Taking the Guesswork out of Rigging

The challenge presented by dismantling trees safely can be quite unique since it involves lowering unknown weights from untested anchor points. In this article Richard Olley of Kingswood Training looks at the physics behind the operation, and suggests ways that we can help ourselves to reduce the inherent risks.

If we had answers to the following questions, dismantling would be much more predictable:

1. What does the load weigh?
2. What forces are being applied to the anchor points?
3. In what direction are these forces being applied?

The weight of an object is determined by its volume and its density. The densities of various timbers are well known, so we only need to calculate the volume to know the weight. Don't be put off if you have a maths allergy – this information is available in tables on various sites, including the recent Rigging Research Document on the HSE website.

Let us start with a section of stem that is roughly cylindrical. The volume of a cylinder is calculated using the formula Pi x R^2 x H, where R is the radius (half the diameter) and H is the height of it. For this calculation to work, all the measurements must be in the same units – i.e. metres. These calculations are by definition approximate, so we will give Pi a value of 3.

For a section of trunk 1m in diameter (so R = 0.5) and 2 metres long the calculation would be as follows:

3 x 0.5 x 0.5 x 2 = 1.5 — so our trunk section contains 1.5 cubic metres of wood.

A heavy hardwood such as green oak is known to weigh approximately 1,000kg per cubic metre, so the section would weigh 1,500kg. If the timber in question weighs 700kg per cubic metre, its weight will be 700 x 1.5 = 1,050kg – about 1 ton. There is a very useful table of adjustment figures for different timbers in the HSE document.

When undertaking calculations of this sort, always ask yourself if the answer is 'reasonable' – a decimal point in the wrong place has serious safety implications!

How can we apply this equation to branches? Most arborists know that if a branch is suspended halfway along its length, it will sometimes hang tip down, and sometimes tip up. The way it hangs depends on a variety of factors, including the type of timber and the time of year. If the branch hangs level when suspended by its mid-point, we could regard the branch as a cylinder and do the same calculation as above, because the weight per linear metre of the tips is clearly the same as the weight per linear metre of the butt. The way to adjust the weight calculation for the tip-up or tip-down scenario is as follows:

Let us imagine that we have a 10m branch for which the theoretical weight is 1,000kg, but it is hanging butt down, and it actually balances at the 4m point. This implies that the 1,000kg figure is an over-estimate, because the 6m tip end weighs the same as the 4m butt end. Therefore if we re-calculate using a length of 8m (twice the length from the butt to the attachment point) we should have an accurate figure – in this case 800kg. Dividing 800 by 1,000 we arrive at a figure of 0.8, so we have learnt that for that tree, at that time of year, we need to multiply the theoretical 'cylinder' weight by a factor of 0.8 to arrive at the actual weight. It therefore follows that if a branch hangs tip down the correcting factor will be greater than 1. In reality I would usually expect these factors to range between 0.8 and 1.2.

No-one is suggesting that these calculations are done for each cut section, but once in a while they are worth undertaking. If you really do not want to do the maths, all you need to do is print off a copy of the tables, measure the timber and read off an approximate weight. In this way you can be confident that you are respecting the Safe Working Loads of the various items of equipment you are using.

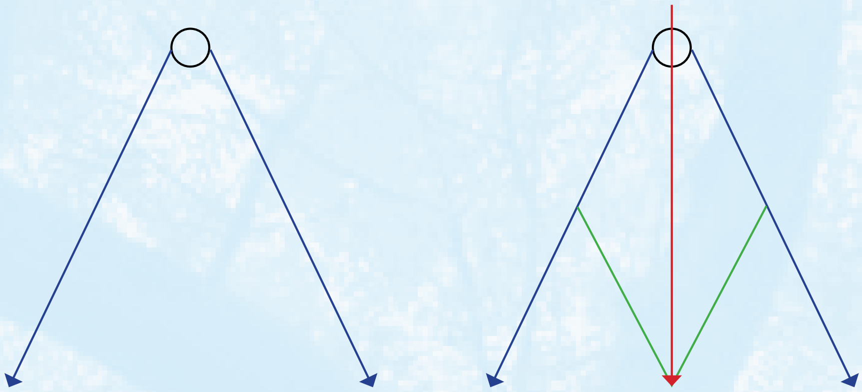
Once we know the weight, we know the tension that the load will apply to the rope. We then need to consider how to position our anchor points to apply this force to the tree as safely as possible. When a pulley is used as a re-direct, the tension in the rope applies this force to the point in the tree where the pulley is attached. What we need to understand is how great the force is, and in what direction it is acting. The answer is in fact very simple, and it doesn't involve much maths. In the diagram top right, a blue rope runs over a pulley.

