Deutscher Alpenverein
Sicherheitsforschung

Webbing and cordage update
Tales from the sling jungle

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Slings and cordage were traditionally manufactured from the same material as dynamic climbing ropes, namely polyamide. In the early 90s, the first cords made from aramid (Kevlar) arrived on the mountain sports market, toward the end of the 90s slings made from Dyneema (polyethylene) showed up – we have already acquired fifteen to twenty years of experience with those 'new' textile materials. But there is still a lot of uncertainty as to which materials can be used for what purpose.

What's what?

Open tubular or flat material is called *webbing* and sold by the metre; it is only available in polyamide. Marker threads indicate its breaking strength in a single strand without knots (5 kN per thread). Open webbing is now only used to connect the hip- and waist belts of climbing harnesses. For all other applications, webbing must be connected into a ring with a knot – and that is always a weak point. Several serious and fatal accidents in which the tape knot pulled through are documented (Fig. 1). For that reason, webbing knotted into a ring is no longer recommended. Sewn slings are a better alternative!

The EC norm calls *slings* pieces of webbing or cord that are positively and tight-fittingly connected. They must possess a minimum breaking strength of 22 kN. Slings are commonly made from polyamide, polyethylene (Dyneema) and mixed fabrics consisting of both fibres. More recently, Aramid (Kevlar) has become available as a sewn cord sling.

Cords are made from polyamide, aramid, and polyethylene. The formula for determining the minimum strength is $Ø^2 \times 0.2$ = strength in kN. So, a 6 mm cord must hold $6 \times 6 \times 0.2 = 7.2$ kN. The strength of polyamide cords is slightly higher than the minimum requirement. Cords with a polyethylene or aramid core surpass those requirements by a wide margin.

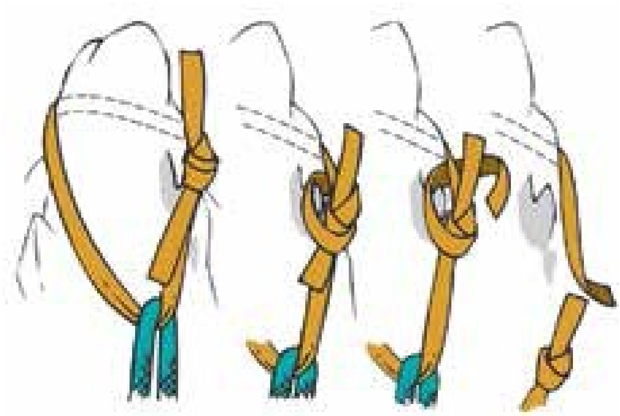

Fig. 1: Caution – knotted webbing slings can open. Sewn is better.

What performs how?

There are some significant differences between the physical properties of polyamide, polyethylene, and aramid. So each fibre has applications for which it is more or less appropriate. To understand the advantages and drawbacks, it is necessary to know the most important properties of the various materials (Table 1).

Polyamide – well known brand names are *Perlon* or *Nylon* – is very tear resistant, but still relatively weak when compared to other materials. That means that a polyamide webbing sling has to be significantly thicker and heavier than a polyethylene or mixed materials sling to conform to the EC norm standards. Polyamide's decisive advantage is its elasticity. The dry fibre will stretch up to 20% before breaking (in an indoor climate, it's even more than 50%) and can absorb a large amount of energy. It's only because of those material properties that climbing ropes can be manufactured that stretch and so reduce the impact force in a fall (that means the braking force that applies to the falling climber).

Polyethylene – known under the brand name *Dyneema* – is highly tear resistant and very light at the same time. In addition, it has the highest cut resistance of our three fibres. At first glance one might wonder why Dyneema has not fully replaced the other materials yet. But for some applications further details are really important! The materials' elongation at breaking is only about 3.5%. That means it is almost comparable to a steel cable and not appropriate for applications in which energy absorption is important, like dynamic ropes. Polyethylene's melting point is relatively low at about 135°C. This made for long discussions earlier. But a number of experiments have shown that because of the material's smooth surface little frictional heat develops and so the low melting point is compensated. Knots may start to run under load because of the smooth surface, but melting through is not likely.

Aramid – known under the brand name *Kevlar* – is almost as tear-and cut resistant as Dyneema and superior to polyamide in those respects too. Its breaking elongation is similar to Dyneema's which is why it is not appropriate for manufacturing dynamic ropes. Aramid is so heat resistant that on the end of Kevlar slings only the PA sheath but not the core can be fused.

Fig. 2: The 'alpine quickdraw' can be readily extended to straighten the course of the rope.

Knots weaken slings

When used outdoors, synthetic materials are exposed to many factors that affect their strength negatively. Knots reduce strength significantly; by how much depends on the sling material and the knot that is used. A 7 mm polyamide cord, for example, will hold 'only' 12 kN without knots in a single strand. A 5.5 mm Dyneema cord on the other hand holds 20 kN that way. With a follow-through overhand the polyamide cord still holds 7 kN while the Dyneema cord will fail at 6 kN already! (More info in DAV Panorama 4/2007 'Knotenfestigkeit' and in Alpin-Lehrplan 5: Klettern. Sicherung und Ausrüstung)

Practical tips

- Never use sling material in a single strand! Webbing strength in a single knotted strand drops to critical values in all materials. A 16 mm polyamide webbing sling holds only 6.4 kN when used in a single strand with a figure 8 knot in a teardrop shape. A polyethylene webbing sling will hold only 5.4 kN! Forces of about 6 kN can apply in hard belayed leader's falls.

