Are Your Cow's Tails Safe?

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It has been said that the most abused part of caver's gear is the cow's tail. They get dragged around, trodden on, loaded over rough limestone, shock loaded and with all this, cavers still ignore the basic facts with some only discarding them when the sheath is worn and they can see the inner core.

Whilst one does not want this to happen because they are worn, there always seems to be a number of cavers who admit during discussions each year around BCA's rope test rig at Hidden Earth, "Oh well, mine is many years old and it seems OK". A quick glance at the British Cave Rescue Council's annual statistics since 1995 (BCRC) indicate that no one has had to be rescued following an injury caused by a failure of their cow's tails. (We excluded events caused by the lack of use of a cow's tail and those stated as taking place during abseiling. One incident was reported in which the injured person was found attached by their cow's tail at the head of the pitch, see BCRC incident 24 in 1998.) But how many people have suffered lesser injuries and got out under their own steam? This article is prompted by the recent publication of a report on some work undertaken in part on behalf of the French Federation of Speleology into the performance of cow's tails (2006).

Shock Loading & Impact Force

The focus of concern around a cow's tail is the potential for the caver to receive an injury following a fall onto their cow's tail. As the adage has it, "it is not the fall which kills you, it is the sudden deceleration at the end". Crawford (2003) reviewed the literature relating to the nature of injuries resulting from shock loading, which arose mostly from studies on use of aircraft ejector seat and parachutes. Of note in the review was the fact that the harness can deliver a shock loading into the body which does not break any bones or cause spine damage, but can result in severe impact trauma to internal organs (brain, heart, liver, spleen, etc.) resulting in death (Crawford 2003). Although the topic is complex (depending not just on the deceleration force, but also upon the rate of change of the deceleration force as well as the type of harness and the weight of the person), work has led CEN (European Committee for Standardisation) to adopt a limit of 6kN so as to minimise the risk of injury from sudden deceleration (Crawford 2003). In the USA a value of 8kN has been adopted (Crawford 2003). The review found evidence which suggested that physically fit persons could withstand up to 12kN in parachute type harnesses without being injured (Crawford 2003).

A typical SRT setup when using a cow's tail, will include in order of connection, some rock, an anchor (usually steel), a crab, the cow's tail, a maillon, and a harness within which the body sits. Clearly the rock and steel components will hardly absorb any energy of the shock loading from a falling mass. Harnesses are made from tape and tape is a poor shock absorber when compared to rope (FFS 2006). Curiously, the European standard for dynamic rope (BSI 1997) only requires that the impact force from dropping an 80kg mass through approximately 4.8m on a 2.8m length of single rope shall not exceed 12kN. In contrast the European standard for semi-static (i.e. low stretch kernmantle) rope (BSI 1998) only requires that the impact force from dropping a 100kg mass through approximately 0.3m on a 2m length of single rope shall not exceed 6kN. Whilst it is not possible to compute an equivalent impact force for a standard weight and drop, it is clear from the figures that a semi-static rope is far less absorbent of a shock than a dynamic rope. This is borne out by tests undertaken by French Federation of Speleology (2006) which shows higher peak force loads due to semi-static ropes than dynamic ropes.

Drop Testing

Lyon Equipment Ltd carried out a large amount of work for the UK's Health and Safety Executive into items of personal protective equipment used in industrial roped access (Lyon 2001). Part of this work focused on cow's tails, or as they are known in the rope access business, attachment lanyards. Their work, which used a 100kg mass falling through fall factor 2, was constrained by the limit of the measuring equipment being only 10kN force. Some of the tests did result in readings going off the scale. Even so, it was clear that using loops in dynamic rope made by sewing resulted in a larger peak force than using loops made by knots in a semi-static rope which in turn resulted in a larger peak force than using loops made by knots in a dynamic rope (Lyon 2001). The report noted that "With all the knots tested, extreme tightening occurs during the impact: this would be obvious on inspection and in the workplace the cow's tail should be replaced immediately" (Lyon 2001).

The work undertaken by the French Federation of Speleology (2006) expands this knowledge base by a substantial amount. Some 294 dynamic fall tests were conducted together with 28 strength tests on a range of cow's tails including both manufactured (loops made by stitching rope or tape) and knotted (dynamic and semi-static rope of various diameters). The dynamic tests used an 80kg mass to represent the caver, which is probably an underestimate of a caver's weight. Recent work undertaken for the Health and Safety Executive (LUABS 2005) indicates that it is likely (95% confidence) that the interval 112.3kg to 118.4kg covers the true value of the 95th percentile for the weight of workers without equipment. The French pre-tensioned their knots to 3kN whereas Lyon Equipment used 2kN. (For comparison, a strong person may be able to pre tension a knot to about 0.5kN by simply pulling on it.[1]) The value of 3kN was based on previous work done by the French Federation of Speleology (2006). Interestingly, Lyon Equipment measured forces generated by a person abseiling and prusiking (2001) which were all less than 1.6kN.

