

Laboratorio di Tecnologie Biomediche *Collegamenti meccanici*

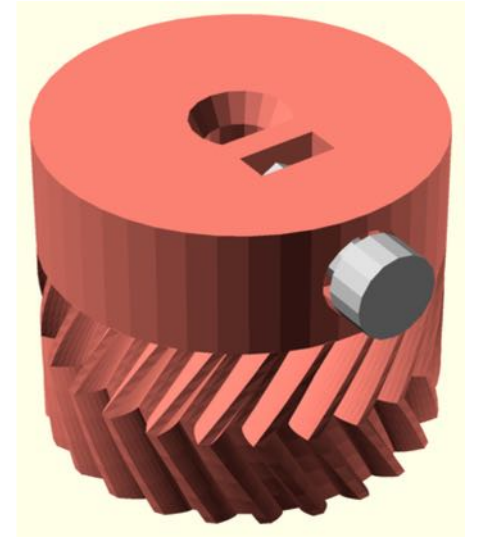
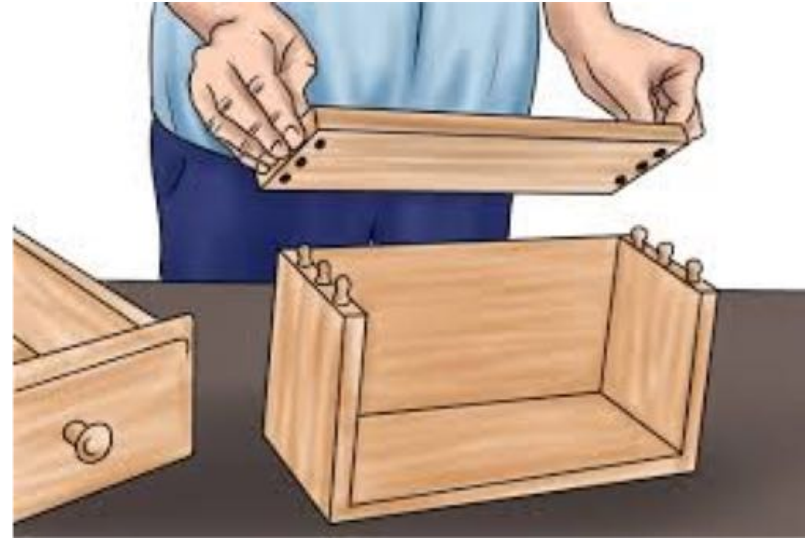
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Imbiettamenti

- collegamenti di tipo smontabile che hanno per scopo quello di impedire la rotazione relativa di due elementi accoppiati (in genere albero e mozzo). Gli elementi più comuni sono i seguenti:
 - chiavette;
 - linguette;
 - perni;
 - spine;
 - profili scanalati.

Imbiettamenti



Imbiettamenti

- Possibili esigenze
 - evitare la rotazione reciproca (trasmissione del momento torcente)
 - evitare la traslazione reciproca
 - effettuare il centraggio reciproco (riferimento)
 - impedire lo smontaggio spontaneo o gli spostamenti relativi

Imbiettamenti

Elementi	Chiavette	Linguette	Perni/Spine	Anelli elastici	Profili scanalati
Esigenze					
impedimento rotazione					
impedimento traslazione					
centraggio o riferimento					
sicurezza o arresto					

Chiavette

Le *chiavette* permettono di collegare un albero con un mozzo in modo da consentire la trasmissione del momento torcente.

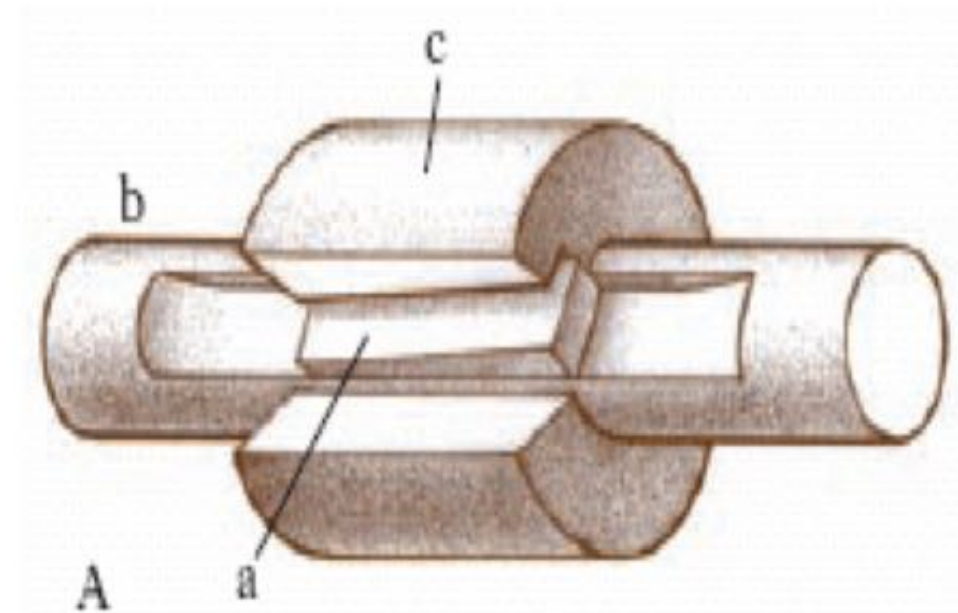
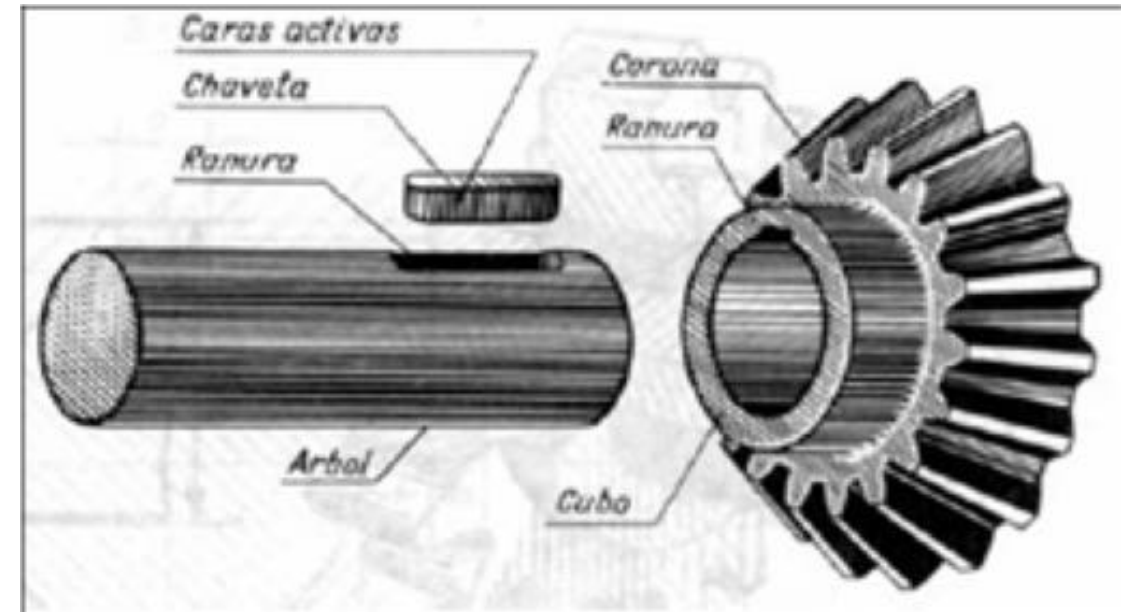
Le chiavette hanno forma di *prisma a sezione rettangolare* con la faccia superiore inclinata rispetto a quella inferiore di 1:100. Le chiavette agiscono quindi come un cuneo ed il forzamento radiale che nasce consente la trasmissione del momento torcente. Le facce laterali presentano gioco con le corrispondenti superfici delle cave.

Vengono inserite in apposite scanalature dette *cave* ricavate, in genere, sull'albero e sul mozzo.

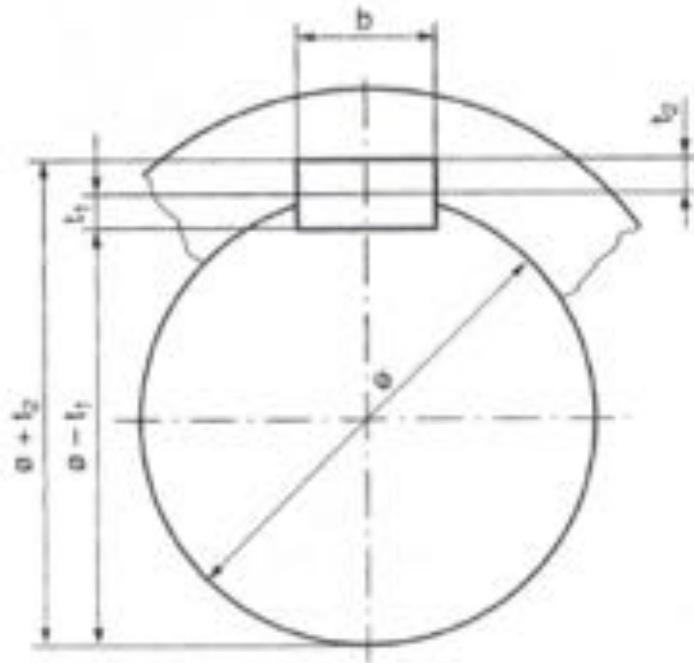


Chiavette

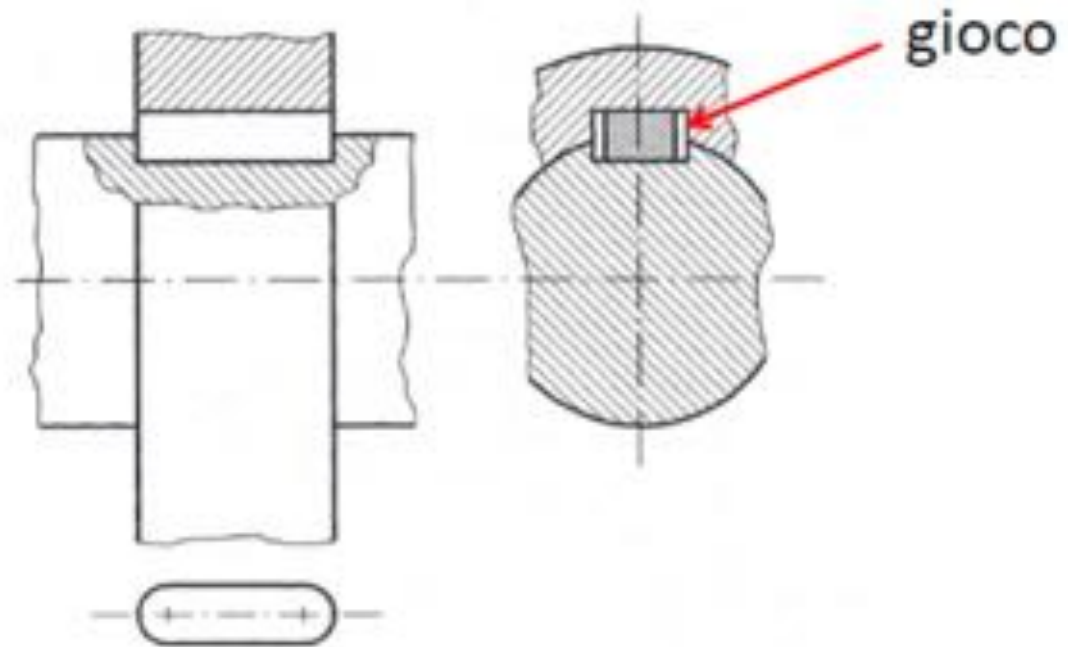
- Vantaggi/svantaggi
 - Il forzamento radiale produce disassamento fra albero e mozzo.
 - Le velocità di rotazione devono quindi essere basse per evitare vibrazioni e quindi danneggiamenti.
 - E' una soluzione economica adeguata alla trasmissione di coppie non elevate in presenza di basse velocità di rotazione.



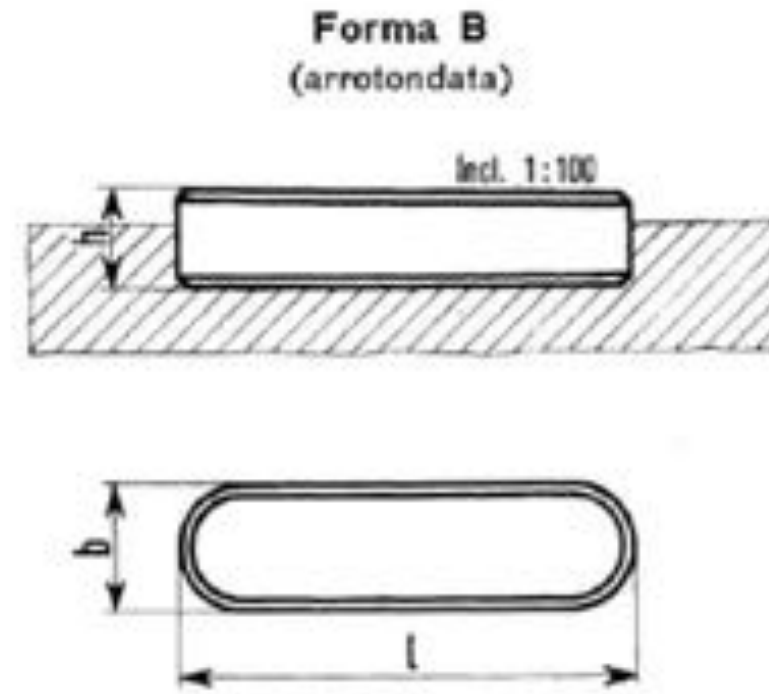
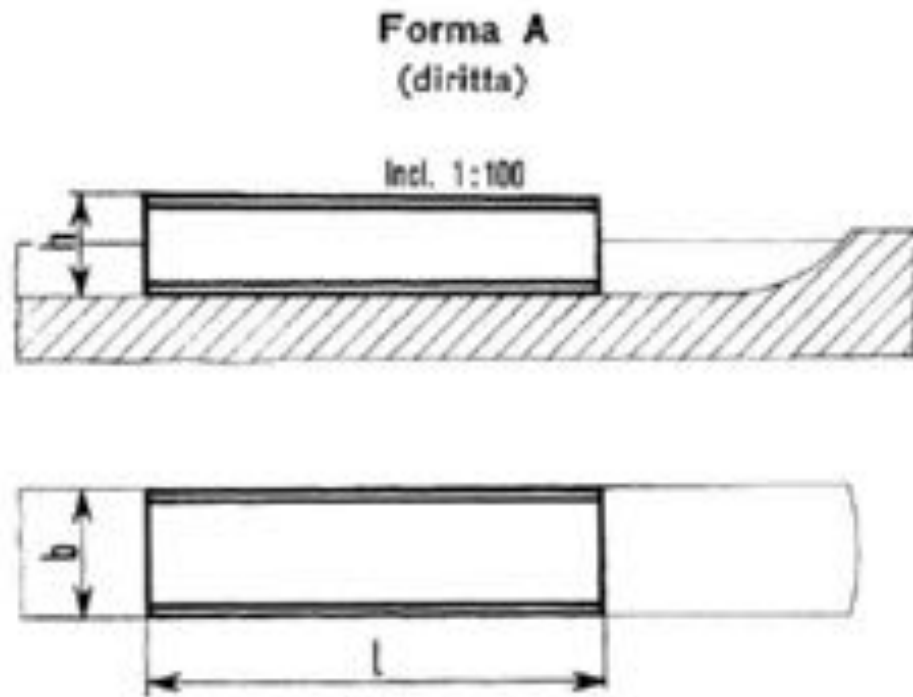
Chiavette



Le cave si ottengono, in genere, per fresatura sull'albero e per brocciatura sul mozzo.



