10. Primjena spojeva

Ishodi učenja:

(a) **Usvojena znanja iz nerastavljivih spojeva** (definicija, spajanje i vrste spojeva)**.**
(b) **Usvojena znanja iz zalijepljenih spojeva** (osnove, lijepila, oblikovanje i proračun, tehnologija spajanja)**.**
(c) **Usvojena znanja iz zakovičnih spojeva** (osnove, lijepila, oblikovanje i proračun, tehnologija spajanja)**.**
(d) **Usvojena znanja iz nerastavljivih steznih spojeva** (osnove, lijepila, oblikovanje i proračun, tehnologija spajanja)**.**
(e) **Usvojena znanja iz nerastavljivih oblikovnih spojeva** (osnove, lijepila, oblikovanje i proračun, tehnologija spajanja)**.**

Spojevi glavina i vratila
- Osnove spojeva glavina i vratila
- Nerastavljivi spojevi glavina i vratila
- Rastavljivi nepomični spojevi glavina i vratila
- Rastavljivi pomični spojevi glavina i vratila

Spojevi u kućanstvu
- Spojevi opskrbnih instalacija
- Spojevi bijele tehnike
- Spojevi namještaja
- Spojevi elektroničke opreme

Spojevi različitih materijala
- Spojevi metala
- Spojevi keramika i stakala
- Spojevi polimera i elastomera
- Spojevi kompozitanih materijala

Ostali spojevi
- Kombinirani spojevi
- Spojevi vozila
- Spojevi plovila
- Spojevi u radioni
- Spojevi s osobitim poteškoćama