Considering an example of the loads expressed within the diagram top right, if the green line is 2cm and the red line is 3cm, a rope suspending 1 ton will apply 1.5 tons of force at that angle. This has obvious implications for the arborist.

Firstly, and very importantly, if the tree is rigged so that the rope leaves the craning branch at the same angle that it approaches it, there will be no lateral load on the craning point. All the force is applied compressively down the branch, and since timber is extremely resistant to compression, this is very unlikely to break a reasonably sized branch.

Secondly, if the red line is longer than the green line, (i.e. the angle between the ropes is less than 120 degrees) it tells us that the SWL of the pulley and its attachment will need to be up rated compared to the SWL of the rest of the system. When the angle is reduced to zero and the ropes become parallel, it explains why the load on the pulley is doubled. This has obvious implications when topping a stem down on itself. These principles also apply to re-directs used during winching, and demonstrate when re-directs need up rating and when they don't. All this can be demonstrated mathematically with great accuracy, but for our purposes it can be done visually.

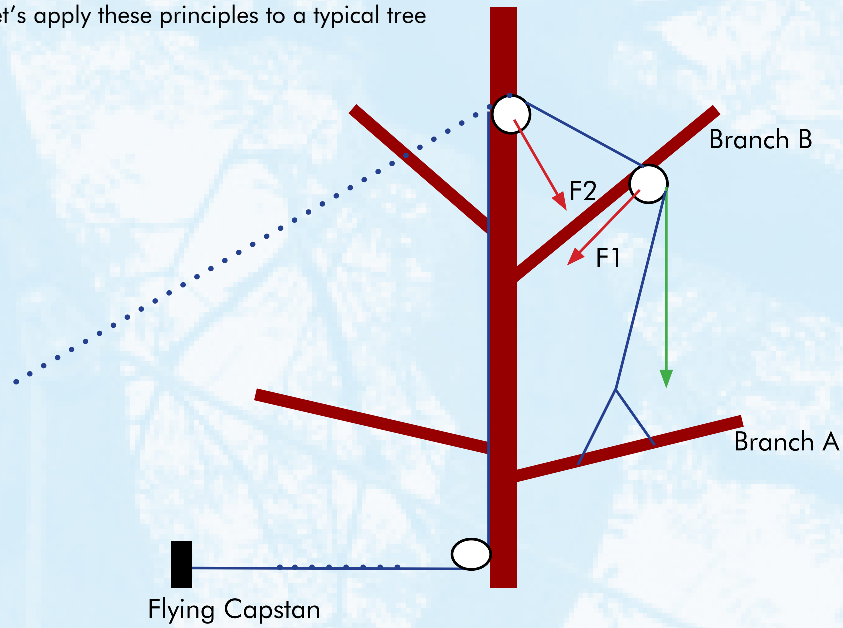
In the diagram green lines have been drawn in to form a diamond, and then the red line has been used to join the pulley end to the opposite corner.



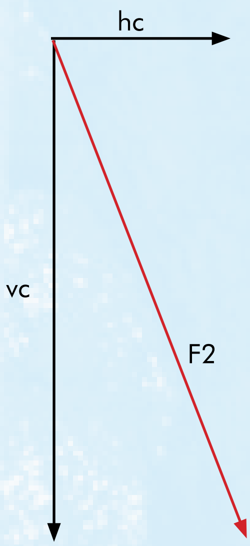
The direction of the red line shows the direction of the resultant force.

The ratio of the length of the red line to the length of the green line tells us the ratio of the force on the anchor point compared to the tension in the rope.

