Polyethylene Shock Absorber

TIBERIU STEFAN MANESCU[1], NICUSOR LAURENTIU ZAHARIA[2*], MIHAI BEJAN[3], TIBERIU MANESCU jr.[1]
[1] University Eftimie Murgu Resita, 1-4 Traian Vuia Square, 320085, Resita, Romania
[2] Romanian Railway Authority, 393 Calea Grivitei, 010719, Bucharest, Romania
[3] Naval Academy Mircea cel Batran, 1 Fulgerului Str., 900218, Constanta, Romania

Working on high structures is one of the jobs in the cities vertically developed. The abilities of climbing workers are used for the purpose of mounting publicity banners, cleaning building face, mounting objects on buildings etc. The use of fall arrester equipment is made under strict surveillance and training of the workers because of imminence of the accidents. Before sailing, the fall arrester equipment is tested and certified.

Keywords: polyethylene, shock absorber, fall arrester, climbing, HBM MGC

Fall arrest

Fall arrest is the form of fall protection which involves the safe stopping of a person already falling. It is one of several forms of fall protection, forms which also include fall guarding (general protection that prevents persons from entering a fall hazard area e.g., guard rails) and fall restraint (personal protection which prevents persons who are in a fall hazard area from falling, e.g., fall restraint lanyards).

The U.S. Department of Labor's Occupational Safety and Health Administration specifies under Title 29 of the Code of Federal Regulations that individuals working at height must be protected from fall injury. Fall arrest is one of several forms of fall protection as defined in 29CFR.

Fall arrest is of two major types: general fall arrest, such as nets; and personal fall arrest, such as "lifelines". The most common manifestation of fall arrest in the workplace is the Personal Fall Arrest System, or PFAS ("lifeline"). A personal fall arrest system is a series of components designed to safely arrest a worker's fall, preventing him from striking the next lowest level and minimizing the possibility of serious injury.

The fall arrester is one of the most important elements for life survive in climbing works. The purpose of the fall arrester is to stop and absorb falling energy of the climber by its function of energy dissipation. Usually there are used the following fall arresters:

-shrink fall arrester;
-sliding fall arrester;
-sliding fall arrester with rigid lifeline;
-sliding arrester with flexible lifeline (anchor line).

Personal Fall Arrest Systems

These systems must include 4 elements referred to as ABCD's of Fall Arrest:

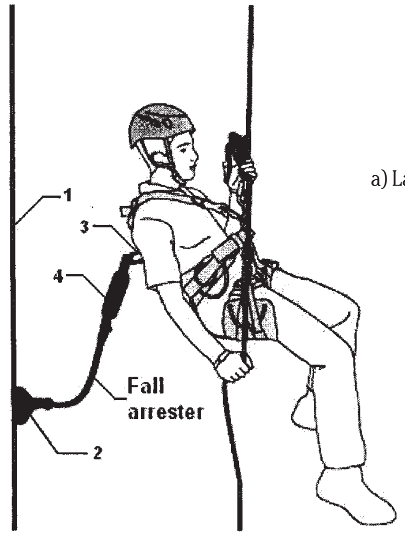
A - Anchorage - a fixed structure or structural adaptation, often including an anchorage connector, to which the other components of the PFAS are rigged;

B - Body Wear - a full body harness worn by the worker;

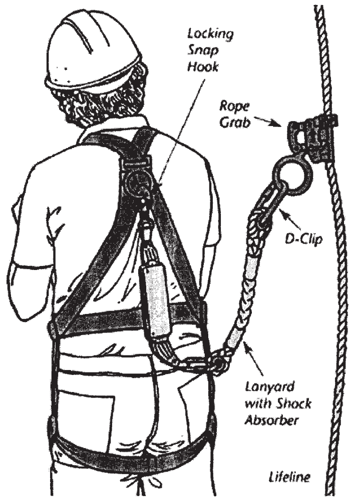
C - Connector - a subsystem component connecting the harness to the anchorage - such as a lanyard;

D - Deceleration Device - a subsystem component designed to dissipate the forces associated with a fall arrest event.

Each of these elements is critical to the effectiveness of a personal fall arrest system. There are many different combinations of products that are commonly used to assemble a personal fall arrest system, and each must meet strict standards (ref 29CFR1910.66 appendix c). The specific environment or application generally dictates the combination or combinations that are most appropriate.



a) Lateral view of the climber



b) Back view of the climber

Fig. 1. The fall arrester wearing

The fall arrester with flexible lifeline is a subsystem made from flexible lifeline (1), self-locking fall arrester (2) connected at flexible lifeline with a link element (3). Between the fall arrester and lifeline a dissipation energy element (4) is mounted.

