Baena-Extremera, A. y Granero-Gallegos, A. (2012). Desarrollo de un modelo de utilidad en descensores para deportes de montaña / Development of a utility model in descender for the mountain sports. Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte vol. 12 (48) pp. 681-698 Http://cdeporte.rediris.es/revista/revista48/artdesarrollo315.htm

ORIGINAL

DEVELOPMENT OF A UTILITY MODEL IN DESCENDER FOR THE MOUNTAIN SPORTS

DESARROLLO DE UN MODELO DE UTILIDAD EN DESCENSORES PARA DEPORTES DE MONTAÑA

Baena-Extremera, A.[1] y Granero-Gallegos, A.[2]

1 Doctor of Physical Education. Professor of Adventure Sports. Facultad de Ciencias del Deporte (Universidad de Murcia, Spain) abaenaextrem@um.es
2 Doctor of Physical Education. Professor of Activities in the Wild. Facultad de Ciencias del Deporte (Universidad de Murcia, Spain) agranero@um.es

Spanish-English translators: Inés Vasco Díez; inesvasc@gmail.com

Código UNESCO / UNESCO code: 3315.01 Tecnología metalúrgica del Aluminio / Metallurgical Technology of Aluminum
Clasificación del Consejo de Europa / European Council Classification: 17 Otras: nuevas tecnologías aplicadas al deporte) / Others: new technologies applied to sports.

Recibido 7 de noviembre de 2010 **Received** November 7, 2010
Aceptado 27 de abril de 2011 **Accepted** April 27, 2011

THANKS

To the South Fire Station of Granada (Spain), for being allowed to do friction tests at the Tower of Vertical Maneuver Techniques. To D. A. Lorca from the Scientific Calculation Service of the CSIC, whose counseling allowed us to do the tests and computer calculation simulation of the new device.

ABSTRACT

Mountain sports constitute one of the most practised and with the highest technological development disciplines in the world in recent years, creating materials mostly made of steel and aluminium. The aim of this paper is to present the way a utility model has been designed and constructed, innovating on a previously existing "eight descender", made of aluminium 7075 T6 and offering greater utility than the previous product. Five interviews have been done to experts, and the program Catia V5 has been used with simulation tests of strength, supporting up to 18 kN in the longitudinal axis. Later, it has been proved and compared to the eight existing model by experts, verifying the proposed improvements. This innovation is less bulky and heavy than other descenders, and has more uses than "eight descenders", such as a higher friction with possibility of graduation.

KEYWORDS: descender, mountain sports, innovation, utility model.

RESUMEN

Los deportes de montaña constituyen unas de las disciplinas más practicadas en el mundo, y que mayor desarrollo tecnológico han experimentado en los últimos años, creándose materiales fabricados en su mayoría en acero y aluminio. El objetivo de este artículo es presentar cómo se ha diseñado y fabricado un modelo de utilidad, innovando sobre un descensor ya existente, fabricándolo en aluminio 7075 T6 y ofreciendo una mayor utilidad que el producto anterior. Se han realizado cinco entrevistas a expertos, y se ha utilizado el programa Catia V5 realizando las pruebas de simulación de fuerza, soportando hasta 18 kN en su eje longitudinal. Posteriormente, se ha probado por los expertos y se ha comparado con el modelo en ocho existente, verificando las mejoras propuestas. Esta innovación es menos voluminosa, menos pesada que otros descensores, y presenta mayores utilidades de los descensores en ocho, como un mayor rozamiento con posibilidad de graduación.

PALABRAS CLAVE: descensor, deportes de montaña, innovación, modelo de utilidad.

1. INTRODUCTION

The number of people practicing such mountain sports as climbing, mountaineering, canyoning, etc, has increased highly in the last decade, thus contributing to an increase of the scientific interest in these disciplines (Giles, Rhodes and Tauton, 2006; Sheel, 2044; Watts, 2004). This results in an increasing research and development, both in techniques and materials, which give place to new products which make sports practice safer and much better. One of the great innovations in climbing was the use, in 1940, of such materials as steel to make carabiners and the later development of other elements such as SPITS (España-Romero et al., 2009). These materials made it possible for this sport to develop worldwide, offering the possibility to climb, for the first time in human history, the high lime walls of Eastern Alps, thus highly increasing the scientific interest in this discipline. However, due to the lack of this material during the Second World War, Bill House, a mountaineer belonging to the U.S. Army material development team, collaborated with Alcoa Company to produce the first carabiners made of aluminum alloy (S-T 24). This type of aluminum presents low density and it was three times lighter than the existing steel carabiners, although having a similar resistance, thus the rest of the climbing devices started to be made of this metal. Nowadays, most of the descenders, carabiners and other metal devices typical of these sports are made of aluminum alloy, and are subjected, as Schubert (2007) explains, to a heat treatment to increase their alloy resistance. If it is accurately carried out, the heating and cooling process results in alloy T6, being one of the most useful processes to get high resistance (Toledano et al., 2010).

