Assembly Technology

Lecture 6: Industrial grippers and gripping technology

Acknoledgement

Lecture based on the keynote held by Dr. Gualtiero Fantoni at the NEWTECH 2013 conference in Stockolm. The work was inspired by the, by then, ongoing work for the Keynote on industrial grippers from the CIRP annals 2014.

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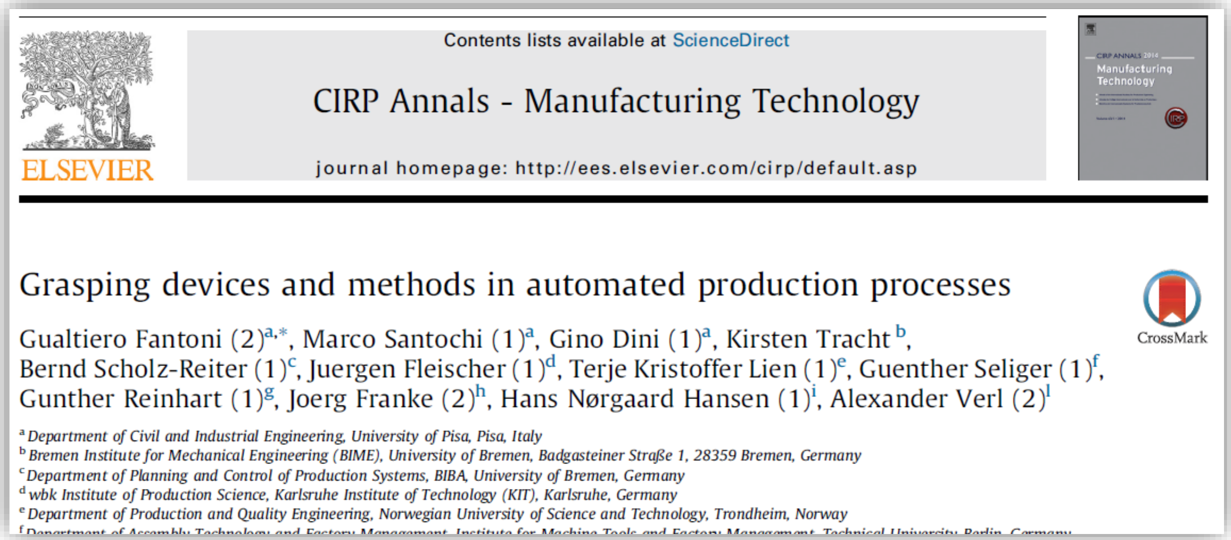

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Grasping devices and methods in automated production processes

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Outline

- Standard definition and abstract definition
- Grasping process
  - Grasping principles
  - Releasing principles
  - Monitoring principles
- Hybrid Grippers

Intended Learning Outcome

- Describe the grasping process and place it within the wider scope of the assembly process
- List and classify according to the gripping principle the main types of industrial gripper. Describe possible applications for each technology

Gripper: definition

"a subsystems of handling mechanisms which provide temporary contact with the object to be grasped [..] and ensure the position and orientation when carrying and mating the object to the handling equipment [..]; the term "gripper" is also used in cases where no actual grasping, but rather holding of the object where the retention force can act on a point, line or surface [..]"

Monkman et al. Robot grippers

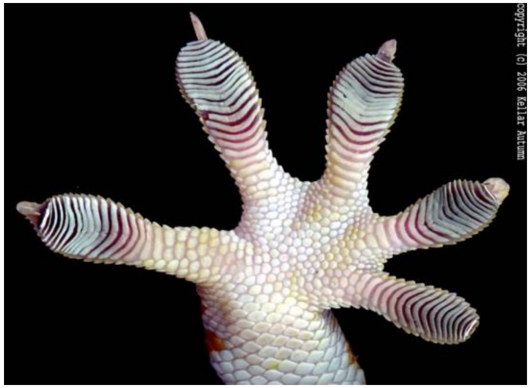
In abstract terms:

h. mechanisms + Block/Hold + object + temporary

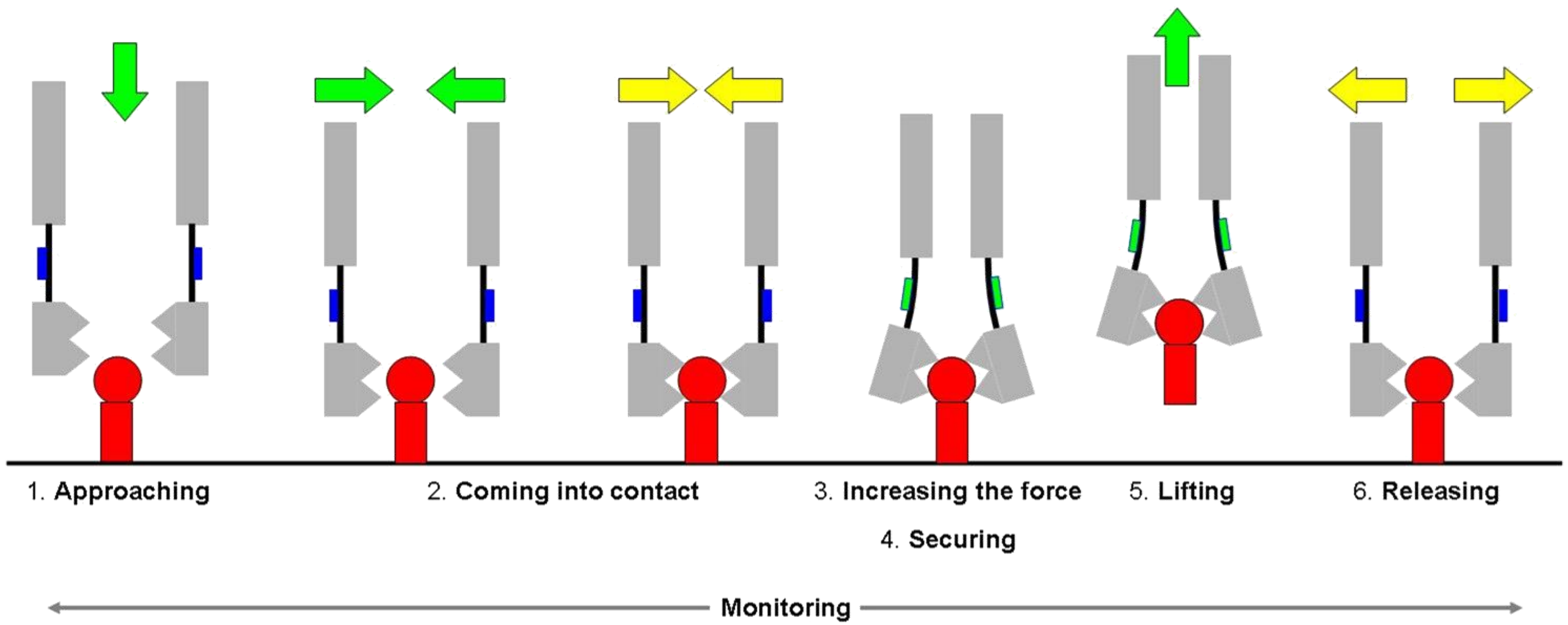
That means that after grasping

some of the DOF of G. and O. are the same

Case of «non standard» grippers



The grasping process (1)



The grasping process (2)

1. **Approaching** the object: the gripper is positioned nearby the object.
2. **Coming** into contact: the contact is achieved. In case ofcontactless handling, the object is in the range of the force field generated by the gripper.
3. **Increasing** the force within certain limits.
4. **Securing** the object: the force stops increasing when the desired degrees of freedom of the object are removed and the object stops moving independently from the gripper.
5. **Moving** the object. In such conditions the gripper and the object are joined and the object can be moved. Sometimes the process can be carried out by the gripper itself.
6. **Releasing** the object. Usually at the macroscale it is caused by gravity when the grasping force is deactivated. At the microscale the problem is more complex since surface forces overcome gravity, therefore other releasing strategies are needed.

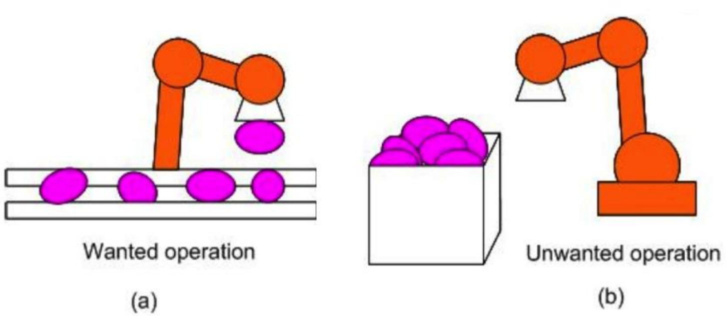
Monitoring the grasping: force and torque sensors, stick slip sensors, contact sensors, etc. can be used to detect and monitor all the process and particularly the effectiveness of grasping.

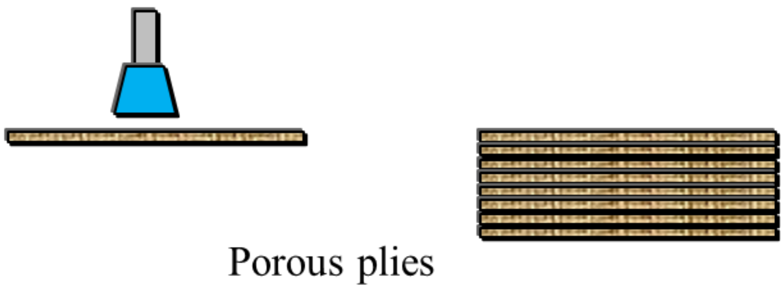
Beyond grasping

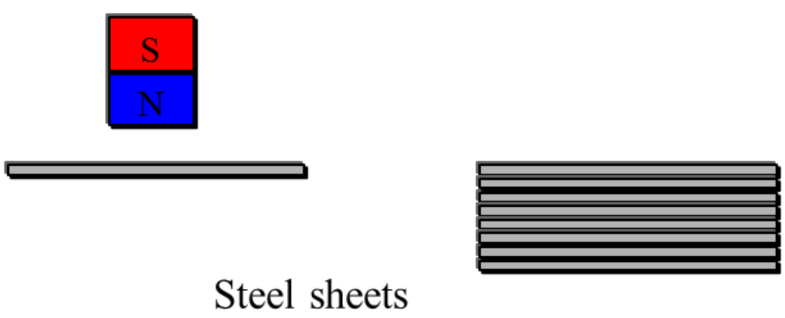
The complexity of the grasping process is often underestimated since it looks very familiar for human beings. However the automation of this process creates many problems. In fact the design of a gripper does not depend only on the object characteristics but it is also affected by previous phases as feeding and the following phases such as handling, positioning and releasing. In general correctly fed parts require less versatile grippers with respect to a bin picking situation where the gripper has to face problems such as pieces with different orientation, part tangling, etc. Similarly, handling needs such as high acceleration, reorientation, high precision releasing generate constraints in the gripper design or choice

