, is that this scenario typically utilizes a revolving sheave block (a pulley) as the upper anchor. Due to the inherent nature of this system, to slow or stop the falling load on one side of the system, a similar force must be exerted on the opposite side. The result is a magnification of the falling load to approximately 2× what the anchor point must bear. However, research has demonstrated the frictional properties of even a smoothly rotating sheave reduce this loading, and forces are typically more in the range of 1.8× (Donzelli and Lilly 2001; Detter et al. 2008).

A recent alternative to a rotating sheave for the upper anchor point has been the evolution of rigging rings and rigging thimbles. These fixed devices intend to maintain a consistent friction point at the upper anchor point, which in theory would reduce the magnification of forces that occurs with a rotating sheave (dissipation of energy as heat from friction). While a variety of devices and techniques have been introduced, there has been very little empirical research on the efficacy of these systems. In a negative rigging scenario, Kane (2019) showed little difference between rigging rings and a rotating sheave anchor for peak loads. However, in this test, the load was dropped into the rigging system from above and stopped abruptly (worst case scenario: tied-off rigging system). Since the assumed intent of the rigging rings is to dissipate energy over time as heat, and in this case the duration of deceleration was very short, more work needs to be done to examine these systems in a more realistic working scenario.

We set out to test a variety of rigging rings under a running rope scenario, where the falling load would be repeatedly brought to rest over time, and test a variety of stationary anchor devices as compared to a traditional rotating block.

Rope Control

To decelerate the falling piece with a consistent rate and distance, a rising rate inclined ramp was devised to mimic the role of the ground person in "letting the rope run" (Figure 1). Constructed of wood (plywood and dimensional lumber), the ramp was 3 m (10 feet) long and had a total rise of 1.5 m (5 feet)(Figure 2). A 4-wheeled cart ran on rubber wheels along the track with an attachment point for the rigging rope. As the cart climbed the parabolic curve, the resistance increased, mimicking the increasing grip of the ground person.

Rope Tension (Load)

To measure tension in the rope, a pancake-style cell was installed between the base of the tree and the portawrap (Figure 1). Data capture was realized through a Wheatstone Bridge Phidget (DAQ1500_0, Phidgets Inc., Calgary, Canada) routed through the VINT Hub Phidget (HUB0000_0, Phidgets Inc., Calgary, Canada) at a sample rate of 50 Hz.

Figure 3. Accelerometer mounted inside drilled hole for protection.

Stem Strain

Built-from-scratch "strain gauges" utilizing a Wheatstone Bridge (steel substrate, full bridge, 1 kΩ) and a linear potentiometer (3048L-5-502, Bourns Inc., MN, USA) were used to measure fiber elongation of the trunk. The measured span of the device was 20 cm (7.8 in). Similar to the tension load cells, electrical amplification and signal processing were managed by a Wheatstone Bridge Phidget (DAQ1500_0) and the VINT Hub Phidget (HUB0000_0) at a sample rate of 50 Hz.

Block Acceleration

A 3-axis accelerometer (X16-1D, Gulf Coast Data Concepts LLC, MS, USA) with sampling at 50 Hz was mounted to the falling piece (Figures 1 and 3).

Rigging Set-Up

Four rigging anchors were compared: a DMM Impact Block Small (IMB-S, DMM International Ltd., Gwynedd, UK; working load limit [WLL] 40 kN); an Elevation Canada Single Rigging Thimble – Size 3 (Elevation Canada, Quebec, Canada; maximum break strength [MBS] 110 kN); a Notch Double Rigging Thimble – Size 2 (Notch Equipment, NC, USA; MBS 15,000 lbs); and the X-Rigging Safebloc (SHERRILLtree, NC, USA; WLL 2,700 lbs). The rigging rope was Samson Rope's 9/16 Stable Braid (Samson Rope, WA, USA; WLL 1,200 kg) with minimal use (less than 10 previous rigs). The friction device was a Notch Large Portawrap (Notch Equipment, NC, USA; stainless steel, WLL 2,000 lbs) (Figure 4).