As we can see, sports technological development is giving place to safer disciplines, allowing sportsmen and women to improve their performance (Schad, 2000). It is in this technological development where we can find descenders, which are the materials most often used in climbing and mountaineering. Descenders are devices used to go down on a rope in rappelling, and sometimes to fasten a partner, using it as a brake in case of fall (Peter and Peter, 1990; Long, 1997). The basic principle of all descenders is to pass a rope through the descender to give place to a friction force so as to balance the lowering speed, or to stop a climber falling down. The friction force of common descenders varies from 1.0 and 3.0 kiloNewton (kN, where 1 kN equals 100 daN or 102 kg of force) (Randelzhofer, 1997), according to its performance, the force of the fastener and the rope stiffness among other factors.

Nowadays, metal devices, such as carabiners and descenders are part of the Individual Protection Equipments (E.P.I.) used by firefighters, mountaineers, workers, and even the Civil Guard, and are regulated by the law 89/686/C.E.E., where these metal items are included in the third category. According to Bianchi, Gallo, Mantovani and Zappa (2003), the design and making of the E.P.I. of third category is subjected by law to a series of very strict requirements, which are to be taken into account by the commercial brand if they want to get a European Conformity mark (C.E.) issued by an authorized control institution. The C.E. brand distinguishes the certified materials and devices according to European certification regulations, where the relative reference norms are not a quality mark, but a conformity testimony regarding resistance tests.

In order to understand the tests used for its regulation, they will be explained below, so as to understand the force generated to break any climbing equipment.

Impact force

The impact force is the strong pulling movement transmitted to the climber (who is falling down) in the precise moment of fall detention. It is the residual force, which is not spread over the different elements of the safety chain nor by friction (Creasey, Banks, Gresham and Wood, 2008; Luebben, 2007).

The International Mountaineering and Climbing Federation (U.I.A.A.) tests the impact force of metal devices using a blocked rope (in the hardest case). If a static rope is used in climbing, in case of the climber's fall, the physiological safety limit would be exceeded, due to the effect of a very strong deceleration; such physiological limit has been established as 15 times a person's body weight, which, if we take a standard weight of 80 kg, would be equivalent to a force of 1200 decaNewton (daN) (1 daN = 1.02 kg force). This force should be supported by all the metal pieces, such as carabiners and descenders, among others (Bianchi et al., 2003; Schad, 2000). If a carabiner did not support more than 12 kN, it would break in the case described above. Besides, we must consider the tests proven on the fall factor. This factor is the relation existing between the flight length when the climber is falling down (H) and the rope length between the belay station and the climber (L). Taking into account some exceptional cases, the numerical value is usually between 0 and 2 (in the worst cases).

The following are four possible cases, to see how many kN must be supported by the metal devices (Figure 1 and Table1).

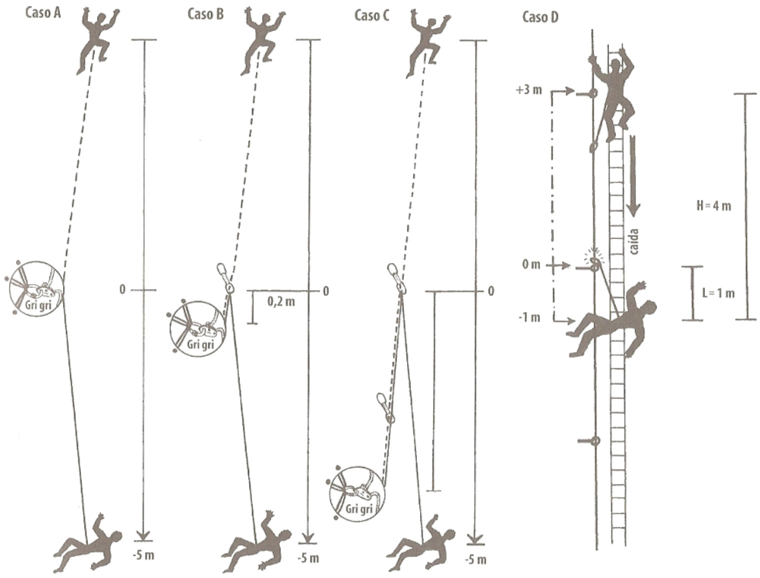

Figure 1. Impact force (see Bianchi et al., 2003, p. 17)

Table 1. Impact forces.

