Test and Certification Procedures of Pulleys as a Part of Personal Fall Arrest System

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Abstract: The personal fall arrest system, or the personal protection equipment (PPE), is considered as the solution of an actual problem of serious injuries due to falls from height. The pulleys, as components of personal fall arrest system, their functional purposes ensuring safety of working at heights and preventing falling from heights with hard injuries during works and also rescue operations are analyzed in this article. The analysis of obligatory certification procedure for personal protection equipment was carried out on the example of pulleys. A number of certification faults revealed that pulleys have certified as the anchorage points of a certain class that contradicts technical and functional criteria of requirements to such equipment. Analysis of this problem has shown that in the territory of the Customs union there are no approved methods and technical requirements to this type of products. The aim of this work is to create test methods that meet the functional requirements for this class of products. The tests were conducted in accordance with the presented methods. The differences between the functionally focused test methods and the anchorage test methods have been shown on example of the conducted tests. The final part of the work shows that the obligatory certification should be improved and the number of tools for its implementation as the system controlling quality and safety of many products including such important as PPE should be expanded.

1. Introduction

The pulley is a unit with one or more sheaves coincided with wheels of different shapes and sizes with a groove, mounted in a body or block, which can be used to connect a rope (EN 892[1] or GOST EN 1891 [2]) to an attachment point (EN 12275 [3] or GOST R EN 362 [4]) and to reduce the friction during its movement over a rope under loading. Pulleys are also used to change direction of rope movement and to create the block-and-tackle systems. Pulleys have found wide application in various fields of activity connected with works at height (Figure 1-3).
**Figure 1.** Rescue operations.

**Figure 2.** a) Lifting of oversized cargo; b) Arborism.
It should be noted that application of pulleys is particularly connected with safety of people. At the same time the problem of safety when working at height in the Russian Federation is quite important [5-11] therefore it is necessary to pay special attention to design and certification of pulleys.

The basic normative documents (hereinafter-ND) regulating the area of personal protective equipment against falls from a height (hereinafter PPE FH) are the Technical regulations of the Customs Union 019/2011 on the safety of personal protective equipment [12] and rules on labor protection when working at height [13]. Requirements of ND provide application of PPE FH which should have obligatory certification to ensure the safety of works at height. At present on the territory of Russian Federation we have no approved technical requirements and test methods that meet the functional assignments or pulleys that is why manufacturers have certify such units as the anchor devices (Figure 4) according to the method of GOST EN 795-2014. Occupational safety standards system. Personal protective equipment against falls from a height. Anchor devices. General technical requirements. Test methods [14].

**Figure 3.** а) Zip Line Trolley; b) Stunt rigging, cinematography.

**Figure 4.** «Spasatel Luxe» («Rescuer Luxe») single pulley.
Thus, according to GOST [14], the pulleys can be classified as the mobile anchor points and can additionally use in anchor line or anchor rail, i.e. pulleys are classified as a component of the C and D classes anchor devices. Therefore they pass certification tests which respond only to strength test requirements, but not the functional one.

The aim of this study is to develop test methods for pulley units that can become a basis of the Russian standards. To achieve such aim the following tasks have been carried out:

- Consideration of the test methods presented in BS EN 12278:2007. Mountaineering equipment. Pulleys. Safety requirements and test methods [15];
- Tests by the method based on EN [15] and analysis of the test results.

2. Test methods

At visual inspection of the pulley, sheave axle has to be fixed to prevent unintentional disassembly of the unit into components. The size of hole for attachment point on pulley unit is checked by means of a core with diameter $(12 \pm 0.1)\,\text{mm}$. The core needs to move freely inside the hole. Each sheave should be rather big to contain a rope of such diameter as it is specified on the pulley. Thus it have been used the core which diameter is $(1 \pm 0.1)\,\text{mm}$ more than maximum diameter of a rope or auxiliary cord for such sheave. The core should touch the bottom of the sheave groove (Figure 5).