Chiavette



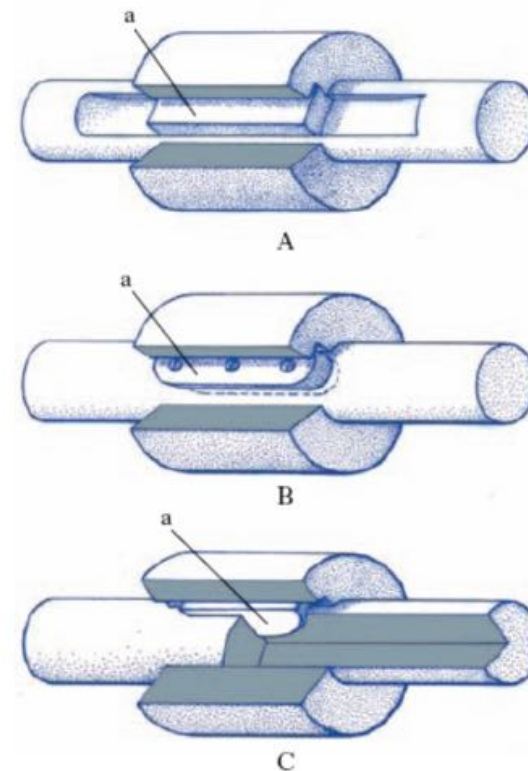
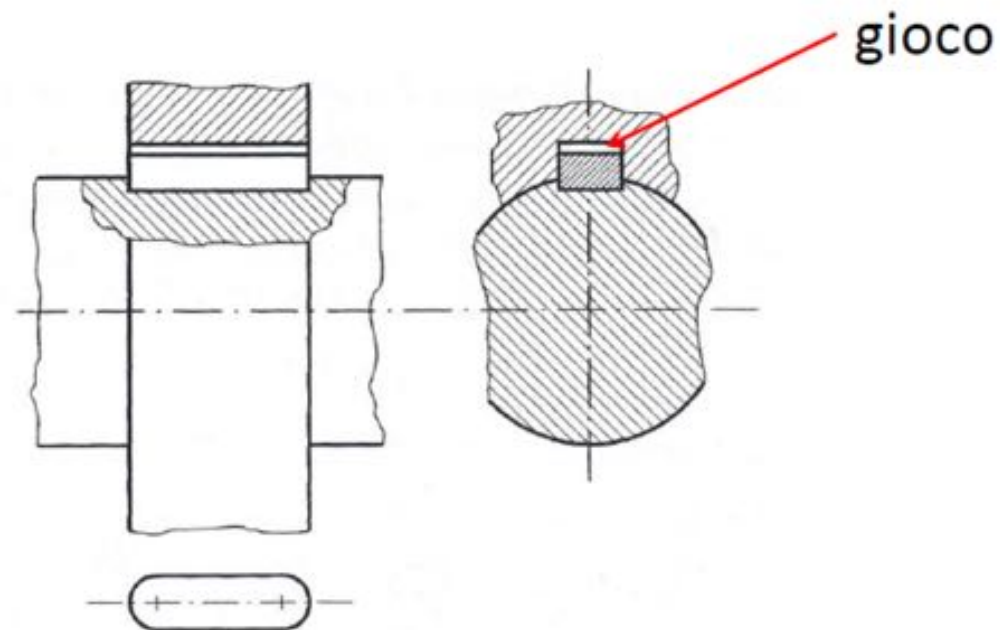
Esempio di designazione di una chiavetta, forma A (diritta), avente sezione $b \times h = 22 \text{ mm} \times 14 \text{ mm}$ e lunghezza $l = 140 \text{ mm}$:
Chiavetta A 22 x 14 x 140 UNI 6607-69

Linguette

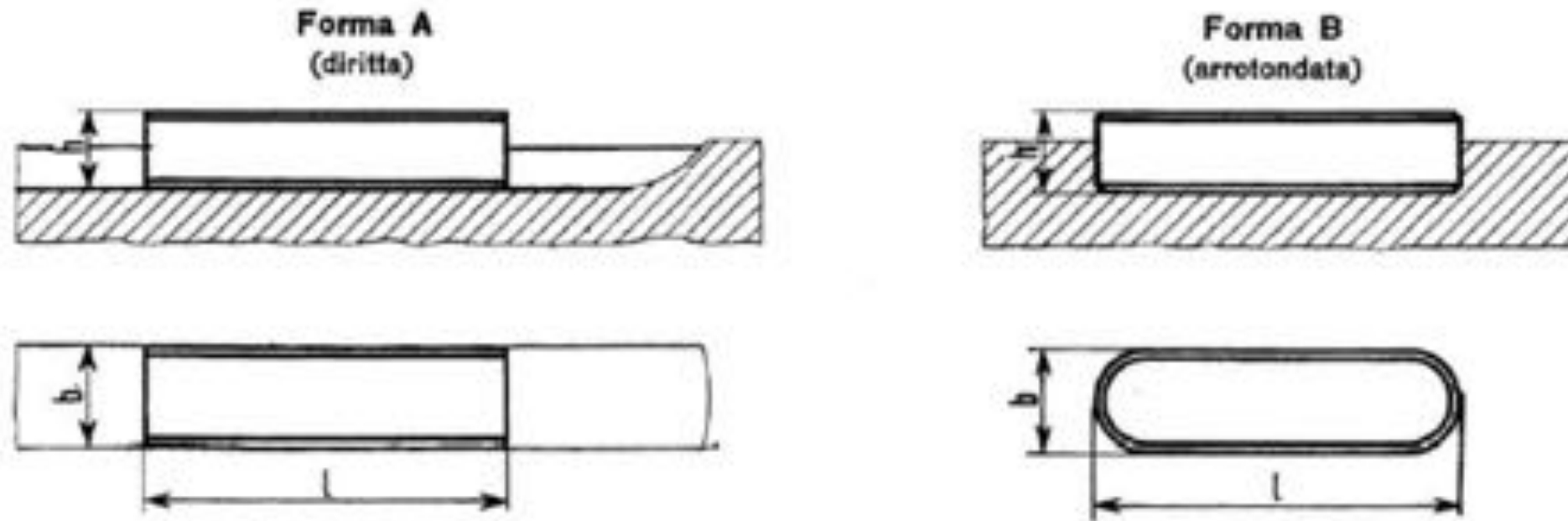
- Le linguette sono organi di collegamento calettati su cave ricavate su alberi e su mozzi ma, a differenza delle chiavette, hanno le facce a due a due parallele fra loro.
- Il moto viene trasmesso per contatto con le facce laterali fra le cave e l'organo di collegamento .
- Esiste quindi gioco in direzione radiale ed il momento torcente viene trasmesso dallo sforzo di taglio agente sulle linguette stesse.

Linguette

- Vantaggi/svantaggi
 - Richiedono lavorazioni più precise (costose) delle chiavette.
 - Non ci sono disassamenti e quindi le velocità di rotazione possono essere più elevate.
 - Possono trasmettere coppie più elevate.
 - Non vincolano lo spostamento assiale relativo (si devono prevedere sistemi di arresto).



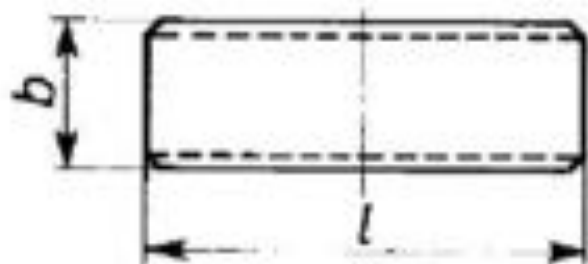
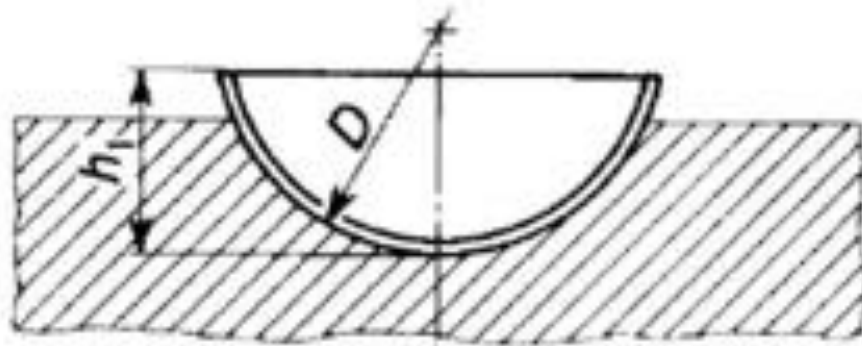
Linguette



Esempio di designazione di una linguetta, forma A (diritta), avente sezione $b \times h = 22 \text{ mm} \times 14 \text{ mm}$ e lunghezza $l = 140 \text{ mm}$:
Linguetta A 22 x 14 x 140 UNI 6604-69

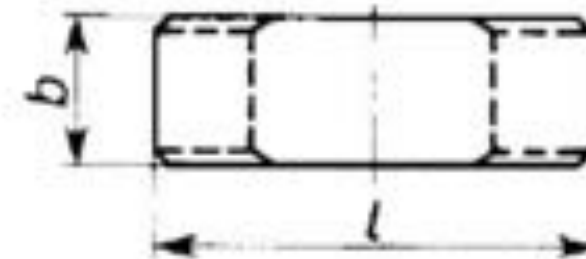
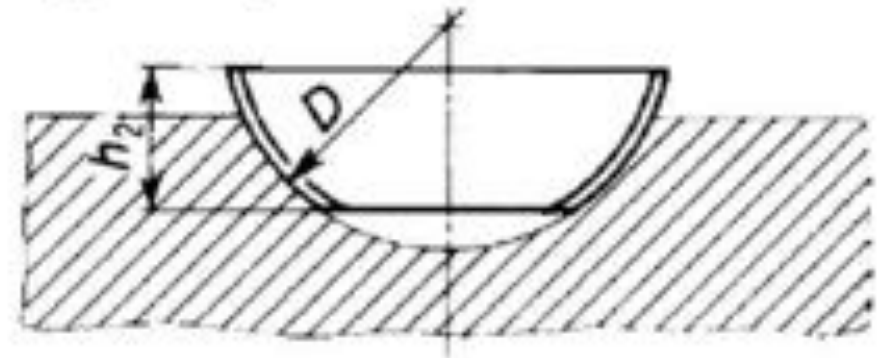
Linguette a disco

Forma normale



Forma tronca (vedere punto 2)

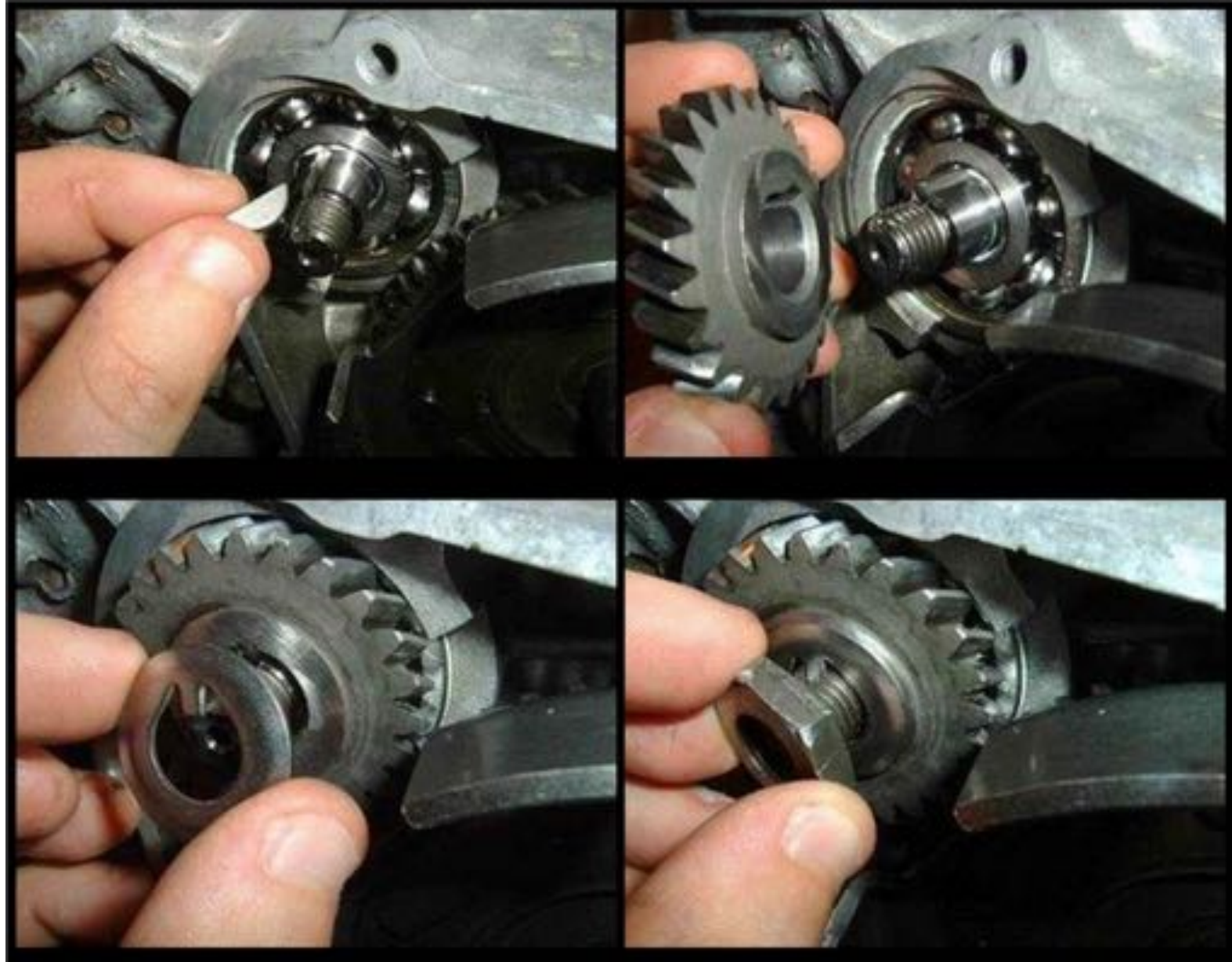
$$h_2 = 0,8 h_1$$



Esempio di designazione di una linguetta a disco, avente sezione $b \times h_1 = 6 \text{ mm} \times 9 \text{ mm}$:

Linguetta 6 x 9 UNI 6606

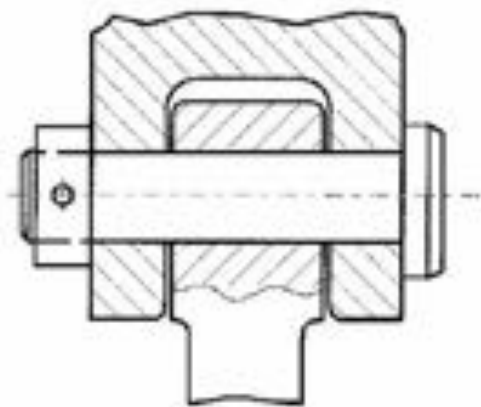
Linguette a disco



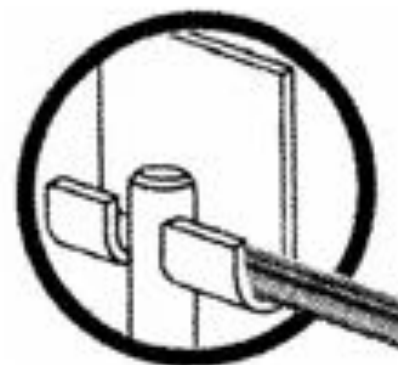
Spine e perni

Spine e perni: elementi di macchine (cilindrici o conici) con funzioni di:

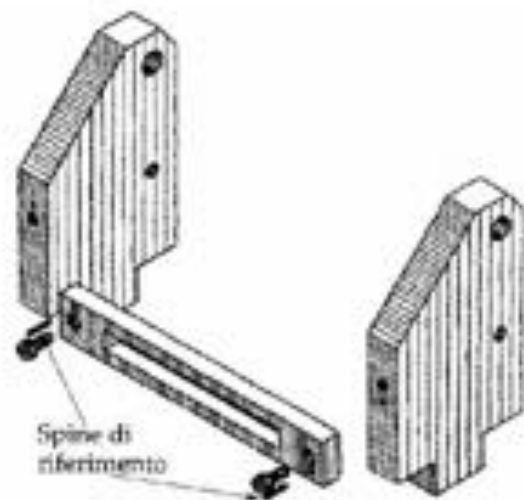
- Fulcro



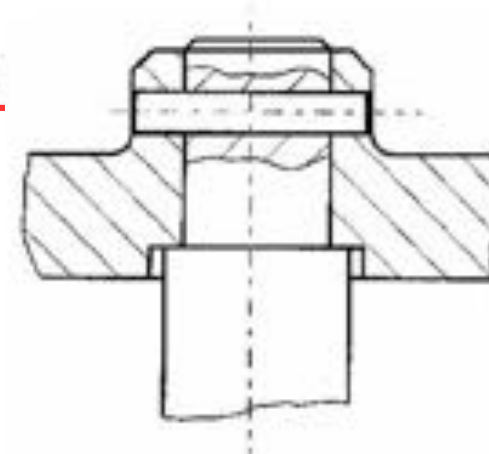
- Arresto



- Centraggio



- Collegamento



Spine e perni

- Spine:
 - Elementi, di forma conica e non, possono essere realizzate con gambo filettato o con foro filettato.
 - Si possono avere anche spine elastiche (cave con intaglio longitudinale) o a spirale per impedire lo sfilamento.
 - Servono a trasferire il momento torcente o a prevenire il moto relativo fra gli elementi collegati e tipicamente, vengono accoppiate agli elementi con leggero forzamento

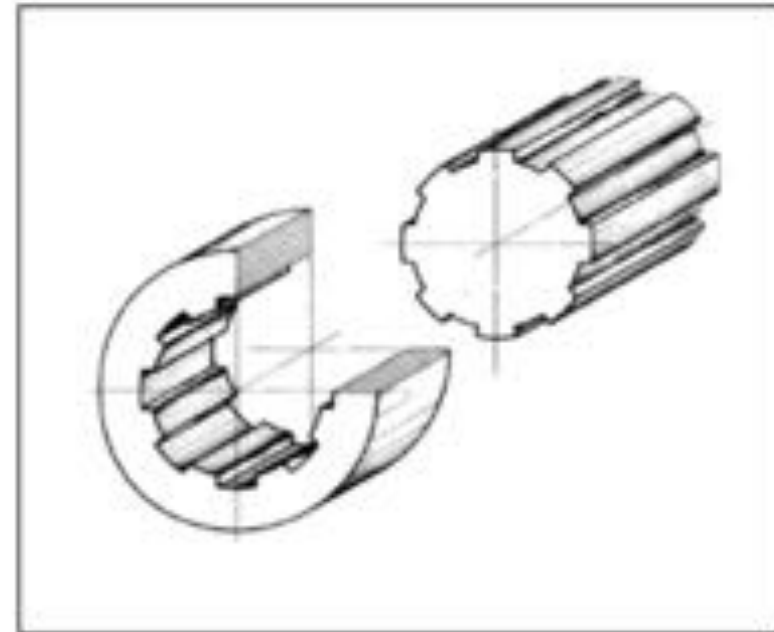
Spine e perni

- Perni
 - elementi di forma cilindrica, si inseriscono in fori praticati negli elementi da unire. Possono essere senza testa, con testa piana stretta o larga (con o senza estremità filettata);
 - hanno funzione di impedire traslazioni relative degli elementi collegati, consentendo moti relativi di rotazione o di oscillazione;
 - devono essere accoppiati con gioco, consentendo la realizzazione pratica di cerniere cilindriche

Profili scanali

Nei casi di alberi fortemente sollecitati i collegamenti con chiavette o linguette sono inadeguati sia per la mancanza di un adeguato centraggio fra albero e mozzo (causa di vibrazioni) sia per gli sforzi eccessivi che si concentrano su elementi di piccole dimensioni.

