PA3DJS

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Distel Offset friction hitch (HAH-hitch)

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Additional disclaimer

Climbing, lifting, working at height and related activities are dangerous. Friction hitches don't have anti-panic features that are present on several mechanical devices. The use of friction hitches may be prohibited or discouraged in your industry sector, or community.

Good operation of friction hitches depends on many factors, not limited to; hitch type, weather conditions, rope/cord thickness, rope/cord construction and tightness of the hitch. You should be well trained/instructed before using friction hitches in situations where expected and unexpected behavior can lead to loss or damage. You need to be your own devil's advocate. The information shown in this document is not a substitute for good training.

Wim Telkamp, PA3DJS

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1. Introduction

This document discusses a Distel Friction Hitch where the eyes are created by feeding the cord ends back into the hitch (in fact partial retracing). This also provides more offset between the climbing rope and the cord section that runs down from the top turn. This improves locking. It has to work well with standard Nylon (PA) or Polyester (PES) accessory cord (to Std. EN 564).

The required knot opposite to the side of the carabiner receives about 25% of the load. It uses the same retrace technique as used for the Hedden-Autoblock Hybrid hitch to create the eyes for the carabiner.

Various versions of the Distel-Offset friction hitch were tested, and used, including full double cord versions. It turned out that this single cord retrace version works best. All other versions are now removed from this document When a full double cord hitch version is required (less wear, stronger hitch), the Hedden-Autoblock Hybrid friction hitch is a good candidate.

The goal of the document is to encourage experimenting with friction hitches. Testing must be part of experimenting, as lot of things can go wrong. The focus is on climbing use of friction hitches.

1.1. Friction hitches in general

Friction hitches can be used for many purposes:

- temporary or permanent connection to rope and solid objects
- means of adjustment in work positioning lines
- binding things together, similar to using cable ties.
- anchor points during climbing on solid objects (choking anchors)
- ascending/descending aid (with a foot loop, or foot/hand ascender)
- rigging for lifting loads

A friction hitch enables to connect a cord to the main rope without tying a knot in the main rope. The cord can be the main rope itself to form an adjustable loop (for example Blake's Hitch). These hitches are not discussed here.

When the cord is not loaded, the friction hitch can be moved along the main rope. Once loaded, the hitch can't be moved in most cases (it is "locked" onto the main rope, or "grabbed" the main rope). When the load is removed, or sufficiently reduced, the hitch can be released and moved to another position on the main rope.

> In this document "**Rope**" is used for the main rope, "**Cord**" is used for the rope that you use to tie the friction hitch. In most cases the "cord" is called accessory cord, prusik/prussik cord, cordelette, reepschnur, or hitch cord. All are designed for climbing applications.

Lock and release behavior is less important for static applications. As long as it holds when locked onto the rope, and it is not too difficult to release. Nearly every friction hitch works in that case, as long as it has sufficient turns and doesn't slide down when the load is (temporary) removed.

There are applications that require frequent locking, releasing and moving. There is a tradeoff between locking, releasing and no-load friction. You can't have all three at the same time. A hitch that moves very easy after release may not lock when it should, and that can be really dangerous.

For some applications backlash is also of importance. During the transition from unlocked state to locked state, part of the hitch moves in the direction of the load. This effect is called backlash, or sit back.

1.2. Locking and holding power

A friction hitch must grab the line when it should. Whether or not a hitch grabs depends on many factors. Important factors are:

- Hitch cord over (climbing) rope diameter ratio (large ratio increases risk of not locking)
- Surface finish of rope and hitch cord (affects friction, especially glazing can be dangerous)
- flexibility (knotability) of the hitch cord (the more flexible, the better it locks)
- tightness of the hitch (improves locking, but also increases no-load friction and may increase holding power)
- Wet or dry rope (as this affects friction)
- Rope diameter variation of (climbing) rope (for example due to sheath slippage or heavy load onto the rope below the hitch)
- of course the type of friction hitch,
- number of top turns (more turns improve locking due to higher friction)

Locking is not the same as holding power. A hitch may lock (that is grab the rope). However, when increasing the load, it may (temporary) slip at some load. Slippage limits the holding power of the hitch. Slipping may occur at relative small load, and when it doesn't stop, Nylon or Polyester accessory cord will melt. Factors affecting holding power:

- Insufficient top turns,
- using relative large hitch cord over rope diameter ratio (increases slippage),
- using double cord for the hitch (larger advance per turn gives higher slippage risk),
- rope or hitch cord is contaminated with a greasy substance.
- The hitch is loose, resulting in deformation of the turns pattern
- Excessive cord stretch, resulting in deformation of the turns pattern (Polyester stretches less compared to Nylon (Polyamide))
- Glazing of the surface of the hitch/prusik cord (reduces friction).

Slipping is not always problematic. It should happen well beyond the intended load and should not result in fusion between rope and cord fibers (due to melting). It will only slip shortly in case of an unforeseen shock load. When it slips, it reduces the peak load.

Your operation should never rely on slippage to reduce shock load, as the weight where slippage occurs shows large variation.

1.3. Long term effects, locking and holding power

There are some things that may affect both locking and holding power. These effects occur when a friction hitch is used several times, without retying the hitch.

- Change of cross section of the cord.
- Glazing of the surface of the cord that is in contact with the rope.

Change of cross section

The first effect occurs relatively fast. Initially a cord or rope has circular cross section. However when you wrap it around an object, its cross section becomes more or less oval. This is shown in figure 1.1A.

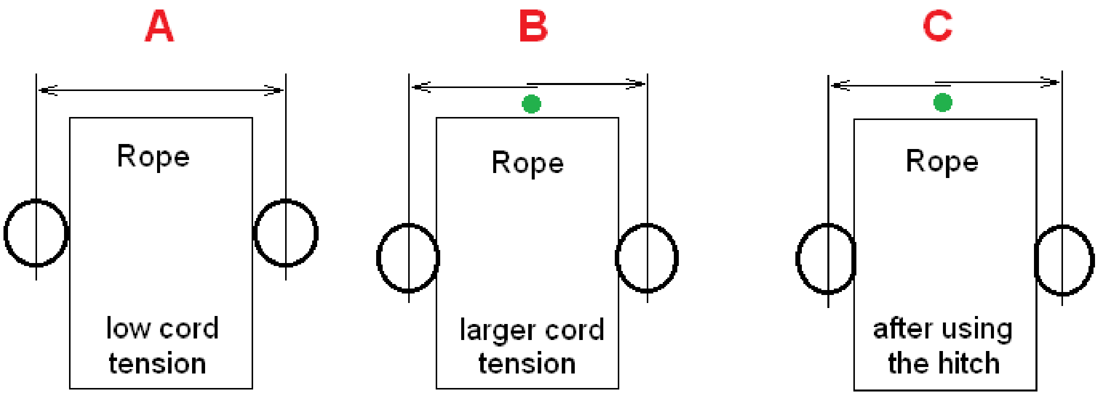

Figure 1.1; Change of cross section of prusik cord

When you wrap it more tightly (or load a friction hitch) the cord's cross section becomes more oval, and it bites somewhat into the rope. This is shown in figure 1.1B. The average cord diameter reduces as can be seen at the overlapping ends of the arrows at the green dot. Thin rope protrudes into the rope relatively better, as its contact pressure is higher. This increases the friction due to the deformation of the rope at the contact area. It is one of the reasons that friction hitches out of thin rope grab and hold better. It is also said they "bite" better.

After some use of a friction hitch, the cross section becomes even more oval, so the average diameter reduces further. This can be seen above the green dot in figure 1.1C. Smaller diameter creates excess cord (slack) inside the hitch.

The cord area that is in contact with the rope flattens, see figure 1.1C. You can see this when untying a friction hitch out of regular accessory cord. A flat surface bites less into the rope so has less friction.

Both effects (flattening of the contact surface and average diameter reduction) reduce locking behavior, and reduce holding power of a friction hitch.

Glazing of the cord surface
After some use, especially when the hitch slips (can be on purpose), there will be plastic (permanent) deformation in the cord fibers, due to heat. The cord fibers that make contact with the rope will stick to each other and deform forming a compact surface that may be even somewhat glossy. This effect is called glazing.

A glazed cord surface has lower friction coefficient towards the rope. This will negatively affect locking, and reduces the holding power. When the holding power reduces below the rated load, the hitch will slide and keeps sliding.

Polymer cord (such as PA (Nylon) or PES (Polyester)) will melt completely. This can be fatal in case of human load. Cord with an Aramid sheath (Kevlar, Technora, etc) will not glaze as aramids don't melt, but just disintegrate (blacken, carbonize) like many natural fibers. Disintegration of Aramids happens at a temperature where all polymer rope is molten completely. That is why Aramid hitch cords are used by arborists.

Friction of Aramid sheathed cord may reduce when rope fibers from the Nylon (PA) climbing rope transfer to the cord and creep into the space between the Aramid fibers.

Conclusion regarding long term effects
Hitches that use a double rope (loop) such as the Autoblock hitch (Marchad hitch) are more friendly to the climbing rope, but have less holding power given the same number of turns.

In the beginning, a friction hitch may lock very well and has good holding power. Holding power can be checked by jumping onto a foot loop that is connected to the hitch. Breaking the hitch under load and see how it slides may give you an idea of its holding power due to further flattening of the cord and deformation/reorientation of turns.

After using the hitch for certain time, locking may be less reliable and holding power may reduce over time. This is potentially dangerous as you may not notice this. Deformation of cord cross section goes relatively fast, however glazing may occur slower, depending on the use of the hitch. Making many short descents may give you a good idea about the influence of glazing when using PA or PES cord.

It is therefore recommended to experiment with the rope-cord combination you want to use. Holding power can more then halve referenced to the initial holding power just after tying. Test your hitches close to the ground so that you can handle unexpected hitch behavior. See chapter 6 for testing your hitches.

1.4. Improving locking using lateral force

Easiest way to improve locking is to force the cord turns onto the rope by having a tight hitch. The downside of a very tight hitch is that it moves difficult when not loaded. This is acceptable for several applications (think of rigging). For applications where the hitch has to be repositioned frequently, this is at least annoying.

There is another way to improve the locking behavior (not holding power) of a friction hitch without increasing its no-load friction: having the load bearing strands offset from the rope so that a diagonal cord section appears. This introduces lateral forces in the top turns. When a small force (F_{load}) is applied, additional friction appears proportionally. This helps locking of the hitch.

The effect of offset is shown in figure 1.3.

