Technical Conference on Nylon and Ropes - Turin, 8 –9 March 2002

Rope testing and wear: equipment of the CMT

(Commission for Materials and Techniques, Italian Alpine Club)

Mechanical features

Patrizio Casavola and Carlo Zanantoni

Summary

This presentation covers:

a DODERO for energy absorption measurement,

a slow-speed rope testing machine,

a machine for artificial rope wear.

1 - Why are presenting a description of our equipment at this Conference?

Our machines are just operational now. We were bold enough to – unfortunately very slowly – have them built, though we knew that their full advantages had still to be demonstrated by practical experience. We are bold enough to present them now, since we hope that useful comments, criticisms and proposals will be provided by the audience.

2 - Why new equipment?

The DODERO.

The recent UIAA-CEN review of DODEROs' performance prompted the CMT to modify its DODERO, located at the Laboratory of the Padova University. Other modifications had been planned a few years before: the measurement of energy absorption at rupture was indeed considered to be a promising way to transform the DODERO into a device suitable for a real *measurement* of rope's performance. A careful evaluation of this performance is necessary to proceed with our studies on rope wear: the accuracy and the very significance of the measurement of the number of falls at the DODERO were not considered to be sufficient for our studies about rope wear, which require accuracy in comparing different stages of rope degradation.

The low-speed machine.

The DODERO will almost certainly continue to be the basic instrument for the qualification of ropes: the force is determined by the properties of the rope itself. However, for a number of studies, quasi- static tests may be useful. E.g., the breaking load is practically the same in dynamic and static conditions; the breaking process can be studied carefully by filming a slowly proceeding breakage; static tests may be found out to be good enough for comparing various stages of degradation of a given rope.

Let us not insist too much in trying to guess what we could do. It is sufficient to say: the aim of the CMT is to try and substitute dynamic tests with "static" (low-speed) tests whenever we can. If it turns out that, *for our purposes*, the force/elongation curve for a rope can be considered independent from the elongation speed - as many tests suggest – this machine could frequently be used instead of the DODERO.

The machine for artificial wear

The results of the tests on worn ropes carried out during the last two years are presented in a companion paper. The conclusion of that paper is that the tests must continue: there is still a long way to go for achieving satisfactory evaluation of rope wear. The tests performed on ropes worn "in the field", i.e. mountaineering and climbing, are necessary for obvious reasons, but require a lot of time; in addition, the history of the specimens is not accurately known (what percentage of abseiling/climbing, atmospheric conditions, various terrains etc.). For this reason the CMT has decided to build a machine, where a rope can undergo friction under a specified load in defined conditions. An annulus of rope runs through a braking device; the tension of the rope is kept constant, e.g. at 40 kg to simulate abseiling. The rope can be clean or made dirty by passing through different types of rock powder of given granular size, or by rolling with water and rock powder in a revolving sifter. Various braking devices can be used, friction over rock can be simulated (not done yet). One tour of the annulus is equivalent to one pitch in "climbing" or to one "abseil of one person". It is perhaps too early to express optimism about this way of simulating the real wear, but the data presented in a companion paper show that the results in terms of rope degradation are in line with real rope wear. Frankly, we are still wondering about this; further investigations are necessary. Obviously, improvements can be made in our procedure.

3 – The DODERO

Our DODERO is characterised by:

- Laser measurement of mass position during the fall (accuracy: 1 mm)
- electronic equipment to record forces and mass position as a function of time. The energy absorbed by the rope can therefore be accurately calculated. This equipment is described in the companion paper by Claudio Melchiorri.
- variable distance between the line of fall of the centre of gravity of the mass and the orifice. This feature was designed when the UIAA Safety Commission was discussing about this distance. It was decided that keeping it variable could add something to our DODERO, in the sense of making it possible to investigate the role of the inclination of the rope during the braking action. During the UIAA enquiry, the horizontal component of the force, acting on the guiding columns, was found to be important in generating a braking action on the falling mass; therefore, the above-mentioned distance was defined in the rope standard as 80 ± 10 mm (when measured from the *middle plane* of the orifice). A DODERO where this distance can be reduced to "zero" (better: as much as necessary to have the rope vertical) may provide useful elements for further improvements. A vertical position of the rope could also reduce the absorption of energy due to vibrations in the rope; this absorption reduces the amount of energy that goes into rope elongation, hence rope tension. This energy loss is practically the same in all DODEROs for a given rope, but not so obviously the same for different ropes. How much does the inclination of the rope affect this energy?