Beyond grasping

Feeding → Grasping → Handling → Placing

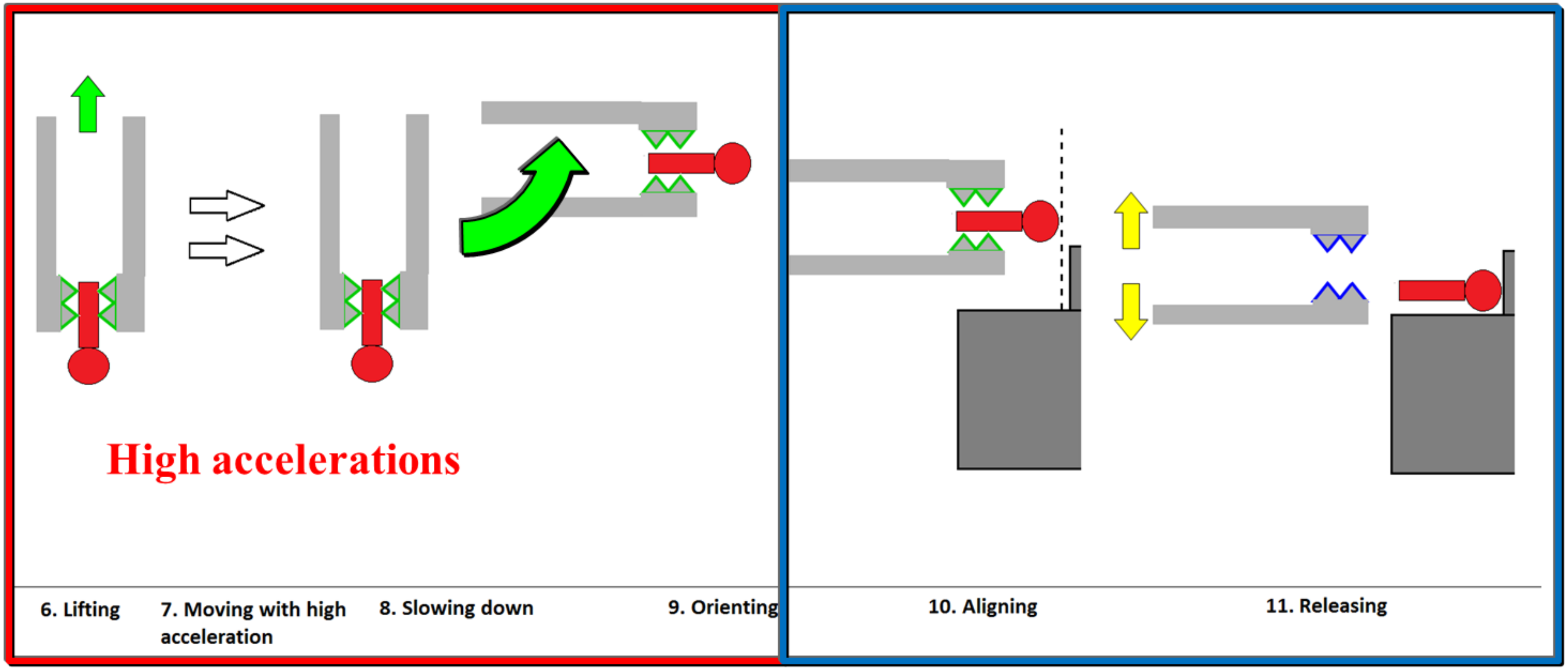






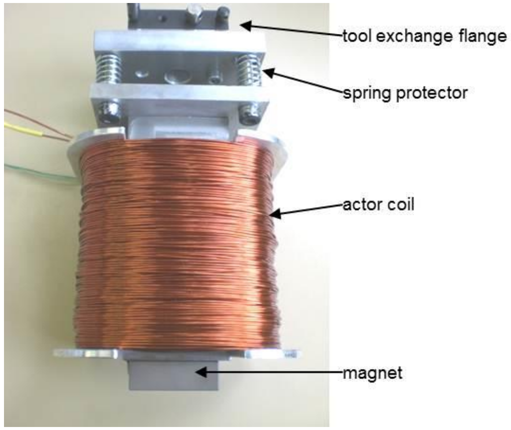
Patented end effector design uses multiple switchable magnets to create a shallow magnetic field for destacking sheet metal. *(Courtesy of Magswitch Technology Inc.)*

Beyond grasping



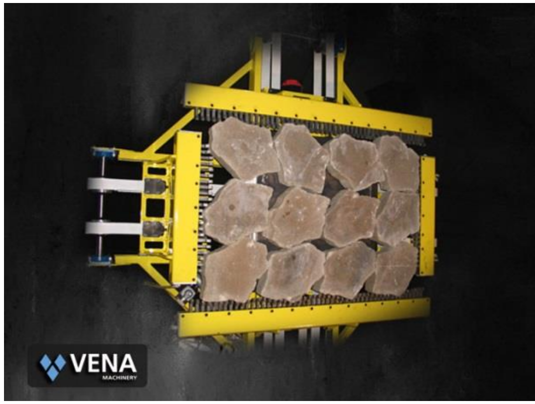
Releasing

Sometimes releasing can be a problem...



Permanent magnets on rotors of electric drives

Sol-Gel dough products



Frozen products

Adhesion problems in micro assembly

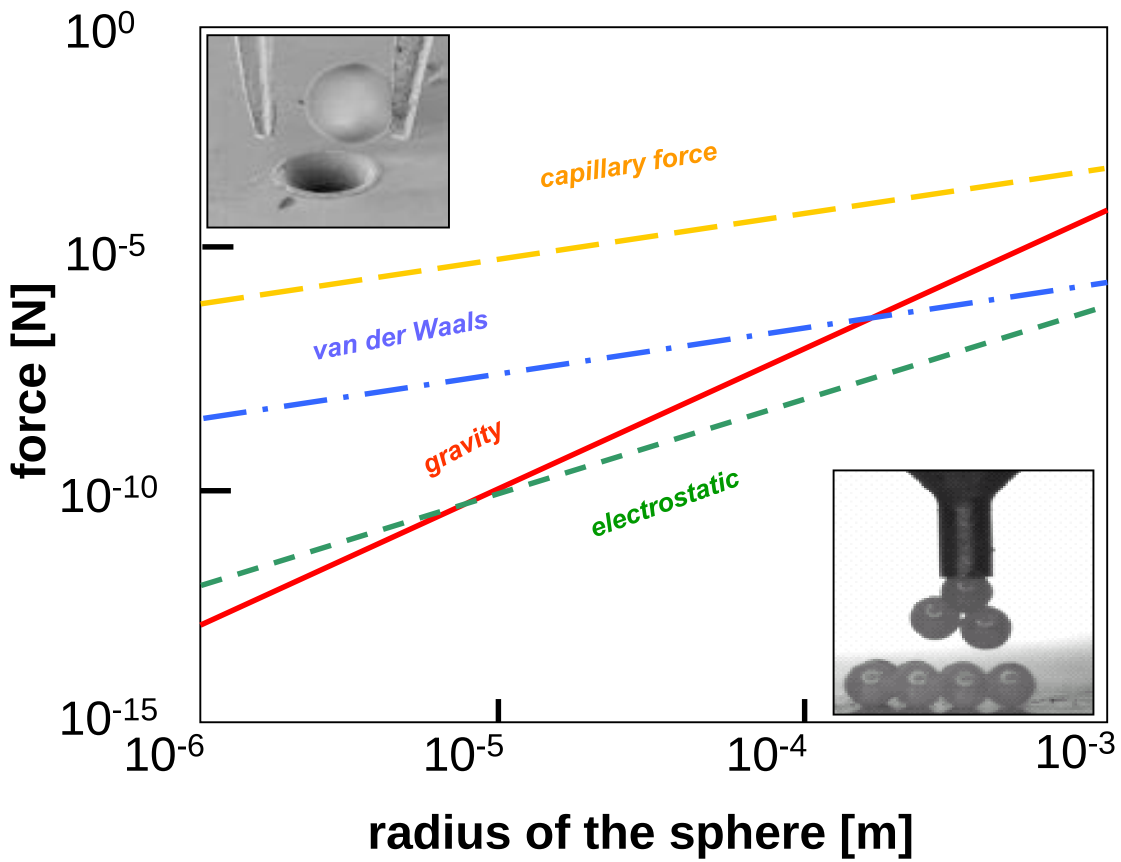
Decreasing size of part reduces the:
- surface area by 2nd power
- volume by 3rd power

Adhesion forces:
- surface tension
- Van-der-Waals
- electrostatic

Detaching force out of gripper:
- gravity

Results:
- with decreasing part size the relevance of adhesion force increases

Force between a silicon sphere and plane (by Fearing)