- Rule of thumb: Knots reduce strength by 50 to 60%, up to 75% in Dyneema and Kevlar!

- Knots in teardrop shape (overhand, figure-8, reef knot and a single fisherman's) reduce knot strength the most. For permanent cord connections, a double or even better a triple fisherman's knot work best. For non permanent connections like a threaded sling or crevasse rescue knots in teardrop shape are acceptable.

- Dyneema webbing slings can be used with knots, for example as a cordelette at stations. The fact that the knot starts running under relatively low loads will not lead to system failure as those slings are only available sewn.

Fig. 3: Webbing in a single strand is dangerously weakened by knots. Never in a single strand!

Fig. 5: Caution! Big falls into a clip-in sling can cause it to fail.

How slings age

The manufacturers specify a maximum life span of ten years, even if the product was never used. Depending on the frequency of use, they may not last that long. From 2007 on the year of manufacture has to be shown on the product. Mechanical damage and signs of wear are immediate grounds to retire webbing and quickdraws. The more fibres of a sling are damaged, the greater the loss of strength. The most significant mechanical aging is caused by flexing. It can be recognized by intense 'furrification' of the material. Aramid's vulnerability for changing flexing loads was discussed early on, but has shown itself to not be relevant in real life. The number of flexes required to weaken the fibre cannot really be reached during the product's ten year life-span. More recent experiments however have shown that caution must be used with respect to the aging of narrow Dyneema slings (6 and 8 mm width). With their small diameter area, the breaking strength of those slings when they are new is just a little bit above the norm requirements of 22 kN. After three to five years of use, some of them drop down to 13-15 kN. They should be retired after no more than five years, earlier if they are heavily used.

Besides aging, mechanical damages like rockfall, rubbing on rock or falls in which the material is loaded over sharp edges or 'ground' over rough rock are most relevant in real life.

To judge fixed tape like permanently fixed quickdraws or belay stations that have been exposed to UV radiation for extended periods of time, we have to know how much radiation can damage the specific material and how deep it penetrates (table 1). For one's personal gear UV aging is not relevant.

Practical tips

- The longer the exposure to weather and UV, the more the material weakens.
- Discolouration (bleaching) and stiffness are considered indicators of UV damage.
- Polyamide sheaths protect the core fairly well against damage by UV radiation. Therefore, flat material will be damaged more than round material. Use caution particularly with bleached webbing slings on belay stations!
- Mechanical damage occurs most frequently in slings fixed on the mountain where the material lies under stress – that means where we can't usually see it (on the inner back side in slung horns, the spot where a rappel sling is threaded through the pin, in the locking-gate with fixed quickdraws in toprope routes, etc.)
- Fixed-in-place slings must be checked and evaluated before use. No compromises should be made at belay stations! Rappel stations can be treated a bit more leniently – as long as no other negative factors must be considered – because rappelling loads the anchor with no more than about double body weight. You will be on the safe side if you always exchange weathered or damaged material for new.

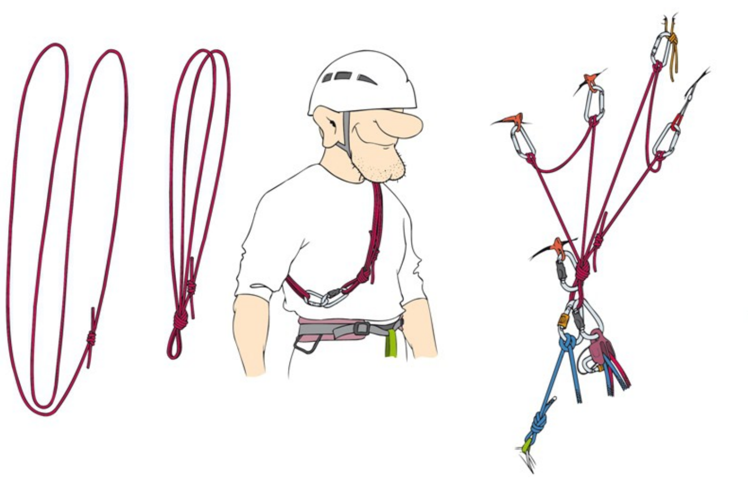

Fig.4: Equalizing multiple dubious anchors with webbing or strong cord.

Short and sweet

The following essential principles apply to all slings, no matter if it's webbing or round, or what material they are made from:
- Never load them in a single strand! (fig. 3)
- Falls into a station clip-in can lead to failure of the sling. (fig. 5)
- Evaluate old fixed slings found on the mountain critically, back them up or even replace them if possible!

Webbing slings are generally appropriate for all uses to which they are commonly put in mountain sports. Because of its ability to absorb energy, polyamide features a bigger safety margin. Dyneema is thinner and lighter, but it ages faster. The table on the left shows in detail which fibre has which particular advantages and drawbacks for which application. For cords, the classic polyamide can now generally be replaced with stronger Dyneema and Kevlar.

This compilation reflects the current status of knowledge. It is certain that there will be further new webbing designs, raw fibres, and combination of fibres used in mountaineering, and that there will always be new knowledge gained in the future.