Figure 4. Selection of rigging apparatus tested.

▶

Figure 5. Craning piece back into place.

Tests

A total of 13 drop tests were conducted. This included the initial rigged piece with a conventional notch and hinge and then 3 repetitions for each device. After each test, the piece was hoisted back into position with a crane, and the event was repeated (Figure 5). To control the flight path of the piece and ensure consistent release, a false hinge was created by cutting a kerf cut in both the standing stem and the piece to be dropped. A plywood "hinge piece" was then inserted in the cut to align both pieces.

Results and Discussion

An example of the strain gauge and load cell data can be seen in Figure 6; due to the variability in the stem oscillation from the falling piece contacting the stem, all max strain events focused on the initial strain peak during the initial loading of the system. This can be noted in Figure 6 as well, indicated by the red circle. Note the graphs display the relevant data synchronously over time; observe that the initial peak load in the portawrap corresponds with the initial peak in stem strain.

To analyze these data, we isolated the peak rope loads, stem strains, and acceleration data for all events and compared them using a one-way analysis of variance (ANOVA).

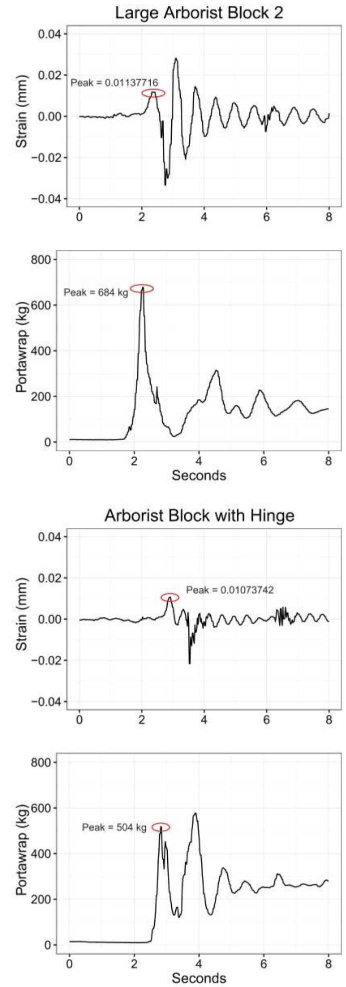

Figure 6. Stem strain data in millimeters of strain (over 20-cm span) and load at the portawrap in kg of force. Also includes comparison of peak strain and load between hinge types—note the original piece (third and fourth graphs) weighed 87 kg more.

The force measured at the portawrap is shown in Figure 7: all stationary rings routinely saw approximately 1/2 the load compared to the block at the portawrap. This matched our expectations, as experience says we typically remove a few wraps from the portawrap when we are using a ring or thimble. The initial strain on the stem can be seen in Figure 8; it can be noted there is an approximate 1/3 reduction in measured stem stress for the 3 stationary anchors as compared to the rotating block. By adding the load from the portawrap and the calculated load from the accelerometer mounted in the falling piece, we can get a proxy for the load on the upper anchor point. Here we also see a decrease in anchor load (Figure 9), which maps nicely with the decrease in stem strain seen in Figure 8. If we isolate the calculated load from the accelerometer, we have what can be considered the load in the lead section of the rope, and here we do not see such a decrease. In fact, there was no significant difference in the load on this section of the rope for the Safebloc as compared to the standard block (Figure 10). This of course makes sense, as we still have the same potential energy to dissipate, and the only way to realize a deviation in this result would be from a change in the time to slow the falling piece once on rope.

