



## Kriminalistický a expertízny ústav Policajného zboru

Sklabinská 1, 812 72 Bratislava



Člen Európskej siete ústavov  
forenzných vied - ENFSI

**Submitter:** Ministry of Transport and Construction of the Slovak Republic  
Aeronautical and maritime investigative unit  
6 Freedom Square  
810 05 Bratislava

**File / order number:** 6154 / SL

# EXPERT TESTIMONY

ENG: PPZ-KEU-BA-EXP-2020/1507

**In case:** damage to hanging carabiners used in paragliding - air  
event SK12020001 of 01/01 2020.

**Number of pages (including attachments):** 8 (0)

**Number of copies:** 3

## I. Introduction

### 1. Role of expert and subject of expert examination:

In the case of damage to hanging carabiners used in paragliding flying (air event SK12020001 of January 01, 2020), to prepare an expert opinion from the department of forensic science, from the field of forensic technical diagnostics and forensic chemistry, based on the order of the Aviation and Maritime Investigation 6154 / SL on 3 February 2020 and to answer the questions, respectively, to fulfill the tasks assigned to the expert in the order in question.

### 2. Purpose of the expert opinion:

The expert opinion is prepared for the internal investigation of the causes of the air event SK12020001, dated 01/01 2020.

### 3. Date on which the expert report is made: 26 March 2020.

### 4. Background to the expert opinion:

1. Order of the Aviation and Maritime Investigation Unit, issued under number 6154 / SL, on 3 February 2020, and delivered to the KZÚ PZ Bratislava on 4 February 2020;
2. Piece n°1 - Woody Valley CAMP broken carabiner;
3. Piece n°2 - partially broken Woody Valley CAMP;

## II. Review

In order to ascertain the facts that had to be known in order to answer the questions given in the expert assessment order, the above mentioned carabiners, presented as piece n°1 and n°2 (photo n°1), were examined.



Photo n°1: Woody Valley CAMP carabiners presented as piece n°1 & n°2

Carabiner n°1 was broken just above the bottom bend. It was a fatigue fracture with four initiation regions (see unusual lines of the fracture propagation strips and the resulting four initiation regions and initial fracture propagation directions marked with red and green arrows in photo n°2), as well as the clearly profiled area of the final fracture of the material (indicated by a yellow arrow in photo n°2). The location of the crack initiation areas corresponded precisely to the slight longitudinal surface protrusions at the bottom of the carabiner at the pressure point of the carabiner harnesses (quasi-edges marked by pink dashed line on photo n°3).

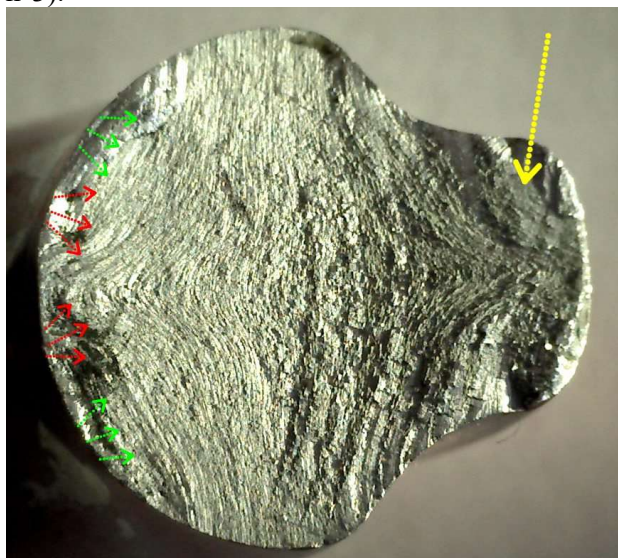
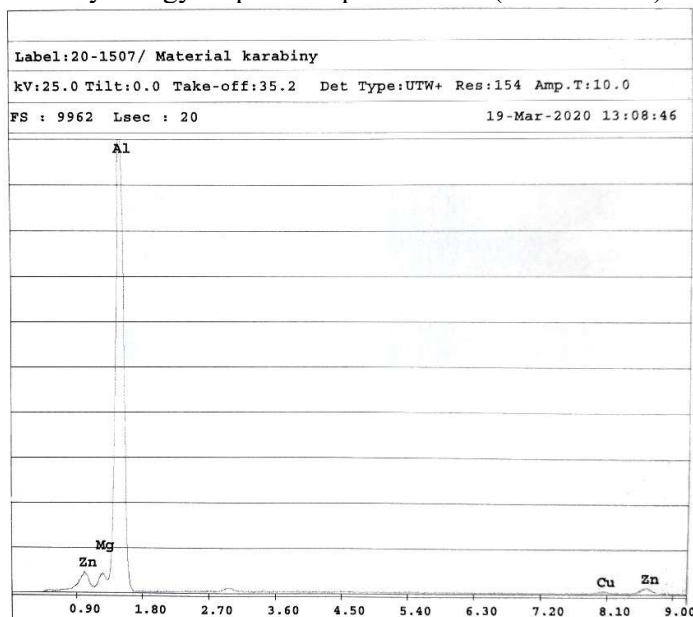