	Case A	Case B	Case C	Case D
Climber's fall	10 m	10 m	10 m	4 m
Dynamic rope length	5m	5,2m	9m	1m
Fall factor	2	1.9	1.1	4
Impact force of climber's metal device	**8kN**	**7.5kN**	**5kN**	**16kN**
Impact force of anchor's metal device	**8kN**	**14.5kN**	**12kN**	**16kN**

As it can be seen, in case A the climber falls 10 meters (m), having a rope length of 5 m, so that the fall factor results in 2 with an impact force of 8 kN. In case B, the difference is based on the fact that the fastener has a 0.2 m rope up to the anchor of the belay station, the rope length being 5.2 m, which reduces the factor to 1.9, with the same fall length. In case C, the fastener is placed below, the climber falling down 10 m, but the rope length is now 9 m, which reduces the fall factor to 1.1 and the climber suffers an impact force of 5kN. The hardest factor occurs in via ferrate, because the fall is usually 3 m in addition to the length of the lanyard (1 m), the impact force on the climber being 16 kN.

Metal pieces break test

The European Committee for Standardization establishes that the materials such as carabiners must support a minimum of kN, regulated by the EN 12275 regulation. These pieces must resist 20 kN minimum in a longitudinal load with a closed gate. This figure is based on the 12 kN limit imposed on the climbing ropes. The European Committee for Standardization requires a minimum resistance of 7 kN with an opened gate, although some new versions of carabiners support up to 10 kN with an opened gate.

As Schubert and Stückl (2007) explain, a load is applied in each test, which is increased in a controlled proportion until one of the devices suddenly loosens. The load is secured by two 12 mm greased steel screws, which are progressively torn apart until they break (see Figure 2).

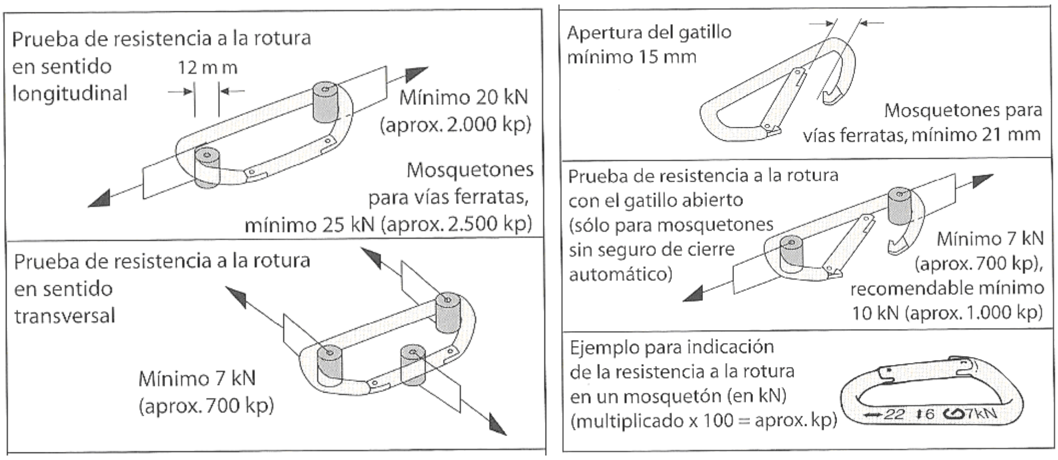

Figure 2. Carabiner break test (Schubert and Stückl, 2007, p.85)

In addition, it is important to say that the cross section of carabiners and other metal pieces, including the angles on which the rope leans, are not issued by regulations. Some years ago, the usual aluminum thickness was 8 to 10 mm, but several models 6 mm thick have recently appeared. This measure in descenders and carabiners are resulting polemic, because the certification tests for ropes are being carried out over a cylinder 10 mm in diameter.

As for descenders, according to Marbach and Torute (2003), they may not be subjected to any compulsory regulation if their characteristics are to be taken into account. For example, if they have a self-block system they should respect the EN 341 rule, which refers to rescue descending devices of the same category. There are several descender models, having both advantages and disadvantages, as it will be seen below. We will deal with non self-block system, which do not need to fulfil any U.I.A.A. or C.E. regulations, and will try to overcome the disadvantages present in existing devices such as the *eight descender.* Thus, the main objective of the present essay is to explain the analysis carried out to design and make a new descender, able to support a minimum of 12 kN on its longitudinal axis (which is the maximum resistance supported by a rope, as seen above), and having more advantages in its use than the *8 descender*. The new design focuses on a wide range of mountain sports and activities, such as canyoning and rapelling, without forgetting climbing and speleology.

2. MATERIAL AND METHODS

Below is an explanation of the layout and patent of a new aluminum climbing material. This innovating idea arose due to the necessity to make a new rope descender, similar to the 8 descender, through which the rope passes, provoking a friction movement which helps the climber to descend (Figure 3).

Figure 3. Eight descender in descending position.