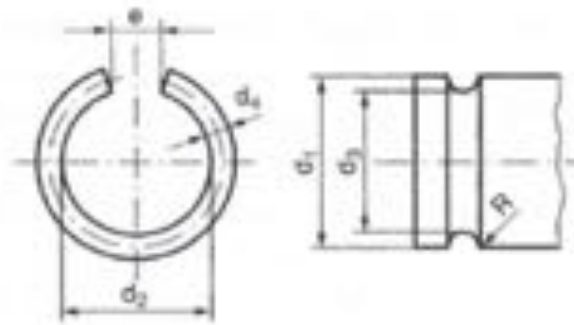
Tutti questi limiti possono venire superati ricorrendo ad alberi scanalati, in cui vengono ricavate (per asportazione di materiale) un certo numero di costole angolarmente equidistanti, che si accoppiano con corrispondenti scanalature del mozzo (ricavate per brocciatura).



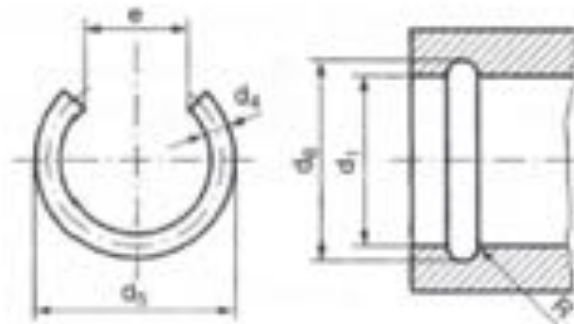
Anelli elastici (seeger)



Gli *anelli elastici* sono realizzati con acciaio per molle, hanno forma circolare discontinua e vengono inseriti nella propria cava o sede per deformazione elastica.

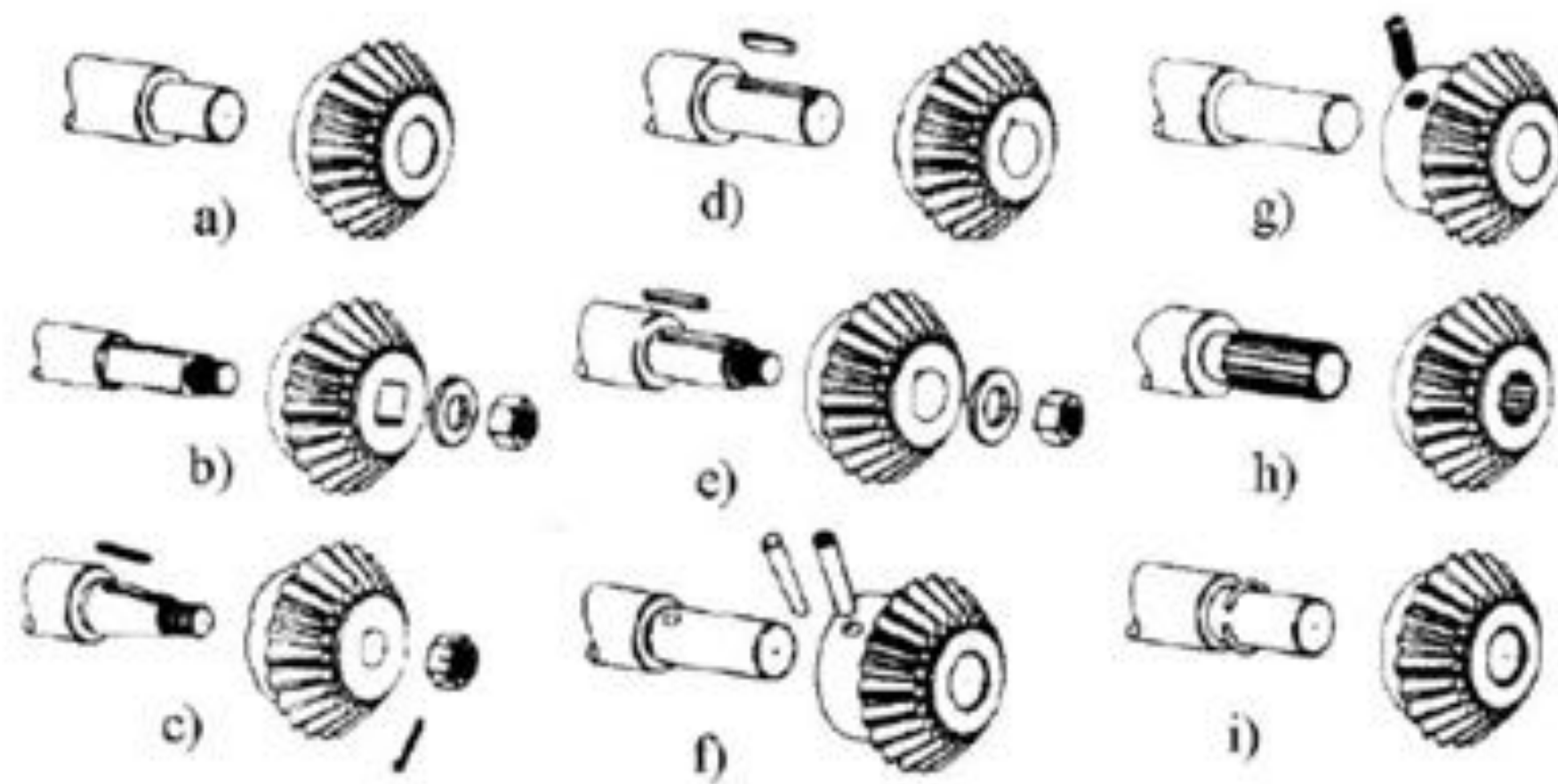


Anello di arresto
Tipo A (albero)



Anello di arresto
Tipo B (foro)

Imbiettamenti - esempi

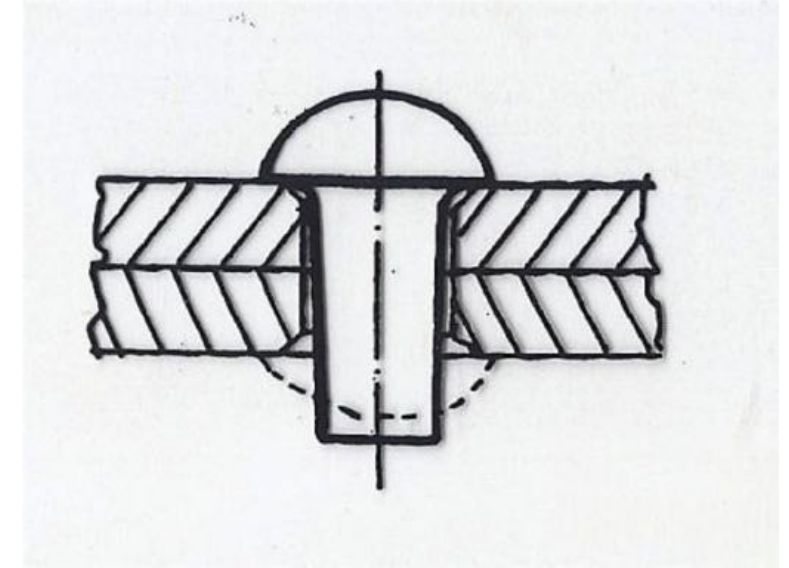


a) forzamento; b) con estremità prismatica e codolo filettato per dado d'arresto; c) su estremità conica con dado o ghiera di forzamento; d) con chiavetta; e) con linguetta e dado d'arresto; f) con spina trasversale; g) con grano di pressione; h) con accoppiamento scanalato; i) per brasatura o saldatura

Collegamenti Fissi

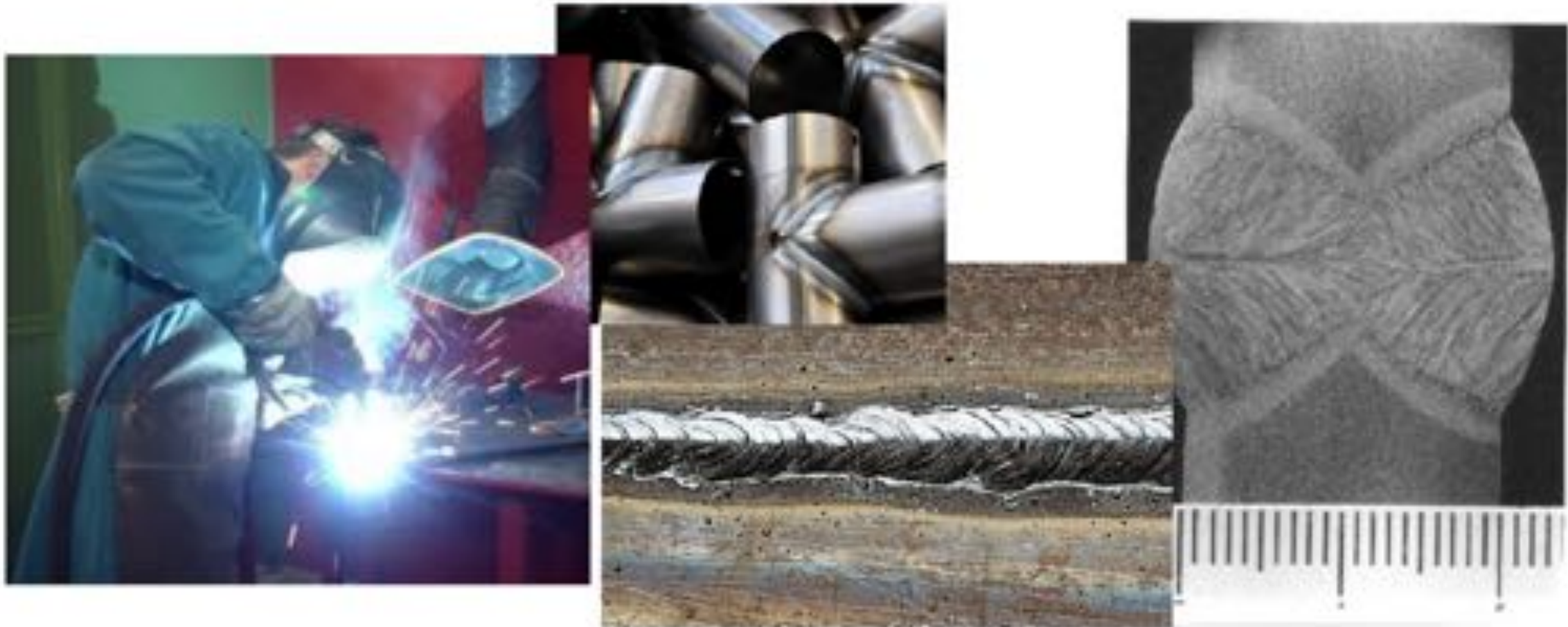
Chiodature

- Oramai abbandonate e sostituite dalla saldatura possono ancora incontrarsi per manutenzioni o ripristino di carpenteria metallica già realizzata (ponti ferroviari). Possono distinguersi in:
 - Chiodature di forza (collegamento strutturale);
 - Chiodature di tenuta (recipienti contenenti fluidi);
 - Chiodature di tenuta e di forza (recipienti in pressione);
 - Chiodature di sicurezza (collegamenti navali).
- Chiodi di diametro superiore a 8mm sono ribattuti a caldo; con diametro inferiore vengono ribattuti a freddo (ribattini – di solito in materiale non ferroso).



Saldatura

Per saldatura si intende una operazione con la quale si collegano due o più parti (giunto) mediante l'azione del calore (o calore e pressione) a creare un unico corpo. L'operazione può essere realizzata con o senza materiale di apporto.

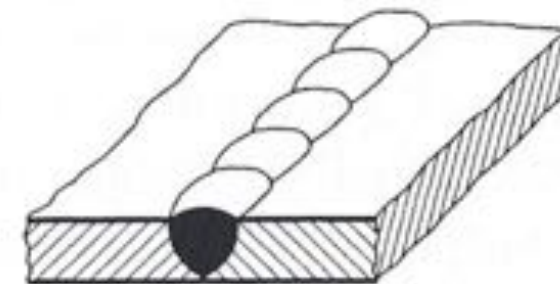


Saldatura

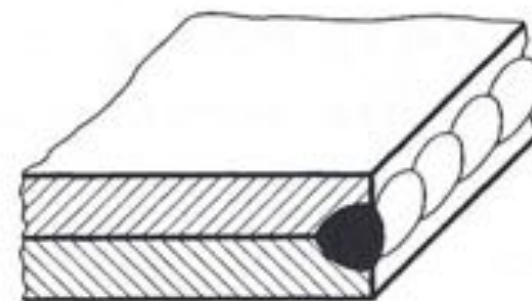
- I collegamenti saldati si distinguono in funzione delle caratteristiche del procedimento di saldatura utilizzato:
 - Saldatura per fusione: implica una fusione localizzata del materiale base ed eventualmente l'utilizzo di materiale di apporto (non vi è pressione);
 - Saldatura per resistenza: i lembi da giuntare sono messi in pressione ed il riscaldamento avviene per effetto Joule (non si usa materiale di apporto);
 - Saldatura per pressione: la saldatura avviene per deformazione plastica localizzata;
 - Brasatura: la saldatura avviene mediante materiale di apporto avente temperatura di fusione inferiore a quella del materiale base (le parti da saldare non fondono).