Photo n°2 : Fracture surface with clearly visible progression zones of crack propagation, with clear initiation areas as well as clearly visible area of final material breaking



Photo n°3 : Direct positional correspondence between the fracture initiation areas and the longitudinal protrusions on the supporting working surface of the carabiner

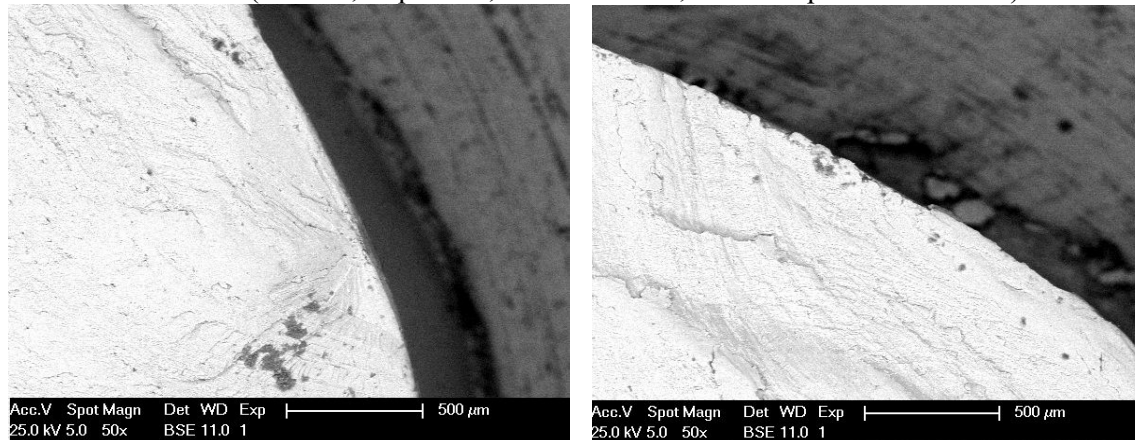
The fracture surface was subsequently examined using a scanning electron microscope with an X-ray energy dispersive spectrometer (REM / EDX).



It was found that the carabiner was made of aluminum very slightly alloyed with zinc, magnesium and copper (see spectrogram n°1). Said alloying elements are added to aluminum alloys in order to improve their mechanical strength properties.

Spectrogram n°1 : Basic material of a damaged carabiner

The initiation areas of the fracture were examined in detail, and no significant material defects were found in them (cavities, impurities, internal cracks, etc. - see photos n°4 and 5).



*Photos n°4 and 5 : Two fatigue crack initiation points of carabiner n°1*

The presence of an initial crack was also found in the same place on the carabiner presented as piece n°2 (photo n°6). From the above findings, it was clear that the occurrence of fatigue fractures in this part of the carabiner (just above the lower bend of the carabiner, on the side opposite the locking mechanism) is not related to any random material defects, but is related to the design of the carabiner. The manufacturer of these carabiners declares their static load capacity of 18 kN in the longitudinal direction and 7 kN in the transverse direction (photo n°7).