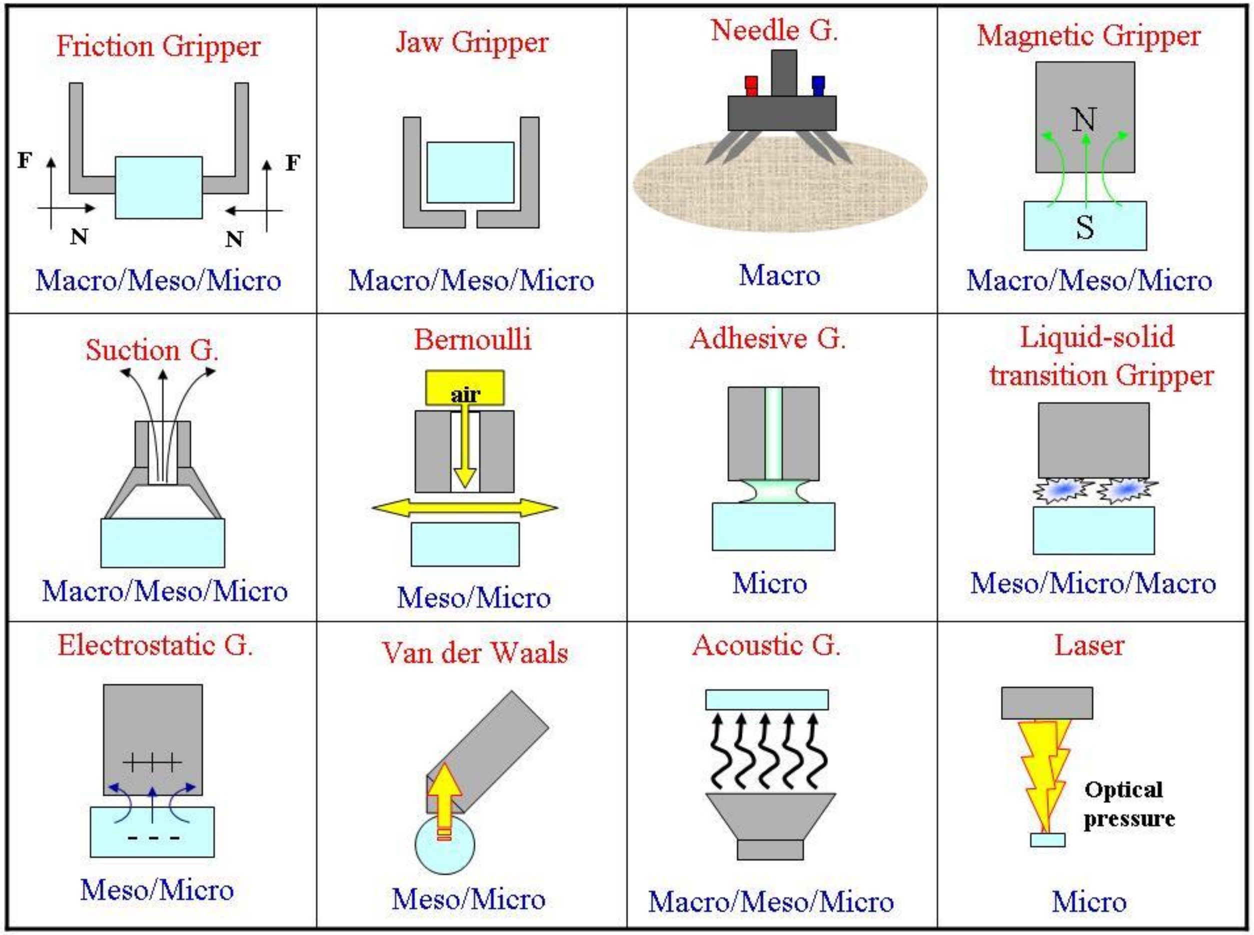


Grasping principles: some definitions

“the physical principle which causes the force effect necessary to get and maintain the part in a relative position with respect to the gripping device”

“subsystems of handling mechanisms which provide temporary contact with the object to be grasped. They ensure the position and orientation when carrying and mating the object to the handling equipment. Prehension is achieved by force producing and form matching elements. The term “gripper” is also used in cases where no actual grasping, but rather holding of the object as e.g. in vacuum suction where the retention force can act on a point, line or surface”

Grasping principles

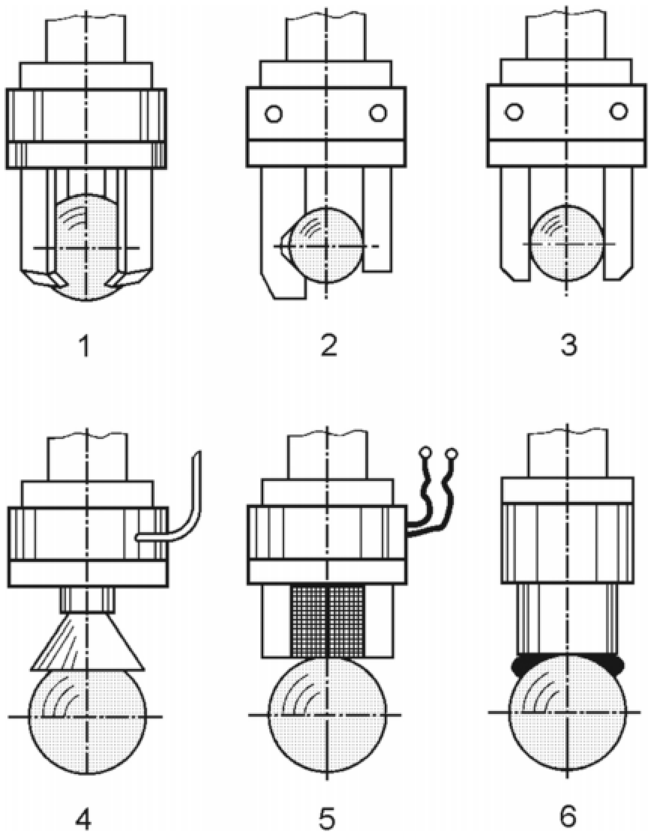


Grasping principles

End effectors may consist of a gripper or a tool. When referring to robotic prehension there are four general categories of robot grippers, these are:

- **Impactive** – jaws or claws which physically grasp by direct impact upon the object.
- **Ingressive** – pins, needles or hackles which physically penetrate the surface of the object (used in textile, carbon and glass fibre handling).
- **Astrictive** – suction forces applied to the objects surface whether by vacuum, magneto- or electroadhesion).
- **Contigutive** – requiring direct contact for adhesion to take place (such as glue, surface tension or freezing).

Grasping of a spherical object



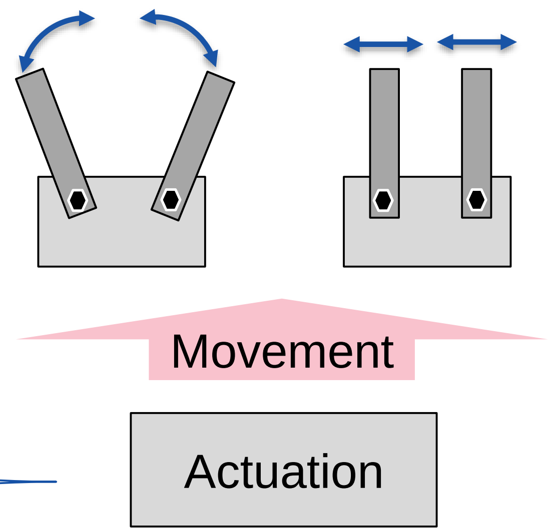
1 pure enclosing without clamping
2 partial form fit combined with clamping force
3 pure force closure
4 holding with vacuum air (pneumatic force closure)
5 retention using magnetic field (force field)
6 retention using adhesive media

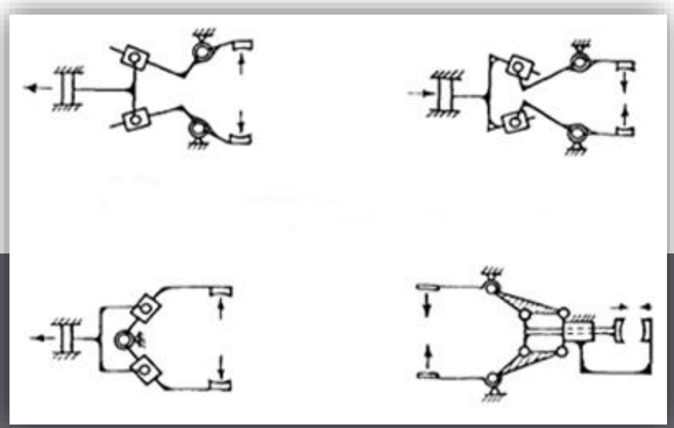
Standard Friction and Jaw grippers

Friction and jaw grippers are the more common in industry. They can be classified in several ways:

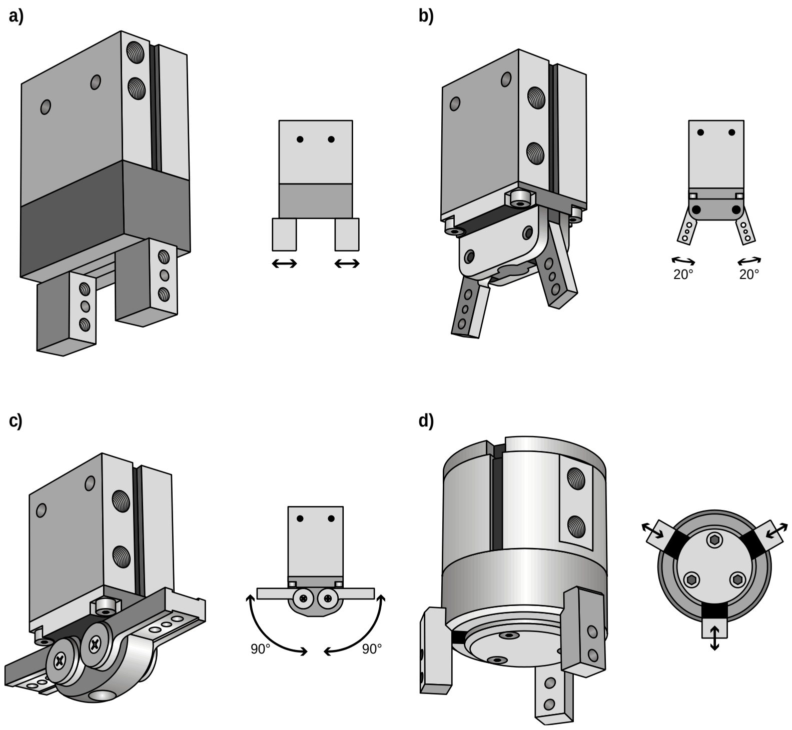
1. Finger movement
   - Pivoting
   - Linear or translational

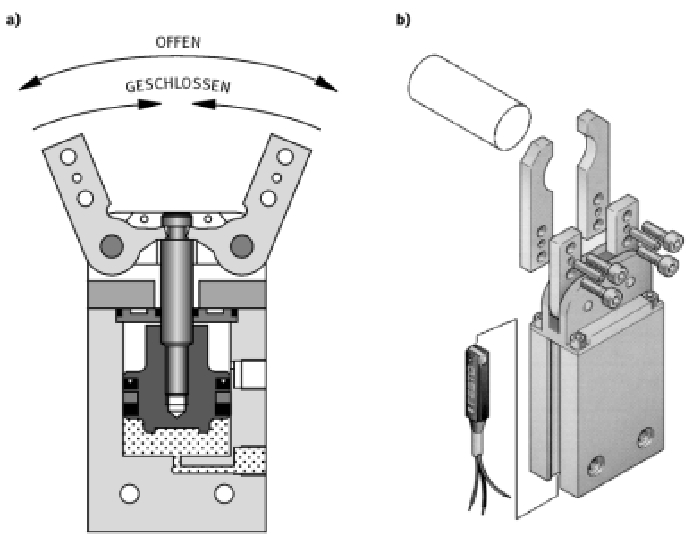
2. Linkage actuation
   1. Screw actuation
   2. Gear and rack actuation
   3. Rope and pulley
   4. Cam actuation