![Figure 5](image)

**Figure 5.** Verification of the pulley size: a) satisfactory, b) unsatisfactory.

Functional tests of each sheave have been carried out separately for each test sample. Test is carried out on a synthetic rope, corresponding to GOST EN 1891 with diameter $(10 \pm 1)\,\text{mm}$ and terminations in the form of knots or stitchings. Each pulley has to rotate separately under the load of $2\,\text{kN}$ about ten times in any direction (Figure 6). After test the pulley should not have visible signs of damage or deformation which can impair its work.

![Figure 6](image)

**Figure 6.** Functional test.

The strength test is carried out on a tensile testing machine until destruction of the test sample in accordance with loading scheme. The pulley has to withstand the load stated by manufacturer, but not less than $15\,\text{kN}$ on each sheave. It is allowed to test more than one sheave at once if the design of pulley or its manual stipulates simultaneous operation of sheaves.
3. Test results
The tests were carried out on samples of block-rollers of various types according to the proposed method. All tests in the framework of the research have been carried out in accordance to offered methods (Figure 7).

![Figure 7. Test samples of pulleys of various types.](image)

Results of tests are given in tables 1-5.

**Table 1.** Results of visual inspection of a sheave axle fixation.

| No | Name of a sample                      | Fixing. Yes/No | Comment                                      |
|----|---------------------------------------|----------------|----------------------------------------------|
| 1  | Single pulley with ball bearing       | Yes            |                                              |
| 2  | Double pulley with ball bearing       | Yes            |                                              |
| 3  | Triple pulley                         | No             | Threaded connection without fixing          |
| 4  | «Kedr» («Cedar») pulley               | No             | Threaded connection without fixing          |
| 5  | «Tandem» («Tandem») pulley with ball bearing | Yes |                                              |
| 6  | Pulley for Zip Line Trolley           | Yes            |                                              |

**Table 2.** Results of inspection of applicable attachment point.

| No | Name of a sample                      | Presence of applicable attachment point. Yes/No | Comment                                      |
|----|---------------------------------------|-----------------------------------------------|----------------------------------------------|
| 1  | Single pulley with ball bearing       | Yes                                           |                                              |
| 2  | Double pulley with ball bearing       | Yes                                           |                                              |
| 3  | Triple pulleyNo                       | No                                            | This sample have no applicable attachment point |
| 4  | «Kedr» («Cedar») pulley               | No                                            | This sample have no applicable attachment point |
| 5  | «Tandem» («Tandem») pulley with ball bearing | Yes |                                              |
| 6  | Pulley for Zip Line Trolley           | Yes                                           |                                              |
Table 3. Results of inspection of the inner sheave diameter.

| No | Name of a sample                                  | Real rope diameter, mm | Compatibility with stated diameter |
|----|---------------------------------------------------|------------------------|-----------------------------------|
| 1  | 2                                                 | 3                      | 4                                 |
| 1  | Single pulley with ball bearing                   | 11                     | No                                |
| 2  | Double pulley with ball bearing                   | 11                     | No                                |
| 3  | Triple pulley                                    | 13                     | No                                |
| 4  | «Kedr» (<«Cedar») pulley                         | 14                     | No                                |
| 5  | «Tandem» (<«Tandem») pulley with ball bearing     | 11                     | No                                |
| 6  | Pulley for Zip Line Trolley                       | 11                     | No                                |

Table 4. Results of functional tests.

| No | Name of a sample                                                  | Number of revolutions | Compatibility Yes/No |
|----|------------------------------------------------------------------|-----------------------|----------------------|
| 1  | 2                                                                | 3                     | 4                    |
| 1  | Single pulley with ball bearing                                  | 9                     | 6                    | No                   |
| 2  | Double pulley with ball bearing                                  | 10                    | 10                   | Yes                  |
| 3  | Triple pulley                                                    | 10                    | 10                   | Yes                  |
| 4  | «Kedr» (<«Cedar») pulley                                        | 10                    | 10                   | Yes                  |
| 5  | «Tandem» (<«Tandem») pulley with ball bearing                   | 10                    | 10                   | Yes                  |
| 6  | Pulley for Zip Line Trolley                                     | 10                    | 10                   | Yes                  |