*Photo n°6 : The beginning of fatigue fracture on carabiner n°2 in exactly the same places where it was initiated in the case of carabiner n°1*



*Photo n°7 : Static loads declared by the carabiner manufacturer in the longitudinal and transverse direction*

The normal operating tensile load of a carabiner should not reach a value of 1 kN for solo flights (nor when considering the oblique direction of the harness straps and the corresponding vector load distribution), which is significantly less than the declared tensile load capacity of the carabiner. Nevertheless, fractures occurred on both carabiners examined. It is known about aluminum and its alloys that it is not possible to precisely determine the so-called “fatigue limit”, as we know e.g. for steel parts. Thus, with the increasing number of



load cycles for aluminum-based components, the value of the load, which is sufficient to initiate the fatigue mechanism of their damage, constantly decreases, even in the range over than  $10^7$  load cycles.

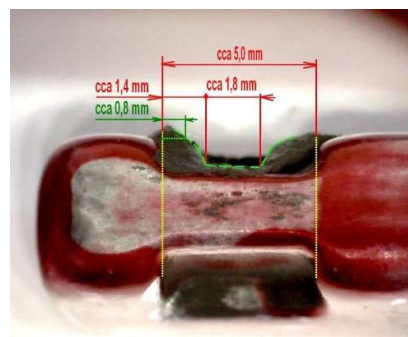
The study was then focused on the working mode of the carabiner in terms of whether it behaves as a closed carrying eye or as an open hook under load. If it were to operate as a closed eye, practically only the axial tensile stress of its bearing cross-section added with a negligible bending stress would act at the fracture location. Another situation would occur if the carabiner worked as an open hook. In such a case, in addition to the axial tension, a significant additional bending stress would also be applied in the damaged area, which could significantly contribute to the proven fatigue damage of the carabiner. In order for the carabiner to behave like an open hook, its locking mechanism (photo n°8) would have excessive gap between the edges of the locking grooves on the fixed part of the carabiner body (groove marked with a light blue arrow in photo n°9) and the contact surface the tilting movable parts of the carabiner (protrusion marked with a dark blue arrow in photo n°9). The approximate value of the gap in this mechanism (in the direction of the applied operating load) was examined on the carabiner n°2 and its value was determined by pressing this locking protrusion in plasticine inserted into one of the locking grooves. Upon subsequent closing and opening of the carabiner in the inserted plasticine, the locking protrusion formed an indentation of a quasi-trapezoidal cross-section with rounded sides (see green dashed line in photo n°10), which was found at the upper edge of the groove, and that this clearance was approximately 0.8 mm (see the green dimension in photo n°10).



*Photo n°8 : Carabiner n°2 and marked side of the locking mechanism where the grooves and protrusion are located*



*Photo n°9 : Half-detail of the locking groove and locking lug*



*Photo n°10 : Location where the locking lug slides into the locking groove*

Furthermore, the tensile load cell and the dial deviation were used to determine the approximate stiffness in the direction of the normal operating load of the type of carabiner under investigation. The tensile test was performed on the carabiner n°2, while in the open (unlocked) state the carabiner was repeatedly loaded with a tensile force  $F = 200$  N, while in the area of the locking groove was measured deformation of the carabiner body in the direction of the applied force = 0.42 mm. From the above findings, it was clear that the carabiner behaves as an open hook up to a load value of approximately  $FI \approx 400$  N (approximately 40 kg) and only at a higher load does the metal-to-metal rest in the locking mechanism and then begin to work as a closed eye. This behaviour can be considered as the main risk factor for the development of fatigue damage of the carabiner in question.

As mentioned above, the fatigue fracture initiation points corresponded to the respective longitudinal protrusions at the point of pressure of the harness straps on the respective support working surface of the carabiner. Thus, in addition to the proven combined tensile-bending stress in the damaged carabiner cross-section, an additional compressive load was applied to the surface of the carabiner, which manifested itself in the position of fracture initiation points, but was not decisive from the material fatigue mechanism. (If the longitudinal protrusions were not present on the contact surface between the straps and the carabiner and the contact surface was smooth and smoothly rounded, the fracture initiation point would probably be only one and the progressive fracture propagation strips would have a slightly different shape).