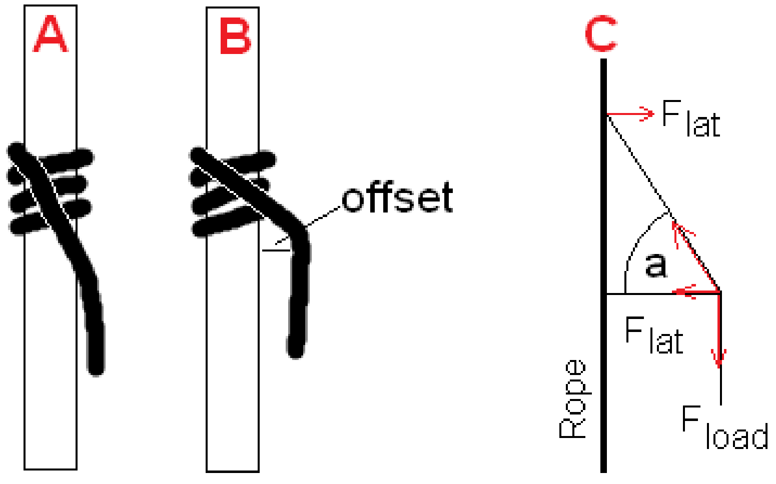

Figure 1.3; Relation between Lateral force and offset

There is always some friction between the hitch cord and the rope. That must be there to avoid that a friction hitch slides down due to its own weight (yes, this can happen with a loose hitch, or stiff accessory cord in combination with climbing rope with greasy contamination on it, or climbing rope that is loaded below the hitch).

Due to hitch cord and rope thickness, F_{load} does not work pure vertically on the turns. This is shown in figure 1.3A. When F_{load} starts to increase, two opposing lateral forces are generated. This is shown in figure 1.3C. The load bearing strand is pulled to the left, and the cord section that comes from the top turn is pulled to the right. These sideways acting forces add friction to the already present rope to hitch cord friction. This additional friction should avoid that the turns slide down along the rope during constricting of the turns that happens when F_{load} is applied.

With certain pretention in the turns, rope and hitch cord combination, increase of friction force due to F_{lat}, may not be sufficient to counteract F_{load}. If so, the hitch doesn't lock and slides down. This risk increases when using relative stiff / bouncy accessory cord.

When F_{load} gets additional offset, angle “a” reduces, see figure 1.3B. This increases the lateral force (F_{lat}) due to F_{load}. Larger F_{lat}, gives more friction between the rope and the hitch cord. This reduces the risk of not locking.

1.5. Taking in or giving out cord

During its use, a friction hitch may take in some cord. This means that there will be more cord in the hitch, resulting in loosening of the turns. This reduces the static friction, thereby increasing the risk of not locking and/or slipping at certain load.

When there is slack inside the hitch, the hitch may still lock when having very flexible cord. It may however slip under load as the advance of the turns increases with more slack. So just checking a hitch by checking whether it grabs/locks is not sufficient.

Whether a hitch takes in cord, or gives out cord depends on many factors and on how you use the hitch. Giving out cord causes the hitch to release or move more difficult, but that is better then a hitch that slides/slips, or doesn't lock at all.

The single cord Distel-Offset friction hitch as discussed here tends to take in cord, so there should be minimal slack in the eyes. The Hedden-Autoblock Hybrid friction hitch tends to give out cord and is therefore more forgiving.

1.6. Rope diameter change and locking

The diameter of (climbing) rope, as mentioned on the label, is measured with certain tension in the rope. Ropes for climbing are measured with a 10 kg load on a new, unused rope. Other specification uses a preload of a certain percentage of the breaking strength.

Without any load it is thicker. With your body weight the diameter reduces below the size on the label.

When using a part of your rope frequently, especially with friction hitches, the sheath may move a bit (milking) and that reduces the diameter further, and increases the no-load diameter where the sheath accumulates. Fiber compaction at frequently used sections also reduces the diameter. A 1..1.5 mm diameter change is not uncommon. That means you can have a slack of 3..4.5 mm per turn of hitch cord that is around the rope.

When a rope bears heavy load, its surface changes, as fibers in the braid become more compact (air is squeezed out). This changes the friction (especially on new rope), thereby increasing the risk of sliding down under its own weight.

Figure 1.4 shows what can happen.

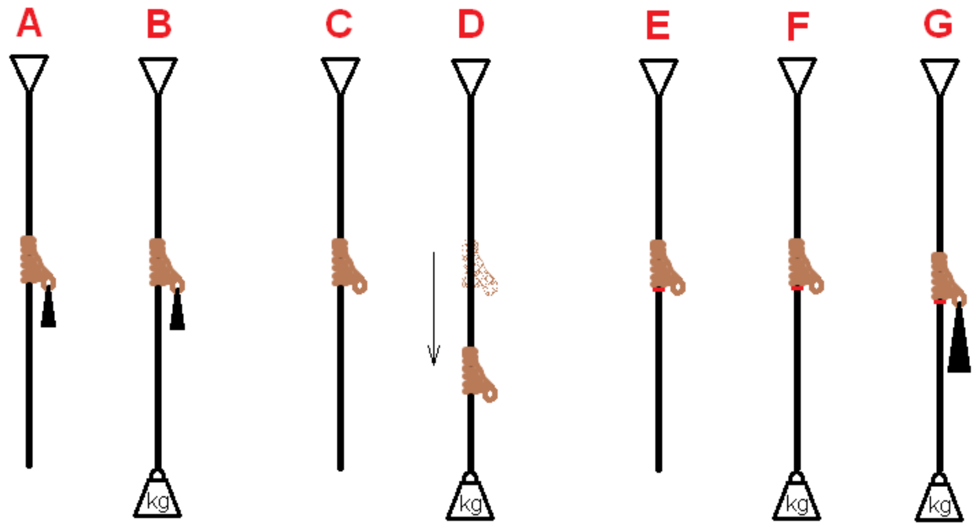

Figure 1.4; sliding of a hitch due to rope diameter change

The A-figure shows a hitch with a small weight, so that it is locked. That weight can be one or two steel carabiners. The weight (force) to move the hitch up or down is well below the weight of the small weight, so you know it is locked. The rope is moved a lot, so that there is no stress in the rope from previous loading.

In the B-figure the rope is loaded (for example with your weight). It becomes 1 mm thinner and nothing happens (the hitch may slide a few cm). The hitch remains locked due to the small weight. The more flexible the cord, the less weight is required to keep it locked during a reduction of diameter.

The C-figure shows a hitch without any load that moves relatively easy along the rope. It doesn't slide down due to its own weight. The eyes are not loaded, so that it is in its unlocked state.

Now in the D-figure weight is added to the rope, the diameter reduces, and the hitch slides down due to its own weight! The D-situation is easy to replicate with both dynamic rope and semi-static (low stretch) rope with hitches using regular accessory cord. When you remove the weight, the sliding stops.

When there would be some load, but not sufficient to lock the hitch in the beginning, the hitch will slide down, but may likely lock at some irregularity in the rope.

The hitch will also lock when you pull it down with a speed higher then the own weight slide speed. In all cases, a sliding hitch is not what you want. You cannot use such a hitch as a backup or other serious application.

Avoiding unintentional sliding of the hitch

You need certain friction; otherwise you can't get force in the diagonal rope section that goes to the top turn (figure 1.3C). Some force in that section is required to start the constriction process of the cord turns that provides the friction to carry the load. The more flexible the cord, the less force is required to start the constriction process.

There is a way to solve the unintentional sliding problem. Make sure to have some cord to rope friction that is independent of the rope diameter.

Best would be a friction that acts at or under the top turns. The provision providing the friction may slip between the rope and the top turns and that is not desired. Second best is to have the friction below the hitch, so that the bottom turn doesn’t slide down. It does work, but isn’t optimal compared to adding friction in the top turns.

The E-figure shows the situation. The friction can be made using elastic cord (shock cord), shown in red.

In the F-figure the rope is loaded, the diameter reduces, but nothing happens. The non-diameter dependent friction avoids that the hitch slides down.

The G-figure shows the situation when a weight is added slowly. The hitch may move a few cm, but then it locks. Moving slowly takes out acceleration forces that help locking.

When you move the hitch up and down with the eyes, it won’t slide down, only up (in case of a self-tending hitch).

Experimentation showed that the friction can be added about halfway the top turns using the “shock cord friction loop”. The advantage is that it doesn’t interfere with tending devices below the hitch, and the hinge function of the lower part of the hitch is not negatively affected. See chapter 4 for practical implementation.

2. The Distel-Offset Friction Hitch

2.1. Introduction

The Distel-Offset Friction Hitch is a regular Distel hitch, but tied with just a single cord without eyes.

The eyes are created by retracing the cord ends back into the hitch. This creates offset as the retraced rope sections push away the section that comes down from the top of the hitch. The rope sections also create some friction in the lower part of the hitch. Both effects improve locking.

Once you know the Distel hitch, the step towards the retraced offset version is simple.

2.2. Tying the Distel-Offset Friction Hitch

Figure 2.1 shows how to tie the DO-hitch.

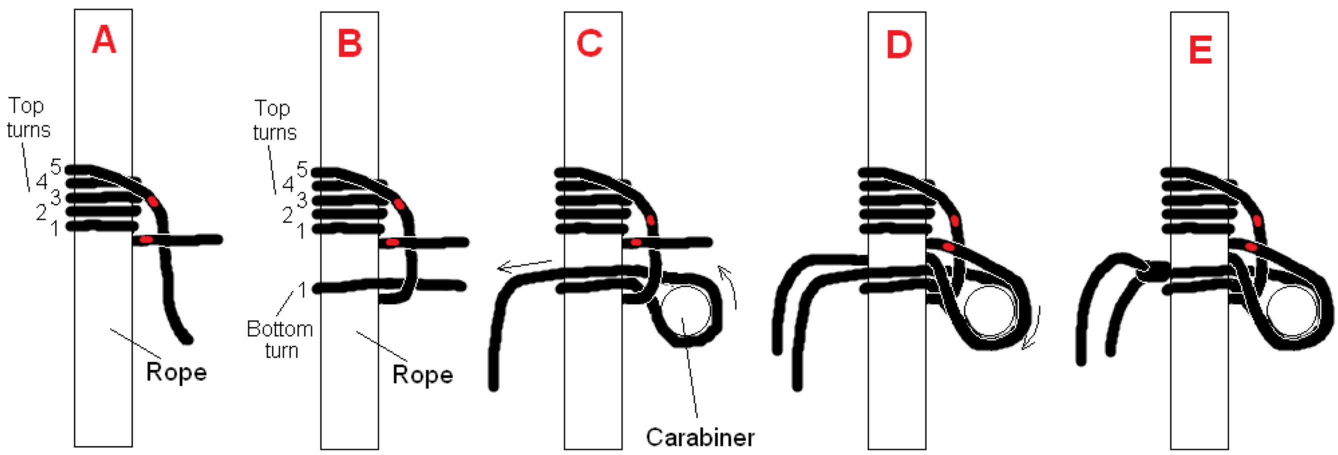

Figure 2.1; DO-hitch retraced version, tying steps

A-figure

Wrap 5 turns around the rope, and make sure the cord end from the top turn goes over the lower cord end. When you hold the horizontal cord end only, the cord end from the top (turn 5) should not spiral down. When it does, you lose one turn.