Table 5. Results of strength tests.

| No | Name of a sample                                                  | Breaking load stated by the manufacturer, kN | Real value of load, kN (minimum value in cycle of tests) | Result                                      |
|----|------------------------------------------------------------------|---------------------------------------------|--------------------------------------------------------|---------------------------------------------|
| 1  | 2                                                                | 3                                           | 4                                                      | 5                                           |
| 1  | Single pulley with ball bearing                                  | 24.5                                        | 22.6                                                   | Destruction of a sheave axle               |
| 2  | Double pulley with ball bearing                                  | 24.5                                        | 27                                                     | Destruction of a sheave axle               |
| 3  | Triple pulley                                                    | 49                                           | 50                                                     | The test sample has sustained the actual value of loading without damages |
| 4  | «Kedr» (<«Cedar») pulley                                        | 24.5                                        | 36.3                                                   | Destruction of a sheave axle               |
| 5  | «Tandem» (<«Tandem») pulley with ball bearing                   | 24.5                                        | 29.3                                                   | Destruction of an attachment point         |
| 6  | Pulley for Zip Line Trolley                                     | 24.5                                        | 25.5                                                   | Deformation of a body                      |

Part of the test samples (see tables 1-4) have not passed test by the following parameters:

- fixings of the sheave axle allowing to prevent unintentional disassembly of the pulley into components and to avoid accident during operation;
- presence of the hole for attachment point;
- compliance of the sheave size in accordance to stated rope diameter (no one sample have not passed test by this criterion). The rope diameter for such units was incorrectly stated by manufacturer due to absence ND with requirement concerning this indicator;
- functional rotation tests, when the unsuitable sample have been jammed during rotation;

All below listed tests can be referred to group of functional tests.

However, all the samples were passed static strength tests.

Analysis of the results shows that it is necessary to pay attention to development of functional requirements for products and to adaptation of static tests for such products. The analysis of results has
shown that it is necessary to pay attention to development of functional requirements to products, and adaptation static tests under this type of products.

4. Conclusion

Today the pulleys have firmly application in various fields of activity connected with works at height. Thus at the territory of the Russian Federation there are no normative documents which would regulate this type of products. Today, as we can see, the pulleys are not exist while we can see that such units are produced by manufacturers and actively applied undergo after the procedure of obligatory certification in accordance to TR TS 019/2011 [12] as the PPE FH according to method for anchor devices. The certification of products is only possible due to the fact that technical requirements for PPE which are presented in TR TS 019/2011 [12], and GOST [14] have regulate only the method of requirement confirmation.

The main problem of this situation is that the technical regulations [12] have not contain functional requirements to such types of units and has rather limited circle of the common technical requirements, and at the same time in the list of "the documents in the field of standardization containing rules and methods of researches (tests) and measurements, including the rules of sampling necessary for application and execution of requirements of technical regulations of the Customs union "About safety of individual protection equipment " (TR TS 019/2011) and assessment (confirmation) of production" missing profile oriented focused ND.

The tests methods have been mentioned in the report are based on EN [15], when the profile European standards consider regulation of this type of equipment as a part of climbing equipment. The conducted tests have demonstrated that the samples have not pass functional tests and do not meet the requirements of the main test technique regulating safety of this type of units.

Based on the current situation, it is necessary to develop a domestic standard of PPE FH for pulley blocks. It is necessary to reflect all areas of application of this type of a product and specify the necessary technical requirements, based on the experience of foreign colleagues [16-23] and the domestic knowledge based on related issues [24-27], and to develop a method of dynamic testing, which would be in some application cases of products.

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