Sharp-edge rope testing. Status and prospects

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Motivation and short history

There is no report of accidents occurring in mountaineering due to ropes breaking on the point of contact with a carabiner: the ropes usually break on sharp edges (sometimes by friction on rough rocks). The standard DODERO test, where the rope passes through an orifice over an edge with 5 mm radius, simulating a carabiner, doesn't tell much about the resistance of a rope on a sharp edge.

The firm EDELWEISS repeatedly proposed, since the early 1980s, to test ropes on a straight sharp edge; the proposal was supported by Pit Schubert, but was repeatedly refused by the UIAA Safety Commission on the basis of a number of appreciable arguments, which may be reviewed during the discussion. Recently (1999) the Board of the UIAA asked its Safety Commission to further investigate the problem. As a consequence of this request, the Commission for Materials and Techniques (**CMT**) of the Italian Alpine Club carried out a number of tests on sharp edge failure of ropes on their DODERO at the University of Padova.

At the same time, the CMT was improving its equipment, as described in a companion paper in this Conference, in order to investigate the significance of the energy absorption at rupture on a single drop, at least for the sharp edge case. For a number of reasons the modifications of the equipment were delayed until now, so we can only speak about our programmes concerning the energy absorption method. We hope this helps stimulating discussions and suggestions.

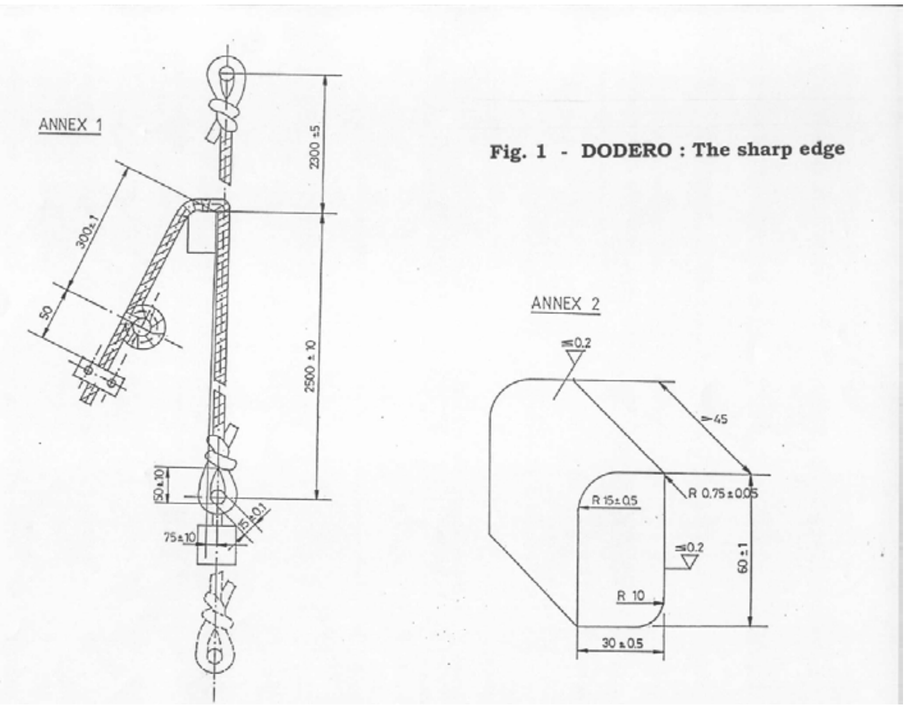


Fig. 1 - DODERO : The sharp edge

Multi-drop sharp edge tests on the DODERO

The edge - The specimens.

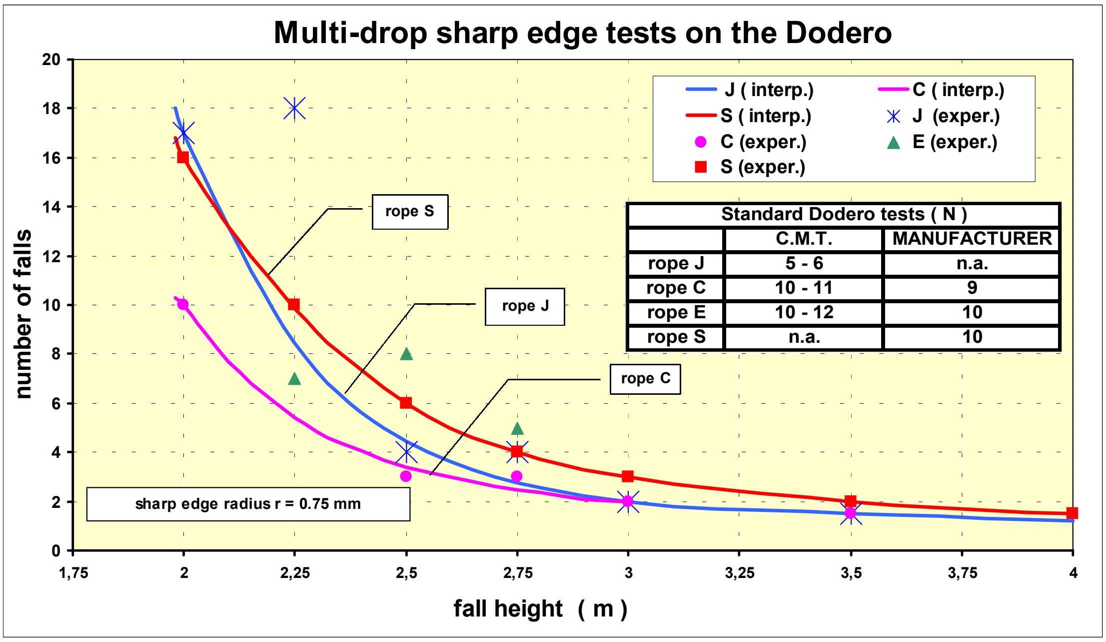
The tests were performed on a straight sharp edge according to **Fig.1**, as proposed for an additional test in the UIAA standard. Most of the tests were made (winter 1999-2000) with a 0.75 mm radius of the edge, some of them (spring 2001) with 0.5 and 0.25 mm radius. Four types of single rope were used, standard length (2.5 m beyond the edge).