Saldatura

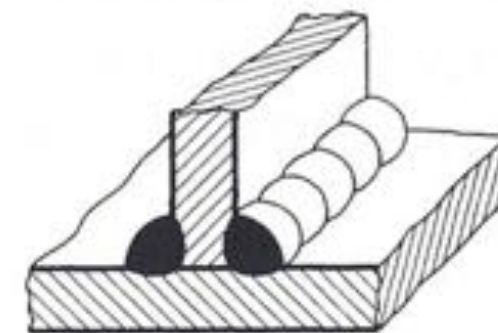
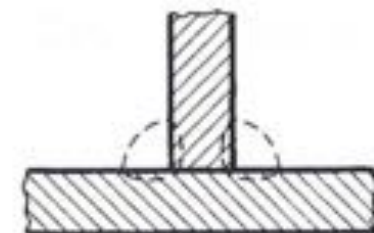
DI TESTA



D' ORLO

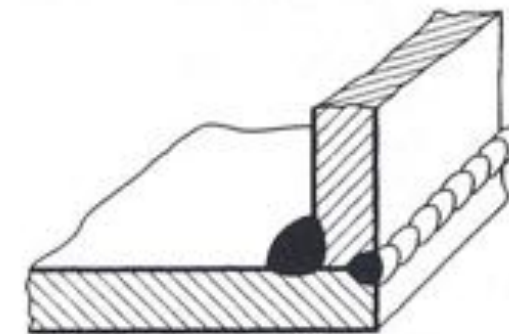
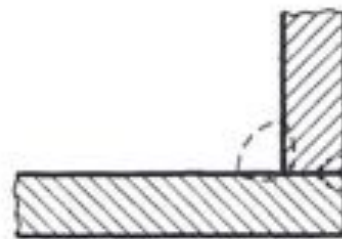


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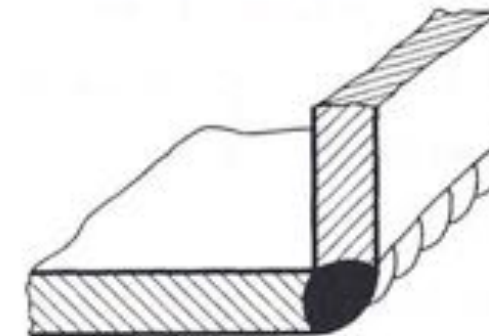
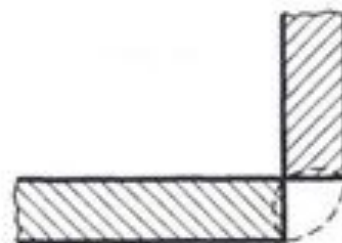


Saldatura

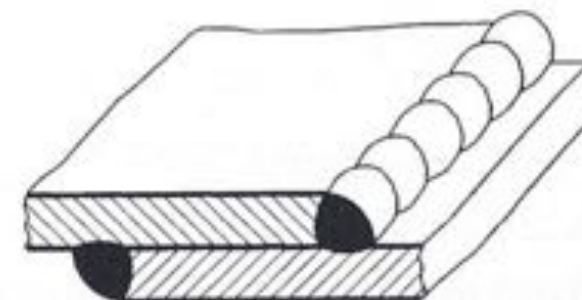
A « L »



DI SPIGOLO



A SOVRAPPOSIZIONE

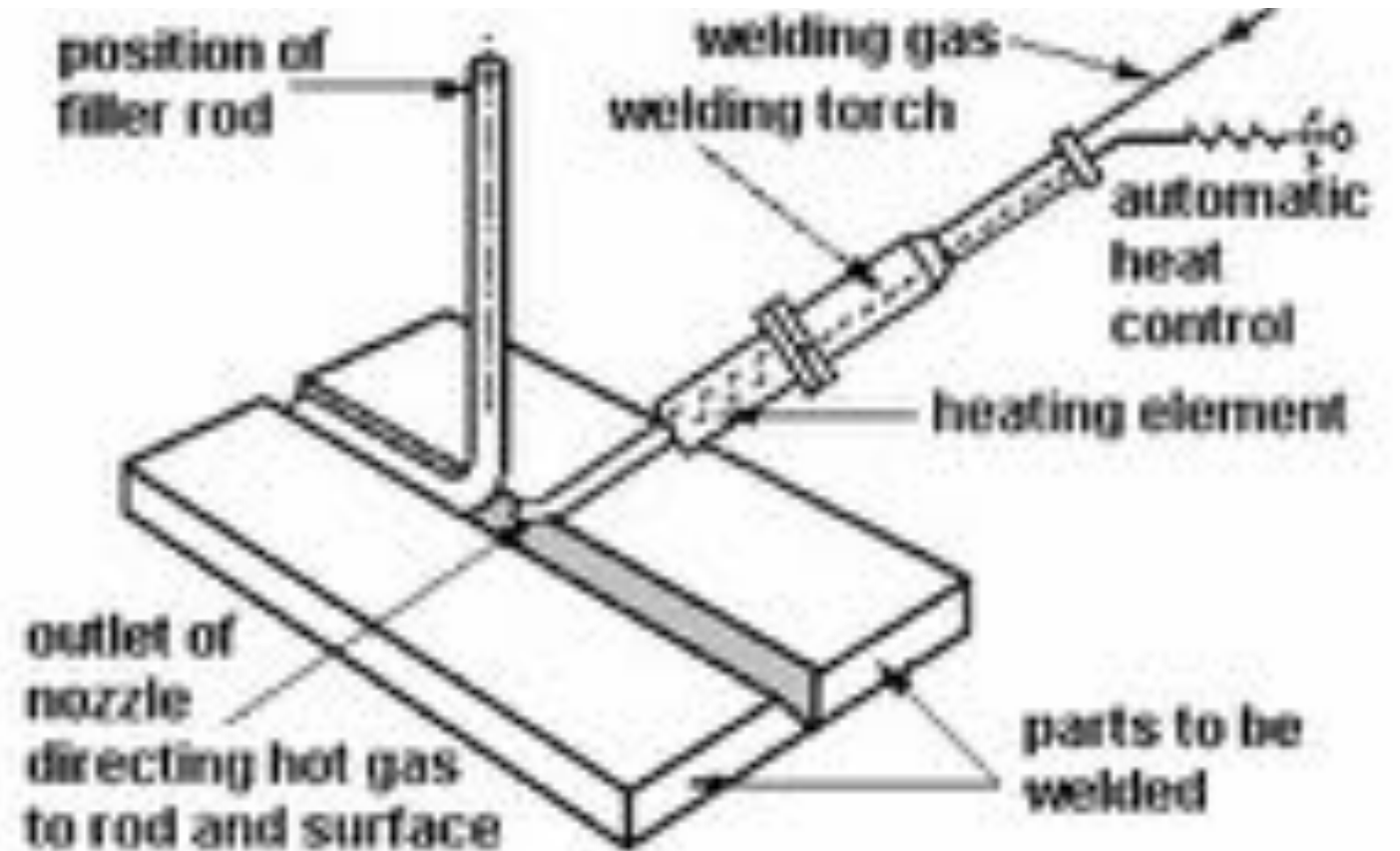




Focus on plastic material

Hot Gas Welding

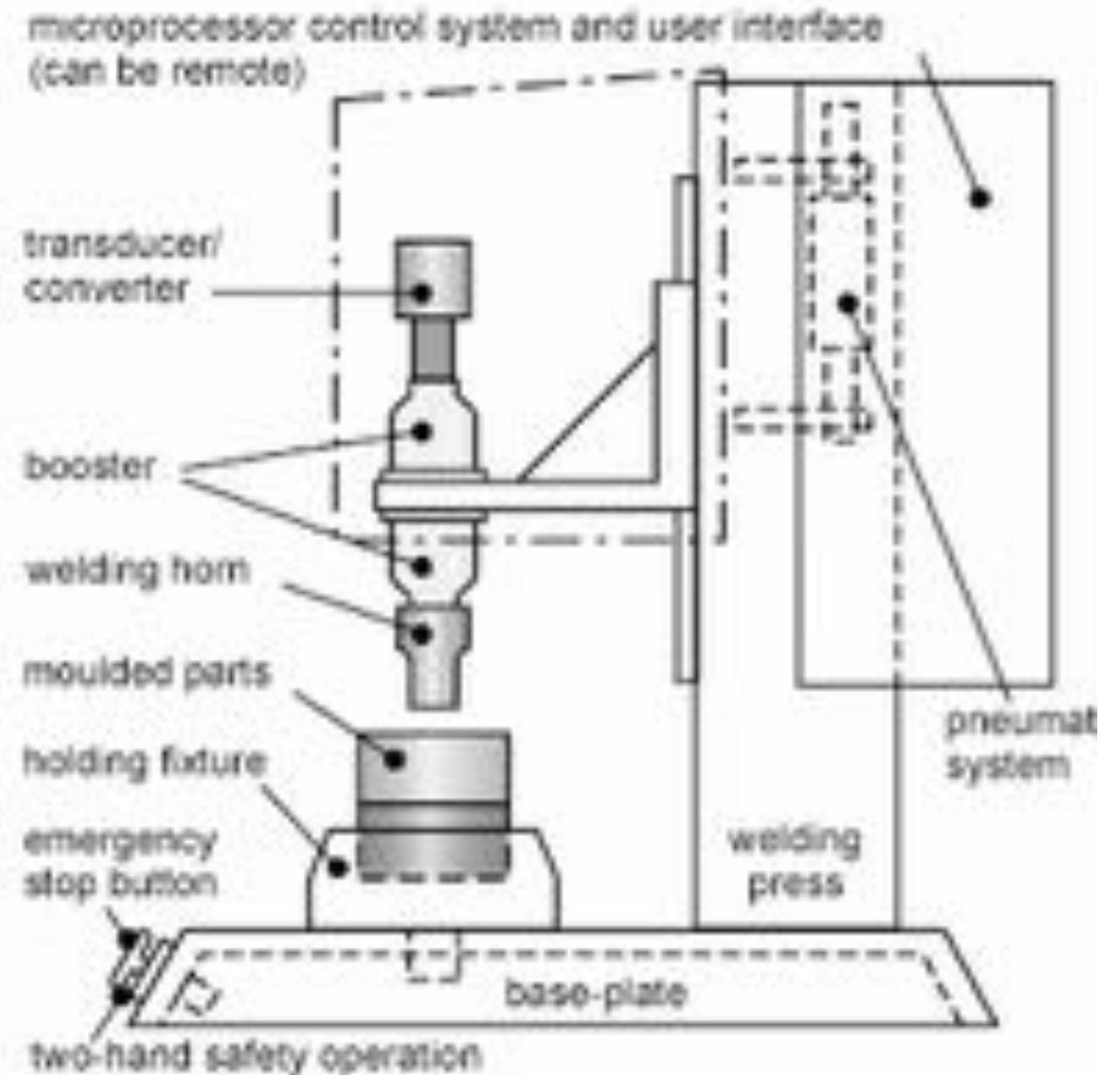
- Most widely applied in the fabrication of plastic assemblies.
- Involves the use of various butt joints & hot gas from a welding torch to melt filler material between pieces of an assembly to create a weld.



Schematic of hot gas welding showing correct position of torch and filler rod

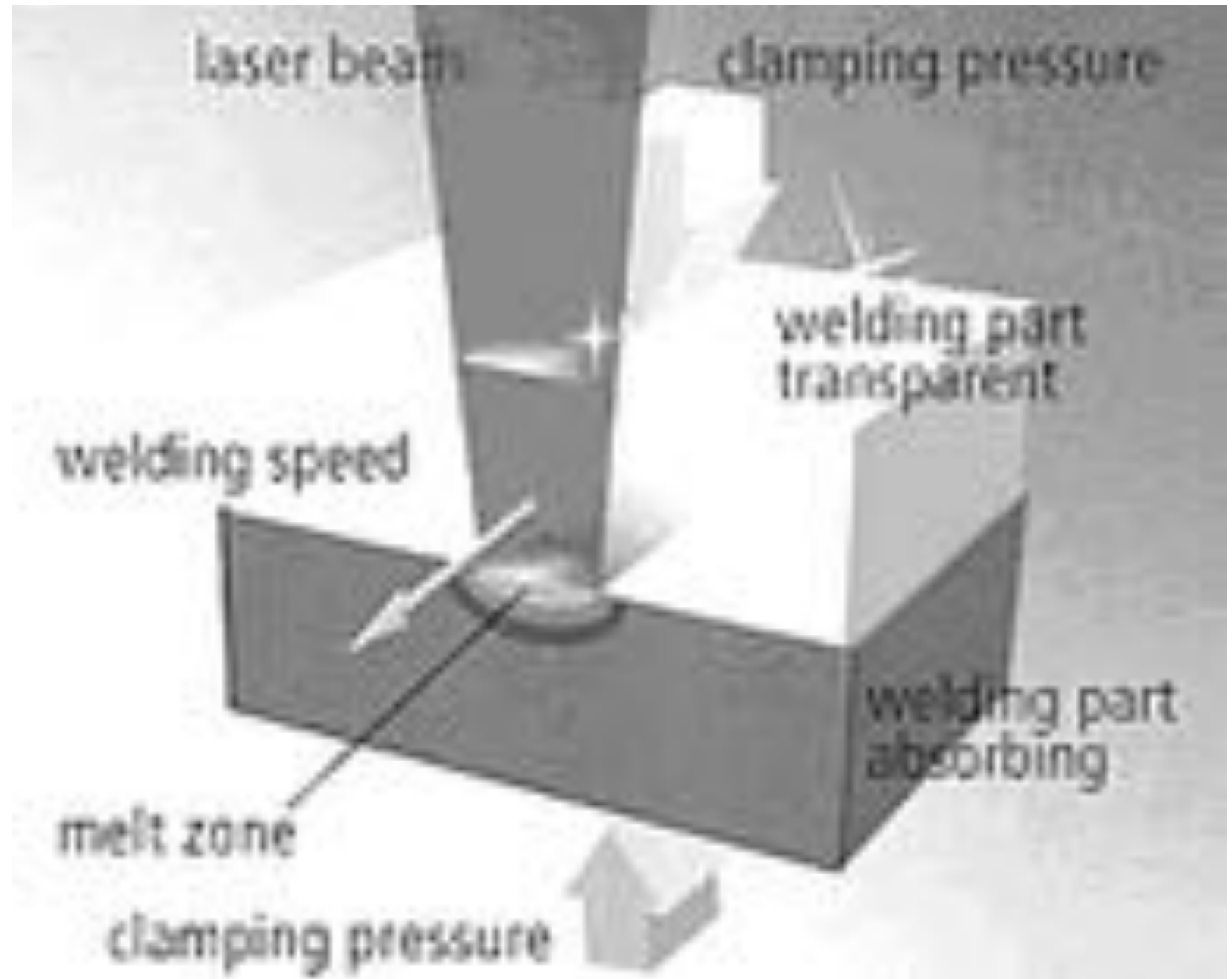
Ultrasonic Welding

- The most common thermal method for joining small and medium-sized parts of amorphous and crystalline plastics.
- The process normally lasts less than 2 seconds and forms a continuous, leak-proof joint that often is as strong as the base material.
- Done using equipment that applies high-frequency energy (20 to 40 kHz) directly to the interface between parts.



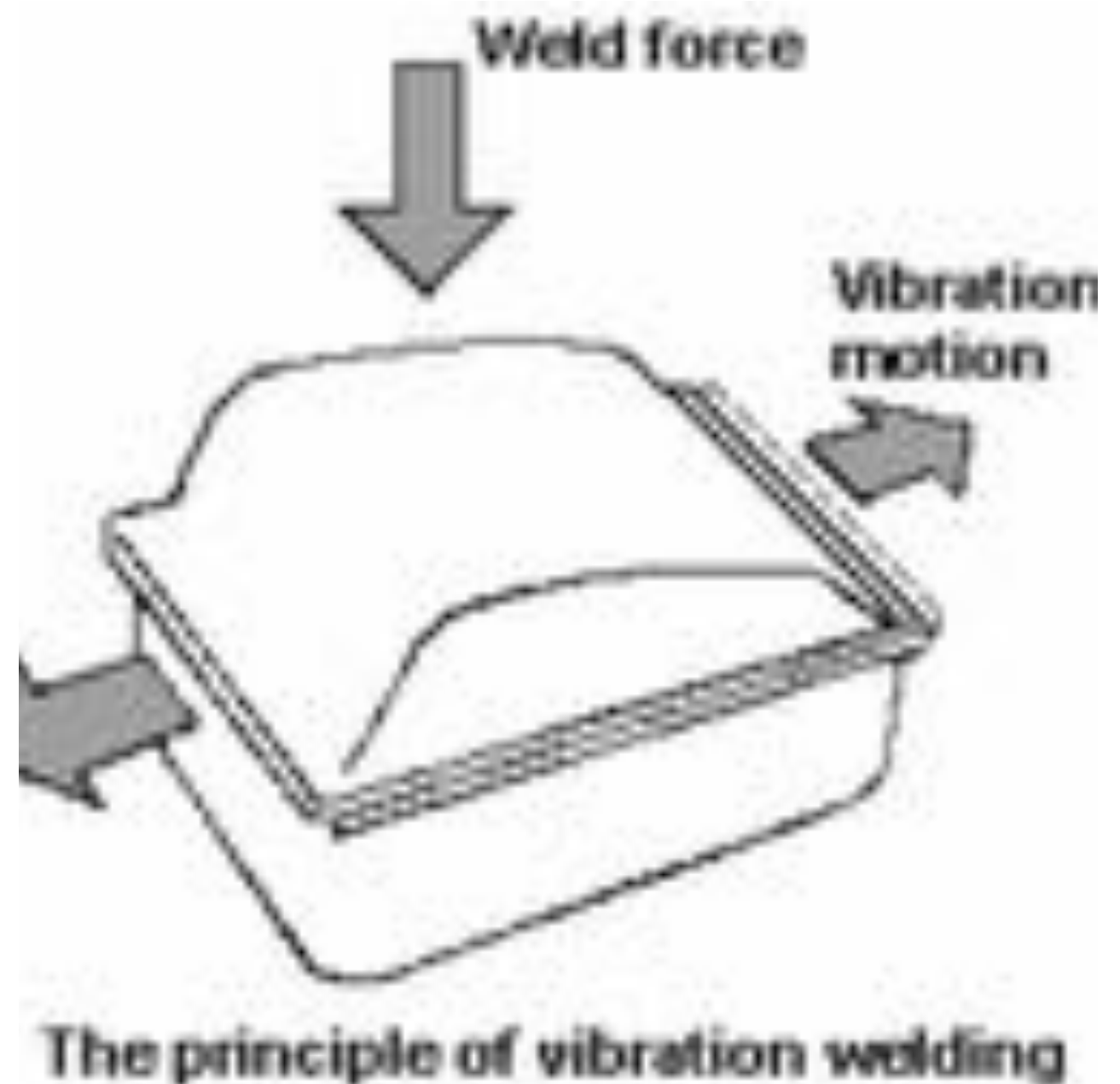
Laser Welding

- Involves use of a laser to melt the bond line between two parts to form a weld.
- This method is a fast, economical, and safe way to weld compatible plastics having similar melt temperatures.