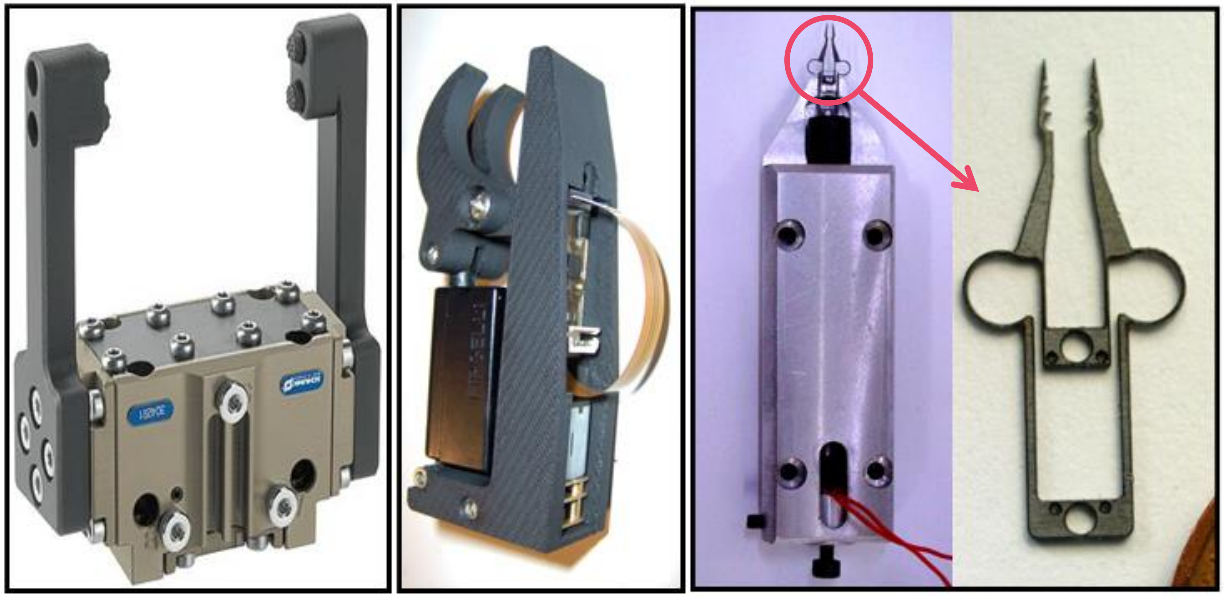
Standard Friction and Jaw grippers





Video:
- Festo Monkman

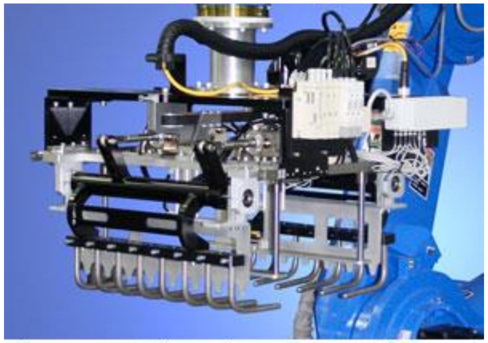
Standard Friction and Jaw grippers



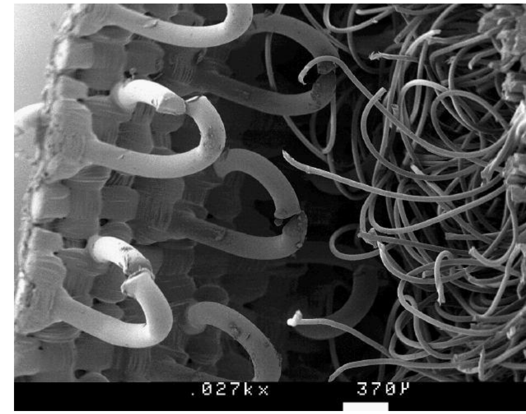
Friction-jaw mechanical grippers

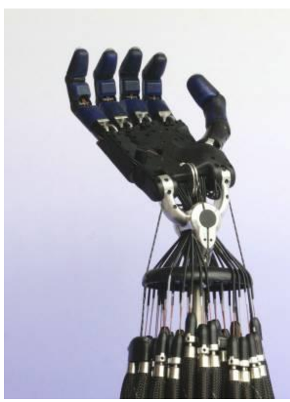
- Left: two fingers;
- Centre: single moving finger;
- Right: micro-gripper piezo-electrically actuated.

Other friction and jaw grippers

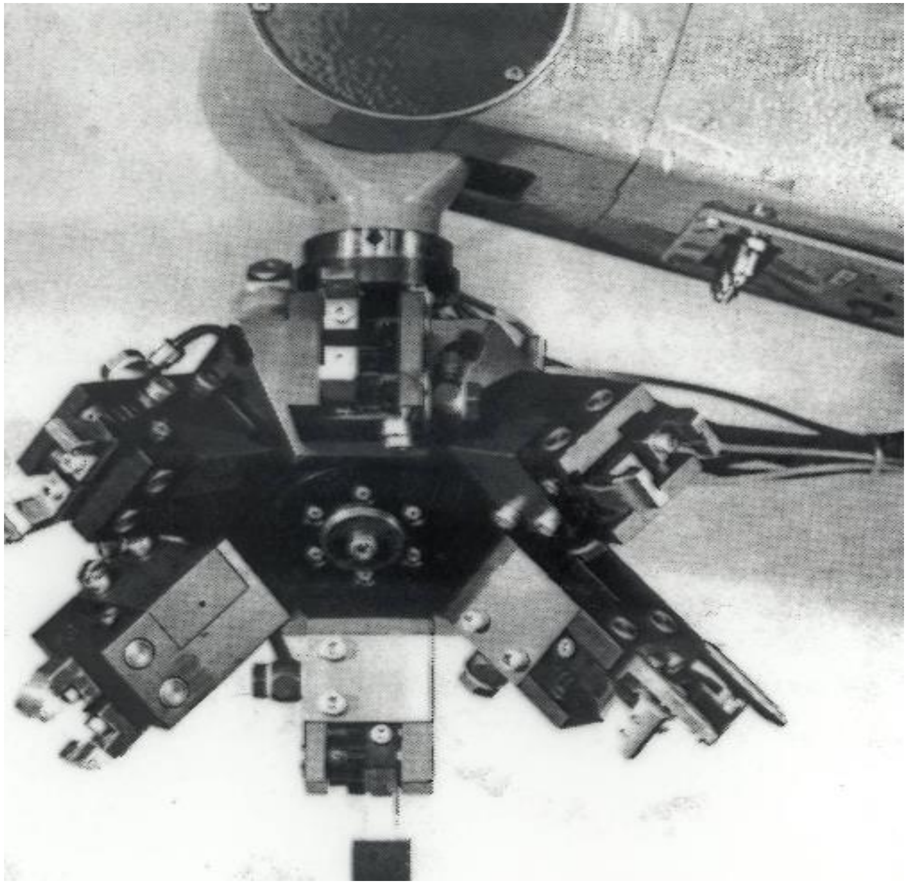


New servomotor bag gripper with automatic, on-the-fly adjustment for bags of different sizes. *(Courtesy of SAS Automation LLC)*





Rotational Flexible Gripper



Gripping force

Gripping force is the maximum effort applicable by the end-effector. As robot grippers are not all alike, different terms exist. Grip force is normally used for claw-grippers, representing the force that the “fingers” can apply on a part. In other cases, magnetic or suction force can be used for applications requiring pneumatic or magnetic end-effectors. This parameter is normally expressed as a force unit (Newtons [N] or pound force [lbf]).

Minimal gripping force calculation

The calculation of the minimal gripping force that the robot gripper must apply will include the mass of the part that must be moved, the friction coefficient between the finger material and the part material and the gravitational acceleration constant.

Here is an approach to the calculation (expressed in metric units) that can be made to approximate the gripping force needed for an application. Notice that the gripping force is the sum of all the fingers' force.

- F: Gripping force [N]
- u: Coefficient of static friction
- m: Mass of the part [kg]
- g: Gravitational acceleration [9.81 m/s^2]
- a: Acceleration (if it is significant)

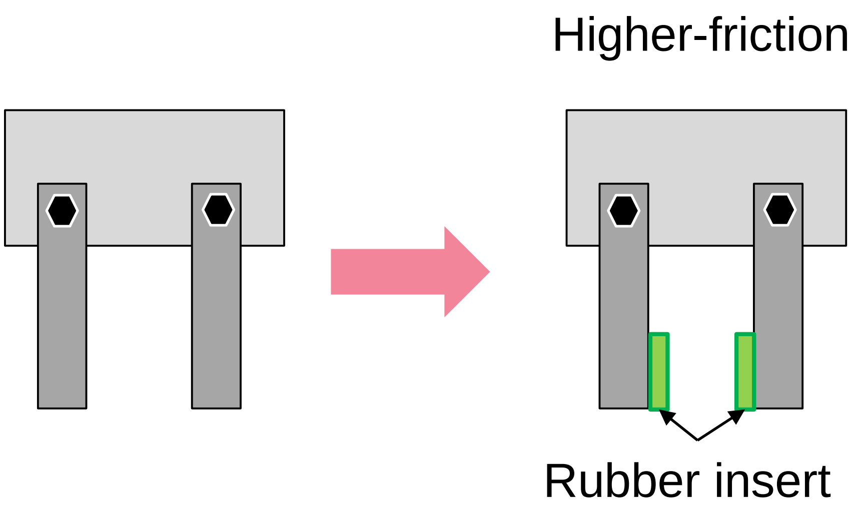
To make sure the part doesn't slip during static prehension, the gripping force should be higher than the weight of the part itself.

$$F > m(g+a)/u * (\text{safety factor})$$

Increasing gripping force

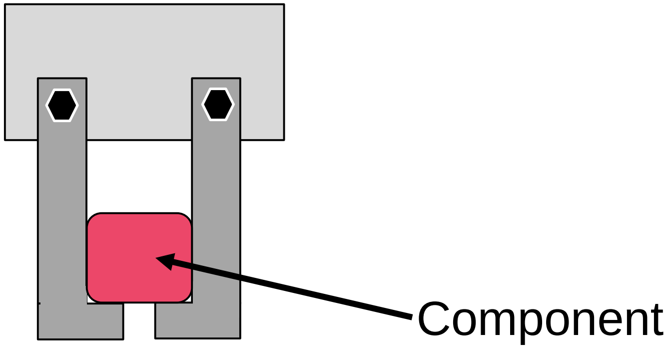
Since each application has its own friction coefficient, the safety factor should be enhanced respectively for a low friction or high friction use. The safety factor should likewise be enhanced if the robot has a strong acceleration/deceleration or the possibility of impact during movement.