The *eight* may be considered the best sold aluminum metal device. It is cheap, versatile and offers a lot of possibilities, and disadvantages, such as:

- In order to pass the rope through it, it is necessary to take the piece out of the carabiner, which may cause its loss or fall.
- It is not a suitable device when the person descending exerts a strong force movement downwards (in case s/he carries a heavy bag, a wounded person or when s/he is placed under a waterfall several meters down). In this case, the friction movement would not be secure enough.
- As for its small friction movement, it is not advisable for big rappelling.
- It has some disadvantages when the belay stations are being set up.

Taking all the previous cases into account, which have given place to lots of climbers' falls and deaths through history, we found it necessary to improve the device introducing the following innovations.

2.1. Material design

In order to solve these problems, we found it necessary to include a third ring in the 8 descender, with a 102º angle, calculated from the degree obtained in the laboratory for the standard disengageable position of two eights. Among the new utilities of the utility design we can point out:

- A blocker, such as Shunt (belonging to Petzl brand), can be installed.
- It offers a progression in the descending friction movement, thus increasing its intensity according to the position of the rope in the new ring.
- It can be used as any other eight descender, but it does not need to be taken out from the carabiner when passing the rope through it, avoiding its loss if it falls.
- Besides, it has the best shape to make a disengageable belay stations setting up (the safest method), one of the most practiced sports in the world.

From that moment on, the following design was created in three different sizes, so that several experts could give their opinions about the most suitable one (Figure 4). One of the premises to take into account in its design was the inner diameter of the rings, because the bigger ring should be wide enough for double rappelling using ropes of 12 mm maximum, and the smaller rings should be wide enough to introduce a simple rope of 12 mm maximum as well as a carabiner.

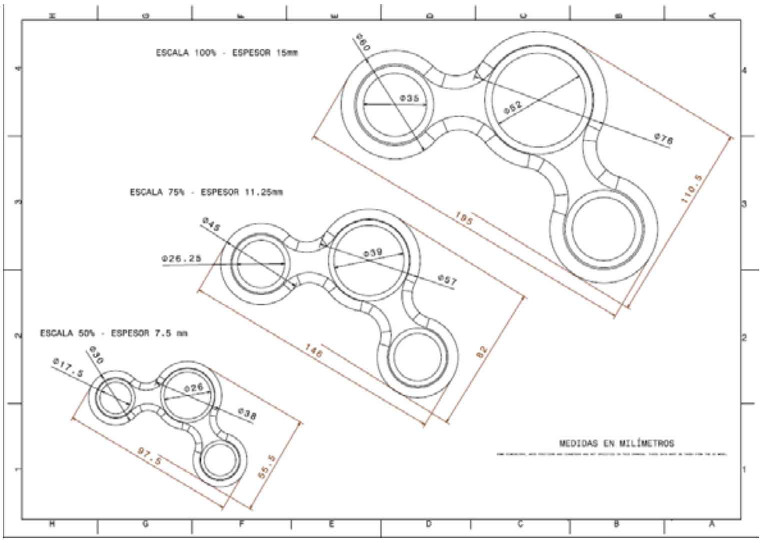

Figure 4. New descender layout in different scales.

2.2. Interviews to some experts

When the shape design was finished, five interviews were made to several experts. In the first place, a structured interview draft was written containing some specific questions previously established (Colas and Buendía, 1994). Later on, so as to improve the content of the interview both from the scientific point of view and from the slang used, the questions were discussed in collaboration with two skilled climbers who did not participate in the interview. Finally, the final interview took place.

In relation to the procedure, three of the interviews were done on professional testers of different sport material international brands, so as to take their opinions about the usefulness of the new device into account. The interviews were done between January and June 2010, the interviewee not knowing the reason for the interview (to avoid possible biased opinions) nor the other people interviewed. Each one of the interviews lasted from 50 minutes to one hour, and was privately recorded. During that time, each expert was given the drawings (Figure 4), an 8 descender and a climbing rope. During the following 15 minutes, s/he was asked about the advantages and disadvantages of the 8 descender. Later on, s/he was shown the new prototype in a 1:1 scale (in relation to the real size of the 8 descender) as well as its functions, so that s/he could compare and give an opinion about the real possibilities of the device. All their comments were written down on a notebook and a *verbatim transcription* (Morse, 2007) was made for future reviews.

Once ratified by experts, two high-level athletes were interviewed. The first interview was done on a high level mountaineer in July 2010, and it lasted one hour. He was shown the material, its properties and was given the opportunity to test the previously mentioned 1:1 sample for two weeks. When this period was finished, he was interviewed again for one hour and a half, where he gave us all the information gathered during the fortnight testing period.

In August the last interview was done on an expert mountaineer firefighter, who has climbed the Everest and Mont Blanc, among other mountains. The process of the interview was similar to the previous one.

