White Paper

Risk of material fatigue in air sports carabiners with conventional snap gate

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Conventional carabiners have a snap gate, for whose frictionless movement a certain amount of gate play is required. Depending on the size of the play, form fit on the side with the closure only occurs at a load of 30 to 150 kg. The side facing away from the closure is thereby exposed to relatively high tensions. Due to the oscillating load, which permanently affects air sports carabiners during flight, there is a risk of material fatigue in this area. In the following, we explain the background of the problem and describe how the strength of some currently used conventional paragliding carabiners is tested by a uniform method. It turns out, that fatigue strength for a time span of 5 years is not always given, and that there are very different ways to achieve it with regard to carabiner design.

Almost all connecting links between pilot and wing, that are currently used in air sports, are carabiners with a snap gate as known from mountain sports. These carabiners are popular, because they are easy to handle and the automatic locking of the snap gate largely excludes any maloperation. Also their low weight at high breaking loads and the small dimensions make them attractive for hang glider and paraglider pilots. In addition, the production of such carabiners is relatively inexpensive. We, too, manufacture conventional carabiners, although we have been developing alternative air sports carabiners in parallel since 1993.

It should, however, be noted that carabiners are not only exposed to static, but also to dynamic loads during flight, which in the long run can lead to material fatigue. Material fatigue would necessarily only occur, if the critical stresses are excessively exceeded. But since the snap gate becomes form-fit before, this is prevented. But still, a certain probability of occurrence remains. It tends only slowly towards zero, depending on the size of the gate play and the number of load changes. This also explains why to date only a few cases have become known in which carabiners broke during use due to material fatigue, although hundreds of thousands of conventional carabiners have been used in air sports since the 1970s.

However, the danger is that a fatigue fracture usually occurs suddenly and without warning. The two videos from India and Georgia show this drastically.

Infinite fatigue strength is actually standard in engineering, especially in aviation. Due to the problem of gate play, however, there is to date no compact conventional carabiner with infinite fatigue strength. One of the reasons is, that it is difficult to guarantee a low form fit point. Only limited fatigue strengths of 5 years have been achieved so far. But limited fatigue strength involves the general problem that it is not possible to tell how many load changes a carabiner has already endured, and many pilots do not seem to be aware of the potential danger of using it too long. Just recently, at the beginning of 2020, the case of a fatigue fracture in Slovakia became known, in which the maximum allowed operating time of the carabiner was exceeded (see the expert testimony by the Ministry of Transport and Construction of the Slovak Republic of March 26, 2020).

Since standardized tests are still lacking, manufacturers currently apply own test methods and consider different safety factors when determining fatigue strengths. The strength tests described in the following on some currently common paragliding carabiners

>> CIC aluminum carabiner

Aluminum carabiner of the Taiwanese manufacturer CIC, as it is currently used in various harnesses.
Weight: 60 g
Static breaking load: 2 000 DaN
This carabiner withstood 2 000 load cycles with an upper load of 252 DaN and then broke after 68 000 load cycles with an upper load of 115.4 DaN. A limited fatigue strength of 5 years for mono paragliding use is not given. The aluminum carabiner has a rather wide belt support, which in combination with too much gate play led to exceeding the permissible tensions.

>> Camp aluminum carabiner

Aluminum carabiner of the Italian company Camp, as it is currently used in harnesses from Woody Valley.
Weight: 46 g
Static breaking load: 2 000 DaN
This carabiner withstood 2 000 load cycles with an upper load of 252 DaN and then 5 mio. load cycles with an upper load of 115.4 DaN. The very light aluminum carabiner has a rather wide belt support. Since it is relatively flexible, the gate becomes form fit already at low loads. A limited fatigue strength of 5 years for mono paragliding use is given.

>> Edelrid aluminum carabiner

Aluminum carabiner “Forsas” of the German company Edelrid, as it is currently installed in harnesses from the company Advance.
Weight: 51 g
Static breaking load: 2 300 DaN
The carabiner endured 2 000 load cycles with an upper load of 252 DaN and then 5 mio. load cycles with an upper load of 115.4 DaN. With this relatively stiff carabiner, form fit occurs rather late. Due to the extremely narrow belt support, however, this carabiner still has a limited fatigue strength of 5 years for mono paragliding use.