- By improving the coefficient for static friction between the part and the **robotic** gripper's fingers you can reduce the gripping force needed on an object



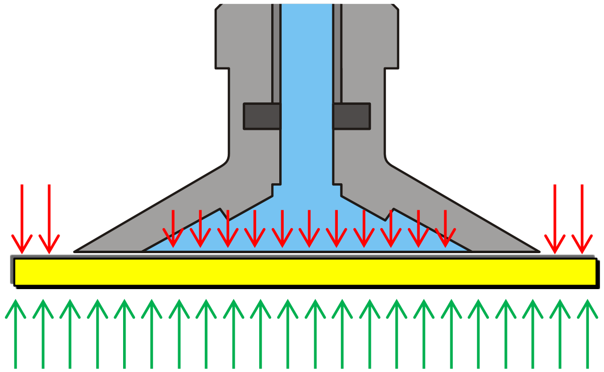
Going around gripping force

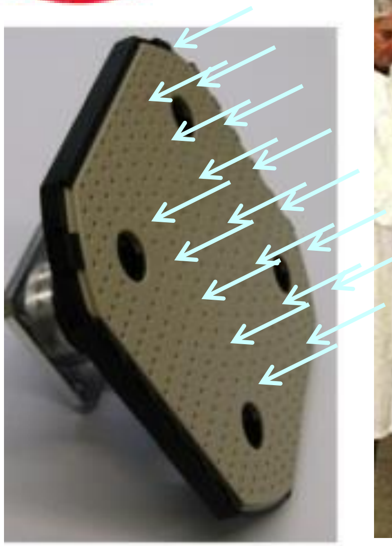
By using a robot gripper that can encompass a part - such as the Robotic end effector - you can lift more than the sum of the above formula (but keep in mind you still need to respect the **payload** of the end effector and the robot!).

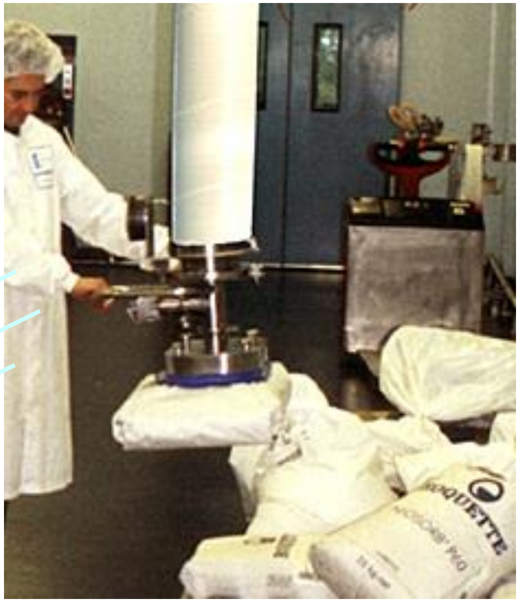


Vacuum grippers

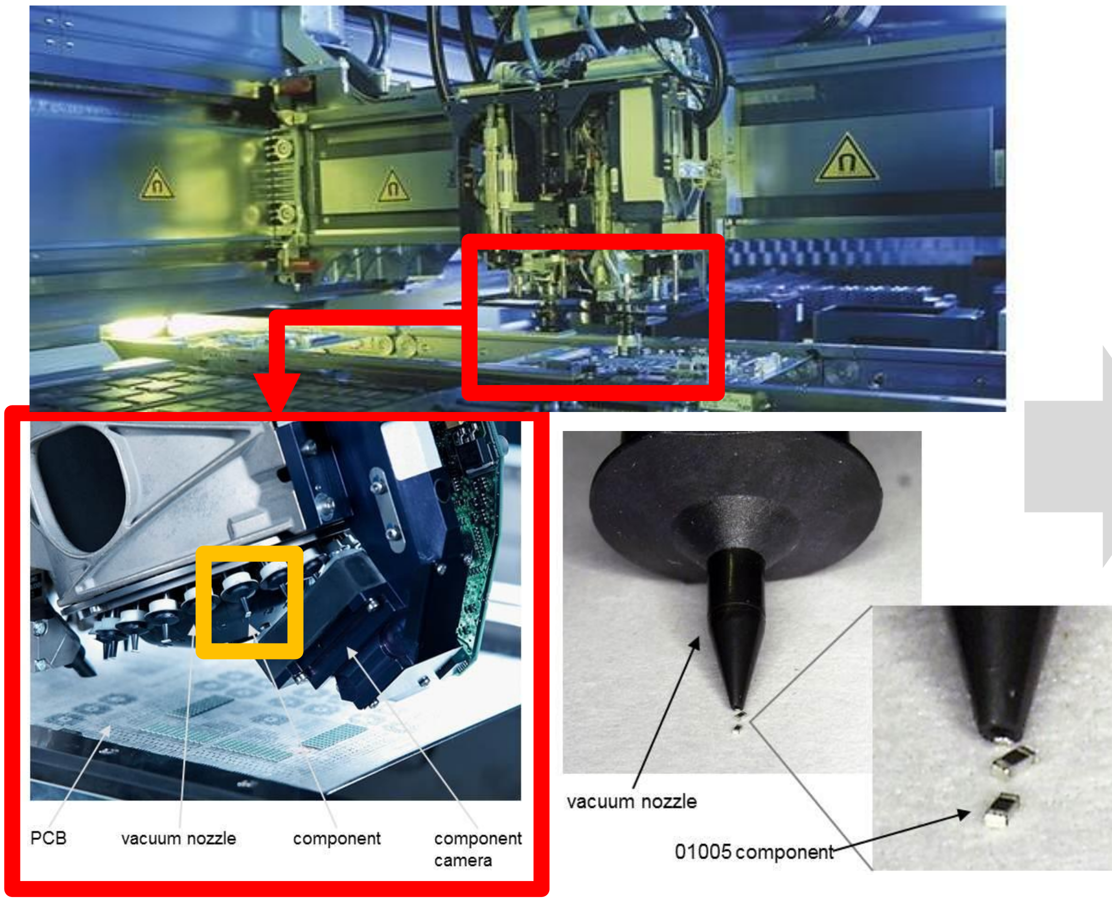
Suction cups are used
to hold flat object

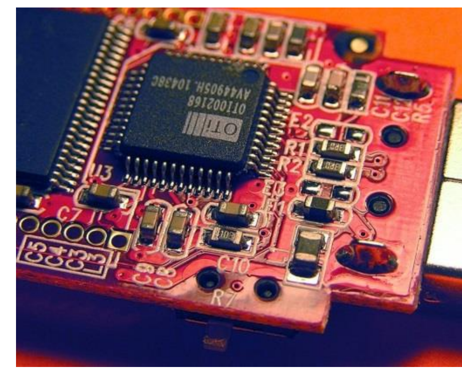






Vacuum: the key tech in Surface-Mount Devices assembly



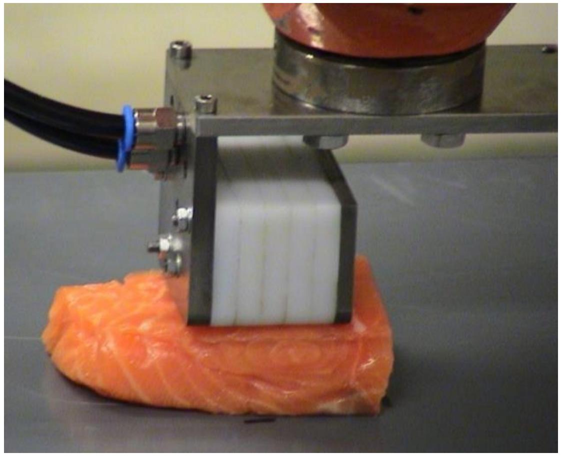


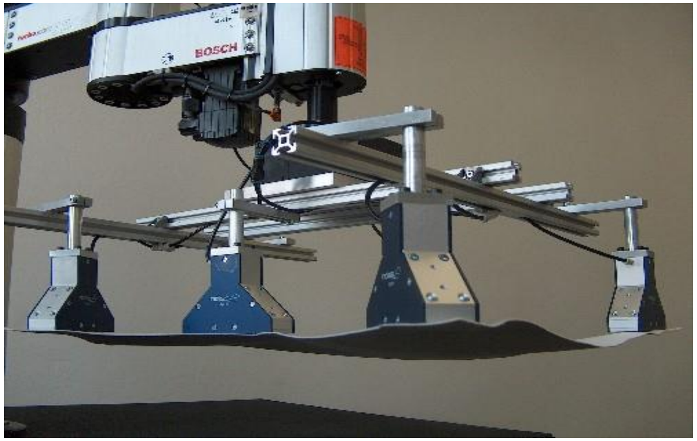
Magnetized Gripper

Used to hold ferrous components

Needle Gripper

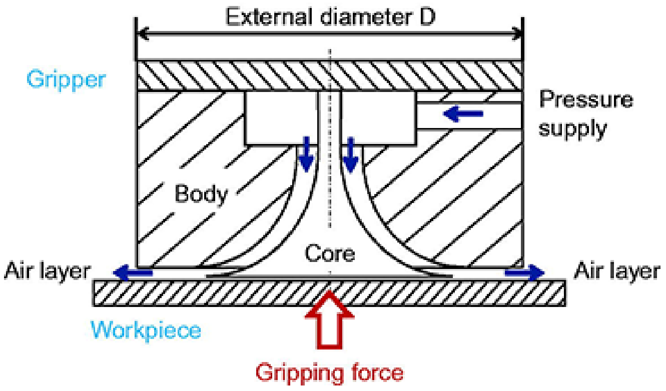
Used to hold tissues and other material that can be penetrated without damages





Bernoulli Gripper

Bernoulli grip uses airflow to adhere to an object without physical contact.[1] Such grippers rely on the Bernoulli airflow principle. A high velocity airstream has a low static pressure. With careful design the pressure in the high velocity airstream can be lower than atmospheric pressure. This can cause a net force on the object in the direction normal to the side with lower local pressure. A Bernoulli gripper takes advantage of this by maintaining a positive pressure at the gripper face compared to the ambient pressure, while maintaining an air gap between the gripper and the object being held



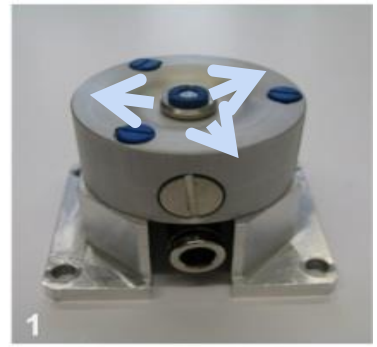
Intersting because is like a vacuum gripper without contact!