Let's apply these principles to a typical tree



In the diagram above pulleys have been positioned so that the craning branch (B) splits the rope angle in half. If the rope between branches A and B is not vertical before the cut, it will be afterwards, and this is the position that needs to be considered (indicated by the green arrow).The resultant load (F1) can be seen to be straight down the branch with no lateral component. At the top of the tree, the arborist has a choice. If he runs the rope down to the bottom of the tree the resultant force (F2) on the top pulley can be seen to be applied in a '5 o'clock' direction. This force has a vertical and a horizontal component as shown in the diagram on the left.



The resultant force (F2) has a vertical component (vc) and a horizontal component (hc), and the length of these lines is also in proportion to the forces involved. Therefore, in this diagram, if the resultant force on the anchor point is 1 ton, the horizontal component is roughly 250kg.

If the arborist decides that the stem is not strong enough to withstand this lateral load, there is a simple solution available. Re-route the rope from the top pulley in the direction indicated by the dotted blue line in the previous diagram, and the problem is solved. There is then no lateral force on the stem, and it is in simple compression like the craning point. This concept is particularly important when dismantling trees with co-dominant stems. The resulting tight forks are very prone to failure, so particular care should be taken to avoid loading them laterally.

Another important question that is frequently asked is how the arborist can tell whether a suspended load will move towards or away from him when it is severed. The answer is simply that the branch will always move in a direction that puts its Centre of Gravity (CoG) directly under the craning point. If the CoG of the branch is beyond the craning point, and the branch does not have to be cradle rigged, the safest option is usually to 'butt tie' it and remove it with a freefall sink cut.

Ideally, if the arborist can judge roughly how much the rope is going to stretch under load, he should attach the rope that distance from the cut. In this way, the load will be applied to the system gradually, and the full weight will be taken when the branch becomes vertical. As the branch swings down and inwards, its CoG comes inside the craning point, and it then moves away from the climber as the hinge is severed.

You do not need to be a mathematician or a scientist to understand how these ideas apply to tree work. By considering them when dismantling trees, the behaviour of loads should be more predictable, and more predictable means safer. Once the basic principles are understood, it often allows an arborist to remove larger branches with the confidence that he is still observing the correct safety factors. Candidates on my dismantling courses are often surprised at the size of limbs that can be removed in a very controlled way.

There are a whole host of other ideas to help to make dismantling safer that have been described in other articles, and I list some of them here for the sake of completeness.

1. Pretension the lowering rope to the approximate weight of the load if at all possible. This cuts out shock loading if the load is directly below the craning point.

2. Use as much rope in the lowering system as possible – this reduces the 'fall factor' where shock loading is inevitable.

3. Let the rope run on the capstan and slow moving loads down as gently as possible.

4. Use freefall sink cuts to apply the load to the lowering system in a controlled way.

5. Make sure that you have a 'matched' rigging kit which takes into account the fact that a given load can exert different forces in different parts of the system.

In what I consider to be an ideal rigging system the rope does not touch the tree at all. If chokered slings are used to attach the load, their SWL in that configuration is known. If they are clipped to a hard spliced eye on the lowering line there are no knots to weaken the system, and they are quick and easy to attach and detach. The rope runs through pulleys whenever a change of direction is needed, and the branch splits the rope angle as previously described. In this way wear on the rope and the tree is minimised, anchor point failure is extremely unlikely and the arborist on the ground should find it easy to control the load. This all makes the job easier and safer.

Please note: I have deliberately not mixed kilograms (Kg) and Kilonewtons (Kn) in this article, for reasons of clarity. The relationship between them is simple – gravity exerts a force of 10 Newtons on a 1 Kg mass. Therefore 1 ton (1,000kg) applies a 10,000 Newton (10Kn) force to a lowering system. Some equipment is marked in Kg and some in Kn, and to complicate matters further, some figures are MBL (Minimum Breaking Load), and others are SWL (Safe Working Load). Make absolutely sure that you understand which is which – if in any doubt contact the equipment manufacturer or your Loler Inspector for clarification.