* Tel.: 0723344258

The fall arrester is gliding on lifeline simultaneously with the climber without manual manipulating during up and down position changing, and stop the falling of the worker by its self-locking function. This element is manufactured from steel (usually stainless steel).

A flexible lifeline can be a synthetic fibers rope or a metallic cable and it is design for anchoring at a superior fixed point. In our case, the rope is manufactured from polyethylene.

The shock absorber is the “key element” because of dissipation function of the mechanical energy occurred during falling. This element is made from polyethylene.

Energy absorption

To arrest a fall in a controlled manner, it is essential to be is sufficient energy absorption capacity in the system. Without this designed energy absorption, the fall can only be arrested by applying large forces to the worker and to the anchorage, which can result in either or both being severely effected.

An analogy for this energy absorption is to consider the difference in dropping an egg onto a stone floor or dropping it into soft mud. Even for the same fall distance and weight of egg (the input energy), there will be more damage with the stone floor as the arrest distance is smaller and so forces must be higher to dissipate the energy. For the soft mud, the arrest distance is longer and so arrest forces are lower but the egg is still stopped and is hopefully undamaged.

Because fall arrest designs require high-rate-energy capacity design methods, fundamental fall arrest design is tedious and esoteric. Thus, most fall arrest parts and systems are designed to the force standards contained in Federal OSHA 29CFR1910.66 appendix c, a force-type design standard which accounts for required energy considerations. The standard mitigates PPE inter-changeability problems, allow wide use by designers not versed in high rate energy methods, and it limits the force into the worker to a survivable level.

Actual loads on the user and anchor-anchorage vary widely with user weight, height of fall, geometry, and type of line/rope. Excessive energy into the support and user is avoided by the use of energy absorbing PPE designed for the 1800 lbs maximum of the referenced Federal OSHA standard. (Designers should be cautioned that the force values of the standard are based on high rate energy system design and thus its force values are not necessarily inter-related.)

The most common fall arrest system is the vertical lifeline: a stranded rope that is connected to an anchor above, and to which the user’s PPE is attached either directly or through a “shock absorbing” (energy absorbing) lanyard. Once all of the components of the particular lifeline system meet the requirements of the standard, the anchor connection is then referred to as an anchorage, and the system as well as the rope is then called a “lifeline”.

Anchors used for lifeline anchorages are designed for 5000 lbs force per connecting user, and the standard permits an anchor to deform in order to absorb energy (adhesive anchors have higher design requirements because of aging loss).

The rope can be lifeline rope, which stretches to lengthen the fall distance as it absorbs energy; or static rope, which does not stretch and thus limits the fall distance, but requires the fall energy be absorbed in other devices. It is essential that the PPE be rated for Fall Arrest and PPE used with static line to include an energy absorber. While the energy absorbing lanyards hold in excess of 5000 pounds when fully absorbed, most limit the load during the fall to under 1400 lbs.

Another common system is an HLL (Horizontal Life Line). These are linear anchoring devices, which allow workers to move along the whole length of the anchor, usually without needing to disconnect and fixing points of the anchorage.

It is normally essential to include energy (or shock) absorbers within HLL in addition to those within the workers’ PPE. Without such absorbers, the horizontal life line cannot deform significantly when arresting the fall. Because of the geometry of pulling across the horizontal line, this in turn results in large resolved forces being generated within the anchor system, sufficient to cause failure of the anchorage. This can occur even with energy absorbers being included in the PPE of the worker.

The load and horizontal line geometry in horizontal lifelines usually creates falls in excess of the 6 ft limit of the standard, limiting HLL design to standard-defined “qualified persons”. (The recognition of these basic weaknesses have resulted in most temporary “wrapped structure” HLL anchors, which were anchors made from a wire rope wrapped around a structure and its ends fastened together by wire rope clips, being replaced by fixed-point anchors or HLL systems designed by defined “qualified” persons).

Fall clearance

In arresting a fall in a controlled manner, the distance required to arrest the fall must be considered. Federal OSHA limits the fall distance to 6 feet unless the specific system is designed by a “qualified person” meeting the requirements of OSHA 29CFR1910.66 appendix c. The user also may not fall so as to strike protrusions or adjoining walls during the 6 ft fall.