The tests with edge radius 0.5 and 0.25 mm are not reported here, since they would not significantly contribute to the conclusions of this paper.

Why multi-drop

The tests were repeated with variable fall heights, smaller than or equal to the standard DODERO height of 4.8 m, in order to achieve resistance to a number of falls considerably higher than 1. The idea behind this is rooted in the history of the UIAA Safety Commission: a reasonably high number of falls must be achieved, in order to be able to differentiate between two ropes (or between two different stages of wear in a given rope), in other words to provide a result that may approach a decent measurement of the rope's performance. Indeed if, say, the resistance to a single fall at full height (4.8 m) were required as standard, it wouldn't be possible to appreciate the difference between a rope which is just able to hold one fall (result : 1) and a rope which is just a little weaker (result : 0).

The same principle lies behind the classical DODERO test, in particular in the case of half-ropes: in the Plenary Session of the UIAA SAFCOMM held in Venice, 1979, Mr Lacoste of the Laboratoire de l'Armée, Toulouse, and the writer of this note proposed a test for half-ropes based on 5 falls of a 55 kg mass: a long set of experiments had been carried out to find a multi-drop test which could, roughly, be considered as equivalent to **1** fall of an **80** kg mass. Resistance to this fall was indeed considered as the minimum requirement for a rope that could have been loaded by the fall of the leader on a single strand.



Standard Dodero tests (N)		
	C.M.T.	MANUFACTURER
rope J	5 - 6	n.a.
rope C	10 - 11	9
rope E	10 - 12	10
rope S	n.a.	10

Figure 2

The tests – a critical view

The ropes had been conditioned for a long time in the same environment (the humidity varied between 60 and 75 %) in the University underground, but not conditioned according to the UIAA standard; this was considered to be sufficient for a preliminary investigation. For the same reason each test was limited to one specimen. The easy interpolation in plotting the results seemed to justify this approximation.

The results of the tests over a 0.75 mm radius straight edge are reported in **Fig.2**. It's a pity that not enough specimens were available to cover the complete range of fall heights for all ropes: in spite of this, Fig.2 is eloquent enough to justify a number of conclusions:

1. Rope S, typically built for resistance on sharp edges, is the best in high falls, but not so much better than rope J, although J has poor performance on the standard test (5-6 falls instead of 10 for rope S).
2. When the fall height is reduced, some ropes tend to become even better than rope S. This seems to depend on the ability of the core yarns to spread over the edge; it occurs when the sheath is soft, particularly so (rope J) when the sheath breaks soon after the first fall, thus allowing all threads to spread freely over the edge. This had been discovered many years before (1980s) by Pit Schubert , but unfortunately not much attention had been given to it.
3. So, whilst going to lower fall heights is necessary to give us something similar to a decent measurement of the rope performance, it leads us far away from the physical phenomena that really occur during failure on a sharp edge. This remark is similar to the reproach that is usually made to the conventional DODERO test, when its ability to simulate the real occurrences during a breakage of the rope in a *single* drop over a

carabiner is questioned; however, whereas in that case that breakage is not probable, in our case (sharp edge) we are trying to simulate a very probable occurrence.

4. We must look for other means of measuring the rope performance over a sharp edge. The prospects of the *energy absorption* at rupture as a significant parameter must be investigated. In addition, measurements of the *breaking load over a sharp edge at low speed* may provide useful information. This matches with the intentions that prompted our CMT to increasing its experimental equipment (as described in a companion paper) in order to perform a real *measurement* of the rope performance; this decision was taken many years ago, but unfortunately our equipment is just ready now, thus it was not possible for us to use it to support the feasibility of this approach.