When using relative stiff accessory cord, move the cord end up and down while wrapping the turns around the rope. This rearranges the rope fibers so the cord sits better around the rope. Avoid applying torsion while winding.

B-figure

Make a half hitch with the cord end from the top turn. The half hitch should “run” in the same direction as the top turn (as with a clove hitch). This half hitch creates the bottom turn.

When done you have a 5 top turns standard Distel hitch. Check that one cord end is on the left of the vertical section, and one cord end is on the right. When both cord ends leave the hitch on the same side of the vertical section, the half hitch (bottom turn) runs in the wrong direction.

As a check count the total number of turns you see on the back of the hitch (here the left side of the B-figure. For a 5 top turns hitch, you should see 6 turns.

Adjust the hitch so that both cord ends have same length. Grab the rope ends and pull down and sideways several time to get some stretch out of the cord. To pull sideways you need tension in the main rope.

C-figure
Loosen the hitch a bit. Push the cord end from the bottom turn through a carabiner, go over the carabiner and feed the cord end back into the hitch. You need to feed it back in the same direction as where it came from. Now you created the first eye.

D-figure
Feed the cord end that comes from the top over the carabiner, go through the carabiner and go back into the hitch. You need to feed it back in the same direction as where it came from. This creates the second eye.

E-figure
Tie a square knot for temporary testing. Adjusting the hitch is described in paragraph 2.3.

When the hitch works fine, secure the square knot with an additional knot (paragraph 2.3).

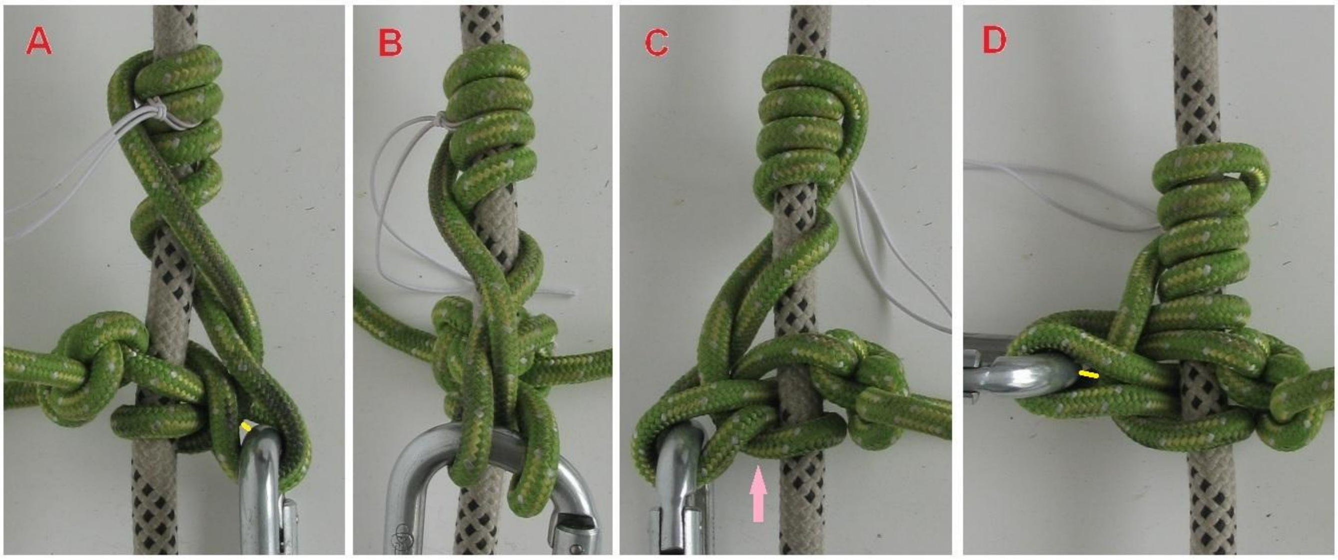

Figure 2.2; DO-hitch retraced version, photos

Figure 2.2 shows 4 photos of the same DO-Hitch. It has 5 top turns, cord diameter is 7 mm, rope diameter is 11 mm. There is a 1 mm thick “shock cord friction hitch” at about 2.75 turns.

Photos A, B and C are after loading with 100 kg. The pink arrow in photo C shows the “sweet spot” for tending the hitch with a thin piece of rope, or shock cord (elastic cord).

The B photo shows the near vertical cord section that runs down in between the two eyes. The shortest distance between that vertical section and the carabiner is of importance for good operation. The distance is yellow marked in photo A.

Due to the offset between the carabiner and the rope, the hitch seems loose, as there is more vertical distance between the top turns and the bottom section compared to a Distel Hitch tied with cord with (sewn) eyes.

Photo D shows the sideways pulling situation that is used to tighten the hitch. The distance between the carabiner and the vertical cord sectionis marked yellow.

Hinge function of the lower part of the hitch
When you compare photo C and D, the eyes function like a vertical moving hinge. To release the hitch, the eyes with the vertical section in between need to be able to bend somewhat upwards. After a human body load, the underside of the hitch becomes part of the hinge during release.

When a tending device impedes the hinge function, the hitch will not release well.

2.3. Adjusting the DO-hitch

The hitch does not give out rope to tighten itself. It is therefore not self-adjusting. Depending on its use, it may take in cord and becomes loose over time when the eyes are large.

It is good to load the regular Distel hitch before retracing the cord ends to make the eyes for the carabiner. This already removes slack out of the top turns. When tying the square knot, the carabiner may touch the near vertical cord section that goes down in between the eyes.

2.3.1. Tightening the hitch

Standard tightening
Tie the square knot so that the carabiner is very close or just touches the vertical cord section.

Load the hitch (to stretch the rope), and pull sideways as in photo D of figure 2.2. You need tension in the rope to generate a sideways force. Press the turns on to each other by hand so that the hitch has the shortest length (or height). When pulling sideways move they eyes a bit up and down so that the cord can reorient itself. This process tightens the hitch. Pull down again hard, and tighten again with the sideways pull.

No matter how hard you pull sideways, you can’t over tighten the hitch with this procedure, provided the carabiner doesn’t touch the vertical cord section during sideways pulling. See the yellow marked distance in photo D.

As long as there is some small space between the carabiner and the vertical cord section during the sideways pulling, the hitch is self-tending on LSK rope to Std. EN 1891, but with increased friction.

Further tightening

Some application may need a tighter hitch (for example to further reduce sitback, or better locking). Make sure all turns touch each other (so no space between the top turns section and the lower part of the hitch). When you did the standard tightening, retie the square knot so that the carabiner is pulled hard towards the rope. The no-load friction is now high because there is large tension in the lower part of the hitch.

Rotate the carabiner so that the long straight side of the carabiner is in the eyes. Pull the eyes away from each other with you thumbs. And wiggle the hitch. This transfers cord from the top turns into the lower part. Turn it back and load the hitch.

The hitch is very likely no longer self-tending, but tending on the sweet spot (Figure 2.2, pink arrow in photo C) is still possible, but with increased friction.

After several load and release sessions, the carabiner still touches the vertical cord section, and that is fine.

Eye size

The hitch operates generally well when there is just some space between the carabiner and the vertical cord section when firmly pulling sideways with all turns pressed on top of each other (short hitch length). See figure 2.2, the yellow marked space in photo D.

When the carabiner is loaded downwards, the carabiner may still touch the vertical cord section, or there may be a few mm of space (figure 2.2, yellow marked space in photo A).

When the carabiner touches the vertical cord section during hard sideways pulling, you have a tight hitch that may not be self-tending, or has increased no-load friction, especially on old ropes with varying diameter.

Tending using a cord that pushes onto the sweet spot (figure 2.2, photo C, pink arrow) works very fine, even with small eyes. Tending onto the sweet spot with a cord is shown in figure 3.2 B and C.

Tending via pulling the carabiner is demanding with very small eyes. A small ring with an adjustable loop that connects the ring to the carabiner is a good option. In case of very small eyes (carabiner touching the vertical cord section), the cord loop should be left and right of the eyes, but not in between.

When having a larger ring, or micro pulley, you need larger eyes. Try to keep the minimum amount of slack in the eyes, as this avoids taking in cord.

The DO-hitch works with large eyes also, but you need some tension on the eyes (for example using shock cord) to avoid taking in cord. An example is using a friction hitch as chest ascender. The hitch connects to the ventral D-ring. Tending goes on the sweet spot via a piece of shock cord (elastic cord) that goes around your neck, or connects to your sternal D-ring. This maintains tension on the eyes providing reliable locking, and lowest sitback (backlash).

Lanyard use with a ring or cord loop as tending device
When using the DO-hitch as a chest ascender, you can use it with very small eyes, but when using it in a lanyard application, you need larger eyes.

In a lanyard application you pull the rope more or less sideways. This creates a bend in the rope, and therefore also in the hitch. You may need about 6 to10 mm of slack in the eyes. This isn't problematic as when you tighten the lanyard, you get a sideways force component onto the carabiner that connects to your D-ring. This avoids that the hitch takes in cord. When your ring is larger, you need to accept more slack in the eyes, as otherwise the ring doesn't tend. It is advised to keep the slack to a minimum, so better is to use a smaller ring.

The cord loop for the tending device goes in between the eyes (similar to using a micro pulley).

Securing the overhand knot
The overhand knot may untie itself after prolonged wiggling the cord ends. Pulling one cord end (tail) will cause a square knot to capsize. It loses its holding power, so does the hitch.

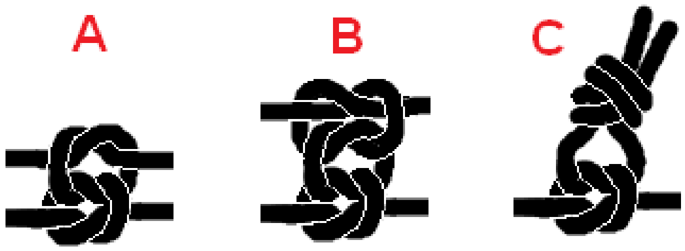

Figure 2.3; securing knots

Figure 2.3A shows the original square knot with another overhand knot that creates two interlaced square knots. For very short duration work where you can be sure that one of the ends will not be loaded, this works fine and is fast.