2.3. Register on the Industrial Property Official Bulletin

After gathering all their opinions and assessing their suggestions, a new shape was given to the descender, as follows, opting to a 85% scale, with respect to the 1:1 scale, with similar measures in relation to the 8 descender, as recommended by the different simulation results.

Figure 5. Descender final shape.

The material was registered through a Utility Model [nº 201000147 (8)], assigned to and published in the Industrial Property Official Bulletin, 4 August 2010.

2.4. Type of metal and simulation procedure

The next stage in the process was to make some computer simulations using different materials, in order to find out the most suitable properties according to our needs and to what the experts had previously advised us. After analyzing the different metals we decided to use Aluminum 7075 T6, which has mostly been used in aerospace industry (Badía, Antoranz, Tarin, Simón and Piris, 2004; Gil, Jiménez, Castro, Puchi-Cabrera and Staia, 2008) due to its mechanic resistance and low weight, and which presents the following characteristics (Tables 2, 3, 4).

Table 2. Characteristics of Aluminum 7075 T6.

Material	Young's Modulus(GPa)	Poisson's ratio	Density	Performance	Coefficient of thermal expansion
ALUMINUM 7075 T6	72	0.35	2.8 g_cm3	480MPa	2.36e-005_Kdeg

Table 3. Chemical composition of Aluminum 7075 T6.

%	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti		Others	Al
Min	0,40	0,50	1,20	0,30	2,10	0,18	5,10	0,20	Zr + Ti 0,25	0,15	Rest
Max			2,00		2,90	0,28	6,10				

Table 4. Mechanic properties of Aluminum 7075 T6.

					Stiffness	
State	**Tensile strength Rm N/mm^2**	**Elastic limit Rp 0.2 N/mm^2**	**Elongation 5.65 V So**	**Windshear resistance N/mm^2**	**Brinell (HB)**	**Vickers**
0	280	150	10	-	-	-
T6	540	480	11	330	145	157

Once the material was selected according to its properties, we used Catia V5 application, which was developed by Dassault Systems and distributed by IBM, because it is the best application used to design and make new products. According to Fernandez (2005), this software makes it possible to design a three dimensional metal device, to define interactively mechanical operations to be performed on the initial stock, and to generate a numerical control application in APT language (Automatically Programmed Tooling; that is, a high level language to define numerically- controlled mechanic operations). In addition, this software is an integral design application, covering CAD/CAM/CAE/KBE/PDM (Design/Mechanization/Finite Elements Calculations/Knowledge management/Product management), thus allowing us to make the necessary simulations.

2.5. Comparison with other descenders

In order to be able to compare it to other previously existing descenders, a friction test was carried out at the Vertical Technical Maneuvers Tower at the South Fire Station in Granada (Spain) (Figure 6), where our device was compared with other descenders of its range, such as the *usual 8 descender* and the *SFD8,* which is the most similar to ours. The test consisted in performing 10 free falls with an 80 kg weight up to 2 m in each of the descenders, so as to calculate the average of each of the devices after studying its kinematics and dynamics. This procedure has been recorded with a Casio High Speed Exilim EX-FH20 Digital Camera, 40 fps continuous shooting, in order to be able to calculate the fall speed of each frame.

Figure 6. Eight descender friction test (left) and innovation test (right)

3. RESULTS AND DISCUSSION

In relation to the results obtained from the interviews, the three experts showed surprised and interest in the new product (**Expert 2**, "I consider its shape very appealing, I would have to test it, but it looks like having a lot of utilities at first sight"), mainly because it offered a solution to the usual problems of the 8 descender.

> **Expert 1:** "*Yes, yes, yes, if we actually pass the rope through the bigger ring and pass it through the other ring, we would not have to release ourselves obligatorily while descending, which is a very interesting utility*".
>
> **Expert 2:** "*Right, it is possible that, as I can see in the utilities shown, it would actually been well designed for a disengageable belay station, something which is very difficult when using the 8 descender*".
>
> **Expert 3:** "*My question arises when I want to exert more friction, because, when you are using the 8 descender, you must carry out some techniques, called Vertaco, I don't know if you know them; on the contrary, it is clear that, if you use this device, more or less friction can be exerted during the belay, without having to take out the descender. I think it is a very good idea*."

Furthermore, the five experts agreed to suggest that we should make the device at lower scale than the original we had shown them (scale 1:1, see Figure 4). In addition, the last two experts thought it a good idea to lower its weight (**Expert 5:** "*In our job, as in climbing and mountaineering, it is essential to lower the* *weight. Many companies even change a small aluminum screw in the carabiner and put it another made of titanium because it is less heavy and they can leave some grams out. Imagine the importance of the weight when you are pulling 100 carabiners down on a 500 m wall! I would also recommend you to make a smaller device. If you were able to design a descender with a break resistance over 12 kN, with smaller rings than the one I have, it would be a great advance, and would deserve our attention as well*"). For that reason, if we reduce its size, we would lower its weight as well. Thus, the final shape selected by the experts and designers of this new product was an 85% out of the 1:1 model and with a thickness of 12.75 mm Aluminum 7075 T6. Thus, we got the lowest weight and the maximum strength required by our innovation.