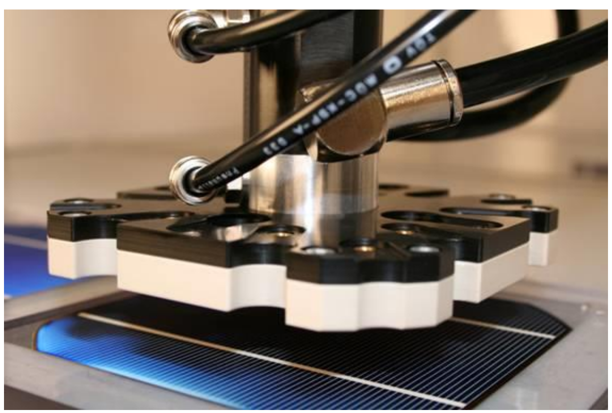
Bernoulli Gripper: application

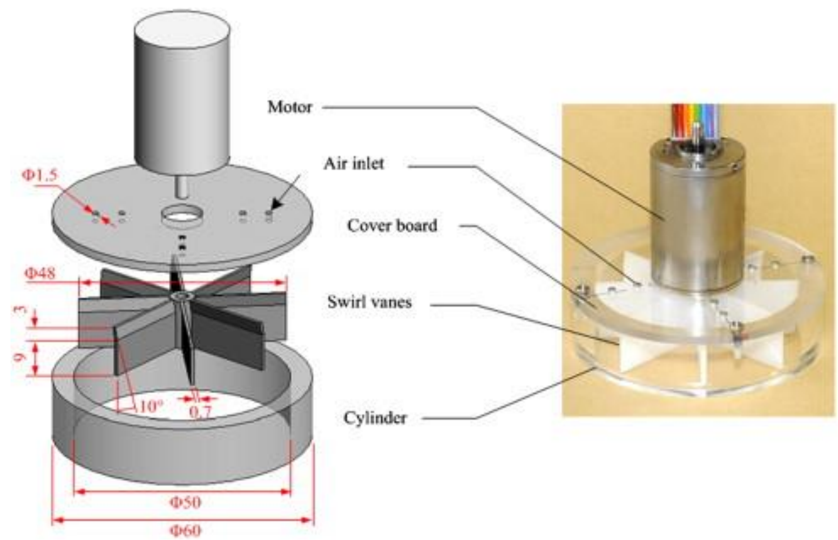
Commercially available Bernoulli grips are commonly used to handle rigid sheet like material such as silicon wafers in circuit board manufacturing, or photovoltaic cell components.

Since the grip is contactless, this form of gripping lends itself to handling sterile material to prevent chemical and/or biological contamination

Bernoulli Gripper

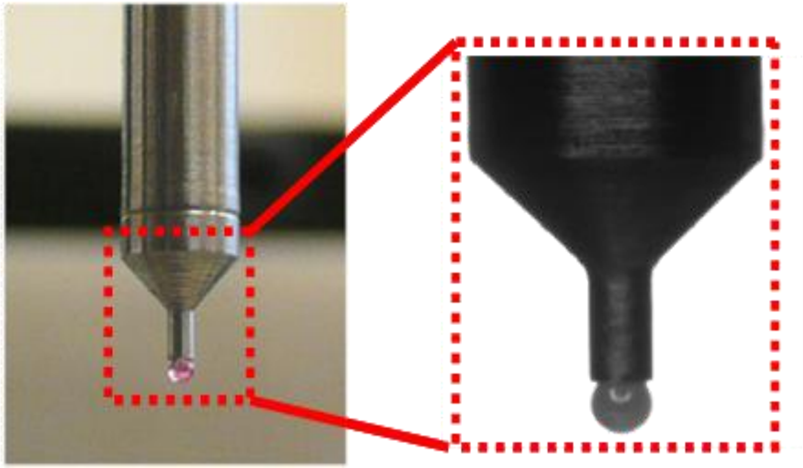






Capillary gripper

At microscale capillary grippers have been used owing to their flexibility and reliability; have a compliant behaviour and a self-centring effect; capability of grasping small and light components in a wide range of materials and shapes; capability of handling delicate components as the meniscus between the gripper and the object has a “bumper” effect.



To release parts grasped by capillary grippers:

- Scratching agaist an edge,
- Two different fluids,
- Changing the gripper curvature,
- Electrowetting.

Capillary gripper pros vs cons

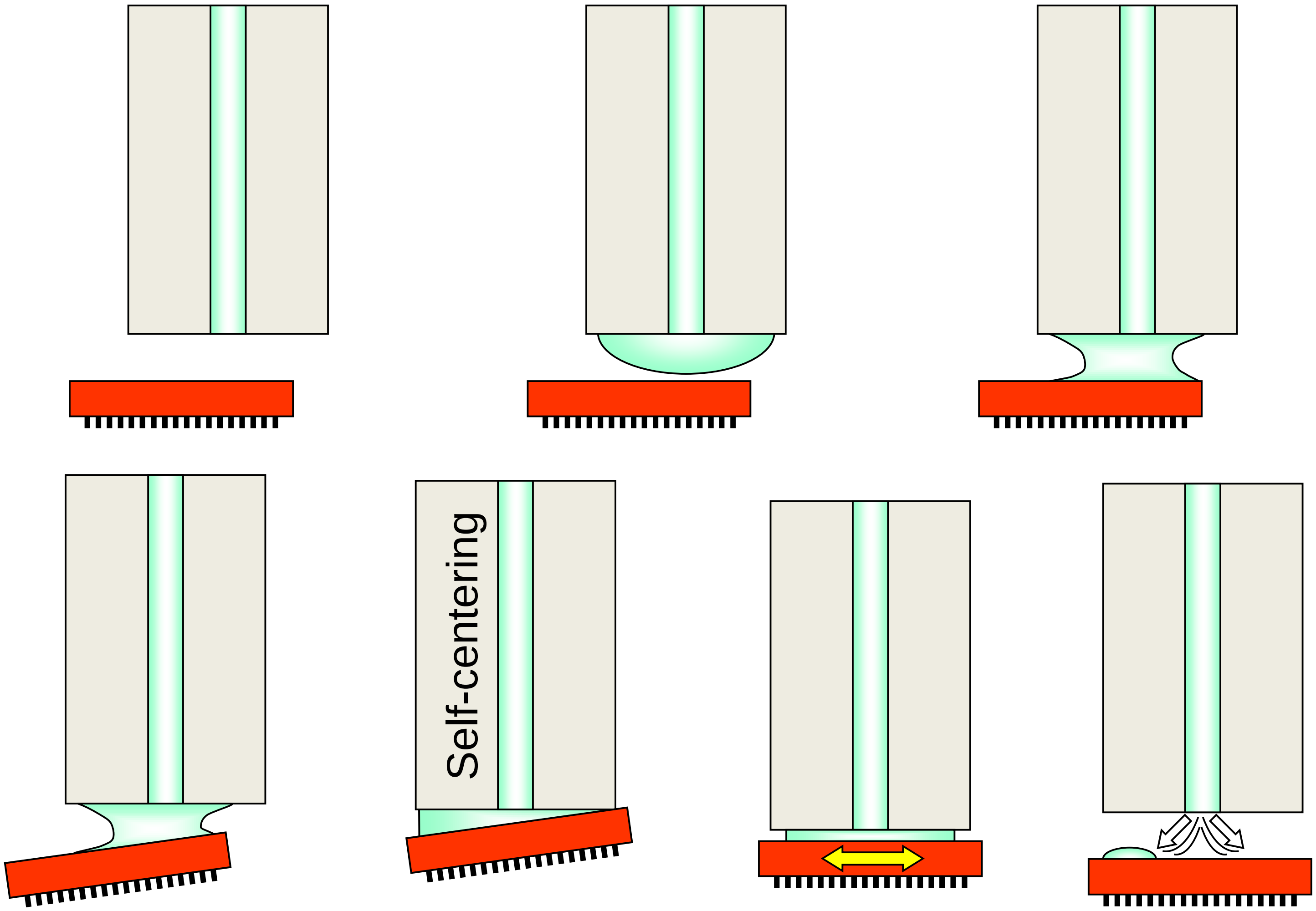
Good:

- Reliable
- Self centering
- Compliant
- It can work without refilling for more than 1000 times (grasping-releasing cycles)

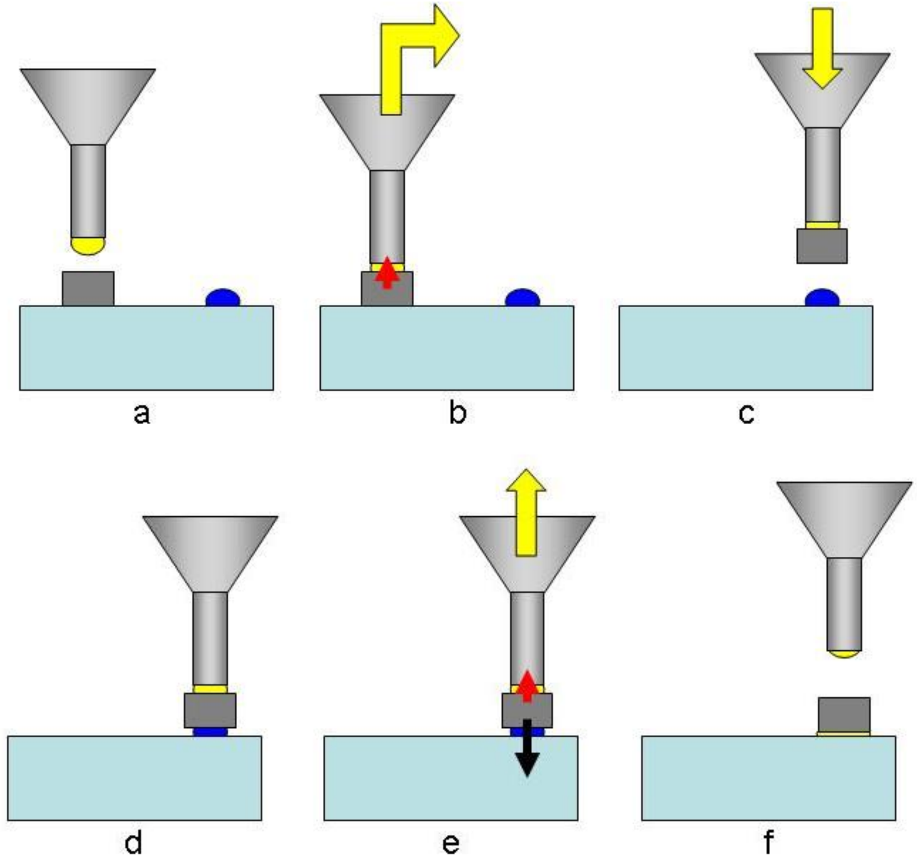
Bad:

- It leaves traces and can stain lenses or surface finished parts (mirrors, optics)
- Particular care in its use with SMDs and other electronic components
- Often the process need for a following phase of heating in order to remove (by evaporation) the liquid

Capillary gripper grasping and releasing

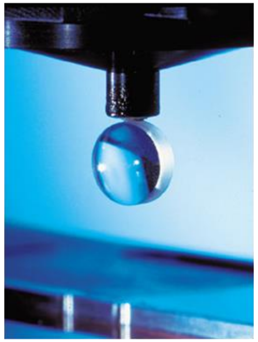


Capillary gripper grasping and releasing

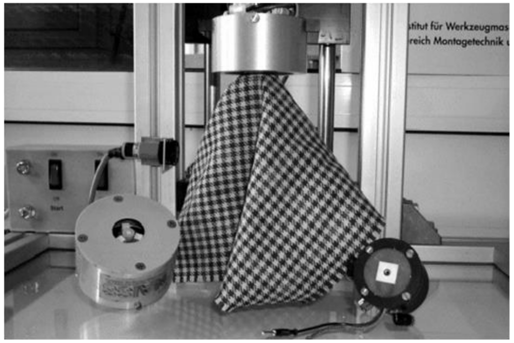


«Ice» gripper

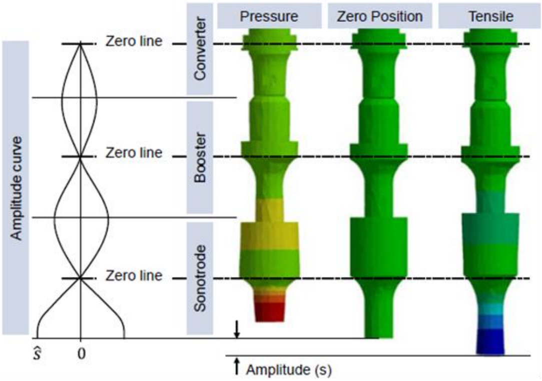
More in general we can define them as «phase transition grippers», they exploit the transition of a material from liquid to ‘solid’.



Ice gripper
for
microlenses

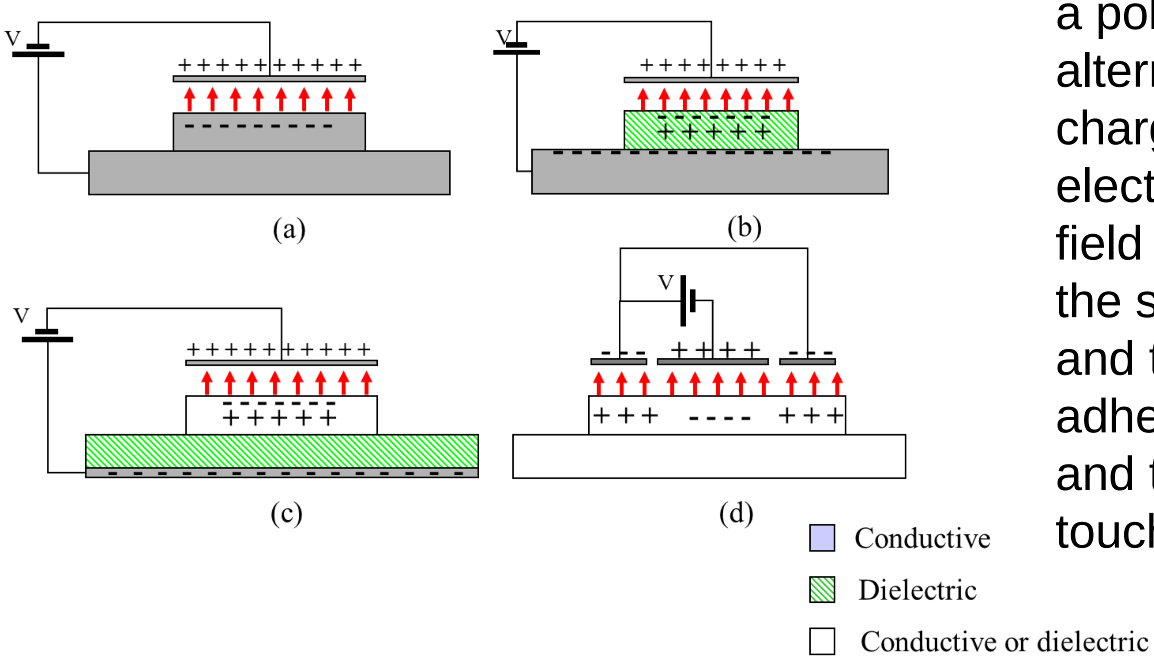


Ice gripper
for limp and air-permeable textiles



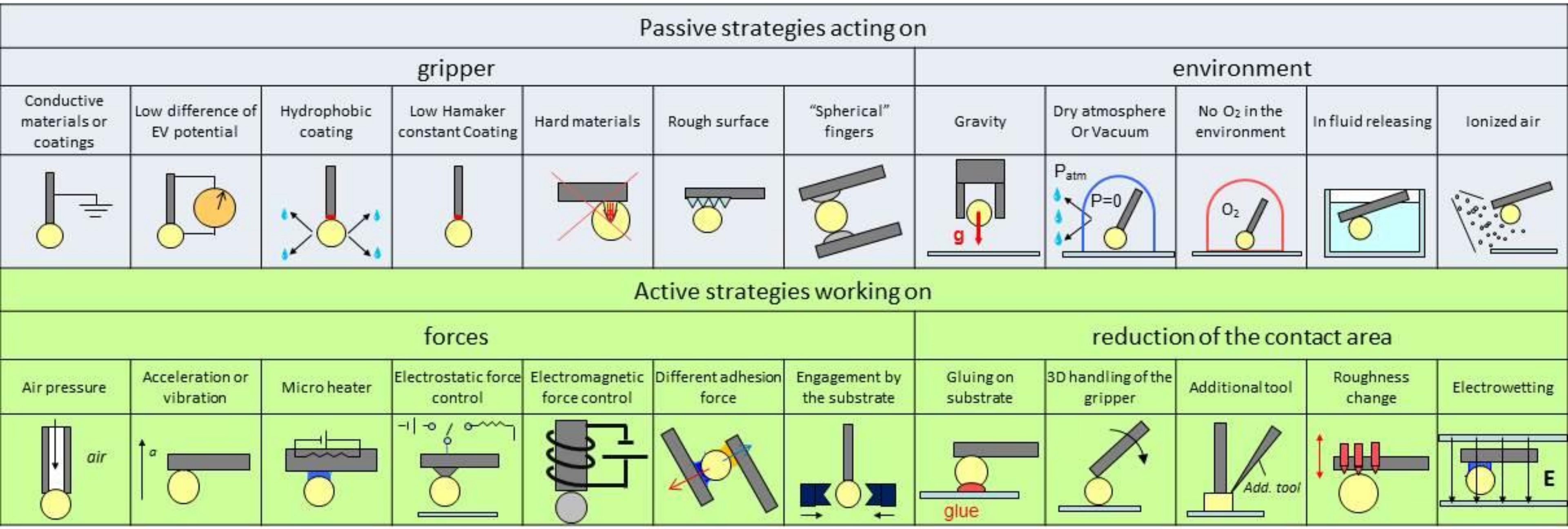
Ultrasonic-assisted adhesive for
limp and air-permeable textiles