Adding another overhand knot as shown in the B-figure makes it more secure and you may get rid of long cord ends (tails) that may get stuck in another part of your setup. Despite the three interlaced square knots, heavy load on one of the cord strands will capsize the square knots.

The C-figure adds an offset overhand bend on top of the square knot. This is a very secure long lasting option, but takes some time to tie, and you need sufficient cord ends (tails). When you don't have sufficient length, you may opt for the B option for temporary use.

Using the "shock cord friction loop"
When in doubt about locking, or very reliable locking is of prime importance, use the "shock cord friction loop".

It is recommended to add the “shock cord friction loop” about halfway the number of turns, as it needs to add the lowest friction at that position. It increases locking significantly, especially on old rope with varying diameter due to use (compaction of fibers and sheath slippage).

It is highly recommended to use the most flexible accessory cord you can get, as locking goes really better. When you need the “shock cord friction loop”, only small friction is required compared to using stiff cord (see also paragraph 5.3.

2.4. Geometry of the turns

See figure 2.2, photo B. The cord section that goes down from the top and runs between the eyes doesn’t run vertically. It spirals down around “old” turns. It spirals over 180^0, so that is a half turn.   The number of turns the last turn spirals down changes the hitch properties.

> More turns over the existing “older” turns, without changing the total number of turns, gives better locking, but reduce the holding power, due to slipping and increases the no-load friction.

When having high number of top turns, make sure to test your hitches with the geometry that is most natural. By applying some torsion in the cord during winding of the last (highest turn), you can affect the natural geometry. This may be on purpose, but also accidently.

2.5. Hitch Properties

The DO-hitch is a short hitch. That may be an advantage for lanyards. It is advised to use minimum 5 top turns. This is to make sure you have margin for cord cross section change and glazing.

The construction strength is comparable to a normal Distel Hitch and is expected to be 100% for PES or PA accessory cord. This has to do with the larger bend radius in the half hitch that makes the bottom turn (see figure 2.1B), and non-equal force distribution in the top turns.

The hitch is good for a lanyard where body weight is not fully onto the hitch. When using sufficiently strong cord, you can descent with the hitch, but wear is significantly more compared to a VT- or HAH-hitch. Full weight descending is not recommended.

Tending

The hitch is self-tending on semi static rope (LSK climbing rope, to Std. EN 1891), but with increased friction compared to using a tending device.

When the carabiner is pulled away from the rope (force component perpendicular to the rope) the friction increases. The hitch may not self-tend on most dynamic climbing rope. It is highly recommended to use a tending device.

Construction strength
The load is partially on 4 cord sections and partially on 2 cord sections. The load is distributed across 4 rope sections that go around the carabiner. Therefore the square knot receives about 25% of the load.

Only two cord sections go to the top turns that carry the weight. The force distribution is not equal in that cord sections. Especially the cord section that runs down in between the eyes to the bottom turn (see figure 2.1B) has relative small bend radius and receives the highest stress. When the limiting factor will not be slipping, the hitch will fail at the bottom turn, and not at the square knot. The construction strength is expected to be 100% of cord MBS (PA or PES cord).

Descending
The stress in top turns is 50% of the load. That is twice compared to the HAH hitch, or an Autoblock. Descending with your full body weight causes lots of wear on especially the accessory cord. Descending is possible, but not recommended. It doesn't go smooth when working in a suspension harness. It goes better when standing in a foot loop that is connected to the hitch.

You need a significant part of your body weight on top of the hitch to let it slip. You definitely need to practice close to the ground, as you need to reduce the force on top of the top turns as soon as the hitch starts to slip. You need to get that into your muscle memory. A wrong (panic) reflex will send you to the ground.

When you plan to descent a short distance with your full body weight, it is advised to use the thickest cord that gives still satisfying performance, as thick cord works better when descending.

> When using thicker cord, you may need 6 instead of 5 double turns, as slippage risk increases when using thick cord,

Note that the "shock cord friction loop" wears always, even when you don't descent with the hitch, so check it regularly. When using thicker cord, you need more friction for reliable locking, as thick cord is less flexible.

Disadvantages
Its main disadvantage is higher risk of human error compared to hitches using (sewn) eyes or cord loops, or mechanical solutions. You need to tie a square knot. It is not advised to use the hitch with only the square knot. When you tied it wrong, the hitch will fail.

Tying two interlaced square knots reduce the risk of human error, as when tying one of the overhand knots the wrong way, it still has sufficient holding power. It is however recommended to use an overhand bend to secure the square knot. Reason for that is that even several square knots on top of each other may capsize when one cord end is heavily loaded (due to getting stuck).

The "shock cord friction loop" improves locking significantly, even with an unhealthy loose hitch, but you need a well tied hitch to start with.

Though the hitch is based on the Distel Hitch, retracing to create eyes gives it a complete other appearance. This makes inspection more demanding, especially at a distance.

It is good to remember the length of the tails when the hitch is finished. When you accidently applied 4 instead of 5 turns, you may notice this because of the longer tails.

It is strongly advised to count the number of turns during final inspection (valid for any Friction Hitch). A hitch with insufficient turns may work well in the beginning, but may slip after some use due to deformation of the cord cross sections and/or glazing.

When using a fixed length eye to eye cord the risk of miscounting turns is lower.

3. Friction hitch tending methods

3.1. *Introduction*

Tending a friction hitch, is to move the hitch in the desired direction. In virtually all cases the hitch is not loaded, and the tending direction is mostly upwards (as gravity acts downwards).

You can tend with your hand, mostly by wrapping your hand around the rope below the hitch, and push the hitch upwards. People may also grab the whole hitch and push it upwards. Some hitch designs can be tended by just pulling the carabiner upwards (so-called "self-tending"). This works reasonably well with the HAH-hitch and the single cord retraced DO-hitch.

Tending can also be done by using a device, a so-called "tender" or "tending device". The reason is simple; you don't want to "spend" your hand to move a hitch upwards. When it goes automatically, you have your both hands free to do your work.

Some examples where tending makes working easier:

- Adjusting a work positioning lanyard around your back, or between the waist D-rings (on your harness). When you pull the loose end, the hitch should release and move in the desired direction (to get a shorter lanyard).
- Adjusting a vertical work positioning lanyard to raise your vertical work position
- Climbing a rope using two friction hitches and a foot loop. The hitch should automatically move upwards as your body moves upwards along the rope.
- "let go" prevention when lifting objects.

Tending devices can be: pulley, ring, piece of rope, very small carabiner, etc.

A tending device has two functions:

1. Removing sufficient load from the hitch so that it can move up or down
2. Pushing the hitch in the desired direction.

The load must be taken off the eyes to enable the hitch to release (unlock) or to avoid high no-load friction.

3.2. *Manual tending*

Pushing up the hitch manually goes easiest by grabbing the rope under the hitch with one hand and moving your hand upwards. Of course there must be tension in the rope below your hand; otherwise you lift the rope also.

When there is tension in the rope above the hitch, there is a sweet spot. You only need to push at the space between the rope and the carabiner. When there is slack in the rope above you, you also need to push upwards the bottom turn to avoid tipping over of the hitch.

When there is still some load onto the eyes, there will be higher no-load friction. You may need to lift the carabiner together with the hitch.

3.3. Basic tending device operation

Figure 2.1 shows the basic tending operation when using the carabiner and a piece of thin cord.

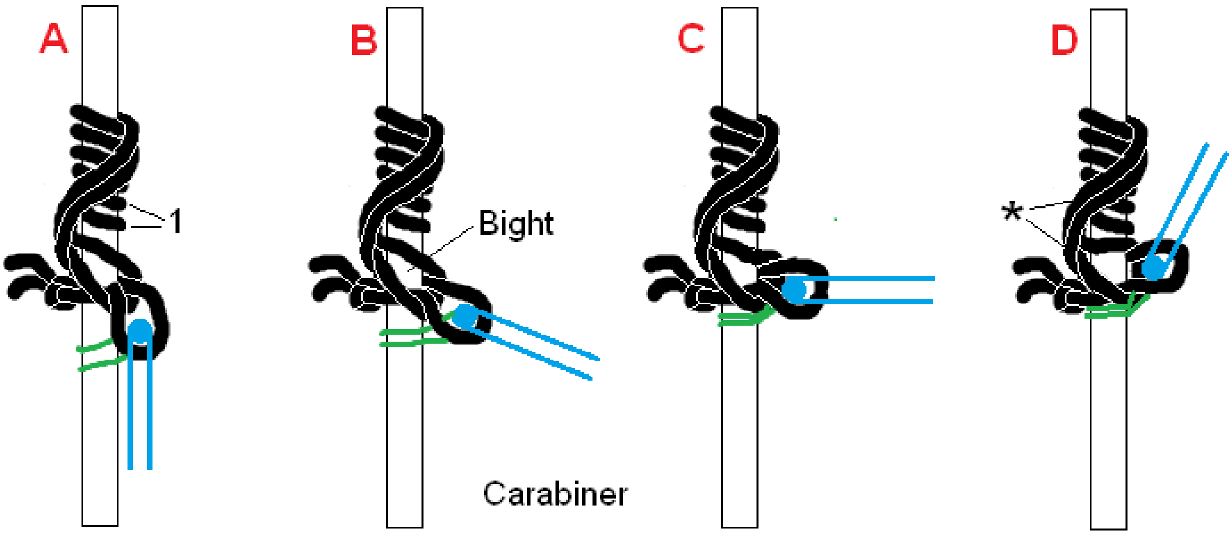

Figure 3.1; 5 turns HAH-hitch with tending device

A HAH-hitch is shown in figure 3.1A with a blue carabiner and a green cord loop (as tending device) that goes around the carabiner and the rope. The green cord loop should be adjustable. 3 mm Nylon (PA) or Polyester (PET) cord works well. See Annex 1 for a simple loop friction hitch. You may have a ring around the rope that connects to the green loop.

The rope below and above the hitch has tension. The green cord doesn't interfere with the hitch when the carabiner is pulled down (A-figure). When you pull a bit sideways, you arrive in the B-figure. The green cord still has slack so doesn't interfere with the hitch or rope.

In the C-figure the carabiner is pulled fully sideways. The force goes to the rope via the green tending cord. The eyes are loose around the carabiner and move a bit into the hitch. The bight also moves a bit upwards so that there is no tension in the top turns anymore and the hitch starts to release. .

In the D figure the green cord lifts the lower part of the hitch (the bight) and that pushes the top turns upwards. The eyes are loose around the carabiner. The eyes may further go into the hitch releasing tension from the two cord sections marked with a star.

A well-adjusted green cord length assures that the eyes are tensioned as long as possible. This increases the locking reliability of hitches that may take in cord (such as the DO-hitch).

The green cord has friction with the rope. A ring or a pulley reduces the friction further.

