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Biomimetic adhesion device holder for easy detachment

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Detachment mechanism in stick insects

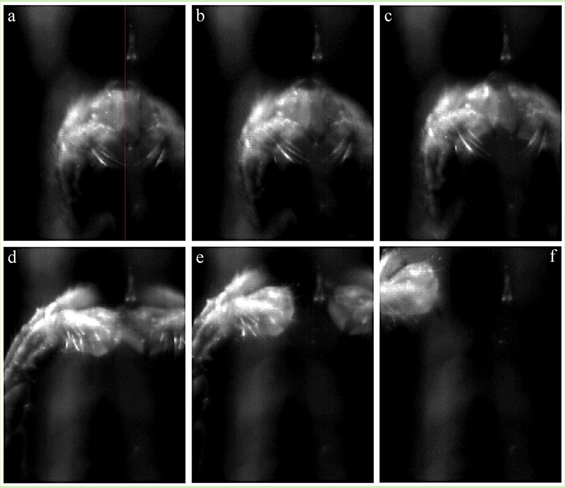


Figure 1: Frames taken from a high speed video showing the detachment of an arolium due to a distal upward movement of a foreleg. a normal position of the tarsus, **b-f** detachment of the arolium. A rolling off movement of the arolium is visible, **d** last frame in which the arolium stayed in contact to the substrate. Between each of the frames **a-d** there is a time span of about 100 ms and the time span between each of the frames **d-f** is about 1.8 ms. The glass plate on which the arolium adhered and in which it mirrored itself is highlighted in image **a** by a red line. The high speed video was recorded at 20000 frames per second.

New design for an adhesion device holder

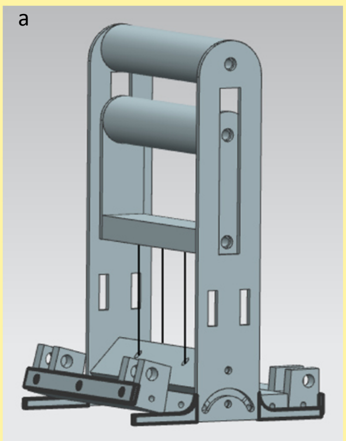
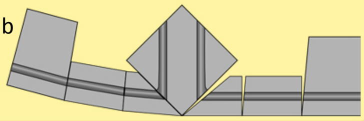
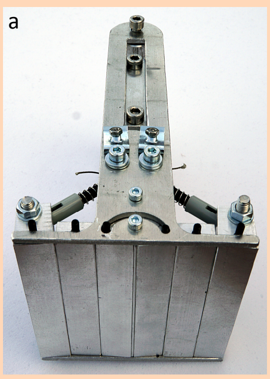


Figure 2: CAD sketches of the adhesion device holder. a CAD sketch of the whole adhesion device holder. The holder consists of a baseplate, which is divided into subunits. The subunits are connected though a cable control, which goes through holes in the subunits (figure b). The subunit in the middle is connected to the upper part of the holder. This upper part shows a handle to uplift the adhesion device holder with a object adhering on its baseplate and a second handle, which enables to lift the subunits of the holder for easy detachment. The left side of the subunits is lifted up. The adhesion device and the springs, which brings the subunits in the native position after lifting, are not shown.
b CAD sketch of the subunits forming the baseplate. All subunits show two holes for the cable control, which connects the subunits. In figure b a crosssection through one hole plane is shown. The left side of the subunits is lifted up.



Adhesion device holder in native position and with lifted subunits



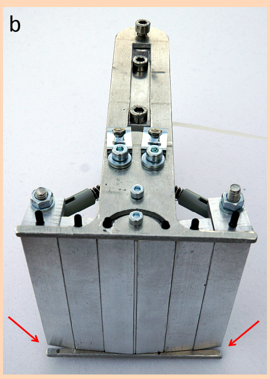


Figure 3: Adhesion device holder with subunits of the baseplate in native (a) and lifted (b) position. The adhesion device is not mounted to show the orientations of the subunits of the baseplate. With lifted subunits (figure b) adhesion devices show little contact to the substrate simplifying the detachment of the adhesion device. The red arrows point on the lifted subunits.

Background

Adhesive organs enable insects to reversibly adhere to substrates even during rapid locomotion. In this process a very fast but reliable change of adhesion and detachment is realised. The stick insect *Carausius morosus* detaches its adhesive organs by peeling them off the substrate, meaning little areas of the adhesive organs are detached one after another (Figure 1). For such a detachment mechanism low pulling forces are needed.

Biomimetic adhesion devices

A detachment mechanism as peeling seems also for artificial adhesion devices to be the easiest and the most effortless mechanism for detachment. However, artificial adhesion devices mostly exhibit a solid backing layer preventing effortless peeling. To lift up and detach a small area at the corner of such an adhesion device the whole backing layer has to be tilted, resulting in a deformation of the whole adhesion device, which requires high forces.

New design for an adhesion device holder

Subdividing the backing layer into small subunits allows a detachment of a small area at the corner of the adhesion device without deforming the rest of the adhesion device. Thereby, less force is needed to initiate and to complete detachment. To realise an easy detachment of artificial adhesion devices we constructed a holder, with which adhesion devices can be gradually detached from two sides off the substrate (Figure 2).

Functional Principle

During normal loading the subunits of the holder interlock with each other so that the pulling force is equally distributed over the whole contact area of the adhesion device ensuring maximal adhesion force. To enable a lifting of the subunits these show wedge-shaped interspaces between each other, which get smaller though the bottom of the baseplate (Figure 2b). Further, each subunit shows two holes though which all subunits are connected by a cable control (Figure 2b). The end of the cable control is connected to a moveable sledge, with which pulling forces can be applied to the cable control (Figure 2a). By pulling on the cable control the subunits were lifted up since in lifted position the subunits come closer together (Figure 2b and 3). Due to springs, mounted between the handle of the adhesion device holder and the outermost subunits, the subunits were brought into their native position, when the pulling force is reduced (Figure 3). In addition to the simplified detachment mechanism, the holder can be used to increase adhesion during application of the adhesion device: When brought into contact with the substrate with lifted subunits, which are lowered subsequently, air trapping is prevented and hence the area of contact can be maximised.

For more information please download my PhD thesis "Biomimicry of the adhesive organs of stick insects (*Carausius morosus*)" here (54.8 MB):

http://publications.rwth-aachen.de/record/565092