10.1 Primjena nerastavljivih spojeva

10.1.1 Primjeri zalijepljenih spojeva

10.1.2 Primjeri zakovičnih spojeva

10.1.3 Primjeri nerastavljivih steznih spojeva

10.1.4 Primjeri nerastavljivih oblikovnih spojeva

10.1.5 Primjeri zavarenih spojeva čeličnih konstrukcija

Dck20

10.1.6 Primjeri zavarenih spojeva čeličnih cijevnih konstrukcija

Dck32

10.1.7 Primjeri zavarenih spojeva proizvodnog strojarstva

10.1.8 Primjeri zavarenih spojeva kotlova i tlačnih posuda

Dck10

10.2 Primjena rastavljivih spojeva

10.2.1 Primjeri spojeva s klinovima i perima

10.2.2 Primjeri spojeva sa zaticima i svornjacima

10.2.3 Primjeri rastavljivih steznih spojeva

10.2.4 Primjeri rastavljivih oblikovnih spojeva

10.2.5 Primjeri vijčanih spojeva konstrukcija

10.2.6 Primjeri vijčanih spojeva proizvodnog strojarstva

10.3 Primjena spojeva cjevovodi

10.3.1 Nacrti, predmjeri i predračuni cjevovoda

10.3.2 Mreže opskrbe pitkom vodom

10.3.3 Mreža opskrbe toplom vodom

10.3.4 Kanalizacijske mreže

10.3.5 Mreže opskrbe gorivim plinom

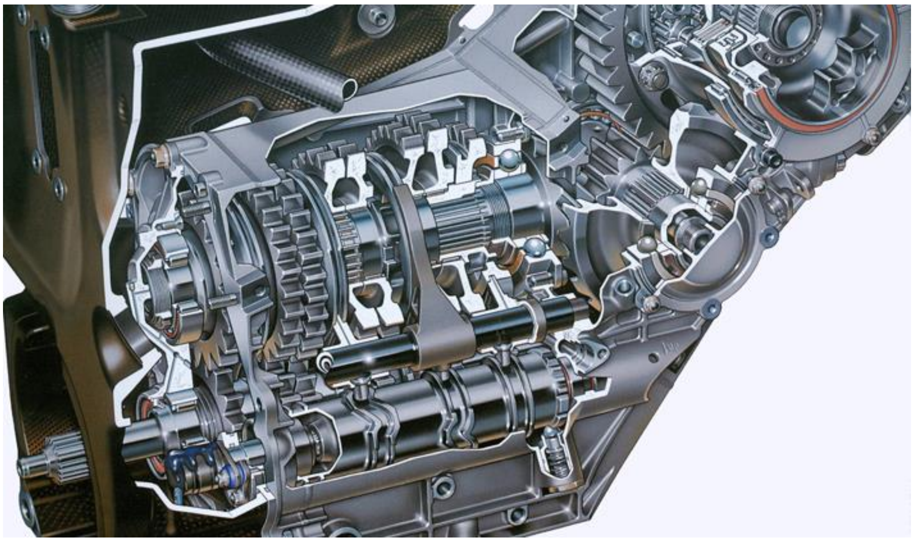
10.3.6 Cjevovodi plinskih bojlera

10.3.7 Cjevovodi motornih vozila

10.4 Primjeri specifičnih spojeva

10.4.1 Spojevi glavina s vratilima

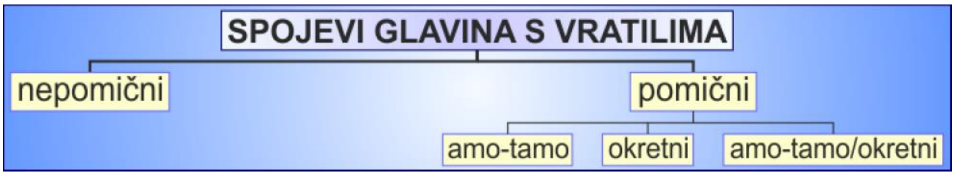
U mjenjačima motornih vozila zastupljeni su brojni spojevi glavina s vratilima *(**S 10.01**)*.



Slika 10.01 Spojevi glavina s vratilima – mjenjač motornog vozila F1

Spojevi glavina s vratilima prenose okretne momente i vrtnju s vratila na glavinu *(npr. rotor turbine, radno kolo crpke, radno kolo kompresora, propeler plovila, zupčanik mjenjača, remenica koljenastog vratila, lančanik bicikla)* ili s glavine na vratilo *(npr. zupčanik mjenjača, remenica generatora električne struje, lančanik bicikla)*. Pored toga, mogu biti opterećeni poprečnim i uzdužnim silama te momentima savijanja *(npr. zupčanici, remenice)*. Ovi spojevi sprječavaju uzajamno okretanje glavine i vratila te u slučaju čvrstih spojeva i njihovo uzajamno linearno gibanje.

Prema broju stupanja slobode gibanja razlikuju se:

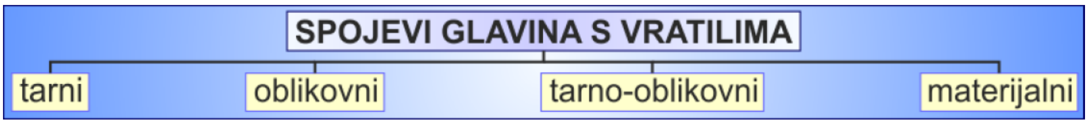


U ovom su dijelu obuhvaćeni samo primjeri pomičnih spojeva koji će biti detaljnije obrađeni u u Elementima strojeva 2 – odjeljak 05 Ležajevi.

Prema mogućnosti rastavljanja razlikuju se:

Prema načinu prijenosa okretnog momenta razlikuju se:

Prema izvedbi mogu se razlikovati:

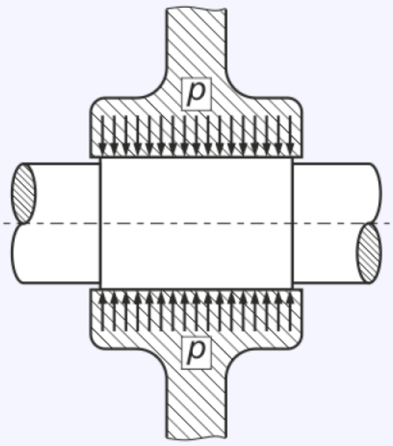


Nerastavljivi spojevi glavina s vratilima

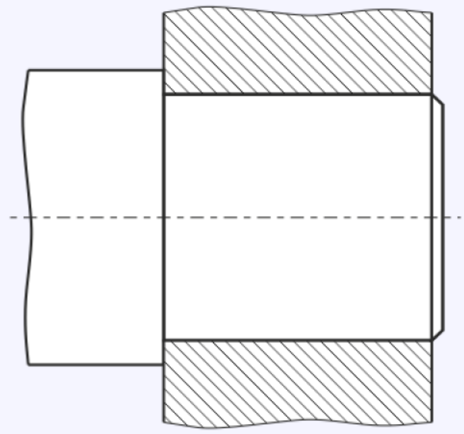
Prema izvedbi mogu se razlikovati:

Zavareni *(zalemljeni)* spojevi glavina i vratila su teorijski mogući ali se u praksi izbjegavaju zbog problema koji prate značajan porast temperatura materijala tijekom postupka zavarivanja.