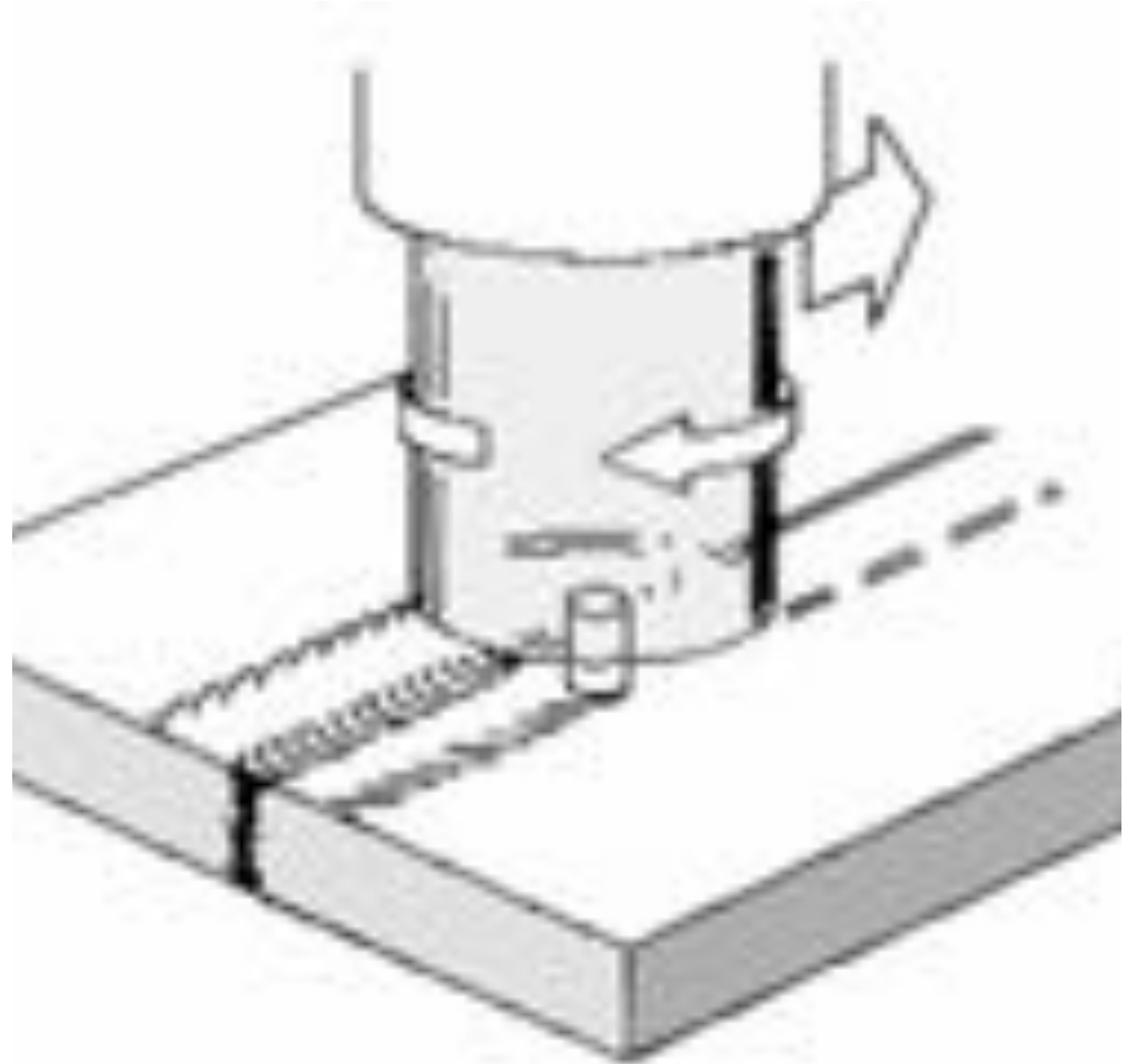
Vibration Welding

- Done by parts being rubbed together to create frictional heat.
- Rubbing usually involves amplitudes of 0.1- to 0.2-in. and frequencies of 120 and 240 Hz.
- It creates strong joints and works best with large parts that have irregular joint interfaces



Spin Welding

- **Joins parts with circular joint surfaces using relatively simple equipment, sometimes just a drill press.**
- **Involves holding one part firmly and pressing a rotating part against it at a steady pressure.**
- **The weld usually forms in less than 3 seconds.**





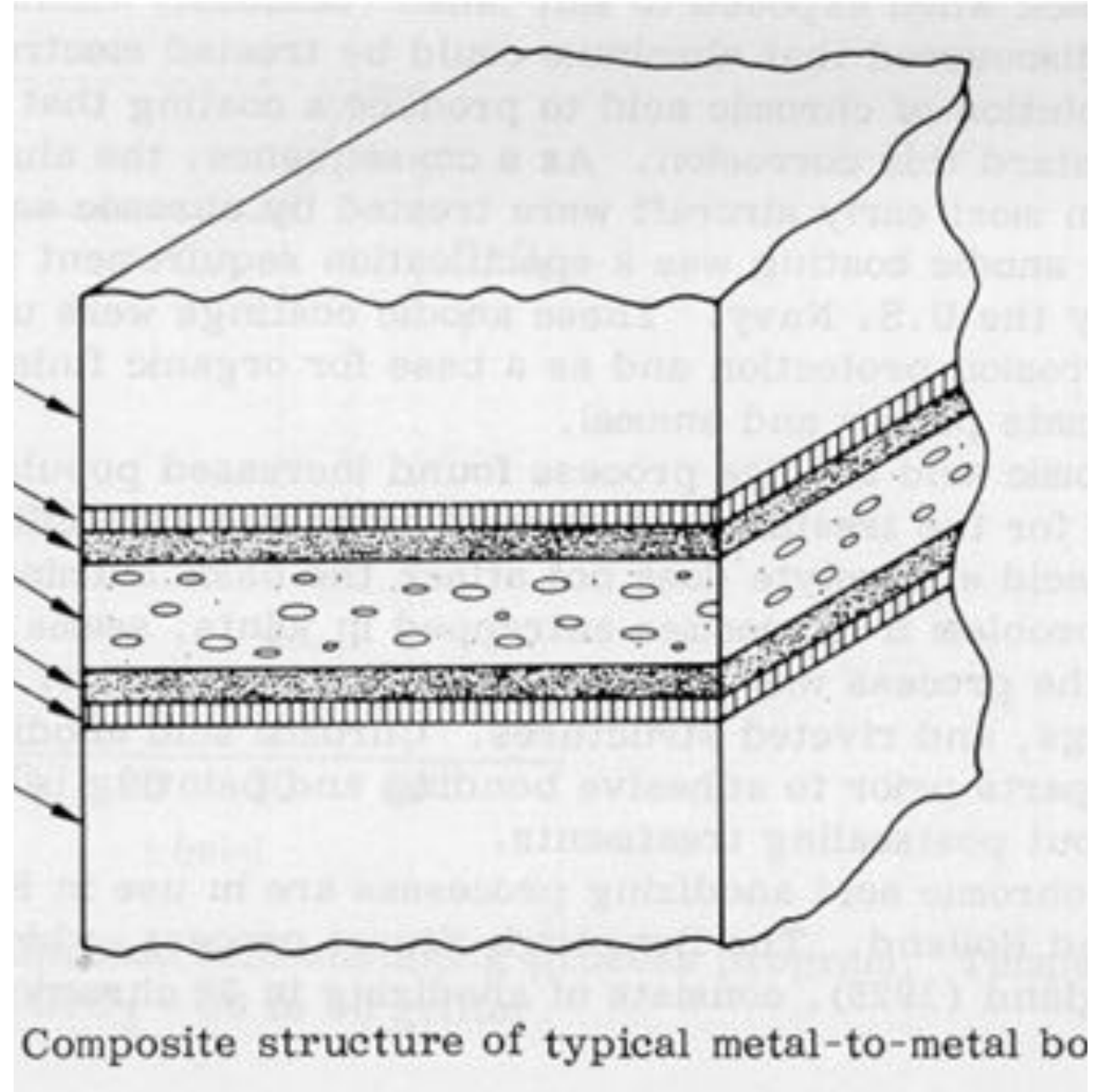
Adhesive bonding

Adhesive bonding

- Natural adhesives
 - Starch
 - animal products
- Inorganic adhesives
 - sodium silicate
 - magnesium oxychloride
- Synthetic organic adhesives
 - thermoplastics (soften when heated, harden when cooled)
 - thermosetting (harden permanently when heated)

Adhesive bonding

- Primers are used as surface conditioners perform these functions:
 - protect corrosion (for metals) sensitive surfaces
 - modify the properties of the bond
- Tacky resins help hold or position bonded parts



Adhesive bonding

- Theories of adhesion
 - Chemical bond theory
 - Weak boundary layer theory
 - Surface energy theory
 - Inherent roughness theory
 - Polar theory

Common Adhesives

- Epoxies
 - Thermosetting
 - metal, glass, ceramic, wood
 - Two-component epoxies
 - Resin
 - curing agent
 - application time: 8-12 hours
- Cyanoacrylates
 - liquid monomers
 - application time: 2 seconds



Common Adhesives

- Anaerobics
 - thermosetting polyester acrylics
 - almost any material
 - application time:6-24 hours;
 - 5 min. with proper additives and heat
- Acrylics
 - Thermoplastic
 - plastics, metals, ceramics, composites, even with dirty surfaces



Common Adhesives

- Urethanes
 - one-part thermoplastic or two-part thermosetting
 - application time: solidifies in 2 min, cures fully in 24 hours
- Silicones
 - silicone thermosets
 - metal, glass, paper, plastics, rubber
 - cures slowly



Common Adhesives

- High-temperature adhesives
 - epoxy phenolics, modified silicones or phenolics, polyamides, ceramics
 - cures slowly
- Hot melts
 - thermoplastic resins
 - not true structural adhesives; applied as heated liquids and bond as they solidify



Adhesive bonding

- Application methods
 - Brushing: performed manually; coating is often uneven
 - Manual rollers: similar to paint rollers
 - Silk screening: brushing through open areas of a screen to coat selected areas
 - Flowing: Using manually operated flow guns; more consistent control than brushing
 - Spraying: Using a spray gun for fast application over large areas
 - Automatic applicators: Automatic dispensers and nozzles for medium and high production rates
 - Roll coating: A roller is partially immersed in the adhesive and transfers it to the part
 - Pull-tab sheets: The adhesive sheet comes prepared covered by a protective layer which is removed before use

Adhesive bonding

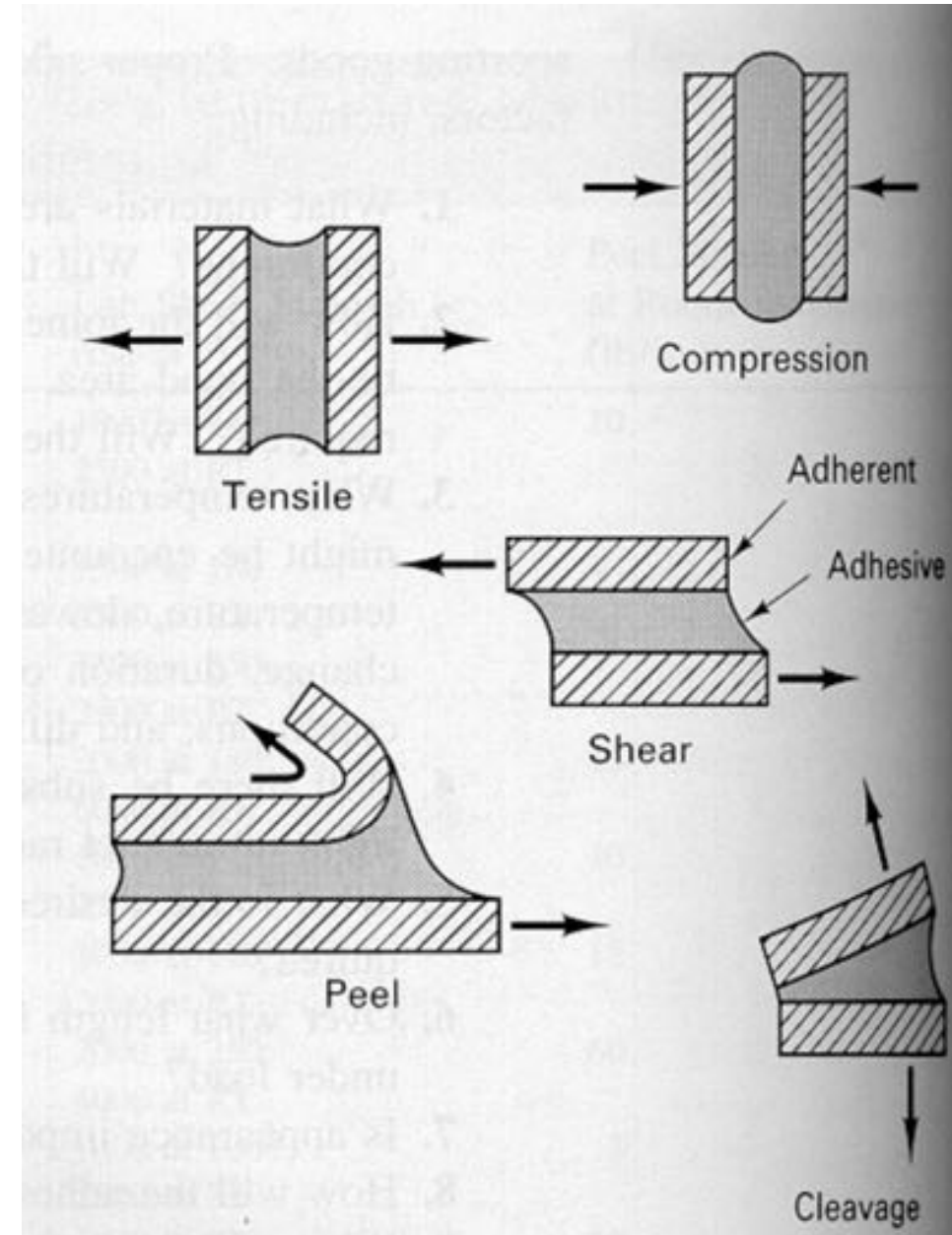
- Design Consideration
 - Material: porosity, hardness, surface properties; thermal expansion
 - Assembly: bond area; stresses
 - Temperature: during use of parts; temperature extremes, rate of temperature change
 - Exposure: to solvents, water, fuels, light, ultraviolet, acid, weathering
 - Flexibility/stiffness
 - Stability: required length of time; load
 - Appearance
 - Adhesive application
 - Cost

Solvent Bonding

- A liquid applied just before assembly dissolves the joint surfaces. This is enough for a weld to remain after the solvent evaporates. This method is limited to compatible materials that dissolve in the same solvent or solvents.
- The chemical resistance of many plastics limit this method from being used.