Calculating the Fall Factor

The report notes that there are a number of factors which need to be taken into account in computing the fall factor of a cow's tail in use. They point out that the length of the crab plus the maillon (typically 0.18m) is significant in comparison to the length of a cow's tail (typically 0.36m and 0.60m). Most of their fall factors were quoted as being either 1 or 2 but the report details what this means. Clearly, when one has an overall fall distance of 0.63m for a 0.36m length of rope (which includes the two knots), the rest being made up of two karabiner lengths (one switching from being below to being above the connection point on the harness), then the fraction of the overall length which is able to absorb energy is nowhere near 100% as is conventionally assumed. (Slightly confusingly, several tests were undertaken using the distance of the setup measured under the 80kg load called 'real fall factors'. This at least reflects the approach used in the standards to measure rope lengths when undertaking drop tests.)

It is worth noting that a simple model of a length of rope whose ends have been made into loops formed by knots suggests that over 20% of the energy is taken by the knots for a 0.30m-long cow's

[1] Based on 100lb force in a modern bow, see http://en.wikipedia.org/wiki/English_longbow as at 16 October 2012.

tail, reducing to less than 5% for a 2m-long cow's tail (Mehew 2005). This influence of the knots was observed in the peak forces experienced by samples of the same rope but having differing lengths (FFS 2006) and also differing diameters. Thus the state of the knots can play a critical role in shock absorbing.

Repeated Falls

The report includes a number of repeated falls on cow's tails which showed an increase in peak force on the second and third fall (FFS 2006). Hence knots which have been tightened up either by prior use or from a fall, will absorb less energy in a subsequent fall, thus resulting in a higher peak force and hence increasing the possibility of injury.

There was only one partial failure on a third fall factor 1 drop (Test 238, see photo on page 6 of report) but this was using 8mm rope. In a number of fall factor 2 drops, the cow's tails failed on the second fall (FFS 2006) but these were in 9mm or smaller diameter rope. This just reaffirms the sense of using at least 10mm dynamic rope for one's cow's tails!

Choosing the Right Knots for Increased Safety

Figure 1

The report covers a wide range of single lanyards and cow's tails including one made from tape, several made from sewn dynamic rope and many made from various combinations of knots and rope types.

The work showed a variation with respect to combinations of knots at each end, see table opposite. For comparison the Lyon Equipment work indicated somewhat larger peak force values.

It should be borne in mind that whilst the French pre-loaded the knots to 3kN, Lyon only used 2kN and that whilst the French used an 80kg mass, Lyon used 100kg. However, the spread of the data for both the French and Lyon work which makes up these averages does not statistically justify a claim that any one combination is better than any other combination (Mehew 2008). Interestingly, tests done with badly positioned barrel knots (FFS 2006) which might interfere with the gate of the crab, see Figure 1, showed the knot would move back to the proper position under the shock load.

Figure 2

Traditional cow's tails comprise of a central knot, normally an overhand loop knot with either a figure of eight knot or a barrel knot to hold the karabiner at each end, see Figure 2.

As the rope used in the construction of most cow's tails is dynamic rope, it makes sense that a knot capable of absorbing energy is also used. The barrel knot is not only a good knot for energy absorption, but it will also hold the karabiner captive once dressed (semi-tensioned). The use of a single knot to the central maillon does give rise to a slight reduction in ultimate safety as a single knot is being used for attaching two cow's tails to a central strong point. For the ultimate in safety each safety link should have it own attachment knot.

Figure 3

By constructing one's cow's tails slightly differently, features can be added that enable them to be used more efficiently and increase their safety margin. In Figure 3 there are two overhand loop knots attaching the cow's tails to the central maillon. This increases the safety margin as each cow's tail is independently attached to the harness. These two knots leave a small loop (which can be lengthened during construction if necessary) between them. This now effectively gives the user a long cow's tail, a short cow's tail and a very short cow's tail. This very short cow's tail has numerous advantages. It can be used to attach to anchors where the user wants to be held in close proximity which certainly makes passing re-belays easier. In the event of rescue it gives a very short attachment point so the casualty is kept close to the rescuer. If teaching SRT it gives an additional attachment point while positioning the long or short cow's tails.

Caring for Cow's Tails

So how should you look after your cow's tails? First if you do fall onto your cow's tails, then at the next practicable opportunity (that is when you have got to a safe location away from the pitch) you should relax the knots and re-dress them. This action will reduce the tension within the knots and thus enable them to absorb more of the force which would arise if you fell again onto them, thus reducing the risk of injury to you. After each trip untie all the knots, rinse the rope thoroughly in clean water and hang in a dry, well ventilated place to dry (not in the sun). Before retying the knots inspect the rope for any signs of damage or wear. Once the knots have been retied, dress them to ensure correct tying and uniformity. If they show any signs of damage, replace them. The choice is yours, extend the life of your cow's tails or your own life!

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Note added in 2012

Subsequent research work suggests that overhand knots are likely to be statistically weaker than figure of eight or barrel knots.

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