The safe fall distance is a function of the fall factor and the deployment of the “energy absorbers”. As a rule of thumb for a factor 2 fall, a fall distance of approx 6 metres will be required. This is equivalent to 2 stories of a building. If the fall clearance is less than this the worker may strike the ground before his fall is arrested.

Design of HLL Systems

This is a complex process. The designer should always perform a design calculation and the results of this calculation should be presented in any proposal and verified as acceptable. The loads applied to the structure and the fall clearance required should be checked.

This paper presents the dynamic test for performance verification of a fall arrester with flexible lifeline. In figure 1 is shown the usage of the fall arrester.

In figure 2 is sliding arrester with flexible lifeline system.

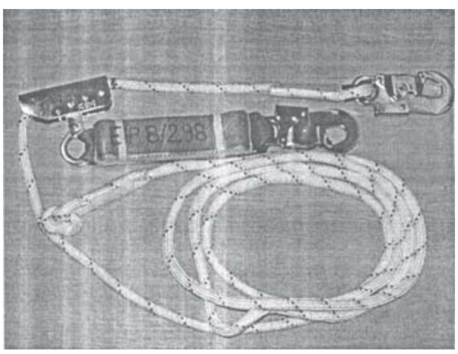


Fig. 2. The fall arrester system

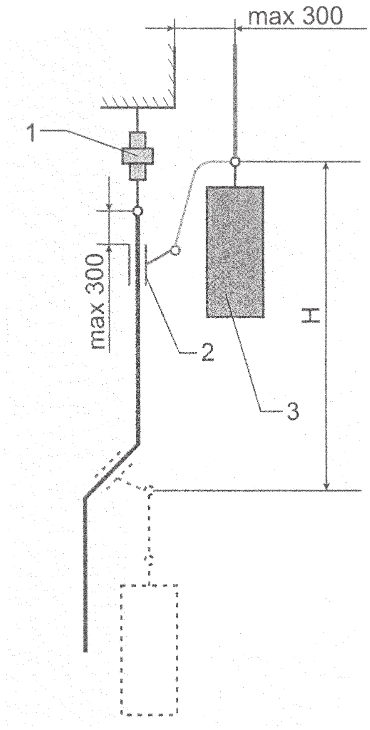
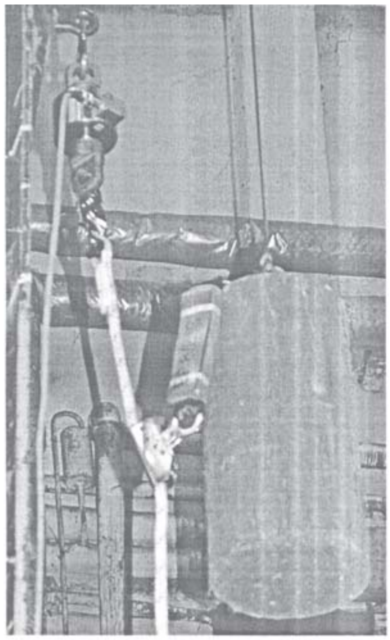
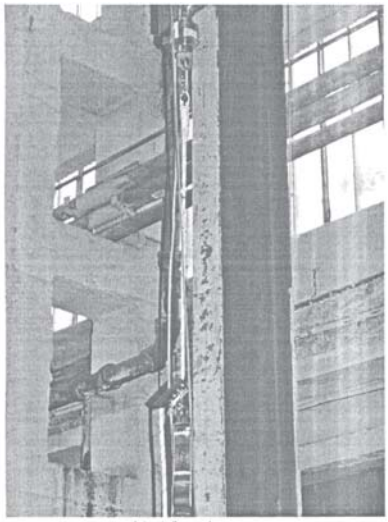


Fig. 3. Performing of the tests (1 – force cell, 2 – fall arrester, 3 – 100 kg test mass)



a) Before the test



b) After the test

Fig. 4. The shock absorber

Table 1

	Measured values	Limit value
Braking force [kN]	3,142	6,000
Stopping distance [m]	1,33	1,65

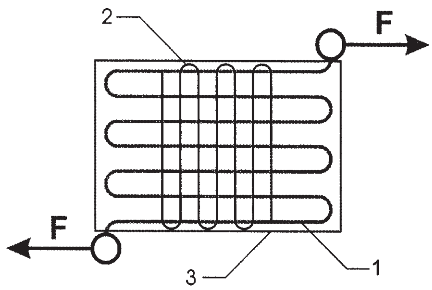


Fig. 5. The construction of the shock absorber

Experimental part

The tests were performed on Falling Bench Test of the Romanian Railway Authority, Romanian Railway Notified Body, Rolling Stock Laboratory (http://www.afer.ro).