The first three experts agreed to suggest a smaller size in the piece of metal connecting each ring to the other (the neck), so that the weight should be reduced as well, without losing its usefulness, as it occurs in the recently created SFD8 descender.

Besides, the five experts unanimously agreed to reduce the size of the inner circles of the central and lateral rings, provided that the central diameter would be 40 mm minimum, enough for double 12 mm ropes.

In order to take a final decision with regard to the measurement parameters, different shape distortion simulations were carried out, developing the forces specified in Table 5 below:

Table 5. Values of the computation direct method.

Components	Force development	Reaction	Residues	Error relative magnitude
Fx (N)	-2.3842e-007	2.3760e-007	-8.2241e-010	3.3246e-0
Fy (N)	**1.8000e+004***	-1.8000e+004	5.3697e-009	2.1707e-0
Fz (N)	-4.0531e-006	4.0528e-006	-3.2958e-010	1.3323e-0
Mx (Nxm)	-1.1475e+002	1.1475e+002	-4.0245e-011	1.3317e-0
My (Nxm)	2.8355e-008	2.8354e-008	-5.6457e-013	1.8681e-0
Mz (Nxm)	4.1057e-008	-4.0934e-008	1.2300e-010	4.0700e-0

The simulation brought up some shape distortions (see Figure 7), though any breaks, and we decided to do some additional tests to calculate the maximum levels of resistance.

Figure 7. Simulation of the metal distortion.

Thanks to the simulation (Figure 8) we were able to adjust the shape of the piece so that it could work and resist 18 kN at the same time, without reaching the elastic limit of its material, thus without having any residual shape distortion. As it can be seen, the elastic limit is 478 MPa, for the 7075 T6 Aluminum.

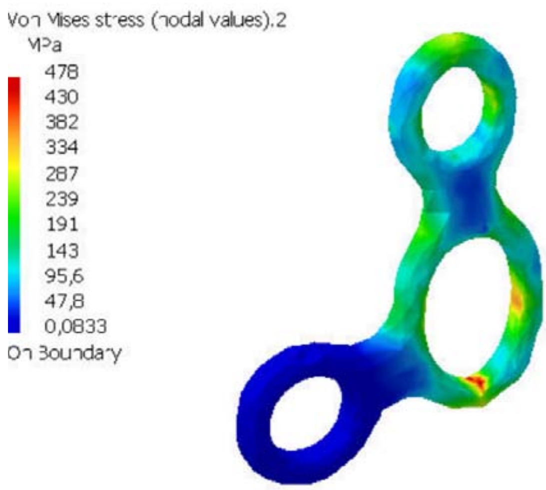

Figure 8. Von Mises stress distribution.

Finally, the displacement suffered during the effort was observed (Figure 9). The maximum compression was applied on the lateral sides of the rings through which the rappel ropes pass, whereas the carabiners anchor ring forces were exerted within permitted limits, and returned to their original state when the application of the force finished.

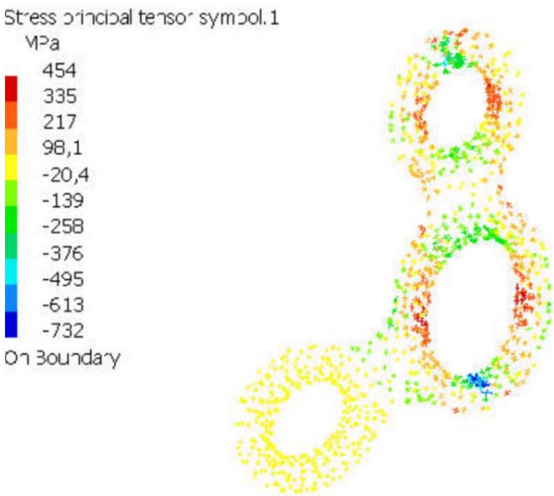

Figure 9. Compression and/or extension after force application.

Certainly, steel is still used in the making of these materials, as it occurs with symmetric carabiners for speleology, Tyrolean crossing pulleys, rope hoist, etc. Nowadays, they are made of several types of steel in different industrial fields, in search for the possibility to get their highest performance qualities with the lowest production cost (Campos, Blanco, Sicre-Artalejo and Torralba, 2008).

