Report on the breaking of a girth-hitched sling, with recommendations for usage of connected slings

Conducted by Mammut Sports Group, Seon, Switzerland. 1/10/2007

Summary:

Recently a girth-hitched Mammut 8mm Contact sling was broken in what was described as a relatively static, low-load application. The climber sent an email to many of his friends warning them of the possible danger of girth hitching the newer skinny slings, which quickly made its way around the inboxes and internet forums in the US. After conducting a series of tests using static, dynamic and cyclic load testing to attempt to reproduce the conditions of the accident, the broken sling was compared to the broken test samples in detail. Through a comparison of the break characteristics, Mammut believes that the broken sling in question was cut by a sharp object, rather than breaking under load due to the weakening effects of the girth-hitch. All climbers should be aware that girth hitching any Dyneema slings, regardless of size, causes them to lose around 50% of their strength.

Full Report:

On 22 October, 2006, John Sherman, a well known Colorado climber, broke a Mammut 8mm Dyneema Contact Sling. John forwarded an email to many of his friends warning them not to girth-hitch their skinny slings together, and this email was quickly distributed to many climbing chat rooms and individuals.

The sling was part of an anchor that Sherman had used to clean several new climbing routes over several days at a new and extremely remote area in Arizona. Figure 1 shows photos taken at the scene that show the anchor.

Fig. 1. The anchor in question on 10/22/06, showing the configuration of the slings

Because the secondary anchor containing the girth-hitched 8mm Contact sling was directly loaded, depending on the direction of load this would have taken the majority of the load. Because the rope was still attached to the main anchor component, Sherman was unhurt when the sling broke. Figure 2 shows photos of the broken sling at the site of the accident.

Fig. 2. Photos of the break taken at the site of the accident

The break of the Mammut sling is exactly located just outside the girth hitch. One strand of the sling is completely broken, while only a few threads on the other strand are damaged. In addition, there is a small area of damage on the spectra sling above the girth-hitch. Because the breaks resulting from loading a sling to failure have never shown this linear of a break, Mammut was very interested in obtaining the sling to do further analysis into the break.

Approximately 2 weeks later, Sherman sent the still-girth-hitched slings to Mammut for further analysis. The slings were a Mammut 8mm Dyneema Contact sling, which was girth hitched to a Misty Mountain 15mm Spectra sling (Fig 3).

Fig. 3. Misty Mountain 15mm Spectra sling, strength 3097.5 DaN; and Mammut 8mm Contact sling, strength 2308DaN.

Dyneema and Spectra are high-strength polyethylene fibers having a tensile strength roughly 15 times greater than steel and 40% greater than aramid (Kevlar) by weight. The fibers, which for the purposes of this discussion can be considered the same, have a long lifespan and a high resistance to abrasion, moisture, UV rays and most chemicals. Dyneema also has the reputation of being "hard and sharp" under load, meaning that it can increase the risk of it cutting when attached directly to other slings.
According to Sherman's statement, the girth-hitched slings had not sustained any dynamic falls, but were only subject to the normal bouncing and swinging forces associated with ascending and descending the rope repeatedly. It is already well-known from industry testing and technical literature that knotted slings lose a significant amount of their strength (Alpin-Lehrplan 6, Alpenverein/BLV; "Bergrettung" by Toni Freudig and Adalbert Martin) —a strength loss of 50% is a generally accepted ballpark of what to expect from any girth hitched sling, although Freudig and Martin state that a knot can reduce the strength of rope and webbing up to 57%. However, even if we allow for a 60% reduction in strength from the 22kn minimum breaking strength of a Mammut Contact sling, 8.8 KN, or 880kg (roughly 2000lbs) strength should remain. In recent years Mammut conducted two series of tests on the issue of knots and how they affect the strength of various materials. The first was conducted in 2004, the second in summer of 2006. Both test series confirm what is already written in the technical literature: the tensile strength of slings girth hitched together will be reduced by around 50%.
Because there were supposedly no falls taken on these slings, and a typical climber of Sherman's weight should never generate this much force on the rope through cleaning a route (ascending and descending, swinging, etc), this demanded a detailed investigation to determine the cause of the breakage, and to determine if the new generation of skinny slings react differently to knots than had previously been thought.