In figure 3 is presented how the experiments were performed. In figure 3 and 4 is shown the tested object before and after the test.

The dynamic tests were performed as follows:

-superior end of the lifeline was linked to D-Clip. The D-Clip was the connection element between the lifeline and the cell force (Hottinger U2A/20 kN);

-the cell force was connected to a Hottinger MGC measuring amplifier. Additionally after the calibration operation done before testing and before dynamic test of the fall arrester system, a static test is performed with 100 kg test mass. The indication of the MGC must be "9810 N";

-the 100 kg test mass was linked to the end of the shock absorber with a D-clip. The test mass was raised at required high with a rope. That rope will be let free before the dynamic test so that a free fall of the 100 kg test mass to be realized (fig. 4,a);

-the height of the test mass was so that its ring (connection level) to be at upper end of lifeline and at 300 mm maximum horizontal distance. The 100 kg test mass must have a 200 mm nominal diameter;

-the 100 kg test mass was let in free fall;

-during the fall, the maximum force was recorded (fig. 6);

-after the falling, with 100 kg test mass in repose vertical displacement H of the mass was measured (fig. 4,b).

Results and discussions

The measured results and their limits are presented in table 1.

According to SR EN 353-2 "Personal protective equipment against falls from a height – Part 2: Guided type fall arresters including a flexible anchor line" the braking force is the maximum force F_{max} in kN measured in anchor point or in anchoring support during braking period for the dynamic performance test, and the stopping di*stance* is the vertical distance H in m measured from the mobile point mass carry of the fall arrester system, from the initial position (during fall) at final position (in balance or after the mass test stopping), excluding the elongations of the complex belt and its linking element.

During the fall, the mechanical energy due to the climber mass can injury him because of the shock. In order to

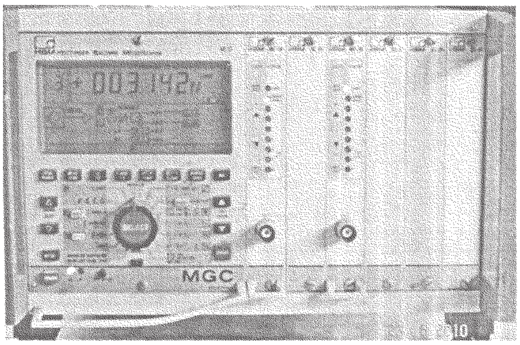


Fig. 6. The measured force during tests

dump the shock, there are used shock absorbers made from a overlay polyethylene belt (1) in many sewed layers. The sewing thread (3) is also made from polyethylene. At exterior a protective coat made from transparent polyethylene is applied (3). Because of the shock, the sewing is braking and the damping of the falling is produced simultaneously with a small heating of a shock absorber. In figure 5 is shown the basic construction of the shock absorber.

In figure 6 is presented the measuring device HBM MGC and the measured force on its display.

Conclusions

From the values presented in table 1 it is easy to see that measured braking force and stopping distance are smaller than imposed limits by reference standard so, we can conclude that the tested fall arrester system and its shock absorber are made according to the standards.

References

1. MĂNESCU T. Ş., COPACI I., OLARU S., CREANGĂ F., Tensometria electrică în cercetarea experimentală, Editura Mirton, Timişoara 2006.
2. HADAR A., CONSTANTINESCU I. N., GHEORGHIU H., COTET C. E., Modelare şi modele pentru calcule în ingineria mecanică, Editura Printech, Bucureşti, 2007.
3. ILIESCU, N., HADAR, A., PASTRAMĂ, Ş. D. Mat. Plast., 46, no. 1, 2009, p. 91
4. *** SR EN 353-2: 2003, Echipament individual de protecţie împotriva căderilor de la înălţime, partea a 2-a: Opritoare de cădere cu alunecare pe suport de ancorare flexibil.
5. *** SR EN 355: 2002, Echipament individual de protecţie împotriva căderilor de la înălţime - Absorbitoare de energie.
6. *** SR EN 364 + AC: 1996, Echipament individual de protecţie pentru poziţionare în timpul lucrului şi prevenirea împotriva căderilor de la înălţime. Metode de încercare.
7. *** http://en.wikipedia.org/

Manuscript received: 19.05.2011