A variation of the inclination of the rope requires departing from the classical DODERO design in two ways: possibility to adjust the horizontal position of the orifice and (in our design) modification of the mass suspension system.
In the following, reference will be made to the **"head of the DODERO"** as the structure that contains the orifice. *The distance between the **outer surface** of the orifice plate and the plane of symmetry of the guiding columns will be called* **δ.**

Variation of the position of the orifice.
The conceptual scheme of our DODERO is described in **Fig. 1**. The measurement of the vertical component of the forces is assured by supporting the DODERO "head" with a frictionless sliding structure, based on ball guides. The horizontal position of the orifice can be manually adjusted; in this way, δ can be varied between **100** mm and **zero**; in the latter case, the rope can be kept completely vertical during the braking action (with δ = ½ rope diameter). **See also the 3D pictures**.

The mass suspension system
The line of fall of the centre of gravity of the mass must lie on the plane of symmetry of the mass-guiding columns; the point of attachment of the rope to the mass must also lie on this plane. This means that the point of attachment would hit the orifice if δ were brought to zero. This is avoided by changing the mass suspension system: the mass is

attached to the rope by means of a rotating fork, which is kept horizontal by a magnet until after the mass has passed the orifice; it is then brought to a vertical position by the pull of the rope.
The fork and the mass are described in **Fig. 2:** the "mirror" for laser measurement of the position of the mass is visible in the upper part of the mass.

The rotation of the fork is arrested when it reaches the vertical position; a small freedom of rotation (2 degrees) is allowed in order to make it possible for the fork to act as a "prolongation" of the rope, in case δ is not zero. A standard DODERO fall can be obtained by having $\delta = 75 \pm 10$ mm and setting the fork vertical before the fall.

For low values of δ, the initial position of the fork must be horizontal: the amount of kinetic energy absorbed by the rotation of the fork causes a certain amount of concern, although the fork is prevented from rotating after reaching its vertical position. Theoretical evaluations of this energy have been carried out, but an experimental confirmation is awaited.
It will be interesting to evaluate the amount of energy absorbed by rope vibrations in a conventional DODERO; it may turn out to be larger than the energy involved in the rotation of the fork.

To the writer's knowledge, there is only one other DODERO where it is possible to bring δ to zero: the EMPA DODERO, t Gallen. In this case, the modifications have not been made on the mass, but on the "head" of the DODERO: this is quickly shifted horizontally into its normal position *just after* the falling mass has passed it. The EMPA DODERO is a nice piece of mechanical engineering; it is a pity that no representative of EMPA is here, it would have been interesting to discuss their motivations and prospects.

4 - The low-speed machine

This machine is devised to measure *and record* the force/elongation curve of a rope *at various speeds* and the breaking load of the rope. The speed can be varied at steps between 27 and 200 mm/s; the steps can be achieved by changing the number of poles in the asynchronous motor from 4 to 8 and by using a gearbox. Continuous variation could be obtained by means of an inverter, but this is not foreseen at the moment. The maximum force developed varies between 60 kN at high speed and more than 200 kN at low speed. In this way, not only a single strand of rope can be brought to breakage, but also an annulus; this is useful for testing the effect of sharp edges on the rope breaking strength and to avoid rope slippage at both ends of a specimen.