In order to determine the specific mechanism of breakage, Mammut conducted a number of tests in order to attempt to recreate the breaking characteristics of the Sherman Sling. Because different types of loads result in patterns of breakage that are consistent and exhibit certain identifying characteristics, this information is important in determining the actual cause of any failure. Dynamic, static, and cyclic load testing were all used.

In a primary phase, girth-hitch-connected slings were statically loaded until they broke, and some were cut with a knife both loaded and unloaded. Figure 4 shows some sample results of this static testing.

	Knot	Break strenght daN	Result
Sling connection 8/12	girth-hitch	1102.7	Break of the 8mm sling
Sling connection 8/Spectra 15	girth-hitch	1333.1	Break of the 8mm sling

Fig. 4

As already implied, the reproduction of the accident was very important to the testing. To attempt to reproduce the swinging and bouncing forces caused by ascending and descending, sling connections were preloaded with different forces, and then exposed to 114 load cycles per minute. The cyclic force alternated between 80% and 120% of the preload force. Figure 5 shows the number and force of loads the slings were exposed to—none broke, even after thousands of repetitions.

Fig 5.

	Knot	oscillations	Force daN min.	Force daN avarege	Force daN max.	Result	Coment
Sling connection 8/12	girth-hitch	2*1140	320/560	400/700	480/840	no damage	
Sling connection 8/8	girth-hitch	342	240	300	360	no damage	
Sling connection 8/8	girth-hitch	20520	220	400	480	no damage	
Sling connection 8/8	girth-hitch	13680	640	800	960	no damage	Loaded till breakage after. Broken by 1411 daN.
Sling connection 8/8	girth-hitch	13680	640	800	960	no damage	
Sling connection 8/12	girth-hitch	2280	640	800	960	no damage	Loaded till breakage after. Broken by 1292.7 daN.
Sling connection 8/12	girth-hitch	2280	640	800	960	no damage	Loaded till breakage after. Broken by 1327.9 daN.

This testing showed that tightened, knotted slings had a higher tensile strength than slings that are only tightened by hand, leading to the conclusion that untightened knots may break at least in part because of a melting impact if the force is lower. Therefore, in a secondary phase we conducted dynamic testing in the drop tower, the results of which are shown in Figure 6.

Fig 6.

	Knot	Drop height	Force daN 1st drop	Force daN max.	Picture	Result	Coment
Sling connection 8/Spectra 15	girth-hitch	-1.3m	452	453		no damage	Test cancelled after 145 drops
Sling connection 8/Spectra 15	girth-hitch	-2.3m	311	506		no damage	Test cancelled after 200 drops
Knotted 8er sling, 120cm	Tightened with 80 daN	-0.9m	308	711		knot slided through in the 9th drop	lightly burned
Knotted 8er sling, 120cm	Tightened with 80 daN	0m	357	357		knot slided through in the 1st drop	lightly burned
Knotted 6er sling, 120cm	Tightened with 80 daN	1m	1046	1046		knot slided through in the 1st drop	lightly burned
Knotted 6er sling, 120cm	Tightened with 400 daN	0m	313	1260		knot slided through in the 2nd drop	lightly burned
Knotted 8er sling, 120cm	Tightened with 800 daN	0m	382	382		knot slided through in the 1st drop	lightly burned
Knotted 8er sling, 240cm	Tightened with 500 daN	0m	276	276		knot slided through in the 1st drop	lightly burned

To begin, two experiments were done to evaluate the strength of the sling connection when exposed to many repetitions of a lower force, as would be associated with the bouncing while ascending and descending a rope—both experiments had to be cancelled after hundreds of repeated impacts without breakage. After this, connected slings were mounted in the drop tower so that the knot slipped under load, generating higher temperatures through friction and finally leading to surficial burning of the slings. The slings tested in this manner showed light melting at the edges which only had a small effect on the strength of the sling.