- When the green cord loop is too long, not all force is transferred to the rope and that increases the friction while raising the hitch
- When the green cord loop is too short, there will be more risk of non-locking and/or the eyes cannot move upwards a bit, increasing friction.

3.4. Tending a hitch without pulling the carabiner

One can tend the hitch by looping a cord around the carabiner as shown in figure 3.2A. That cord is in between the eyes of the hitch. The carabiner goes (for example) to the ventral (belly button) D-ring on your suspension harness. The red cord (shock/elastic cord) goes to your neck or sternal (chest) D-ring. This keeps the hitch as high as possible reducing slack and/or sitback when ascending.

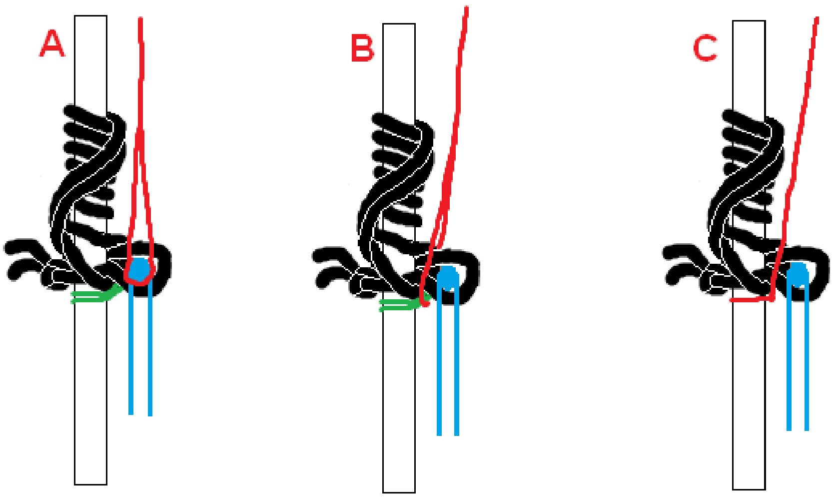

Figure 3.2; 5 turns HAH-hitch with other ways of tending

You can also loop a cord around the hitch with green cord, as shown in figure 3.2B. this goes faster. You may need to change the green loop cord length a bit.

You need to experiment with this option as good operation depends on the length of the green cord loop and the size of the eyes of the hitch.

3.5. Tending a hitch without a tending device

Figure 3.2A and B use the green cord as tending device. When tending the hitch with near zero load onto the eyes, lifting can be done with a piece of cord directly, without any other cord. This is shown in figure 3.2.C. this method introduces the least risk of taking in cord by the hitch (cord eating), as some load at the eyes is maintained by the weight of the carabiner and the tension of the shock cord. It should be noted that the HAH-hitch does (virtually) not take in cord.

A non-tightened overhand knot is tied around the rope. A PA or PET cord with 3...4 mm thickness is recommended. Thin cord increases the friction between the cord and the rope.

The two ends go upwards and connect to shock cord that goes around your neck (in case of ascending a rope). The shock cord provides always some force onto the sweet spot in between the rope and the carabiner.

As soon as the force is removed from the carabiner, the eyes move a bit upwards. This releases / unlocks the hitch and the hitch is lifted by the cord / shock cord combination. The loose overhand knot avoids that the cord moves away from the sweet spot to the right.

When load is applied, the eyes are pulled down, and that locks the hitch. The shock cord keeps some tension onto the eyes, so it will always lock, even with large eyes. This method works very well when used in a hoisting operation (let go protection) or ascender setup.

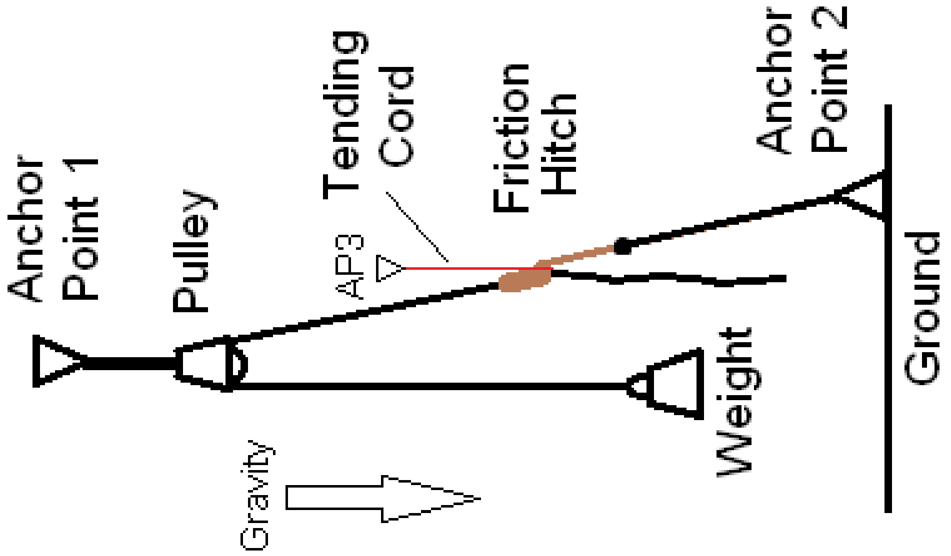

Figure 3.3; Let go prevention in a hoisting application

Example “let go” prevention (figure 3.3)

In this example a friction hitch catches the lifting rope when one would let go the rope. Note that gravity works to the right.

Anchor Point 1 (AP2) and 2 are strong points, where AP2 bears greater then twice the load (depending on pulley energetic efficiency). AP3 is a very weak one. As shown in figure 3.3, the load is fully supported by the friction hitch. AP2 carries the weight now. The red tending cord has slight slack (just a cm).

When you pull the loose rope, the weight is gradually transferred from the hitch to you, as you pull the rope. When all weight is onto the rope the hitch moves a bit down, but is caught by the tending cord at the sweet spot. Now there is no slack in the red tending cord and very small slack in the rope section between AP2 and the hitch. That small slack releases the hitch.

When further lifting the weight, the lifting rope moves through the hitch. When you led go the rope, the hitch catches the rope and moves a bit upwards until the slack is out of the black rope section between AP2 and the hitch.

When using strong enough shock cord as tending cord, the system works without any slack. The only slack that is in the system is because of the backlash in the friction hitch. As this system avoids taking in cord (see figure 3.2C), the backlash of the hitch is just a few cm.

Disadvantage of this system is that you need a third hand to release the hitch when you want to lower the weight.

An ascender setup is virtually the same as the hoisting setup of figure 3.3.

- The hitch goes to your belly button D-ring instead of AP2.
- The red tending cord goes to you neck or sternal D-ring instead of AP3.

When using shock cord, the setup provides a progress capture with very low slack, as the cord / shock cord combination always provides a lifting force onto the hitch. This prevents taking in cord.

The disadvantage is that when the cord / shock cord combination isn't present, you can't lift the hitch by pulling the carabiner (or soft shackle) upwards, as you don't have a tending device. You need to do it manually.

Of course you can have the green cord loop present, but you should enlarge it, so that when tending according to figure 3.2C, the green cord doesn't interfere with the hitch. When you want to switch to another tending method, you just need to adjust the green cord loop.

3.6. Other methods

The next step to make hitch tending easier is to reduce the friction by using a ring. The ring is connected to the hitch via an adjustable (green cord) loop. Further improvement can be made by using a micro pulley. You lose the adjustment possibility with the green cord loop. So adjustment for good operation has to be done by varying the length of the eyes.

When you need 10 mm longer eyes, you need 40 mm longer cord.

4. Solving unintended sliding of a friction hitch

4.1. The problem

You have a hitch that works well. It has acceptable no-load friction and it works perfectly in an ascending setup with a piece of shock cord around your neck. It also works fine as a hitch for a foot loop below the ascender hitch, or in a work positioning line.

However when using the hitch in situations where the rope is loaded below the hitch, without tending the hitch, the hitch slides down and locks not well. When it slides down under its own weight, it can't lock (unless pulling down fast). The reason is the instantaneous reduction of the rope diameter because of the load. It can reduce over >1 mm. This effect is discussed in chapter 1.7.

If you don't want this, you should tie the hitch so tight, that it moves very difficult along non-loaded rope sections, or sections that are a bit thicker (for example due to sheath slippage over time). Other option is to use very flexible (more expensive) special hitch cord. See chapter 5.

Backup use
When you use a friction hitch above you as a backup on a single rope, sliding down is not desired. When you get an instantaneous failure of your primary hitch, your body is completely off the rope, the rope jumps upwards and that will for sure lock every friction hitch.

But when you get a partial failure that results in (slowly) sliding down, there will be still tension in the rope. This may result in sliding down of the backup hitch. In virtually all cases it will lock in the end, and take over your weight, but you want to be 100% sure that it locks immediately, no discussion. Initial sliding will also introduce shock load.

The backup hitch is normally above your ascending hitch, or better on a second rope. You need to reposition it every time so that it is above you to limit your fall distance. This is most important when you are close to an anchor point above you, as then there isn't sufficient rope above you to spread out the shock load in time (so that the peak force is limited).

> Do evaluate the peak load that will occur when your main hitch fails abruptly. You may arrive in a situation where you need a shock absorber. When that is an industrial 6 kN screamer, it is not advised to use a friction hitch.

4.2. Adding static friction

4.2.1. Introduction

The trick to avoid sliding down due to rope diameter reduction is adding some friction at the right spot that is near independent of rope diameter.

Before using the added friction trick

- use a hitch that is tighten such, that the no-load friction is acceptable. You should not use this trick to “correct” a loose hitch, as a very loose hitch has less holding power.
- Use it on a hitch that passed the short descent and long descent (glazing) test (see chapter 6).
- The trick works on all hitches, with double or single cord.

The reason for the above points is that using the trick on an unreliable hitch is not the way to go. The trick only improves locking, but doesn’t increase holding power.