When a single strand of rope is tested, the ends of the specimen are held by two "heads", on which a single loop is sufficient to hold them; nevertheless, the elongation of the specimen cannot be measured by the position of the "heads", it must be deduced from the positions of two reference points on the specimen. This is carried out by means of two TV cameras, as explained in the companion paper by Claudio Melchiorri. In spite of this, a considerable length of the specimen is necessary to achieve good accuracy.

The length of the specimen can be about 3 m; the maximum run of the head is also about 3 m. The total length of the machine is about 8 m. **See photos**.

The movement of the head is achieved by means of two ball screws (pitch = 20 mm); their speed is constant, with an error of about 2 – 3 % at the most usual loads, slightly worse at the highest loads.

5 – The machine for artificial wear

The concept is simple: the rope, passing through a friction/wear generating device, is pulled by friction on a rotating drum, on which the rope is wound a few times. The rope

is arranged in the form of an annulus, which is at present 30 m long, in order to provide specimens for a number of tests. Closing the annulus is not at all easy!
Suggestions are welcomed !! At the moment, **careful** cutting and pressing the molten ends is used.
The tension of the rope can be determined by the weight of the long rope, hanging horizontally between four pulleys, and by changes in the position of one of the pulleys. This requires control by the operator, who must anyway be present, since the length of the annulus varies during the test. Therefore an additional control is provided by a vertically sliding pulley, loaded with appropriate weights.
The **photos** provided can give an idea of the equipment and of the amount of space necessary for its operation.

As already mentioned, several ways of introducing debris in the rope are provided; however, our experience with these devices is too short to enable us to draw conclusions about the effectiveness of those procedures.