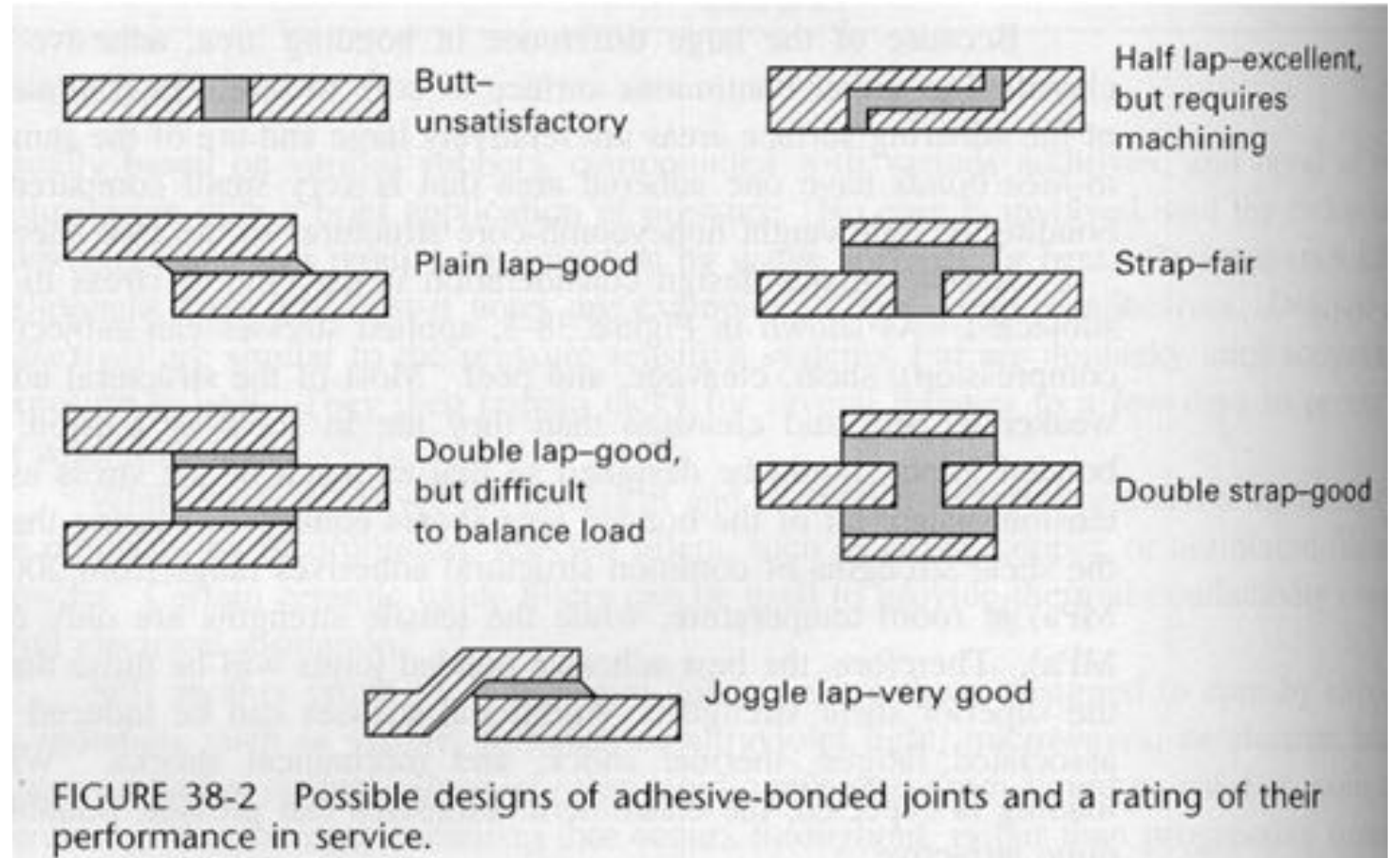
Adhesive bonding

- Design Consideration
 - Type of stresses in adhesive-bonded joints



Adhesive bonding

- Design Consideration

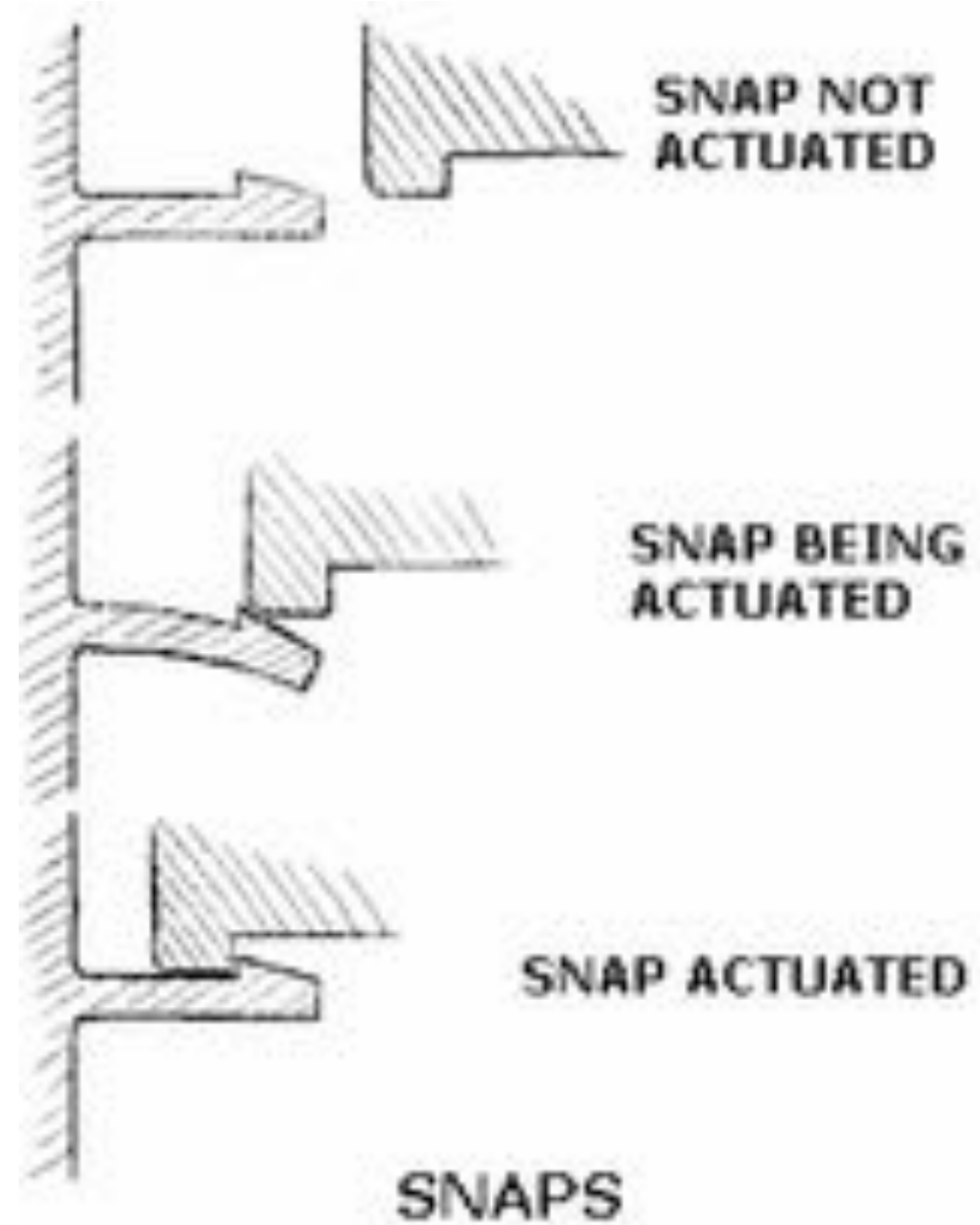


Working with plastics

- Snap fit and press fit and other connections

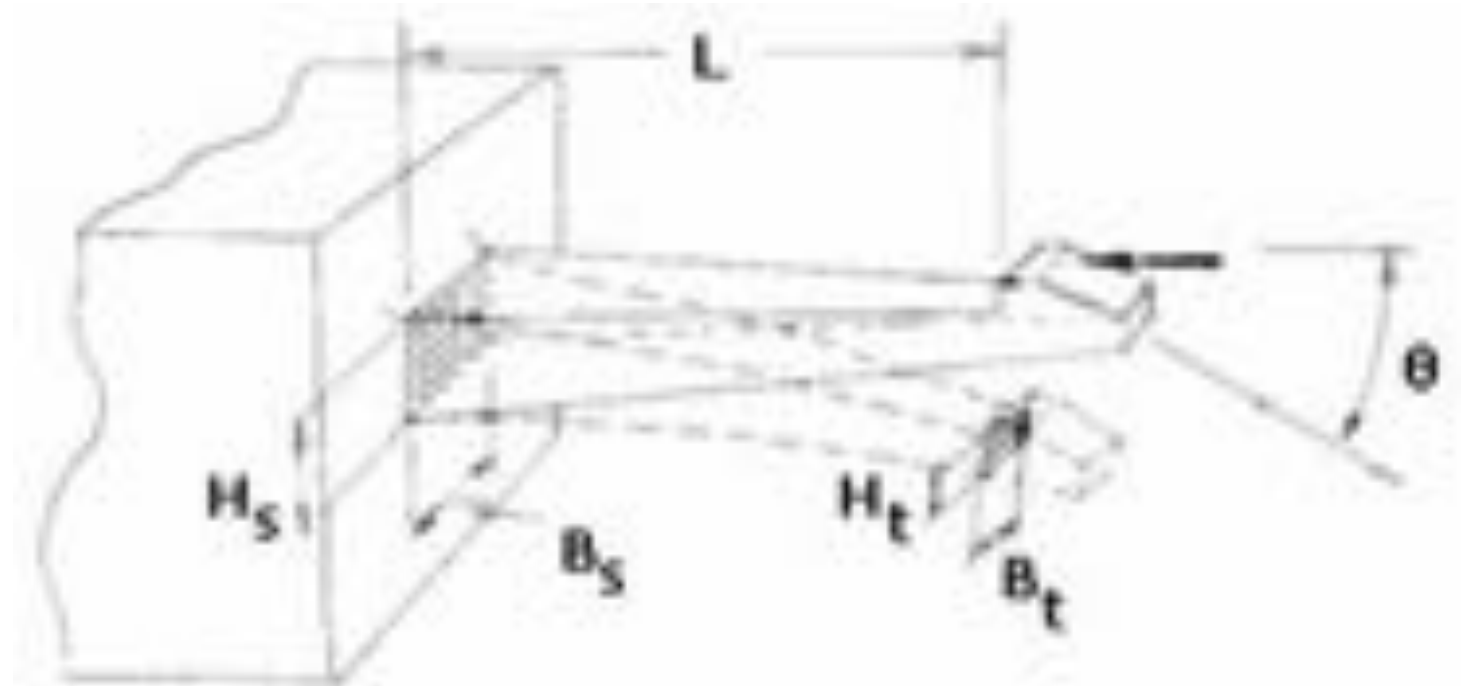
Snap-Fits

- Molded-in pieces in a plastic assembly that are designed to form a mechanical joint system where part-to-part attachment is accomplished with locating and locking features to connect components together.
- Provide for the economical and rapid assembly of plastic parts.



Types of Snap Fits

- Snap-fits are used to assemble parts of all shapes and sizes.
- A snap fit with a *tapered* finger provides more uniform stress distribution and can be used over and over again.
- There are three types of snap-fits: cantilever, torsion, and annular.



**SNAP LATCH WITH
TAPERED CROSS SECTION**

Use of Snap-Fits

- Snap-fits are often used for high-volume production.
- In many products, snap-fits are designed for one-time assembly without any provision for nondestructive disassembly.
 - For example, snap-fit designs, such as those used in the plastic shell of small kitchen appliance or a child's toy, are not designed to be taken apart without destroying the product.
- Where servicing is anticipated, snap-fits can be designed that allow for release of the assembly with an appropriate tool.
 - For example, snap-fit designs, such as those used in battery compartment covers for calculators and radios, are designed for easy release and re-assembly over hundreds or even thousands of cycles.

Cantilever Snap-Fit

- Consists of a protrusion (some type of bead or hook) at one end of the beam and a structural support at the other end.
- Most common type of snap-fit used for plastic assembly.
- Commonly used in applications such as toys or battery compartment doors.
- Most cantilever snap-fits are usually a one-time use but some designs can be used more than once.

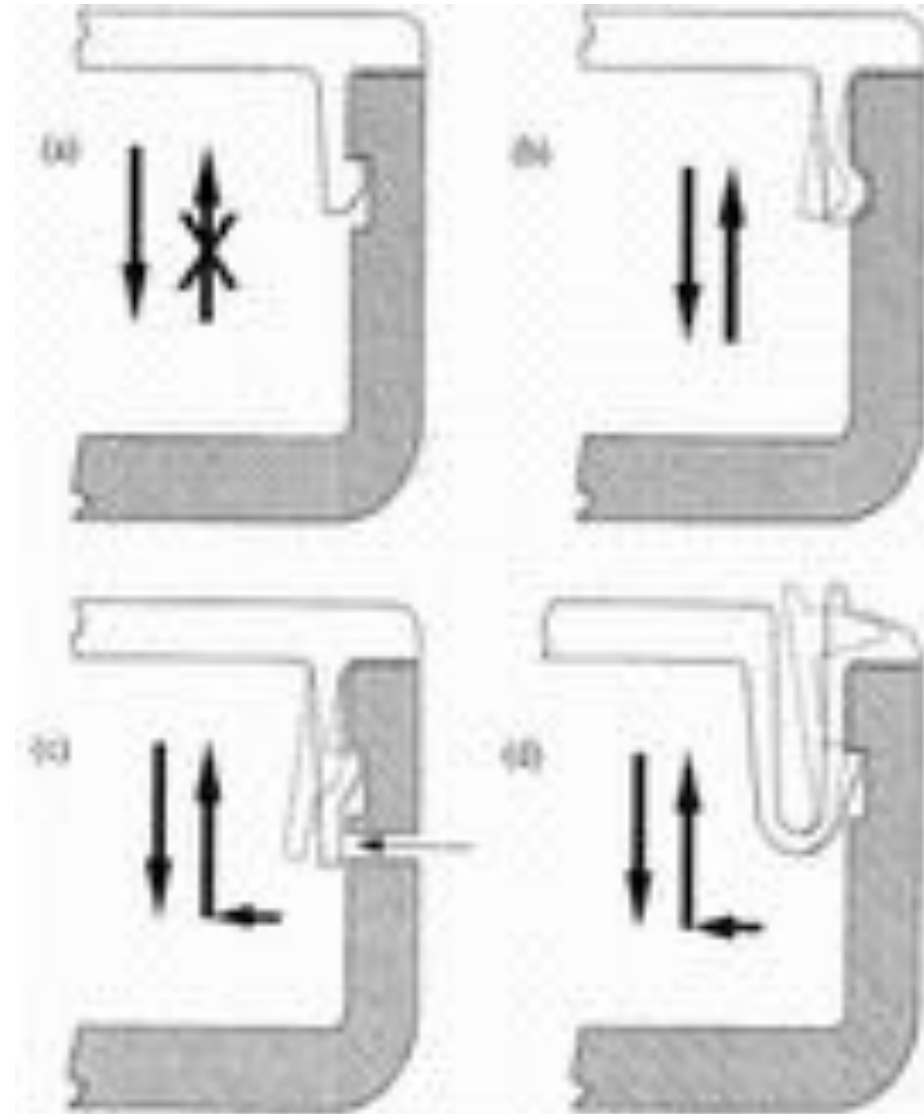


Figure 4: These four snap fit designs allow different types of disassembly.

Cantilever Snap-Fit (continued)

- Snap fits that are intended for one time use have a sharp edge, or tang, that holds the part in place.
- Snaps intended for limited use will have a rounded tang to allow the snap feature to be pulled off yet still have holding ability.
 - With this type of snap fit, the plastic does not experience a lot strain, so multiple flexes are possible without damaging the plastic beam.
 - It also has a built-in stop, so the beam cannot be flexed too much and damaged.

