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MODEL BASED RESEARCH OF CLIMBING CARABINERS

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1. Introduction

The goal of this work was to conduct model based, comparative, experimental research on screw-gate climbing carabiners (HMS type) made form aluminum alloy and steel connectors used in altitude work (OVO type).

Climbing carabiner is a type of openable binding element which is used by an climber to form a direct or indirect connection to an anchor point. It constitutes a part of personal protection system [4]. Another name used for carabiner is climbing connector.

The conducted experimental research had a goal of measuring displacements of two different types of carabiners: oval shaped basic connectors of type B (OVO) and pear shaped carabiners of type H (HMS). The tests were in all cases done on new carabiners, along long axis, with fully closed and locked gate.

2. Methods and material

Even though norms differ on criteria constituting carabiner's endurance conditions of all tests are the same. All endurance tests were done according to norm [1, 2]. In each experiment 3 carabiners were tested.

Displacement measurements were done using optical system Digital Image Correlation System Q-400 (DIC) in a contactless manner [3].

Before the experiments all specimens were covered in stochastically placed markers. Carabiners prepared for test are shown on Fig. 1. Samples were loaded using endurance testing machine Instron 5982. Testing stand together with list of components is shown on Fig 2.

Fig 1. Carabiners prepared for test.
A – type B (OVO), B – type H (HMS).
On the left side – new, before test.
On the right side – prepared for test with Digital Image Correlation System Q-400.

2.1 Experimental research procedure

For HMS (type H) carabiner norm PN-EN 12275:2013 is binding and tests were conducted according to it. Carabiner was initially loaded with a force of 250 N and then loaded to a point of failure with a speed of 20 mm/min.

In case of OVO (type B) carabiner the tests were done according to norm PN-EN 362:2006.

The specimen was initially loaded with a force of 250 N. Next it was loaded with a speed of 20 mm/min until a loading force of 20 kN was reached. This load was maintained for 3 minutes.

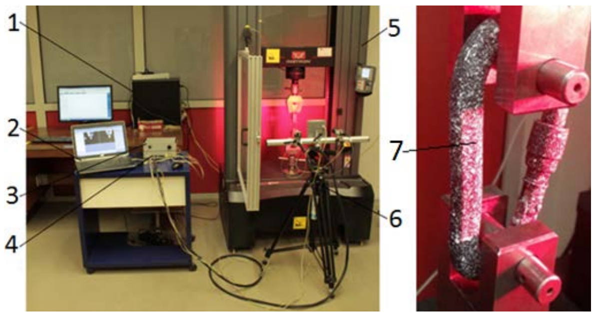

Fig 2. Testing stand:
1–load controlling computer, 2–camera video capture computer, 3–light controls, 4-A/C converter, 5–endurance machine, 6–set of two cameras, 7–specimen prepared for testing.

At the same time, during each test, displacements in 3 directions on surface of carabiner were measured in a contactless manner using DIC.

3. Experiment results

Results of strength tests for HMS (type H) carabiners are shown in Tab. 1.

Test piece	Declared strength [kN]	Tested strength [kN]
HMS 1	24	27
HMS 2	24	29
HMS 3	24	27

Tab. 1 Strength results for type H carabiners.

All OVO (type B) carabiners withstood test load of 20 kN for 3 minutes.

Orientation of displacement	OVO1 [mm]	OVO2 [mm]	OVO3 [mm]
X	0,897	1,027	0,599
Y	2,724	3,663	3,048
Z	2,276	1,744	1,417
total	3,547	3,760	3,346

Tab. 2 Maximum displacements values for type B carabiners under 20 kN load.

Fig. 3 shows maximum displacement values for OVO carabiners, for each axis after loading with speed of 20 mm/min and a constant load of 20 kN maintained for 3 minutes.

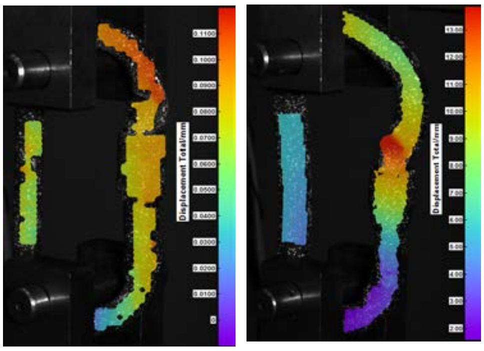

Fig. 3 Total displacement distribution for test sample OVO1, F=20kN and HMS1, F=27kN, obtained with DIC

4. Discussion

All tested carabiners withstood the projected loads. Evaluation of displacement distribution have shown which parts of the tested elements are most prone to damage because of biggest displacements and exactly those fragments failed during test. For OVO type carabiner, after constant load test a breaking load test was done to verify DIC results and establish real breakage point.

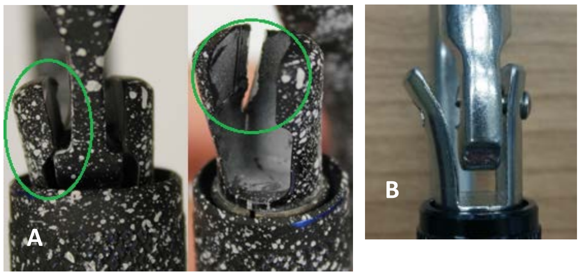

Fig. 4 Damaged gate arm of A – HMS, B – OVO

In each tested connector a gate was damaged, even though the tested elements differed in both construction material and geometric properties. Because of the construction differences the gate damages look different for both carabiner types.

In this study two drastically different - both geometrically and in their construction material - carabiner types were compared. Nevertheless because of their similar application it seems valid to compare their strength properties.

References

[1] PN-EN 362:2006 – „Środki ochrony indywidualnej chroniące przez upadkiem z wysokości – Łączniki"

[2] PN-EN 12275:2013 – „Sprzęt alpinistyczny, karabinki, wymagania bezpieczeństwa i metody badań."

[3] Dantec Dynamics: Q – 400 System - Operation Manual

[4] Alex Strait: „Rock Climbing Clip Analysis Report. A Comparison of Tensile Testing and FEA Modeling for the Black Diamond Neutrino Carabiner.", 2015

[5] Steven McGuinnity: *„What Determines the Strength of Climbing Karabiners?"*, Final Year BEng Honours Technical Paper, University of Strathclyde, Glasgow, 2004.