There exists in international literature a range of works related to climbing security (Smith, 1998; Pavier, 1998), as well as to the resistance of other materials, such as carabiners (Jackson, 2008), knots (Brown, 2008; Diamond, 2007), nuts and anchor systems (Vogwell and Mínguez, 2007), etc. However, there is no research about belay systems or devices, being the technique which is probably most used in these sport activities. Furthermore, the factors which can influence on rappelling activities, such as the type of descender, rope, or belay distance, etc, can affect the risk taken by the climber, who can suffer a mortal accident.

With regard to the experiment where the new utility model was compared to the descenders of its range, in Figure 10 we can clearly see that the friction increased when the fall speed was reduced in our invention. It is quite interesting to note that the descender which exerts a lower friction is the SFD8, probably due to the thickness of its section. On the contrary, the 8 descender has a section of approximately 13 mm, which gives place to a friction increase with respect to the former. Neither device allows us to use a different friction possibility, as it happens to the new model, because, as they are able to re-direct the braking rope, it increases friction in comparison to the other devices of its range (see Figure 6).

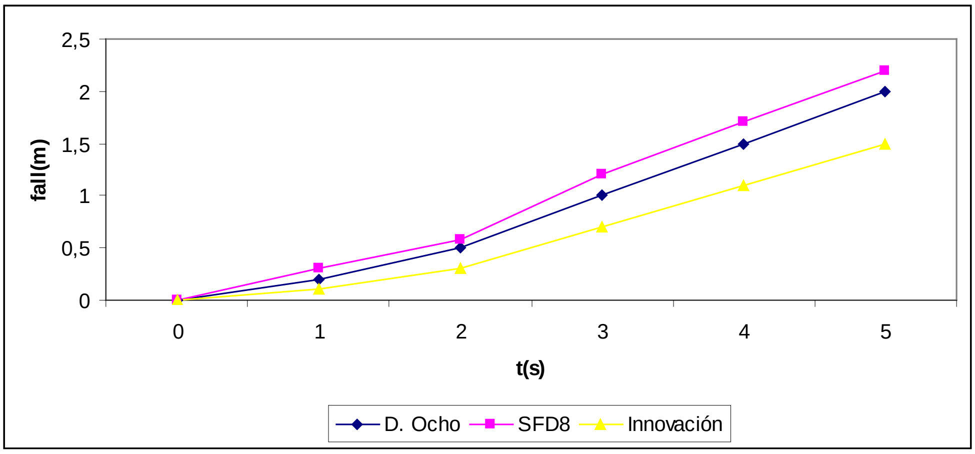

Figure 10. Difference of fall of a 80 kg weight in relation to the descender used.

4. CONCLUSIONS

As a conclusion, we can say that the new descender would have a pull resistance up to 18kN in its longitudinal section. This confers it a great value for these sports, because in fact these values would rarely exist for an 8 descender in this section, and we would be offering the highest security level. In fact, after observing the rope friction in Figure 3, we can notice that it would be impossible to apply such a strong force on its longitudinal axis, because the test calculations applied to other materials are done taking into account a person's usual weight (80 kg) using a non-static rope which exerts a continuous friction on the neck. Thus, the new model offers an excellent security level.

The compression and extension data are quite reliable, because the highest friction is produced on the neck of the device, without suffering any distortion. If an improvement of its longitudinal resistance is needed, we would have to increase the thickness of the cross section in the weakest areas.

In relation to other descenders, our innovation shows a lower weight than other descenders, such as the *Rack* (470 gr), *Stop* (300 gr) or *Gri-gri* (225 gr) descenders, and it is even less voluminous than the *SFD8* or *Hopf* descenders. Moreover, it would solve some deficiencies found in other descenders, as we have previously explained, thus being able to be used with one or even two ropes, something which is impossible for the *Gri-gri, Stop* or *Piranha* descenders.

Another interesting conclusion is that the introduction of the second ring allows the climber to pass the rope through the device when s/he is descending without having to take it out of the security carabiner,- because it is anchored to the carabiner by means of this additional ring-, as it usually occurs with most descenders. Thus, we prevent it from falling down and avoid its loss. Actually, this fact is very interesting for adventure tourism agencies all over the world, because a lot of material is lost and money wasted due to the tourists' lack of experience in activities such as canyoning. As for professional climbers, they will not need to use quickdraws (including their weight and cost) when they are securing the descender from the big ring.

The friction exerted may vary and different positions can be taken when descending (Figure 11), something which is impossible when using other devices such as the Piranha descender. The Petzl Piranha offers more friction positions, but it has the disadvantage that you have to choose and put the rope in the right position according to the friction which is considered necessary before the belay, without having the possibility of changing it during the descending movement if the friction is not the right one.

Figure 11. High friction (left) and middle friction (right) positions.

In addition, our innovation offers the possibility to use it as the only device in the setting up of belay stations, with new disengageable security belay techniques (Figure 12), not possible for all devices.

Figure 12. Double disengageable rappel.