It follows from the findings that in the given design of the studied carabiners (material, shape, dimensions, etc.) the main cause of the development of the fatigue damage can be considered excessive clearance gap of their locking mechanisms, which caused excessive additional bending stress of the carabiner in the damaged cross section. The direct connection between the surface treatment of carabiners and the initiation/propagation of fatigue crack on the investigated carabiner has not been proven. Mechanical wear of the anodized layer on the surface of the carabiner has no significant effect on reducing the static load-bearing capacity of the carabiner. It can only be considered as a certain visualization of the extent of operational use of the carabiner. On the carabiner, the manufacturer does not state any restrictions on its usability in terms of the number of flight hours or in terms of the maximum time of use of the carabiner, which, due to the impossibility of determining the so-called fatigue limit on components made of aluminum and its alloys can be considered as a serious deficiency.

### **III. Conclusions**

Based on the performed research, we answer the questions asked, resp. tasks imposed by the contracting authority in the resolution as follows:

1. How did the carabiner break and what is the type of fracture – fatigue?
  - The carabiner was broken by fatigue fracture.
2. What is the probable cause of the fracture?
  - What is the probable cause of the fracture? - Given the carabiner design (material, shape, dimensions, etc.), the main cause of the development of the fatigue mechanism of carabiner damage can be considered excessive clearance gap of the carabiner locking mechanism, as a result of which in addition to tensile stress significant bending stress was applied in the damaged carabiner.
3. Is there a crack initiation on the second carabiner?
  - There is a crack initiation on the second carabiner in the same area.
4. Does the mechanical wear of the anodized layer affect the strength of the carabiner?
  - Mechanical wear of the anodized layer on the surface of the carabiner has no significant effect on reducing the static load-bearing capacity of the carabiner.

5. What is the probable degree of fatigue of such carabiner version?
  - In the case of components made of aluminum and its alloys, it is not possible to define the so-called fatigue limit, as we know e.g. for parts made of steel. Thus, with the increasing number of load cycles, the value of the load, which is sufficient to initiate the fatigue mechanism of their damage, constantly decreases, even in the range over than  $10^7$  load cycles.
6. Are carabiners made of such material safe for use in paragliders, motorized and non-motorized gliders? If so to what extent?
  - The usability of aluminum alloy carabiners, if used in paraglider and hang-gliders, should be clearly limited by the flight time or the total service life of the carabiner (due to the impossibility of accurately determining the so-called fatigue limit for components made of aluminum alloys).

After examination, the submitted objects and traces were treated as follows:

- Piece n°1 – broken carabiner Woody Valley CAMP - returned to the client;
- Piece n°2 – partially broken carabiner Woody Valley CAMP - returned to the client.

Items intended for return to the Contracting Authority do not form an annex to this expert opinion and the Contracting Authority will take them over in person, together with two copies of the expert opinion.

For the expert act and incurred costs, we charge according to the bill on the basis of the attached document n°1.

Bratislava, 26<sup>th</sup> of March 2020

They have been authorized and can be heard on the content of the expert opinion:

Ing. Pavol Hrdý - forensic technical diagnostics department

Ing. Adrián Švancár - forensic chemistry department

## **IV. Annexes**

No attachments.

## **V. Expert clause**

The expert opinion was prepared by an expert institute entered in the list of experts, interpreters and translators maintained by the Ministry of Justice of the Slovak Republic for the Department of Criminalistics, registration number of the expert institute 900013. The expert opinion is registered in the diary under the number KEU-BA-EXP-2020/1507. The expert institute is aware of the consequences of a consciously false expert opinion.

We charge the expert act and the incurred costs according to the bill on the basis of the attached document.

Ing. Ondrej Laciak, PhD.

Director of the Criminalistics and Expertise Institute

Police Force

Ing. Pavol Hrdý