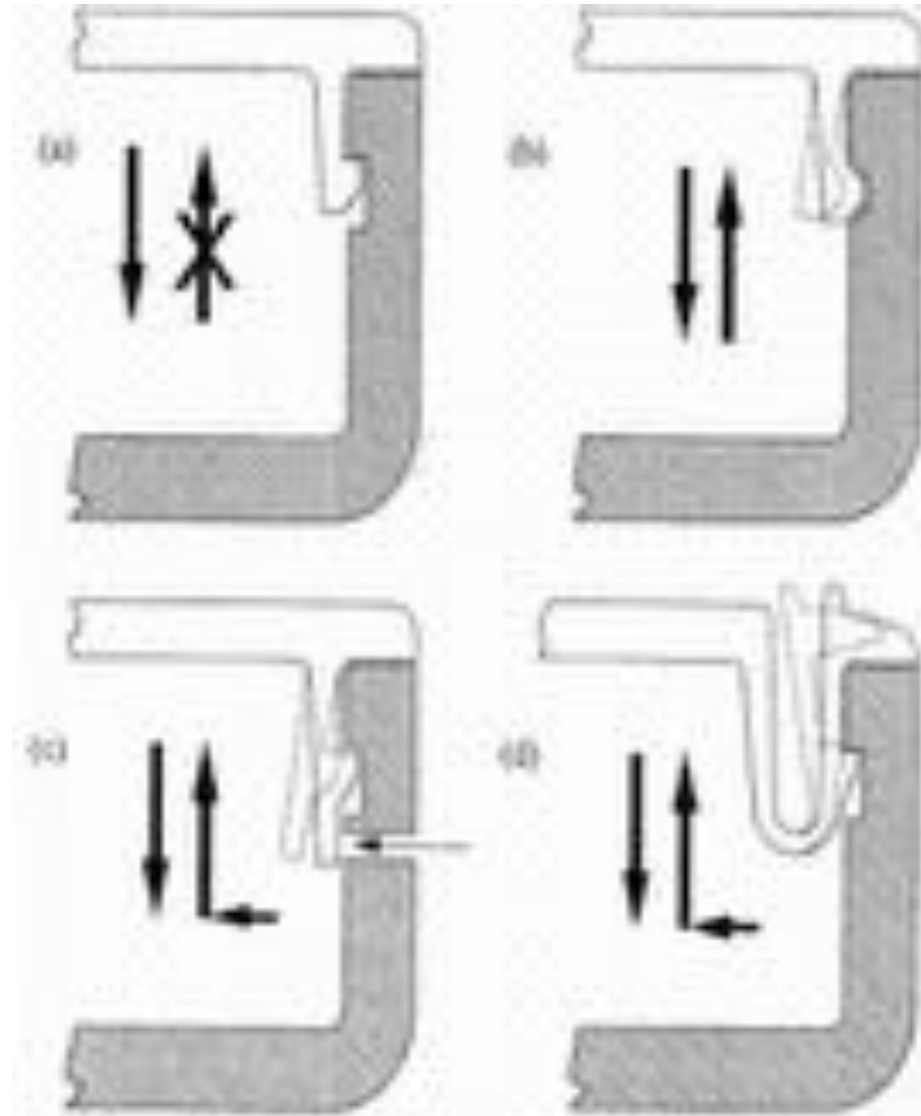
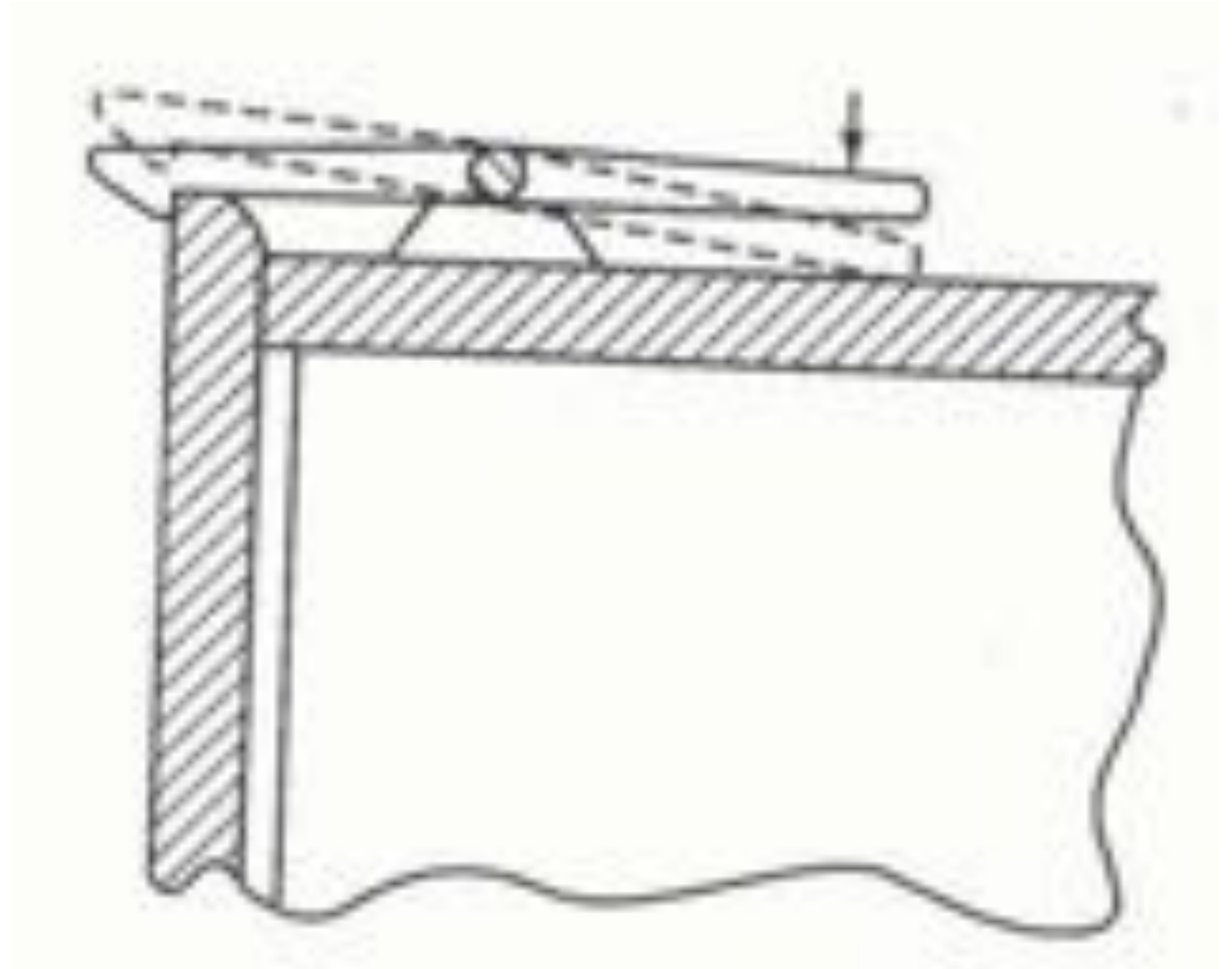


Figure 4: These four snap fit designs allow different types of disassembly.

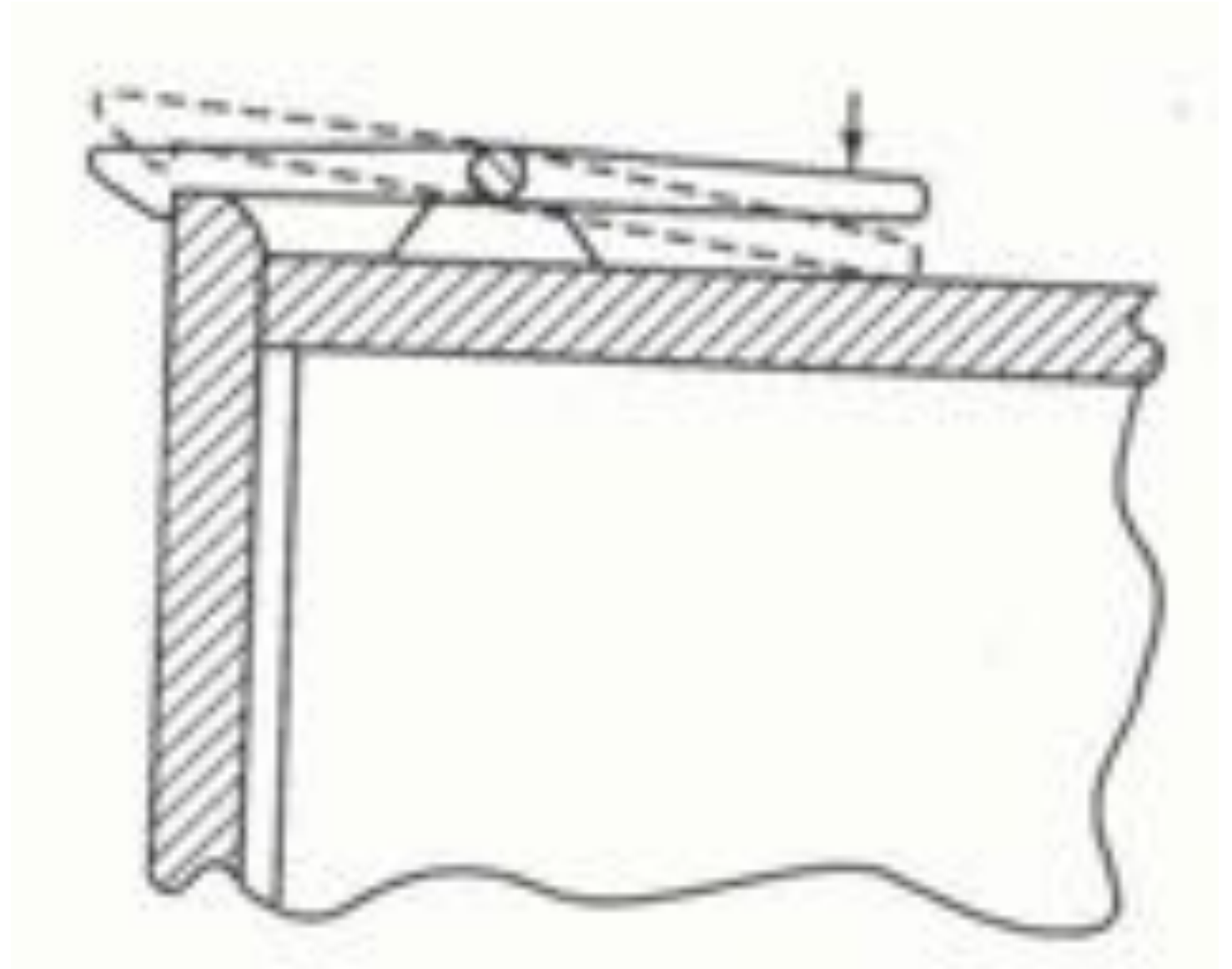
Torsion Snap-Fit

- **Spring-loaded lever that snaps into place when the mating part is pressed into place.**
- **The torsion snap can be released by pressing down on the lever.**
- **This design can be used for frequently assembled and disassembled parts, or to provide constant pressure to the assembly.**



Torsion Snap-Fit (continued)

- The complexity of this type of snap-fit, prevents it from being widely used in industry.
- As its name implies, the torsion snap-fit relies for its spring effect on twisting rather than flexing like the other types.
- It is less common than cantilever or annular snap-fits but it is particularly useful when you want to be able to release the catch easily and often.
 - *For example, a torsion snap fit can be a good way of fastening a hinged lid on a box or container.*



Annular Snap-Fit

- This type of snap fit is best for assembling cylindrical or ring-shaped joints.
 - Classic examples include ballpoint pens with snap-on caps, the child-resistant caps on medicine bottles, and cottage cheese container lids.



Figure 1: A pen sometimes utilizes an annular snap fit to retain the cap.



Figure 3: A ball and socket joint is a kind of annular snap fit.

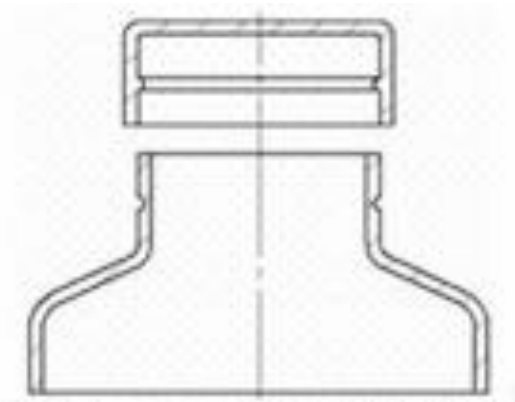


Figure 2: This bottle cap uses an annular snap fit.

Annular Snap-Fit (continued)

- **Generally stronger, but needs greater assembly force than their cantilevered counterparts.**
- **Annular snap-fits are basically interference rings. There is a smaller-diameter male component (plug) which has a bump or ridge feature around its circumference. The ridge diameter of the plug is slightly larger than the inside diameter of its mating tube-shaped female hub.**



Figure 1: A pen sometimes utilizes an annular snap fit to retain the cap.



Figure 3: A ball and socket joint is a kind of annular snap fit.

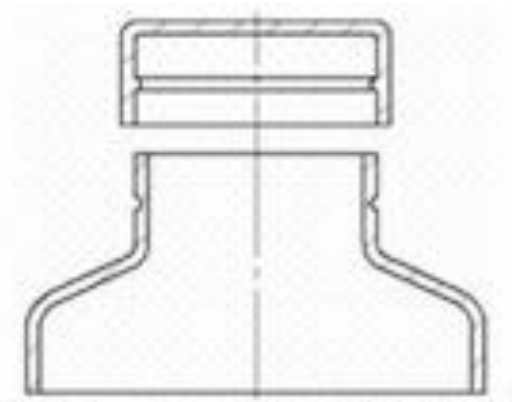


Figure 2: This bottle cap uses an annular snap fit.

Benefits of Snap-Fits

- An integral element of the plastic part – no other components are needed.
- Can replace screws, nuts, and washers.
- Easy automation can reduce assembly costs.
- No other fastener, adhesive, solvent, welding, or special equipment is needed.
- Design can minimize the risk of improper assembly.
- Can be designed to engage and disengage.

Factors Regarding Snap-Fits

- Snap-fits that are assembled under stress will allow creep, a plastic's deformation under load (tension, compression or flexure) over time.
- It is difficult to design snap-fits with hermetic seals. If the beam or ledge of the snap-fit relaxes, it could decrease the effectiveness of the seal.
- Snap-fits can be damaged by mishandling and abuse prior to assembly.
- The key to successful snap-fit design is to have adequate holding power without exceeding the elastic or fatigue limits of the material.

Press Fits

- Press fitting refers to two parts being pressed together, making an interference fit.
 - An *interference fit* occurs when the inner diameter of the hole is slightly less than the outer diameter of the part being inserted. When the two parts are pushed together, they stick.
- A common example is the forced insertion of a metal pin or shaft that is slightly larger than a plastic hub or boss it is inserted into.
- Press fitting is a simple, low-cost method for assembling parts or components.

Example of Interference Fit: Plastic Hub Pressed on Steel Shaft

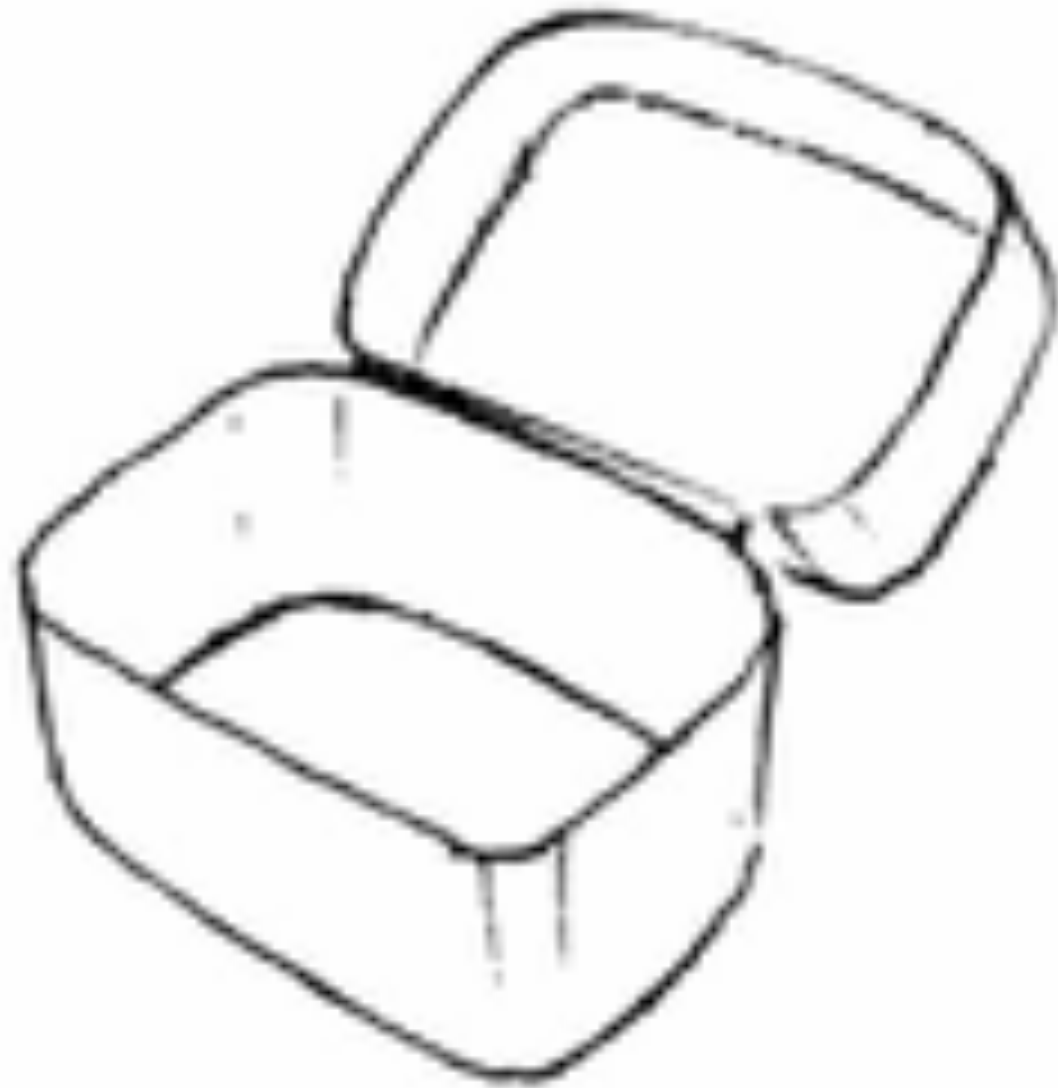


Use of Press Fits

- Used in the telecommunications and computer industries, as well as in automobiles, airplanes, office equipment, and consumer goods.
- Press fitting is a lower quality fitting process. However, once a press fit is in place, it will not come loose.
- The particular application dictates whether a press fit or other fastening method is used. Press fits are sometimes used to get a complete alignment between two pieces.
- Press fits are also used to prevent bearings from spinning. It is a good fastening method for components that undergo temperature fluctuations, such as automotive assemblies. Regardless of the temperature, the interference fit or force between the two parts is always there.