5. BIBLIOGRAPHY

Badía, J.M.; Antoranz, J.M.; Tarin, P.; Simón, A.G. & Piris, N.M. (2004). Influencia del medio ensayo y dirección de aplicación de la carga en el comportamiento a corrosión bajo tensiones de la aleación de aluminio 7075*. Revista de Metalurgia*, 40, 436-441.

Brown, A. (2008). *The strength of knots in dynamic climbing rope.* MEng Aero-mechanical Engineering. University of Strathclyde.

Campos, M.; Blanco, L.; Sicre-Artalejo, J. & Torralba, J.M. (2008). Aceros de baja aleación y alto rendimiento. *Revista de Metalurgia, 44*(1), 5-12.

Colas, P. y Buendía, L. (1994). *Investigación educativa.* Sevilla: Alfar.

Creasey, M.; Banks, N.; Gresham, N. & Wood, R.; (2008). *Advanced rock climbing. A step-by-step guide to improving skills.* London: Southwater.

Diamond, W. (2007). *An assessment of the strength of rope splices and knots in sailing ropes.* MEng Aero-mechanical Engineering. University of Strathclyde.

España-Romero, V.; Artero, E.G.; Ortega, F.B.; Jiménez-Pavón, D.; Gutiérrez, A.; Castilllo, M.J. & Ruiz, J.R. (2009). Aspectos fisiológicos de la escalada deportiva. *Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte, 9*(35) 264-298. http://cdeporte.rediris.es/revista/revista35/artescalada129.htm

Fernández, J.C. (2005). *Manual de de Catia V.5*, [en línea]. Ferrol: La Coruña. Disponible en: http:// www.cisgalicia.org [Consulta: 2010, 22 de Octubre].

Gil, L.; Jiménez, L.; Castro, A.C.; Puchi-Cabrera, E.S. & Staia, M.H. (2008). Evaluation of the effect of Ni-P coating on the corrosion resistance of the aluminium 7075 T6 alloy*. Revista de Metalurgia*, *44*(1), 66-73.

Giles, L.V, Rhodes, E.C. & Taunton, J.E. (2006). The physiology of rock climbing. *Sports Medicine*, *36*, 529-45.

Jackson, N. (2008). *Dynamic testing of climbing karabiners.* MEng Aero-mechanical Engineering. University of Strathclyde.

Long, J. (1997). *Advanced Rock Climbing.* Chockstone Press, Evergreen.

Luebben, C. (2007). *Rock climbing anchors. A comprehensive guide.* Seattle: The mountaineers books.

Marbach, G. & Tourte, B. (2003). *Techniques de la spéléologie alpine.* Pont-en-Royans: Expé.

Morse, J. (2003). *Asuntos críticos en los métodos de investigación cualitativos*. Medellín, Colombia: Universidad de Antioquia.

Pavier, M. (1998). Experimental and theoretical simulations of climbing falls. *Journal of Sports Engineering*, *1*, 79-91.

Peter, A. Y Peter, I. (1990). *The Handbook of Climbing.* Pelham Books, London.

Randelzhofer, P. (1997). Derzeit u¨ bliche Sicherungsgera¨te und ihre Wirksamkeit. *Mitteilungen des Deutschen Alpenvereins 3*, 259.

Schad, R. (2000). Analysis of climbing accidents. *Accident Analysis and Prevention, 32*(3), 391-396.

Schubert, P. & Stückl, P. (2007). *Sicherheit am Berg. Alpin-Lehrplan Band*. Múnchen: BLV Verlagsgesellschaft mbH

Sheel, A.W. (2004) Physiology of sport rock climbing. *British Journal of Sports Medicine*, *38*, 355-9.

Smith, R. (1998). The development of equipment to reduce risk in rock climbing. *Journal of Sports Engineering*, *1*, 27-39.

Toledano, M.; Arenas, M.A.; Galánm J.J.; Ramírez, L.; Borja, S.M.; Conde, A.; & Monsalve, A. (2010). Resistencia a fatiga de la aleación de aluminio 7075-t6 en función del tipo de ensayo y espesor del recubrimiento. *XXVII Iberian Conference on Fracture and Structural Integrity.* Porto: Portugal.

Unión Internacional de Asociaciones de Alpinismo. *Safety standars*, [en línea]. Disponible en: http://www.theuiaa.org/act_risk_management.html [Consulta: 2010, 22 de Octubre].

Vogwell, J. & Mínguez, J.M. (2007). Wire cable failures in climbing anchors chocks. *Key Engineering Materials,* (348-349), 165-168.

Watts, P.B. (2004). Physiology of difficult rock climbing. *European Journal of Appliqued Physiology*, *91*,361-72.

Referencias totales / Total references: 26 (100%)

Referencias propias de la revista / Journal's own references: 1 (3,84%)