>> Supair steel carabiner

Carabiner made of stainless steel from Supair, as it is still available today.
Weight: 132 g
Static breaking load: 2 400 DaN
The tests in 2005 had been carried out with a lower oscillating loads. This carabiner endured 1 mio. load cycles with an upper load of only 40 DaN and then broke at approximately 740 000 load cycles with only 50 DaN. The measured form fit point was reached at 81 DaN. To achieve limited fatigue strength, form fit would have to be reached at less than 50 DaN.
Since steel has a three times higher stiffness than aluminum, it is particularly difficult for conventional steel carabiners to achieve a low form fit point.
Even in two further tests carried out in 2005 with closed gate, the required limited fatigue strength of 5 years for mono paragliding use according to the method described here was not given.

>> Finsterwalder-Charly Titanal carabiner

The “Snaplock” made of Titanal is produced by us since 2009 for various harness manufacturers.
Weight: 76 g
Static breaking load: 3 000 DaN
The Snaplock withstood 2 000 load cycles with an upper load of 252 DaN and then 5 mio. load cycles with an upper load of 115.4 DaN with open gate. Since the test was carried out with the gate open, it is not relevant that form fit occurs late with this carabiner. Due to the high strength of the carabiner body, the limited fatigue strength of 5 years for mono use is given in any case.

show, that this practice leads to very different results. We have carried out these tests during the development of our own air sports carabiners for comparison purposes.
The tests have been carried out with unused carabiners according to the method described below. It turns out that fatigue strength for a time span of 5 years is not always given, but that there are very different ways to achieve it with regard to carabiner design.

Additional information

What is the reason for material fatigue in conventional carabiners?
For a frictionless movement of the snap gate, there must be a play between the nose of the carabiner and the gate. Due to the manufacturing process, this play has a variation range which cannot be exactly defined. Within the play, the carabiner is being stressed as if with the gate open. The load bearing system corresponds to that of an open ring. Depending on the size of the gate play, the material used and the dimensions of the carabiner, form fit of the gate is given only at a more or less strong load. Then, the load-bearing system is that of a closed ring.

Therefore, when dimensioning the carabiner, two different load cases must be considered: within the gate play (“open ring”) and form-fit (“closed ring”). Depending on its width, the lever arm of the carabiner’s belt support increases the tension by a factor of 20 to 35 in the load case “open ring” compared to the load case “closed ring”. Due to the high tensions in this load case, to date no manufacturer has succeeded in designing a conventional carabiner with small dimensions that has infinite fatigue strength.

How can a carabiner’s fatigue strength for a time span of 5 years be tested?
It is necessary to determine the resistance by means of fatigue tests. A special test method has been developed for this purpose. It uses the findings of the SincoTec test specification 05781 of February 22, 2006, which is based on fatigue tests of various air sports carabiners in 2005 (see the SincoTec test report 05601 of June 13, 2005) (both documents are only available in German):

(1) As infinite fatigue strength (without considering safety factors) for the load case “open ring” (open gate), values between 21 and 90 DaN were determined for conventional paragliding carabiners. The examined steel paragliding carabiners had no higher fatigue strength than the aluminum paragliding carabiners. Infinite fatigue strength is given if the upper limit of an oscillating load is endured 2 mio. times for steel carabiners and 5 mio. times for aluminum carabiners.
(2) For the conventional carabiners examined, form fit was provided only at loads of 15.5 to 214 DaN.
(3) It has been determined, that the upper loads during normal thermal paragliding flight at a total flight weight of 100 kg are 60 DaN. During extreme manoeuvres, values of 210 DaN have been measured. The carabiners should be designed for a total flight weight of 120 kg in mono use and 250 kg in tandem use.
(4) According to the DHV, the frequency of load changes during normal flight is about 37 times per minute. A maximum of 2 000 extreme manoeuvres within 5 years is assumed.

Based on these findings and assumptions, and assuming a safety factor of 1.145 for scratches plus a general safety factor of 1.5, the following procedure results for a carabiner fatigue test with closed gate and a limited fatigue strength of up to 5 years in mono use:

2 000 load cycles with an upper load of 252 DaN, subsequently 5 mio. load cycles with an upper load of 115.4 DaN for aluminum carabiners. For steel carabiners, 2 mio. subsequent load cycles are sufficient.

For a limited fatigue strength of 5 years in tandem use, 2 000 load cycles with an upper load of 525 DaN and subsequently 5 mio. load cycles with an upper load of 240.5 DaN must be endured by aluminum carabiners. For steel carabiners, 2 mio. subsequent load cycles with an upper load of 240.5 DaN are sufficient.

For the proof of infinite fatigue strength according to the general rules of aviation with a failure probability of 1%, the carabiner would have to endure the required 2 or 5 mio. load cycles with an upper load of 432.8 DaN in mono use and 901.7 DaN in tandem use.