Measurement of the energy absorption at rupture

Short history

The multi-drop classical DODERO test was subjected to criticisms since it was born, just after the second world war; it was considered to have three main weaknesses:

1) testing occurs over a rounded edge like a carabiner,
2) it is not a real measurement of rope performance *[particularly so at those times, when the number of falls to be held was just 2]* due to the large error caused by a 1- fall difference between two tests. Therefore it is not accurate enough to accurately compare two ropes,
3) there is an obvious difference between the physical phenomena occurring on occasion of a number of falls and those occurring during a single fall leading to rupture of the rope.

For obvious reasons related to the rope technology available at that time, objection 1 didn't lead to any practical initiative, except the one of EDELWEISS mentioned above; objections 2 and 3 led Leonard McTernan, of the National Engineering Laboratory, Glasgow, to develop a DODERO for energy measurement at rupture even for tests over a conventional edge (5 mm radius). To the writer's knowledge, he was first to propose this kind of test. He used a 190 kg mass to bring the rope to failure on a single fall, and an electromagnetic transducer to measure the variation of the speed of the falling mass, thus the energy absorption. That was about the middle 1970s. McTernan's proposal didn't have much success at that time, probably because it didn't provide an answer to objection 1, whilst the improvements in rope quality rendered the objection 2 less stringent as time went by, due to the increase of the number of falls. Objection 3, however, was becoming even more valid with better ropes.

Objection 1 prompted the sharp edge proposal of EDELWEISS, that we are now trying to develop. For sharp-edge tests, objection 2 would play in favour of the multi-drop tests described above; however, the disappointing results of our tests and objection 3 speak in favour of a single drop with energy absorption measurement. So, energy absorption seems to be the best we can propose at the moment. Let us now discuss the prospects - as well as the objections against - this proposal.

Measurement of energy absorption at rupture- Comments and prospects.
Several ways of measuring the energy absorption with sufficient accuracy are now available. The ones available at our laboratory at Padova University are described in a companion paper. Forces and position of the mass are recorded as a function of time, thus enabling us to calculate the energy absorption. The position is measured by means of a laser beam, impinging on a "mirror" attached to the mass.

Several objections can be raised against this method:

a) - there are no clear reasons for choosing a given curvature radius for the edge
b) - the edge of a rock may be sharper
c) - the edge of the rock may not be at a square angle to the rope line, thus its knife-like cutting action may be qualitatively different from the one proposed.
d) - the energy is absorbed by the whole specimen, therefore it has no direct relationship with the phenomena that occur in the short piece of rope touching the edge.

I am trying to respond to these objections in the following way:

- objection a): no rope can stand over a knife blade, we just want to have an indication of the ability of a rope to withstand the action of edges better than other ropes. Moreover, the tests carried out on many occasions by Pit Schubert, comparing different ropes on various edges, down to 0.2 mm radius, have shown that the comparison between ropes is very little affected by the sharpness of the edge. Finally: what else can we do?
- objection b): see previous answer
- objection c): this is a problem. An inclined edge could be used: sensible? I am afraid we must be satisfied with the present proposal; however, we could investigate this alternative with low-speed tests, using the machine described in the companion paper.
- objection d): this objection can also be raised against the conventional DODERO test, and it is more justified there than here: in a single-drop test, a "better" rope will more clearly show its ability to absorb more energy before it is cut by the edge. It will, e.g., be able to stand a fall with a higher fall factor or with a less effective dynamic belay.

The CMT programme
We shall of course use a mass heavier than 80 kg and carry out a large number of tests to investigate to what extent the energy absorption at rupture can tell the difference between two ropes. I am taking the risk here of anticipating what else we could do.

<u>On the DODERO</u>:
with r = 5 mm, M = 80 kg:

- measure the usual N = number of falls sustained

with r = 5 mm, M* > 80 kg

- Fm = maximum force (arrest, Fangstoss) with sharp edge, mass M* > 80 kg:

- Er, energy absorbed at rupture
- compare Er for many ropes, to verify the significance of this test
- Fr, breaking force

<u>On the slow-speed machine</u>, using doubled specimens:

- check the independence of force/elongation curve from speed
- Frs = "static" breaking load on r = 5 mm
- Frsh = "static" breaking load on sharp edge
- compare various types of sharp edge
- study the breaking process with a TV camera

<u>Possible investigations:</u>

- try to find a correlation between Er and the classical N, as an attempt to justify the standard procedures
- try to find a correlation between Fr / Fm and Er
- try to find a correlation between Frsh / Frs and Er

CONCLUSIONS

We believe that we must do our best to develop a sharp edge test; the efforts that we have made in improving our experimental equipment were to a great extent justified by this aim. We are unfortunately confined to speaking about equipment and programmes; we do so because of our desire to take advantage of the opportunity offered by this conference to stimulate discussions and suggestions on the part of a wide and competent audience, such as we would rarely have the opportunity to encounter.