Living Hinges

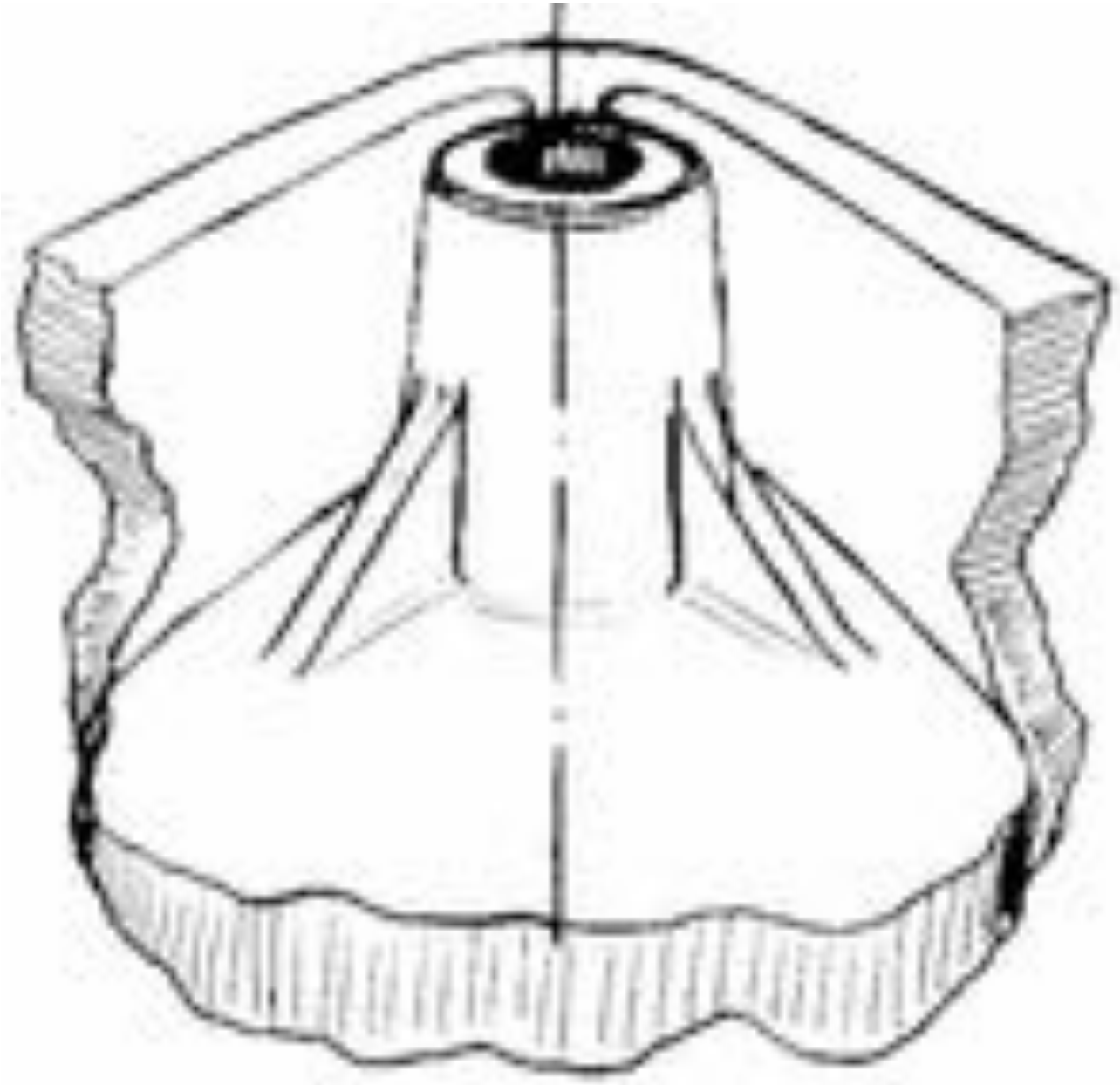
- **Thin sections of plastic that connect two segments of a part to keep them together and allow the part to be opened and closed.**
- **Typically these are used in containers that are used in high volume flexing applications such as toolboxes, fish tackle boxes, file card boxes, etc.**
- **The materials used to make a living hinge are usually a very flexible plastic such as polypropylene and polyethylene. These can flex more than a million cycles without failure.**

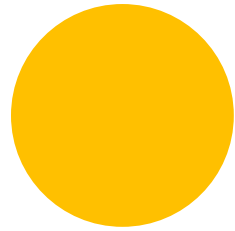
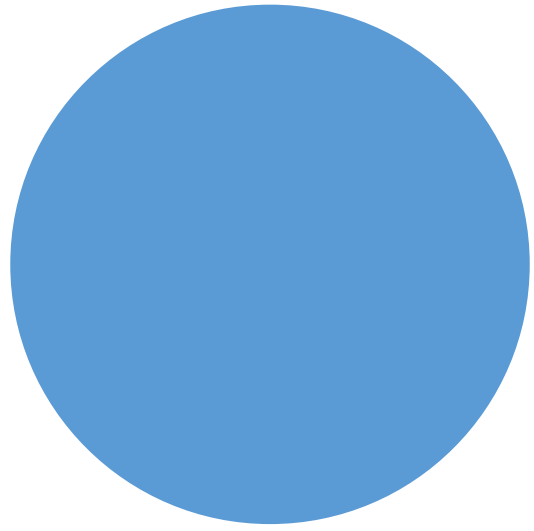


BOX WITH LIVING HINGE

Bosses

- Projection designed into a plastic part to add strength, facilitate alignment during assembly, or to provide for fastening.
- Bosses are used for the purpose of registration of mating parts or for attaching fasteners such as screws or accepting threaded inserts (molded-in, press-fitted, ultrasonically or thermally inserted).



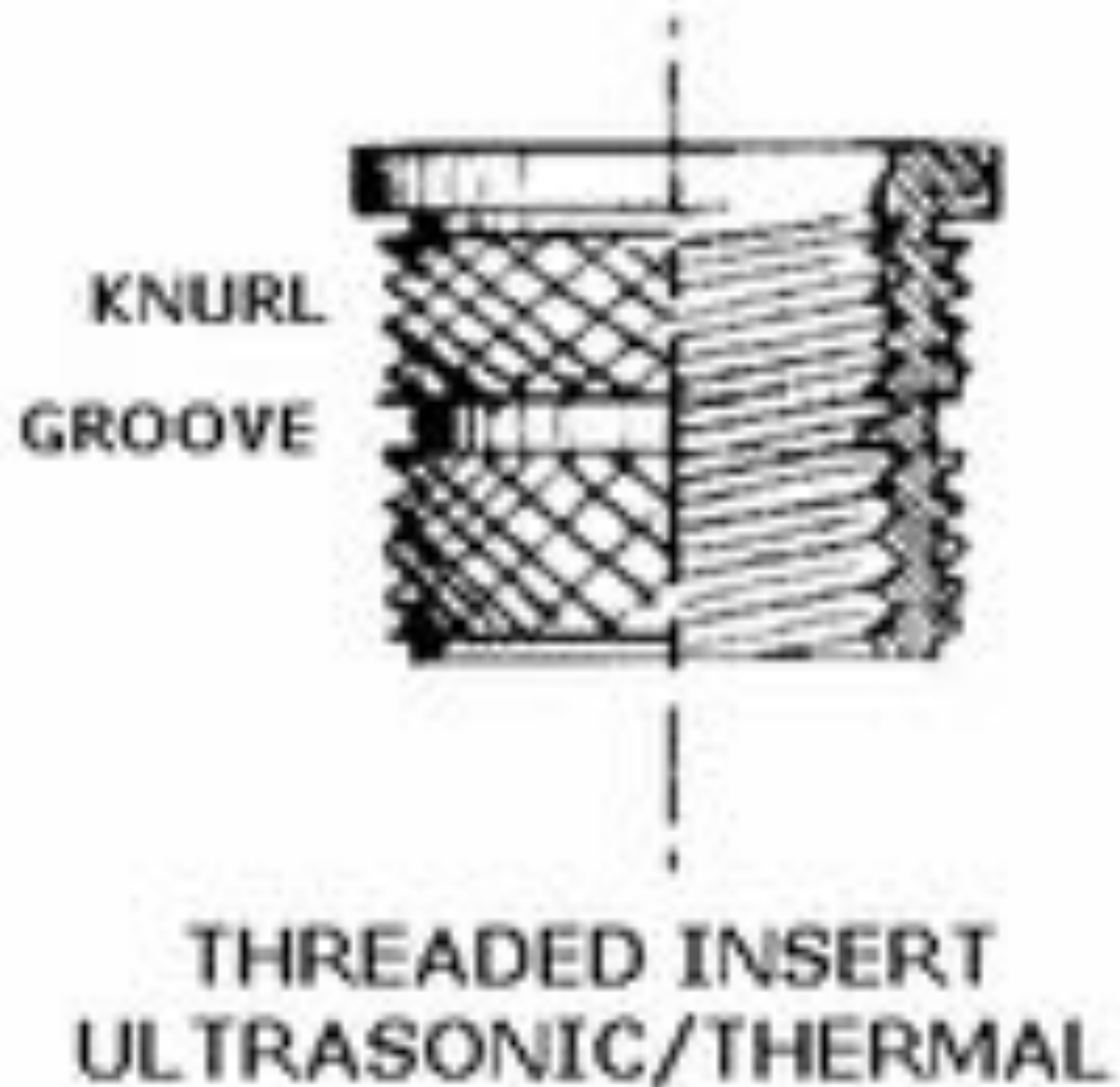


Fastners for plastics



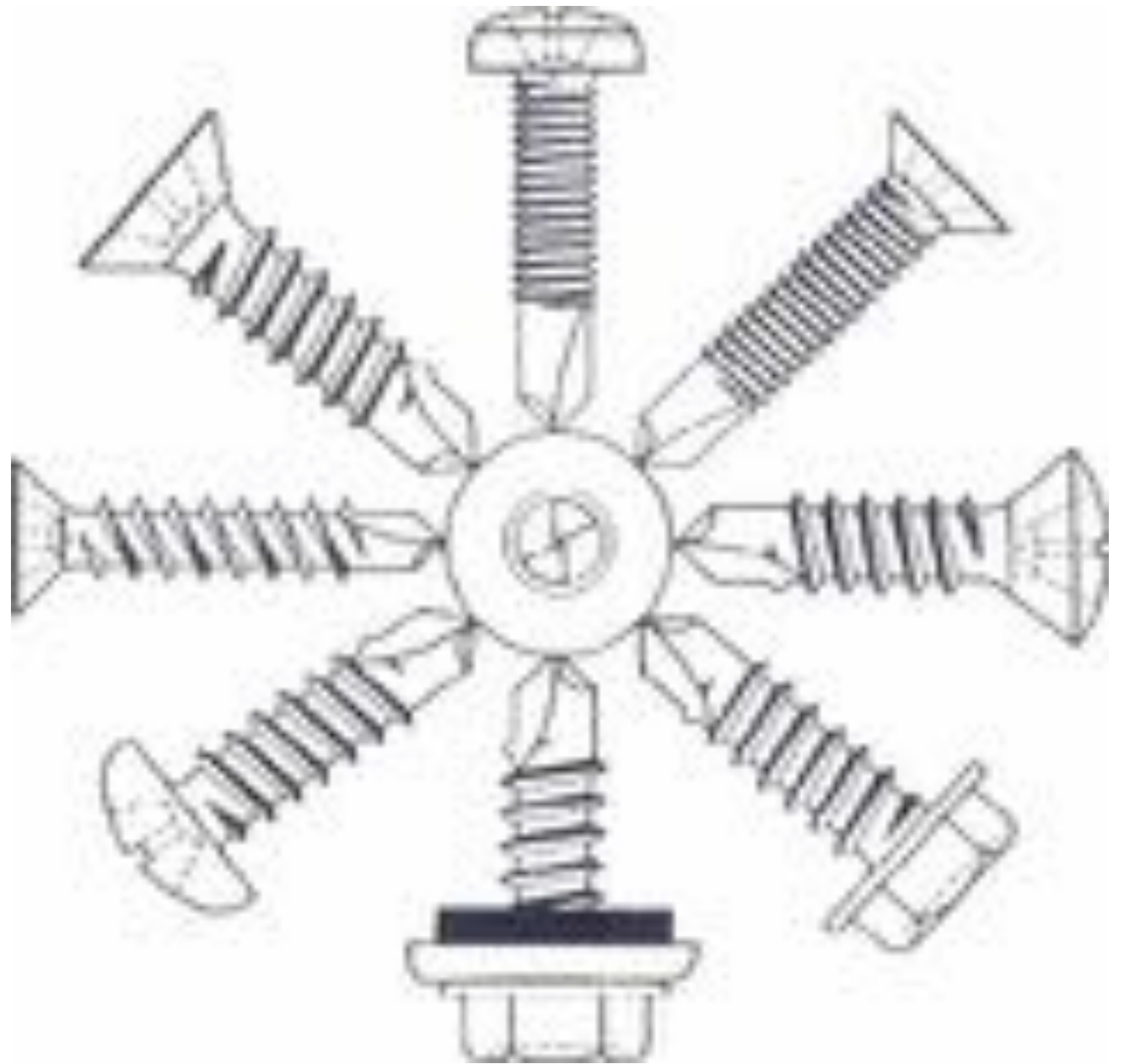
Threaded Metal Inserts

- Permanently installed in molded bosses, eliminate the need for a nut, simplifying the assembly.
- Can include female threads, threaded male studs, locating pins, and bushings.
- Ultrasonically-installed inserts are especially popular, because the surrounding plastic melts around the insert, make it strong and relatively free of stress.



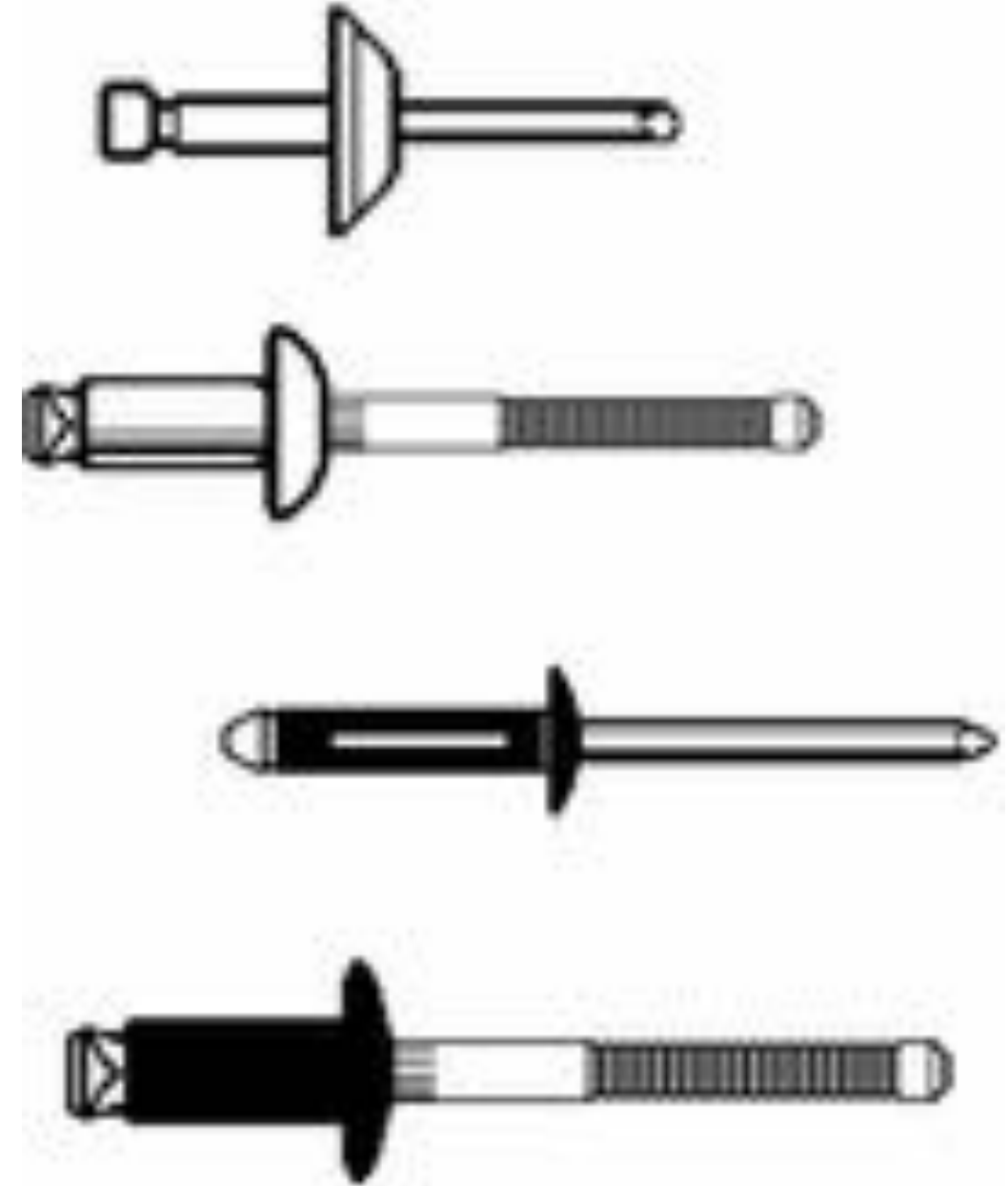
Self-Tapping Screws

- **Cutting-style screws are best because they act like thread-cutting taps and remove material, without generating high stresses on plastic materials as do forming-style screws.**
- **Screws with multiple lobes and those with alternating thread heights offer excellent holding power and reduced stress levels.**



Metal Rivets

- **Allow for fast, permanent assemblies.**
- **Should have large heads to spread the load.**
- **Rivet should be formed against the metal part of an assembly or against a metal washer if both parts are plastic.**



Stamped Sheet Metal Fasteners

- Provide light-duty threads or push-on assemblies. Push-nuts, for example, are simply pressed onto plain, molded plastic studs or bosses in permanent assemblies.
- Easy to install, inexpensive, and vibration-proof.
- Another such fastener, boss caps (cup-shaped parts pushed onto a plastic boss), add partial metal threads for self-tapping or sheet metal screws, and reinforce the boss against the expansion forces of the screw.



Molded Plastic Screws, Rivets and Other Similar Fasteners

- **Used for light-duty plastic assemblies, especially where appearance is important, such as to attach trim and faceplates.**

