Engineering Failure Analysis 60 (2016) 9–19

Contents lists available at ScienceDirect

Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/engfailanal

To replace or not to replace? — An investigation into the residual strength of damaged rock climbing safety equipment

Michael May *, Stefan Furlan, Holger Mohrmann, Georg C. Ganzenmüller

Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institute, EMI, Eckerstrasse 4, 79104 Freiburg, Germany

ARTICLE INFO

Article history:
Received 4 September 2015
Received in revised form 30 October 2015
Accepted 16 November 2015
Available online 17 November 2015

Keywords:
Damage tolerance
Fracture
Impact
Mechanical testing
Sports equipment failures

ABSTRACT

This paper presents a study on the residual strength of carabiners which have sustained impact damage due to accidental dropping during lead climbing. The question answered here is whether damaged quickdraws can be reused for future climbing or whether they should be replaced. Well defined damages were introduced into the main body and the gate of three different types of quickdraw carabiners. The carabiners were visually inspected and tested for functionality before the residual strength was measured following procedures defined in mountaineering standards. Contrary to common perception no micro-cracks were found within the damaged carabiners. In general, the carabiners tested here showed good resistance to impact damage. Impact on the main body does not seem to affect the residual strength. Impact on the wire gate may result in failure of the gate. However, if the gate is still functional, the strength is not affected by an impact.

1. Introduction

In recent years, sport climbing has gained increasing popularity throughout the general public. Despite sometimes being considered dangerous sport, clinical evidence shows that sport climbing is comparatively safe in terms of injuries and fatalities [1]. The low risk of injury and fatality is due to the ever improving standards for safety gear [2,3,4,5] used during climbing. The lead climber ensures safety by securing the rope using quickdraws which are attached to the wall using anchor points which can be bolted or glued to the wall. A quickdraw consists of two carabiners connected by a sling. The belayer secures the rope using specialized equipment providing friction onto the rope. Fig. 1 shows the classic scenario of climbing and belaying during lead climbing. The climber usually clips the rope into the carabiners attached to the anchor points once the hip is at the level of the anchor point. The climber then continues climbing higher than his last anchor point until the next anchor point is reached. If the climber falls, the belayer can stop the drop after a little more than twice the distance between the highest point reached and the last anchor point used (due to elasticity of the rope).

During these falls, high dynamic loads act on the protective equipment as well as on the body of the climber. Due to the height of a fall, material failure may result in serious injury or even fatality. Consequently, research has been conducted, accessing best practice of the use of protective equipment as well as the failure of different pieces of protective gear. In particular, the strength and failure of anchor points, e.g. pitons [6,7], cams [7], and chocks [7,8] were analyzed. Additional research focused on the response of climbing ropes subjected to dynamic loading caused by a lead climber falling [9,10,11]. However, only limited research was carried out investigating the mechanical response of the element connecting the anchor and the rope – the quickdraw — and its constituents – carabiner and sling. Stopper [12] performed fatigue tests on carabiners and

* Corresponding author.
E-mail address: Michael.May@emi.fhg.de (M. May).

http://dx.doi.org/10.1016/j.engfailanal.2015.11.036
1350-6307/

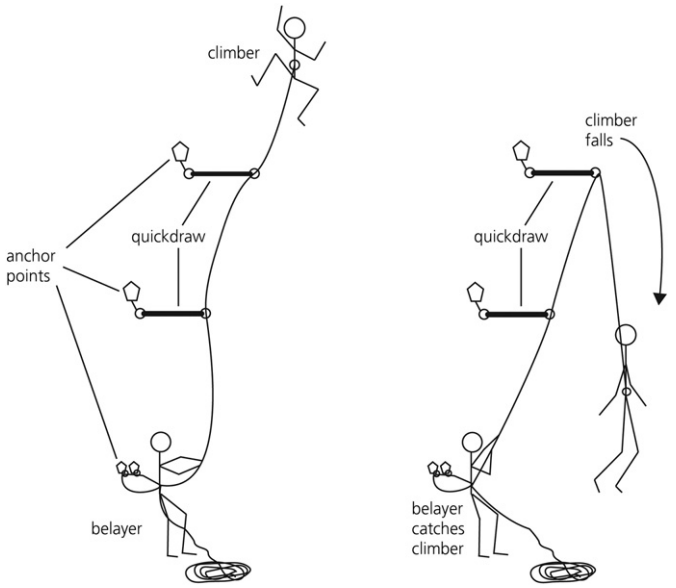

Fig. 1. Schematic of a typical lead climbing situation.

found that despite the absence of visually detectable damage, the residual strength of the carabiners was reduced after 500 load cycles. Another threat for the strength of carabiners is the scenario of a lead climber dropping the quickdraw during the attempt to connecting it to the anchor point. In such a case, it is easily possible that the quickdraw falls for dozens of meters before hitting a rock or solid ground causing visible impact damage to the carabiners. Common perception amongst rock climbers is that dropping a carabiner could result in micro-cracks within the metallic body of the carabiner which would in turn reduce the strength of the material. Therefore, the question arising is whether the damaged carabiners can be reused for future climbing or whether it should be replaced by a new one. This paper addresses this issue by assessing the residual strength of carabiners which have sustained damage due to impact loading. Slings do not suffer any damage during accidental drops and are therefore not tested within this programme.

2. Equipment tested

Three different types of quickdraws, produced by the same manufacturer, were bought from a mountaineering store. The first product is a standard general purpose quickdraw comprising of one wire gate carabiner, one straight-gate carabiner and a 12 cm Dyneema sling. The total weight of this product is 103 g. The strength of the undamaged carabiners, given by the manufacturer is listed in Table 1.

The second product is an extremely lightweight quickdraw for mountaineering projects in which weight matters. It comprises two identical lightweight wire gate carabiners and a 12 cm Dyneema sling. The total weight of this product is 63 g, and therefore 40% lighter than the first product. The strength of the undamaged carabiners, given by the manufacturer is listed in the last line of Table 1.

For the remainder of this article, the wire gate carabiner used in the general purpose quickdraw is named carabiner type A, the straight gate carabiner is called carabiner type B, and the light weight wire gate carabiner is called carabiner type C. Fig. 2 shows the three different types of carabiners under investigation.

Table 1
Carabiner strength provided by the manufacturer.

Carabiner type	Loading configuration		
	Closed gate	Open gate	Transverse
A: Wire gate	24 kN	9 kN	7 kN
B: Straight gate	25 kN	8 kN	8 kN
C: Light weight, wire gate	20 kN	7 kN	7 kN