Electrostatic principle

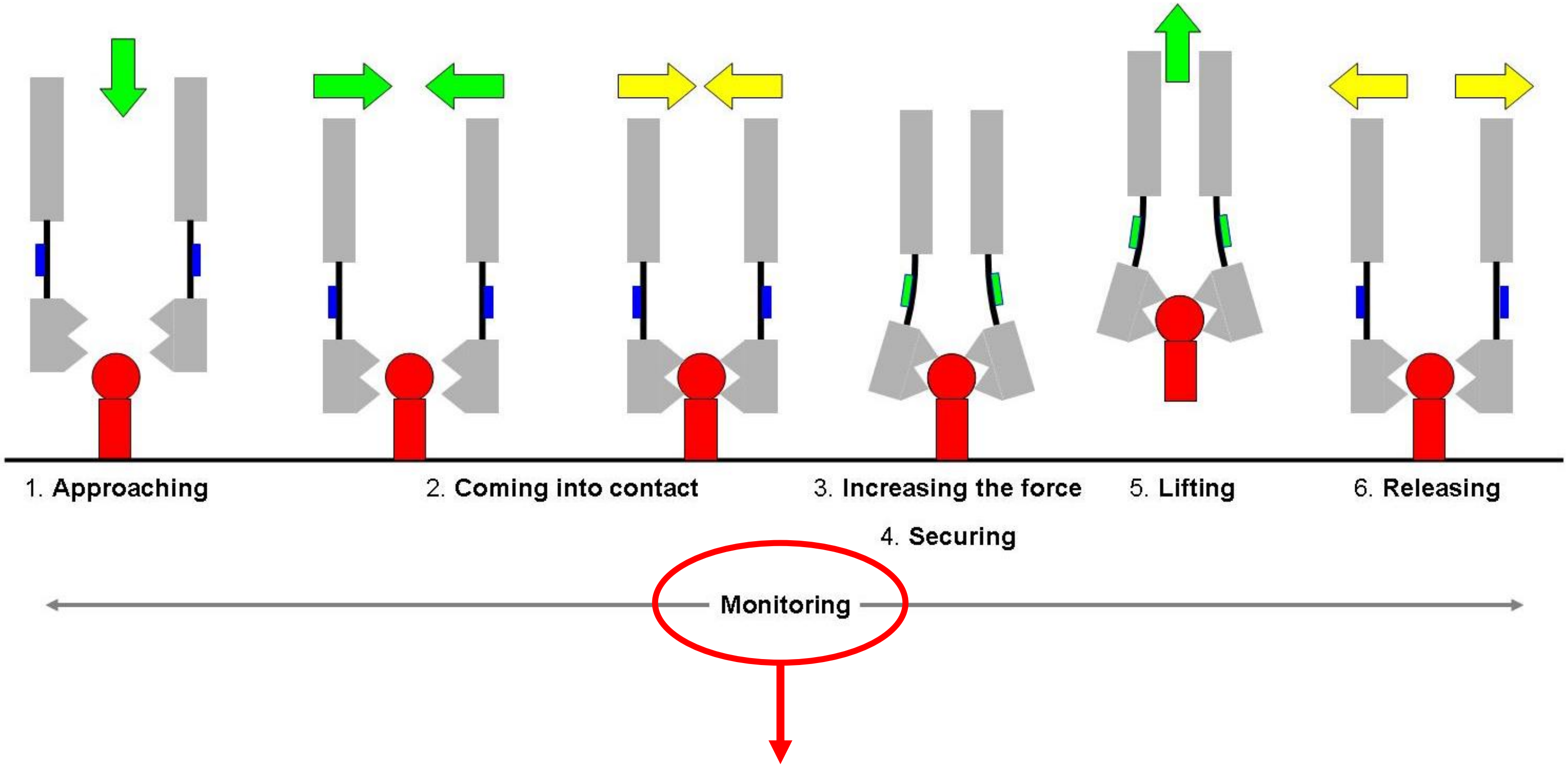


An electroadhesive pad consists of conductive electrodes placed upon a polymer substrate. When alternate positive and negative charges are induced on adjacent electrodes, the resulting electric field sets up opposite charges on the surface that the pad touches, and thus causes electrostatic adhesion between the electrodes and the induced charges in the touched surface material

Releasing principles

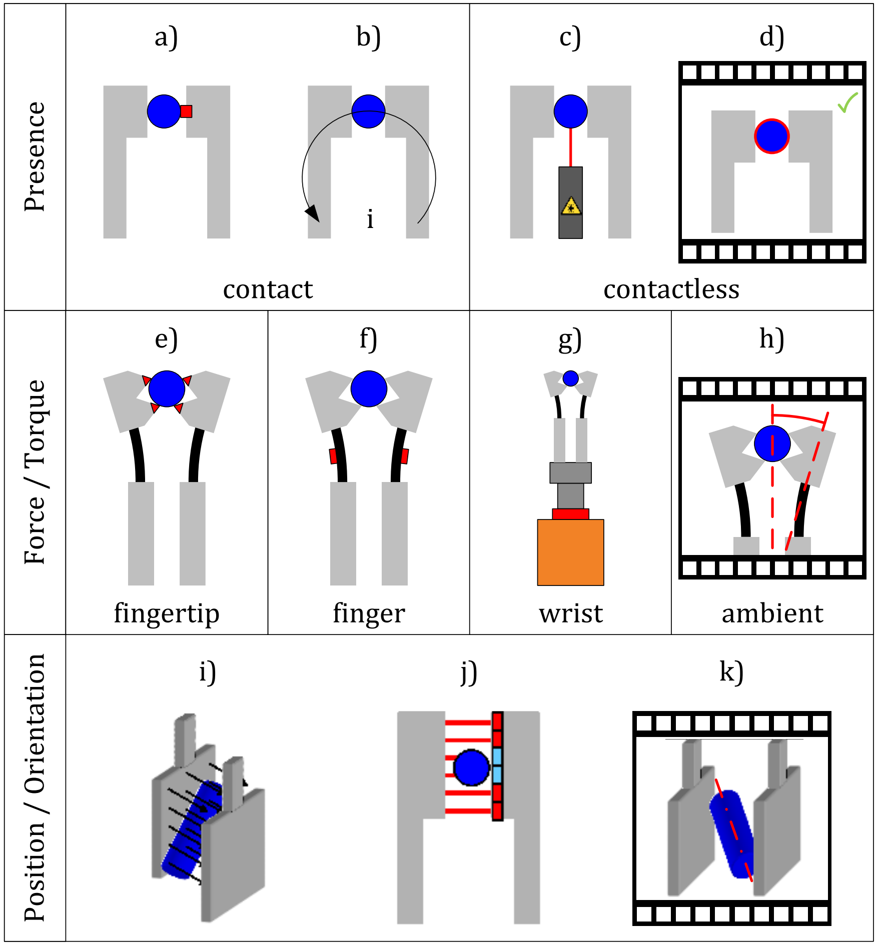


Monitoring



Monitoring the grasp: direct or indirect control of force, torque, stick slip, contact.

The monitoring methods



Sensing principles:

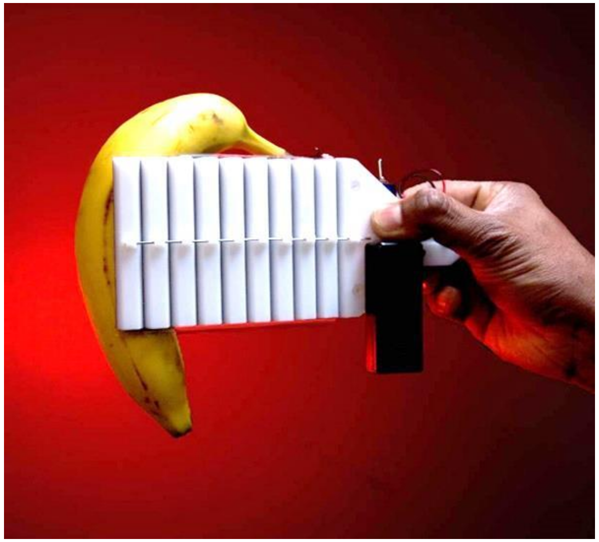
a) Mechanical switch;
b) electrical sensor;
c) photoelectric sensor;
d) vision based;
e) tactile sensor;
f) strain gauges;
g) force/torque sensor;
h) vision based;
i) capacitive or electrostatic;
j) led-photodiode (often IR);
k) vision based monitoring

Hybrid Grippers

Hybrid grippers are emerging:

- More than two principles per gripper
- Increasing object-gripper coupling

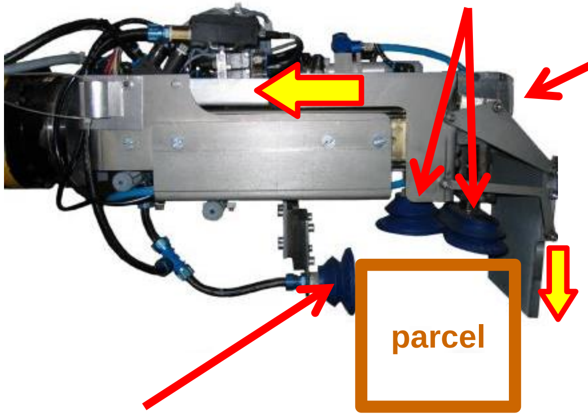
Electroadhesive + Force

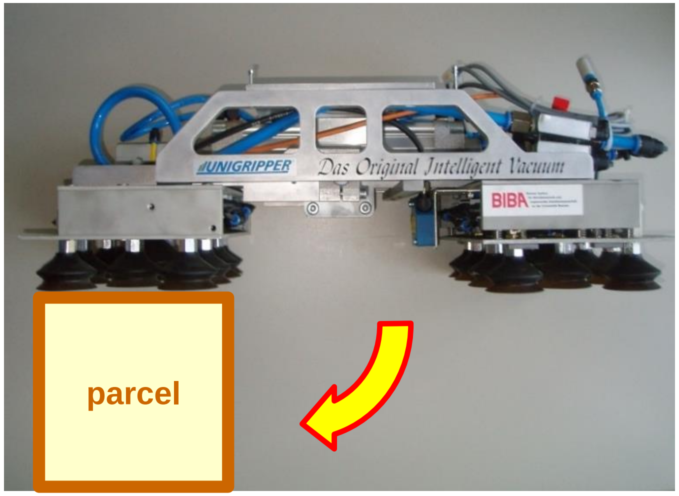


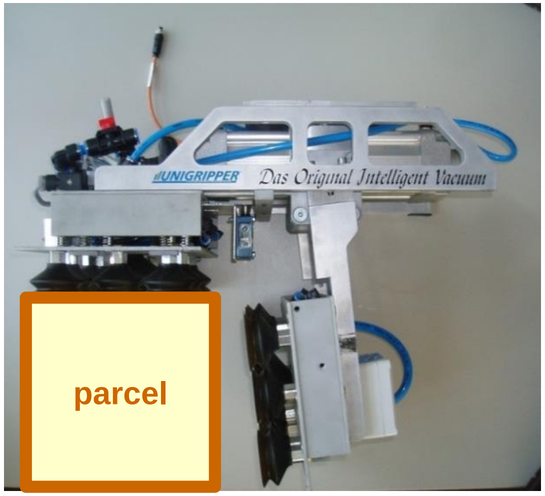
Form + Force + Vacuum

Bernoulli + «Form»

Vacuum+Friction







Video Summary (≈ 17:00)

1. Capillar Gripper 1 (0:08)
2. Capillar Gripper 2 (0:20)
3. Festo - Bionic Handling Assistant (1:35)
4. Festo – FlexShapeGripper (1:46)
5. Festo – MultiChoiceGripper (2:12)
6. Festo Bernoulli Gripper (1:53)
7. Festo ExoHand (1:52)
8. Hang Testing (1:48)
9. Needle Gripper for Handling Composite Textiles and Preforms (0:57)
10. Picks Up Semi-Liquid Materials (3:02)
11. SMT machine for PCB vacuum grippers (1:22)
12. Ultrasound Gripper (0:15)

Questions for the formative assessment*

1. List and describe the step of a typical grasping process.
2. List and describe the four general cathegories of robor grippers. For each cathegory mention at least one of the related gripping principles. You can use a three columns table to structure your answer (cathegory-description-related gripping principles)
3. List and classify the releasing strategies in use for the gripping process
4. List and classify the methods for monitoring the grasping process

*beside the slides you can study on the additional redaing material

Reading material (not in the exam!)

- Keynote on industrial grippers from the CIRP annals 2014 (ask for a copy)
- Robot Grippers. Gareth J. Monkman, Stefan Hesse, Ralf Steinmann, Henrik Schunk. ISBN: 978-3-527-40619-7