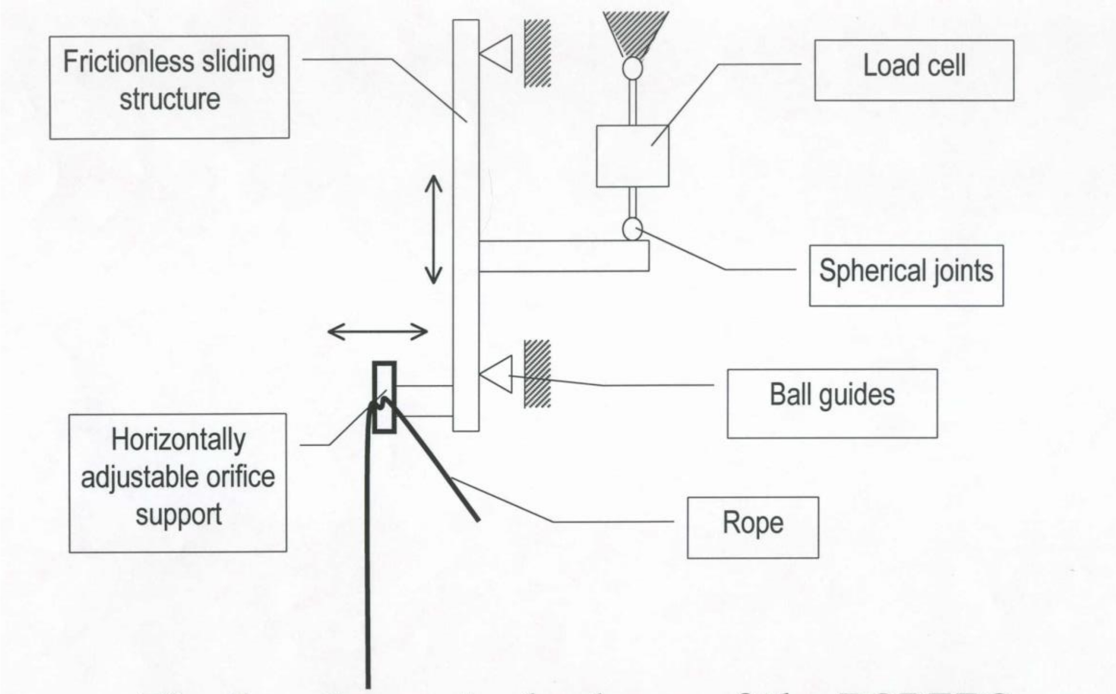

Fig. 1 - Conceptual scheme of the DODERO

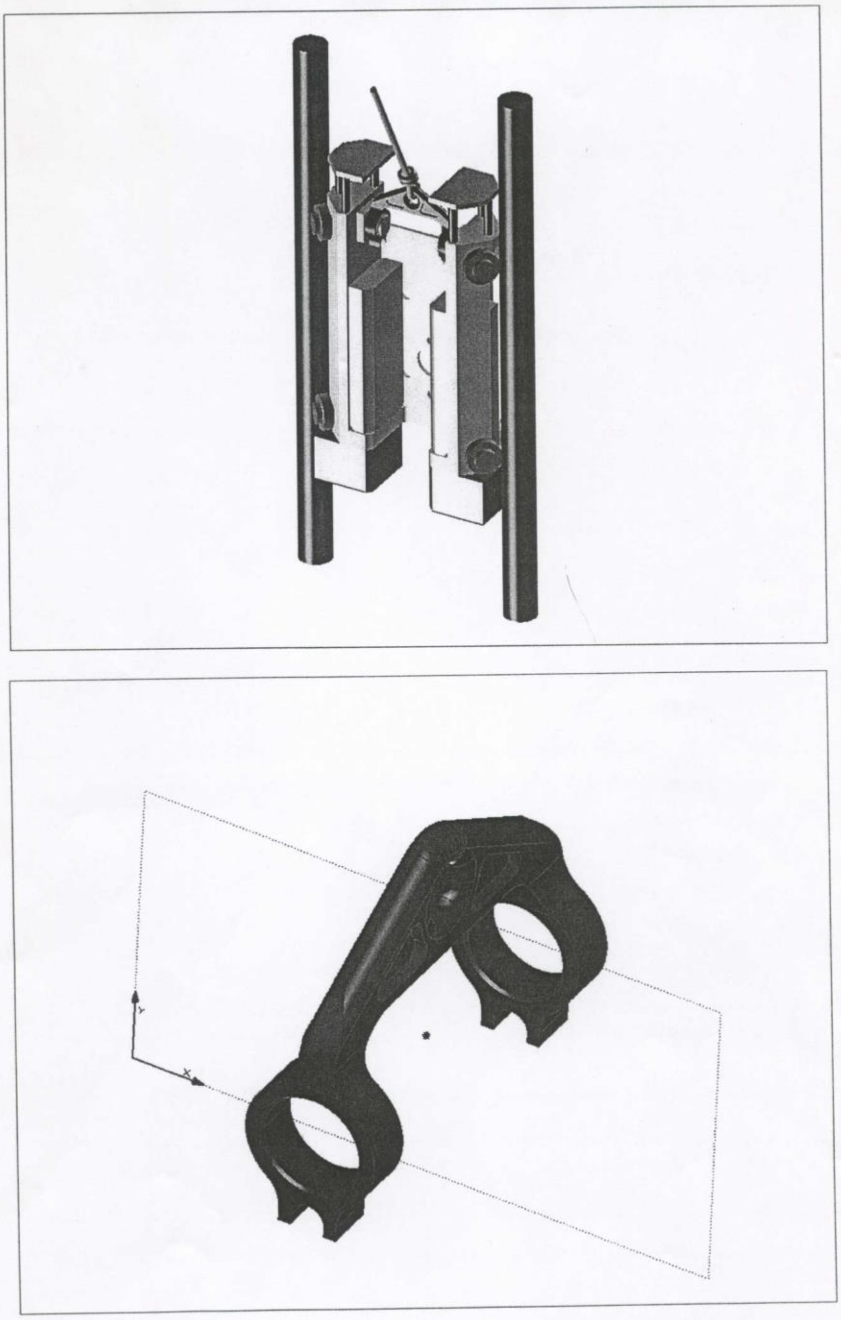

Fig. 2 - DODERO : The mass and the fork