After conducting these tests, Mammut took the broken sling, along with all of the broken test samples, to the textile proofing company Testex, to compare the breaking characteristics of the Sherman sling to those of the tested samples in detail. Microscope photos were taken of the different tested breaks, of which 6 representative photos are shown here (Fig's 7-12). Each photo is representative of the features typical for their respective breaking mechanisms (i.e. a hard dynamic fall, a static load, a cut, etc).

Fig 7. A picture of a typical dynamic break produced in the drop test apparatus. Note the somewhat uneven nature of the break, and the melted ends of the individual fibers


Fig. 8. A picture of a typical break produced by a static pull. Note the uneven nature of the break and the melted ends and melted together areas of the individual fibers


Fig 9. A typical dynamic break in a pretightened girth hitch. Note the long, extended nature of the break with clearly melted-together fibers

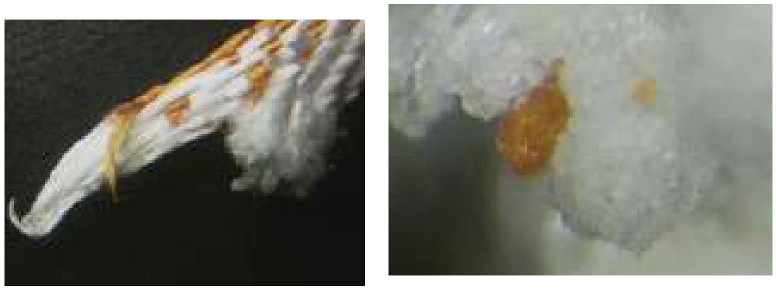
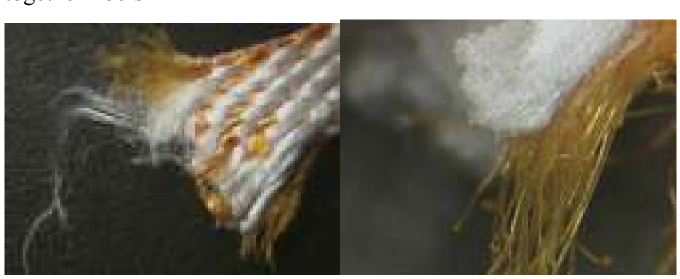


Fig 10. A typical sling cut under an 800 DaN load. Note the even, but slightly diffuse break and the lack of melting at the ends of the fibers

Fig. 11. A sling cut with no load. Note the very precise and straight break and the lack of melting at the ends of the fibers. The dark spots that appear to be melting are the ends of the nylon fibers seen head-on, which makes them appear darker

Fig 12. A typical sling broken over a sharp edge. Note the uneven break and the melting of the ends and melted-together fibers



In addition, one photo (Fig. 13) was taken of a sling broken because of an acid contamination. Because the Sherman sling showed none of the deformation associated with this contamination, chemical analysis of the sling was considered unnecessary.

Fig 13

The Sherman sling was also analyzed and photographed at the same time as the tested slings. In particular, three areas of the sling were looked at in detail, as shown in Fig 14a-14d.