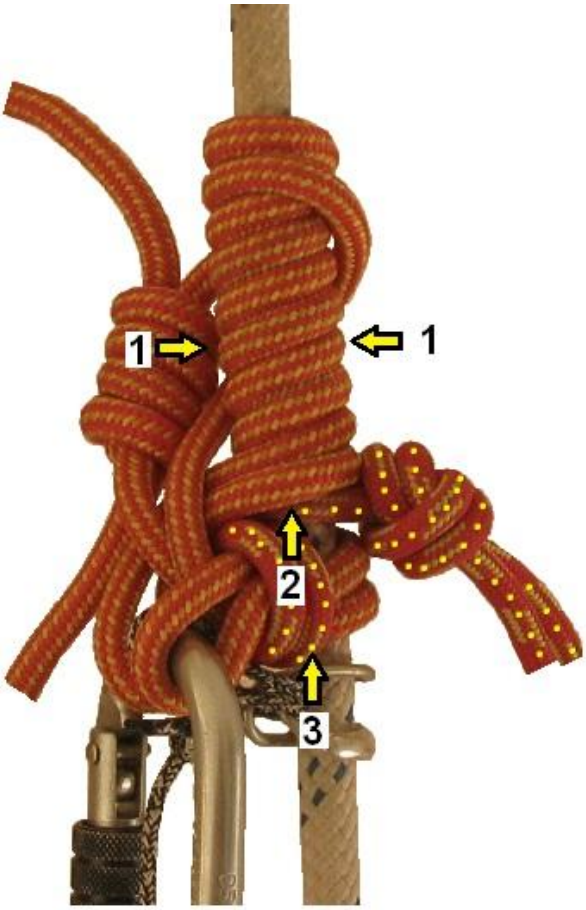

Figure 4.1; Friction hitch with markings for friction positions

Adding static friction nearly independent of rope diameter can be done in several ways.

Figure 4.1 shows a 5 turns double cord DO-Hitch with 2 auxiliary turns.

The best position to add friction is directly onto the top turns, as that directly translates to force in the rope sections that go to the top turns.

It can be done via a constant compression force on a top turn, indicated with “1”, or via friction around the rope that tries to push up the top turns, indicated with “2”.

Other option is by adding friction around the rope just below the bottom turns, indicated with “3”.

By far, option 1 works best using a thin piece of shock cord. It doesn’t interfere with normal hitch operation and/or tending devices. Option 1 requires the least additional friction force.

4.2.2. The “shock cord friction loop”

After experimenting, there is a very simple way to add friction in one of the top turns: a shock cord loop that goes both around the rope (to introduce friction) and around a top turn (so that it cannot get between the rope and the cord). It is shown in figure 4.2. The cord “sits” at about 2.75 turns, counted from below. The shock cord is thin

(1 mm), as it was a test to figure out whether the shock cord gets stuck in between the turns and the rope.

The shock cord is not eaten by the top turns, even under shock load and descending (intended sliding of the hitch). That piece of shock cord is called “shock cord friction loop” throughout this document.

Recommended thickness is 1.5 to 3 mm. When using 1.5 mm shock cord, You mostly use the double loop (upper loop in figure 4.2. When very low friction force is required, use the single loop (figure 4.2). When using 2 mm shock cord, the single loop is recommended. The stopper knot is just an overhand knot. The DO-hitch mostly requires only small additional friction force for good locking. Using 3 mm cord is therefore not recommended.

Tighten the cord just enough so that the hitch doesn’t slide down under its own weight, and check whether the hitch locks (slowly pulling). Excessive tension makes tending more difficult (higher no-load friction and more wear on the shock cord’s braid/sheath).

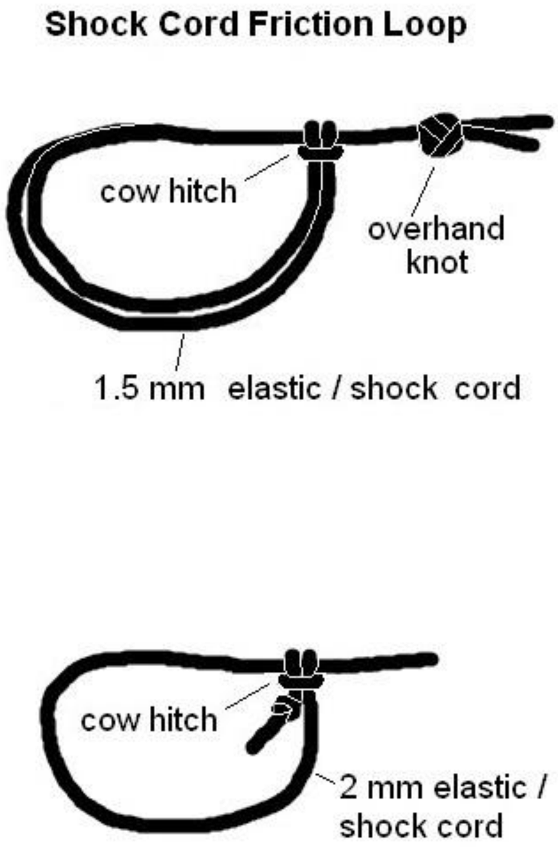

Figure 4.2; Retraced DO-Friction Hitch with shock cord friction loop

The “shock cord friction loop” is normally about halfway the number of top turns. Make sure it does not interfere with the top turn that comes down.

Shock cord friction loop inspection

The part of the friction loop that moves along the rope is in between the turns of the friction hitch. Even when the friction hitch itself is not loaded when moving, the shock cord friction loop provides some friction and therefore wears fast. You can't see the wear, as it is on the inside of the loop.

> Check the status of the braid regularly, especially in the beginning. This will allow you to set the inspection interval. You need to pull the cord out of the top turns to see the braid.

Use elastic cord with a Nylon (PA) braid, as that has better abrasion resistance compared to Polypropylene (PP).

5. Recommended cord

Despite that the carabiner is supported by 4 rope sections, some rope sections experience 50% of the load (instead of 25%). You therefore cannot use thinner cord as you can with a HAH-hitch, or Autoblock hitch.

Aside from strength, flexibility of the cord is important for good hitch operation. The more flexible the cord, the better the hitch locks (and the lowest amount of additional friction with the "shock cord friction loop" can be used). A simple test is to form a bight between your fingers, and observe how it bends, see figure 5.1. When you need force to form the cord into a narrow bend, it is not a good cord for a smooth working hitch.

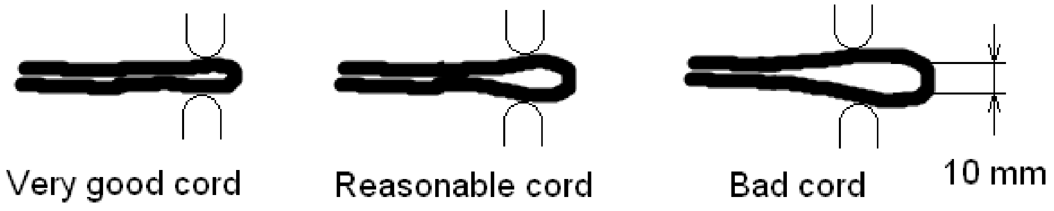

Figure 5.1; testing accessory cord

The width of the bend (inside measure) must be well below the diameter of the rope. 10 mm as shown in the right figure will give a bad locking friction hitch when using say 9.8 mm climbing rope. It may work on a 11 mm (or thicker) semi-static rope.

Stiff cord can be made flexible by removing one core strand, but then the cord is no longer certified.

5.1. Life support application

Use accessory cord that meets std. EN 564. These static (low stretch) cords are designed for use as PPE (Personal Protection Equipment).

When considering performance/price ratio, polyester (PES/PET) accessory cord is a good choice: low elongation, stable performance wet or dry, good abrasion resistance, MBS specification, and good UV resistance. Nylon (PA) accessory cord comes twice, due to larger elongation and moisture absorption.

Strength of PES or PA accessory cord is similar (PA mostly somewhat stronger). You should think of MBS of 7 to 9 kN for 6 mm cord, and 10 to 12 kN for 7 mm cord. Read the manual, besides MBS of the cord, strength of loops made with common climbing knots is also specified.

When price is not an issue or in case of frequent use, you may use a specialist "hitch cord" with aramid sheath (see further down the text).

> Do not use nylon or polyester cord for full body weight descending using a HAH-hitch as a replacement for a figure 8 or other mechanical descender. Only use it in a real emergency.
>
> When there is a need to descent, use a second hitch with a foot loop, when possible. This enables you to transfer your weight to the non-moving hitch.

5.1.1. Occasional work

For occasional work, you can stay with the regular PES or PA accessory cords. Use minimum 6 mm cord for a lanyard that carries half your weight. When your full weight can be onto the hitch use minimum 7 mm. I use 7 mm cord, as that provide MBS > 24 kN for the top turns section (that has no knots). .

For the retraced DO-hitch, the limiting factor is not the square knot, but the bend radius of the top turn that goes down in between the eyes. Therefore the construction strength is not 200%, but about 100% of cord MBS (PES or PA cord).

5.1.2. Professional use

There are so-called "hitch cords" containing blends of aramids (Kevlar, Technora, etc) with other fibers. They may meet Std. EN 564. These cords are specially designed for frequent, heavy professional activity, including descending on moving rope and single/stationary rope systems. These cords can be very flexible so that even hitches using thick cord lock well.

When the sheath is out of an Aramid (Kevler, Technora, etc) these cords do not show glazing. Aramids don't have a melting point. Use them because of their abrasion resistance, not because of their strength.

Read the instruction manual very well, as they behave differently compared to PES or PA cord. All recently manufactured cords that meet Std. EN 564 must be provided with strength loss for common climbing knots. The strength is given for a loop (so not for a single cord).

5.1.3. Not recommended cord / rope types for life support

Do not use

- Polypropylene (PP) utility or sailing rope. It has bad abrasion resistance, low melting point, and has significantly less strength. The low melting point in combinations with the low abrasion resistance makes it dangerous. A single slide of a loaded hitch out of PP can result in complete destruction of the cord.
- Paracord, the word “paracord” is used for everything, so you don’t know what you get. Though the original paracord is made out of Nylon (PA), cord out of PP is also sold as paracord.
- 100% Dyneema, though a very strong fiber, it is very slippery, and most knots in Dyneema cord slip at a load well below the breaking strength of PA or PES cord. In addition, its melting point is even below that of PP. It is useless for friction hitches.

5.2. *Non-critical applications*

You can use Polyester, Nylon or Polypropylene cord from DIY stores. Note that Polyester has best UV-resistance. Polypropylene (PP) has bad UV resistance and wears out fast. If possible avoid PP for friction hitches that may (shortly) slide under (partial) load. This is because of the heat that is generated during sliding.

Use cord that is at least 71% of the diameter of the main rope. When the rope material is the same, you can expect a construction strength that equals half the breaking strength of the main rope. Note that when using PA main rope and PP cord for the hitch, it is recommended to use thicker cord, as PP has less strength then PA (Nylon). When you really need the strength, you may use an HAH-hitch or Autoblock, as it puts less stress on the rope and the cord.

5.3. *Removing a core strand*

Regular PA (Nylon) or PES (Polyester) accessory cord is relatively stiff. The braid is tight around the core. This causes the stiffness.

The core of accessory cord consists of several individually twisted sub cords (or strands). This is shown in figure 5.2.