This specific finding and its implications are perhaps the primary results from this study for climbers using rigging rings to consider. While the forces the stem and upper rigging anchor are subjected to have been reduced, the same cannot be said for the rope attached to the falling piece. We as climbers feel a reduction of the impact and an improvement in the stability of our system, and indeed this is a benefit. However, not all components in the system are seeing less force, which may pass unnoticed because our own experience, through the connection to the system (standing on the stem), has improved

One last tidbit from this project: the initial drop of the test piece with a conventional hinge was done with all the load cell and strain devices in place. This allowed us to compare the strain and load results of a "normal hinge" to our drop tests. If we compare both the portawrap load and stem strain (Figure 6), we see that it is much lower than expected compared to the remaining tests, even though it weighs 87 kg more (it was cut down to 182 kg from 269 kg to improve manageability). We attribute this to breaking of the hinge wood, which would have expended potential energy and reduced the free flight distance of fall for the piece.

In summary, it would appear that in a negative rig, running rope scenario, the use of rigging rings or thimbles will reduce strain on the stem. However, while they appear to be dissipating energy (assumed as heat into the rope and thimble), they do not reduce the load on the attachment point of the falling piece. This has the implication of becoming the unknown/unfelt factor, and furthermore, this is a piece of rope that is repeatedly tied, thus reducing breaking strength, and associated concerns over cycles-to-failure could be raised. Therefore, while

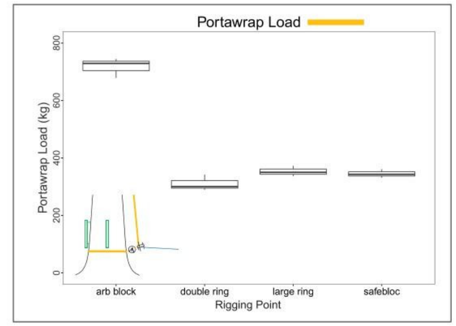

Figure 7. The load in kg of force across all tested devices. Note the stationary rings realized approximately 1/2 the load as the rotating device.

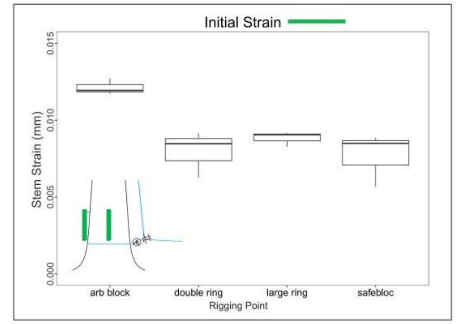

Figure 8. The strain measured in millimeters (20-cm span) across all tests. Note approximately 1/3 reduction in stem stress with the use of rings or thimbles.

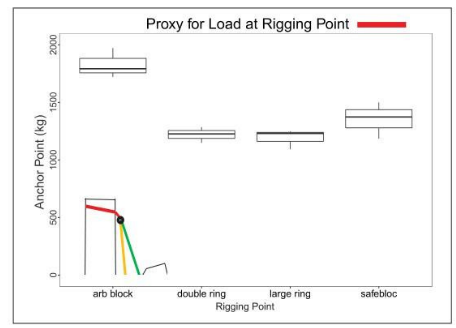

Figure 9. Proxy for load at upper anchor by combining the portawrap load and the calculated load from the acceleration data from the falling piece. Note this is a similar reduction as the stem strain (approximately 1/3).

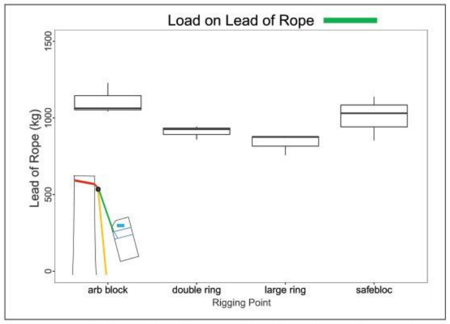

Figure 10. The load on the lead rope calculated from the acceleration data. Note there is no statistically significant difference between the standard arborists block and the Safebloc.

these devices reduce loading to the stem and may help to avoid catastrophic failures of compromised stems during dismantling, we must still be cognizant of the potential energy in the system; this is best managed by reducing both the distance of fall and the mass of the piece being rigged. These devices are a tool for the industry, but like all tools, their limitations must be recognized.

Climb safe!

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