Fig 14a

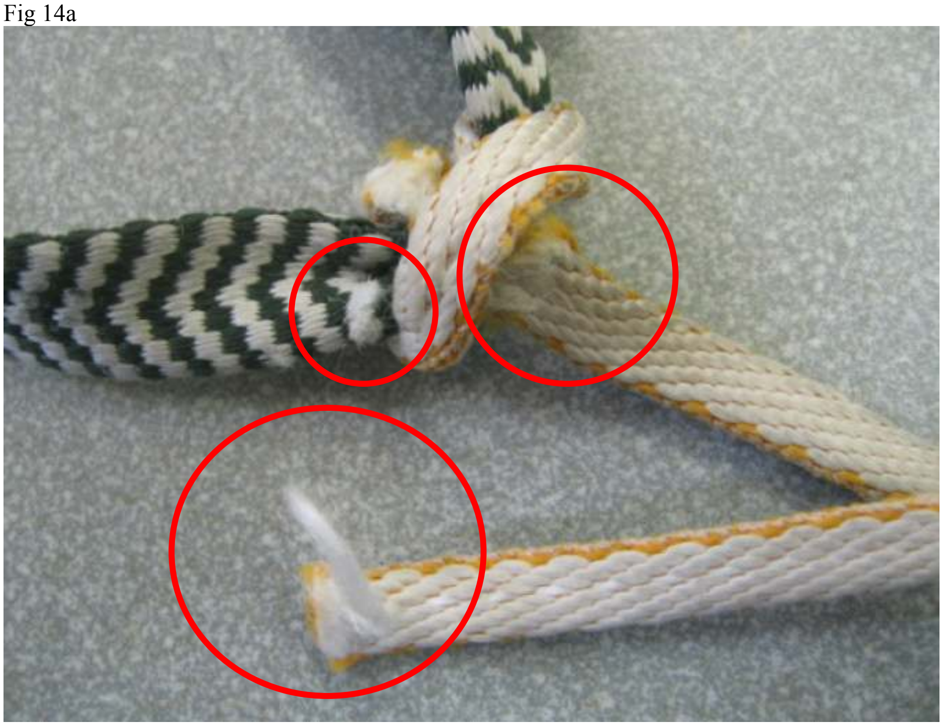


Fig 14b. Broken part of the sling. The break is diffuse, and clearly linear, with one pulled strand. There is no melting of the individual fibers visible.

Fig 14c. Damaged part of the sling. Fibers on top of the sling are broken. There is no melting of the fibers.

Fig 14d. Torn Spectra sling. The Spectra sling is torn about 0.5cm. The break has very linear characteristics, with no melting.

When comparing the photos of the tested slings, it is noteworthy that in all the test slings broken under load, there is significant melting of the ends of the fibers, and often melting together of the fibers—the two exceptions are the two cut slings. In addition, the colored Polyamide (Nylon) cross thread, also called “shot”, is sheared in all the breaking pictures except the cuts.

The Sherman sling shows a linear break with one pulled fiber. There is no melting, or melting together, and the shot is not sheared. In addition, in all three of the damaged areas of the sling, the damage occurs outside the girth hitch, not inside as would be expected if the knot were the cause of the sling being weakened and damaged.

The biggest similarity to the breakage of the Sherman sling is the sling cut while under load (Fig. 15).

Fig 9.


Cut under 800 DaN


Sherman sling

Both slings show a slightly diffuse, linear break and the individual fibers show no melting. The shot remains unscathed in both slings as well. The other damaged parts of the Sherman sling show linear characteristics and no melting as well, indicating a similar mechanism of damage.

In conclusion, as the testing shows and the previous literature on the subject supports, the strength of any slings that are connected with a knot can decrease over 50%. However, based on the fact that a UIAA certified sling holds at least 22kn (roughly 5000lbs), when girth hitched 880DaN or 2000lbs strength should remain. With normal human weight and under the described circumstances, this force could only have been reached with a multi-meter drop. Because of the lack of melting and the lack of similarity to any of the tested breaks, we do not believe the sling broke due to any force applied to it, even taking into consideration the weakening effect of the girth-hitch. The most plausible scenario, borne out by the linear characteristics of the break and location of the break outside the knot, is that the sling was cut with a very sharp object. The only difference is the pulled thread—it seems plausible that this thread could have been the only one not cut through and therefore it held the anchor in place so it appeared to be intact and finally pulled under a low load.

Climbers should be aware that all slings, whether skinny or fat, Dyneema/Spectra or Nylon, are susceptible to significant strength loss due to a girth hitch, and should use any connecting knots with caution. While there may be some additional strength loss when connecting skinnier slings, this additional loss is only a few percent (the equivalent of perhaps 250 lbs out of 5000)--the additional strength loss is not enough to treat today's extremely thin slings any differently than fatter or nylon slings—all girth hitches must be treated with caution. The safest way to obtain a longer sling is to use a longer sling in the first place, rather than connecting them at all. If two slings must be joined, the strongest way to do so is with a carabiner.