Figure 5.2; Accessory cord strands

The cord in figure 5.2 has MBS = 1200 kg, and has 9 strands. When removing 1 strand, 8 of the 9 strands remain in the sheath. The MBS will then be $1200 \cdot 8/9 = 1066$ kg.

> From a regulatory point of view, it is not allowed to remove a strand, as you now modified a certified product and then the certification no longer applies.

Some accessory cord may have just three core strands. In that case it is not recommended to remove a core strand as you lose 33% of the strength.

Removing a strand increases the flexibility, and reduces the static friction of the cord significantly. You can remove one strand by pulling onto one strand and milking the sheath. Gradually the strand will come out of the core. When done you need to milk in the other direction so that all strands are back in the sheath.   Melt the ends to fuse the core with the sheath (braid). Do not shorten the braid. Mark cords with a missing core strand, as they no longer meet the specs.

Higher flexibility and lower static friction does not change the holding power of a friction hitch, but does increase locking significantly and reduces the no-load friction somewhat. Better locking requires less tension on the “shock cord friction loop”, or it is not required at all.

On relatively fresh rope that is used along its full length, the “shock cord friction loop” is not required (from experience) when removing a core strand.

5.4. Storing your prusik cords

Store your cords, especially cords that you use for climbing, out of sunlight in a cool, dry, ventilated place, away from chemicals (think of paint thinner alcohol, oils, fuels, etc.). Note that some specialist hitch cords have moderate to bad UV resistance. In general UV damage is not visible, unless the damage is such that the MBS has reduced so much that the rope or cord is well beyond safe to use.

Keep track of the manufacturing date and use history. Rope/Cord shelf life is 10 years. Check your cords before use. In case of any doubt, don’t use them for climbing or rigging anymore. You can use them for other applications (think of learning knots), as long as they can’t be mixed with cords you use for climbing or rigging.

When you remove a core strand to increase flexibility, mark them as they don’t meet the specs anymore.

6. Test your hitches!

6.1. Testing in general

Testing your hitches should give answers to:

1. Is its construction strong enough?
2. Can it be released?
3. Is its holding power sufficient?
4. Does it lock/grab when it needs to lock?

The first “rule” is to test your hitches under the circumstances that may occur and using the materials that you are going to use in your application. When using new rope, also test on used rope, as new rope becomes used when using it.

The first question is easiest to test, as it is just an administrative one. Use the right cord (type and thickness) in combination with the right knot and safety factor. Read the instruction manual on knot strength.

The second question is also relatively easy to test by applying some shock load and/or let it slide a few cm under load. When it can be released (easily) it is fine. You need to check this under real circumstances. That may be wet, dry, polluted, etc.

Question 3 and 4 are more elaborate, especially question 4. The last two questions are discussed below.

6.2. Holding power

This is the load force where the hitch starts to slip (or fails). A friction hitch may lock very well, but may have low holding power, and vice versa. Holding power and locking are two different things.

> Jerking onto a hitch to check that it grabs, does not automatically mean that it holds well.

The force it should withstand (without sliding), depends on the actual load (including peak load due to dynamics). In a DRT / MRS climbing system, the hitch only carries half your weight. This is similar to a work positioning line that goes around your back or connects to the left and right waist ring on your harness.

In an SRT system, or positioning line that goes directly from your harness to an anchor point, the friction hitch must carry your full body weight, and that is more demanding for the hitch.

The holding power (load were above slipping occurs) is mostly determined by the number of top turns and Dcord/Drope ratio. A double cord hitch needs generally more turns to hold well.

So check the holding power using the short descent and jump/bounce tests (paragraph 6.5 and 6.6) with a well tied hitch. Do it again with a somewhat loose hitch. Then you know whether or not you have sufficient margin.

6.3. Locking behavior

Locking is also very important, as when it doesn't, the outcome can be fatal.

When you tend a hitch with an elastic cord (no other tending device, see figure 3.2C), it does lock, even when the hitch is very loose. This way of tending is typically used during ascend or as let go protection when hoisting things. It can also be used as rope grab function when climbing into a construction where the rope is already in the top of the mast (so you don't need a Y-lanyard) Tending with elastic cord creates (near) zero slack, so you can't make a hard fall.

A very loose hitch you recognize via the large distance between the top turns and the bottom turn when loaded. Note that when using more top turns, the distance between the top and bottom of the hitch under load increases (due to cord stretch and rope compression).

In the event that the hitch doesn't lock during ascend, you can lock it manually and correct the issue.

Grabbing/locking

- Goes well when the no-load friction is relatively high
- Goes better when the cord is very flexible
- Instantly reduces when you load a rope below the hitch, as the diameter reduces.
- Instantly reduces when the hitch enters a region where the rope diameter is less (because of frequent use).

When having a hitch with 5 top turns, and the rope diameter reduces 1 mm (from zero load to full body weight), you have 19 mm slack inside the hitch. A hitch that wasn't already tight, may slide down when it is not loaded. When the load is removed from the rope, the rope becomes somewhat thicker and the hitch no longer slides down.

When you use a second friction hitch as a backup device (for example above your main hitch) it must lock. First sliding and then locking will introduce shock load, and it shows you that the safety margin is insufficient.

Tips to improve locking

- Keep the hitch lightweight, so do not leave longer cord tails then necessary.
- Do not use thicker cord then required for sufficient safety (thin cord is more flexible and weighs less and "bites" better)
- Use flexible cord (removing a core strand increases flexibility)
- Use a tight hitch, yes this may increase no-load friction at thicker parts of the rope, for example rope sections that were not loaded for long time.

6.4. *Testing for good locking*

When using all measures from the previous paragraph optimally, it is likely that on a rope that is loaded and unloaded below the Hitch under Test, an unloaded hitch will slide down. This is just because of the dynamic variation in rope diameter. So be prepared for negative results and that the “shock cord friction loop” is required.

The tests below are for friction hitches that you use as backup above you at the same rope as you use for working. These are the most demanding conditions for a friction hitch.

Required setup

Testing for good locking requires an anchor point at say 2.5 meters above you, a piece of rope that you are going to use during work, and a friction hitch with foot loop (or your harness). The friction hitch with foot loop is to load and unload the rope so that the diameter changes. Instead of the foot loop, you may tie a loop in the rope just above the ground that you use as foot loop. When you have a sit harness, it works great as you have both your hands free.

> When you are not familiar using foot loops, you need to practice first. Be prepared that you may fall during practicing. Start with a short foot loop so that the hitch is well below chest level. This avoids that you accidently press onto the hitch and fall onto the ground.
>
> When you step onto the foot loop, you need to pull the rope to your chest (use both hands). The foot that is in the loop you move somewhat backwards and you straighten your back. You may move your other leg forward, horizontally, as this eases standing in the foot loop. Keep your hips horizontally to reduce stress on your lower back, as you stand on a single leg.
>
> Your torso should contact the rope and your whole body is near vertically. Practice with both your left and right foot and try to stand stable using one hand only (that takes more effort).

Testing for unintended sliding

It is assumed that you already did the descent tests before these tests, as they affect sliding and locking also.

The “Hitch under Test” should be above the foot loop hitch, but not where you put your hands to transfer your weight onto the foot loop. Do not load the rope yet. Move the hitch up and down and let it lock to feel that it is tied correctly.

Wiggle with rope just above the foot loop hitch or eye termination to remove the stress in the core and sheath of the rope. Move the Hitch under Test down (without letting it lock) so that it is at the wiggled rope section. Wiggle with the hitch and the rope, to get the stress from previous loading out of the Hitch under Test.

Now move the hitch above you, without loading it. During moving upwards, avoid that the carabiner hangs onto the eyes of the Hitch under Test. When you remove your hand, the hitch should not slide down. Now put your weight onto the foot loop, this reduces the diameter. The Hitch under test should not slide down. You may repeat this test with a hitch that is somewhat loose. When the accessory cord is relatively stiff, the hitch will slide down when standing onto the foot loop. If so, this is a failure.

Yes, when you pull the hitch it will lock, but it may slide down before locking, and that shows insufficient margin.

When you have a failure, repeat the test with the shock cord friction loop. The hitch should not slide down. Load the rope and push slowly on top of the top turns to feel how much margin you have. When only minor force is required to push down the Hitch under Test, you need to tighten the shock cord friction loop.

When the hitch does not slide down with repetitive loading and unloading of the rope in combination with wiggling, and you have some margin, you can go to the lock test.

Testing for good locking
Move the hitch to a position where the rope is free of stress (wiggling). Wiggle the hitch to remove stress. Move the hitch above you without loading it.

Step onto the foot loop (to reduce the rope diameter). The Hitch under Test should not slide. While standing on the foot loop (or hanging in your harness), slowly pull the load bearing eyes (mostly just pull the carabiner). The hitch must lock. Maximum 10 cm of sliding of the top turns is acceptable. Move it a bit upwards, and pull slowly again. After the first locking test, it locks better next time.

Locking of a previously loaded hitch that has been released
Load the hitch heavily (with a foot loop, jump on it, etc). Remove the foot loop from the Hitch under Test. Release the Hitch under Test with only minor load onto the rope, move it a bit up and down. Stand on the foot loop (or sit in your harness) to tension the rope, and slowly pull the hitch, it must lock without sliding. Sliding of the top turns of maximum 10 cm is acceptable. Move it a bit upwards and pull slowly again. It must lock.

You may repeat this test a few times, and with a hitch that is somewhat loose, so you know your margin.

When it doesn't lock reliably, you may tighten the shock cord friction loop somewhat to increase the no load friction. This will mostly result in a reliable locking hitch.

6.5. Testing the holding power

Testing for holding power should include the effects of

1. Deformation of the turns due to flattening of the cord cross section and stretch, increasing slack inside the hitch (figure 1.1).
2. Reducing of friction due to flattening of the cord surface that is in contact with the rope (figure 1.1C).
3. Glazing of the accessory/prusik cord area that is in contact with the rope, reducing the friction coefficient.

Though most friction hitches are not intended for frequent descending with full body weight, the HAH-Friction Hitch can be used for short descents. This may be useful during an emergency maneuver. Due to the double cord, the friction force is divided over two sets of turns halving the contact pressure. This eases breaking of the hitch, and puts less (but still high) stress onto the rope and the cord.

Breaking the hitch under load is a good test to test its holding power due to reasons 1 and 2.

The Hitch under Test can be loaded via a foot loop, or using a sit harness. When you are not familiar using foot loops, and want to use them, you need to practice first. Be prepared that you may fall during practicing. Start with a short foot loop so that the hitch is well below chest level. This avoids that you accidently press onto the hitch and fall onto the ground.

When you step onto the foot loop, you need to pull the rope to your chest (use both hands). The foot that is in the loop you move somewhat backwards and you straighten your back. You may move your other leg forward, horizontally, as this eases standing in the foot loop. Keep your hips horizontally to reduce stress on your lower back.

Your torso should contact the rope and your whole body is near vertically. Practice with both your left and right foot and try to stand stable using one hand only (that takes more effort).

Required Setup
The setup is virtually the same as for testing locking behavior. You need a short vertical climbing rope section anchored at about 2…3 m above ground. Tie the friction Hitch under Test and add a rope loop of about 0.9..1.2 m of loop length through the carabiner that is connected to the friction hitch. You can use this loop as a foot loop. This enables easy transfer of your weight onto the hitch. Do not use your harness to apply shock load. If so, use a harness that is no longer in service.

Short descent test
Position the hitch so that the foot loop is about 0.6m above solid ground. Grab the climbing rope and step into the foot loop while pulling the rope to your chest, but without pressing onto the top of the hitch. This transfers all your weight onto the Hitch under Test. The top of the hitch should be at about chest/neck level. When not, readjust the foot loop. Jump into the loop to see whether the hitch slips/slides. When it slides, you don’t have to continue. You need an additional top turn (or more).

Be prepared that something slips or breaks during jumping

When standing in the foot loop, push onto the top of the hitch with your hands, so that part of your weight transfers from the foot loop to the top of the hitch. Slowly increase the force on top of the hitch, until it breaks and slides slowly down. You may wear safetygloves.

When it slides down you need to suppress your normal grab reflex, as that will send you to the ground. When it starts sliding, you reduce the force onto the hitch to control the descent rate. Descent about 10..20 cm. When you stop pressing/hanging onto the top of the hitch, it should stop sliding immediately.

Press onto the top of the hitch for the second time so that it slides about 10..20 cm. It should stop again when reducing the force onto the top of the hitch.

Carry out another (third) short descent. You should not step out of the foot loop during these three short descents. Make sure that your feet don’t touch the ground. jump into the foot loop (creating shock load) to check that it doesn’t slip.

Three short descents of about 10 to 20 cm per descent, while remaining on the rope, are important. The descents are required as hitch behavior may change after the first descent due to rearrangement of the turns, cord stretch and flattening of the cross section. When it descent too easy after the third descent, add another turn and/or check for a loose hitch.

6.6. Checking for glazing effects

Three short descent tests are good for checking turns deformation. When doing more short descents, you can check for glazing and further flattening of cross section of the cord. You need to descent over larger distance, think of 3 to 5 m in total. Of course you can do this in many sessions so that you stay close to the ground. Just descent say 50 cm, step out of the foot loop, move the hitch up and descent again. Leave the friction hitch on the rope during all the tests. This assures that cord orientation doesn’t change.

When you experience

- breaking of the hitch becomes very easy compared to the beginning of the test.
- sliding doesn’t stop immediately,
- short slipping during jumping into the foot loop (shock load),
- unraveling of the braid/sheath

there is something wrong. You don’t have sufficient margin.

First check whether the hitch is less tight compared to the situation before the descent tests. This can be due to cord stretch, further flattening of the cross section, or due to a loose square knot. It is therefore advised to start with a hitch that is tight, as it becomes less tight during use. You may mark the cord sections that leave the bend (square knot) to check for giving out rope.

Important note

> When the hitch is still tight enough after the test, but breaking goes easy, or it slips when jumping in the foot loop, there is likely glazing. You must use an additional top turn to increase the friction, and avoid slipping/descending during use.

An additional top turn adds no-load friction, but you can better be safe then sorry.

There is another reason for short descent testing, even when you will never on purpose descent using a friction hitch. You may arrive in a situation that shock load occurs. When holding power is relatively low, peak forces are limited because of slippage. That is a nice feature. However when the slippage causes glazing and flattening of the cord, and the hitch hasn’t sufficient margin, it keeps slipping/sliding. This may end fatally. Therefore you need to be sure that a hitch has sufficient margin for its application.

When you plan to descent using the hitch, use cord with an aramid sheath (Kevlar, Technora, etc), and use a VT or XT hitch as that puts less stress onto the rope.

Better is to use a device that takes over a significant part of your weight, or use a mechanical descender. Descending using a friction hitch with your full weight causes wear of your climbing rope. Nylon accessory cord is not suited for descending over large distance. You should only do it when in an emergency with no other options.

6.7. Let's resume

When the hitch passes all tests, you have a hitch that

- is strong enough, based on the cord, knots, expected load and type of hitch (just administration)
- releases well, also after receiving some shock load or a short descent (intended or unintended)
- locks well, also on rope that is loaded and unloaded below the hitch (diameter change issue).
- can hold the load with sufficient margin, including negative effects because of short descent, minor glazing of the cord and slight loosening of the hitch

When you change something in your setup, the above statements are generally no longer valid.

- When you use thicker cord, you need to test again. The holding power may reduce due to slipping, and locking performance worsens, as thick cord is less flexible.
- When you use thinner climbing rope, the holding power reduces and the locking performance worsens.
- When going from PES to PA accessory cord. When the flexibility is the same, the locking power reduces (slipping) due to the higher stretch of PA (Nylon).
- Increasing the number of turns is fine, the holding power increases and the no-load friction increases.
- When your new accessory / hitch cord is less flexible, its locking performance worsens.

You may think, everything is fine now, so I don't need a backup hitch. When putting your life onto a hitch, a backup is highly recommend (yes, I know many people don't). A backup hitch is on another rope, or above your primary hitch.

It is recommended to have a short lanyard between your hand ascender or your foot loop friction hitch. It is not suited for fall protection, but you may be able to put your weight on it in a slow manner when your main friction hitch behaves unexpectedly. This gives you time and free hands to solve the problem.

Check your gear continuously during and outside your activities, and be your own devil's advocate.

Make sure you have sufficient spare material with you, so that you can resolve problems.

Don't forget, climbing is dangerous. This document is not a substitute for good training on how to tie friction hitches and how to test and use them.

7. Annexes

7.1. Annex 1, adjustable loop hitch

This hitch is intended for creating adjustable loops where the load is inside the loop (ring load, parallel load). It is not suited for eye terminations (such as a figure 8 loop termination).

When tightened, it doesn't come loose when wiggling.
Little effort is required to release the hitch when you need to adjust is.

Tying the hitch
Figure A.1.1 shows how to tie it.

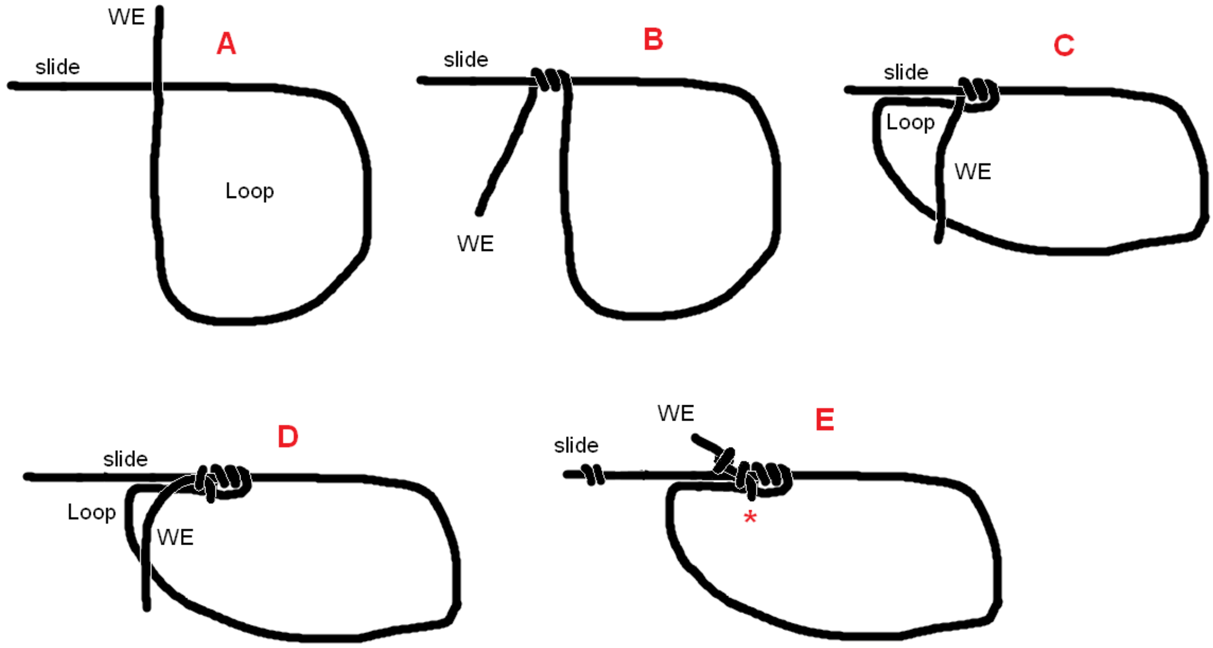

Figure A.1.1; adjustable loop hitch

Figure A, B
Start with a loop and apply 3 turns. 3 turns are mostly sufficient to create a friction hitch that has holding power >35% of MBS when using polyester or nylon cord.

Figure C
Fold a short section of the loop parallel to the slide rope section.

Figure D
Tie an overhand knot around the slide and loop rope section. The winding direction is the same as for the 3 turns.

Figure E

Put an overhand stopper knot in the working end and dress the hitch so that the overhand stopper knot touches the hitch. The E-figure shows some distance between the stopper and the hitch, this is for clarity only. There should be no clearance.

Tie a double overhand stopper knot in the slide rope section so that you can't pull through the sliding end by accident.

Making the loop larger

When the hitch wasn't heavy loaded (see figure A.1.1E)

Grab the hitch with your left hand at the most right turn and pull through the cord with your right hand.

When the hitch was heavy loaded

You first need to release the hitch. Grab the three turns with you right hand, and push the overhand knot with the thumb of your left hand to the left side. You put your thumb at the position of the red star in the E-figure.

This action creates sufficient cord inside the hitch to pull rope through the hitch when you grab the hitch at the most right turn.

Making the loop smaller

When the hitch wasn't heavy loaded

Grab the most left part of hitch with your right hand, and pull through the rope with your left hand.

When the hitch was heavy loaded

You first need to release the hitch. Grab the three turns with you right hand, and push the overhand knot with the thumb of your left hand to the left side. You put your thumb at the position of the red star in the E-figure.

This action creates sufficient cord inside the hitch to pull rope through the hitch when you grab the left side of the hitch with you right hand.

For making loops for tending a hitch without a ring, use 3 to 4 mm of Polyester or Nylon cord. When having very flexible single braid cord, you may use 5 mm as this reduces friction. PP (Polypropylene) is not recommended because of higher friction and low abrasion resistance.

You may also use the good old Blake's hitch.