Nerastavljivi tarni spojevi glavina s vratilima



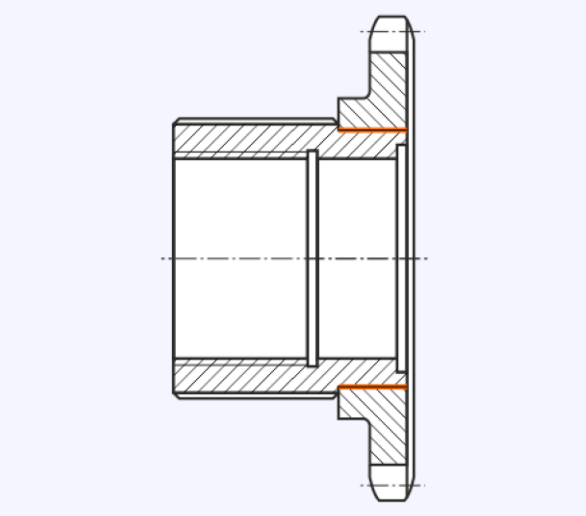
Slika 10.02 Cilindrični preklopni nerastavljivi tarni spoj [Niemann 2005, str. 806]



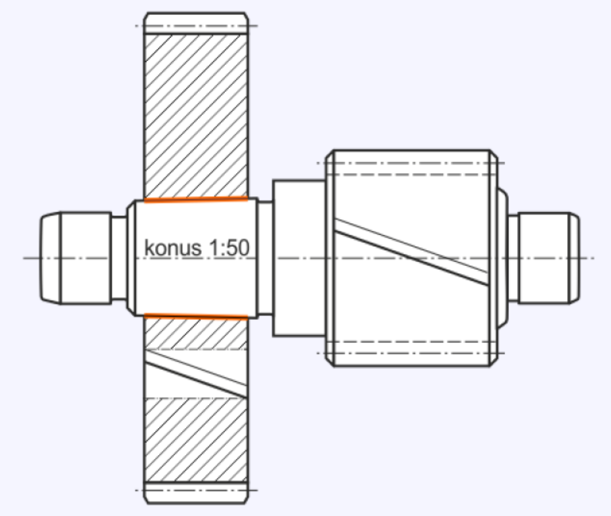
Slika 10.03 Cilindrični preklopni nerastavljivi tarni spoj [Böge 2011, str. I120]

Cilindrični preklopni nerastavljivi tarni spoj ***(S 10.02** i **S 10.03)*** koriste se za prijenos većih, promjenljivih i udarnih okretnih momenata i aksijalnih sila. Primjenjuju se za spajanje na vratila: remenica, zupčanika, spojki, zamašnjaka većih strojeva ali se primjenjuje i u finoj mehanici. Sastavlja se uz izvjesne poteškoće *(sila, grijanje/hlađenje)*, ali je veoma ekonomičan spoj.

Nerastavljivi zalijeljeni spojevi glavina s vratilima



Slika 10.04 Zalijepljeni cilindrični spoj glavine lančanika i vratila [Niemann 2005, str. 882]



Slika 10.05 Zalijepljeni konusni spoj glavine zupčanika i vratila [Niemann 2005, str. 884]

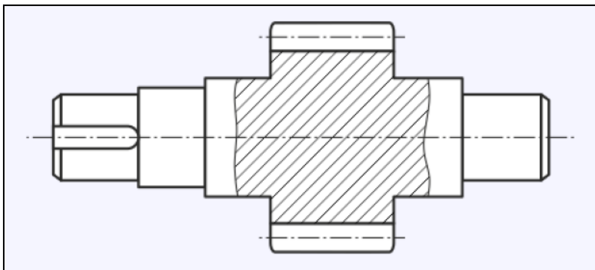
Za spajanje glavina i vratila koriste se lijepila [Avalone 2006, str. 6-134]:

(a) anaerobna akrilna *(obratiti pozornost na kompatibilnost materijala)*,

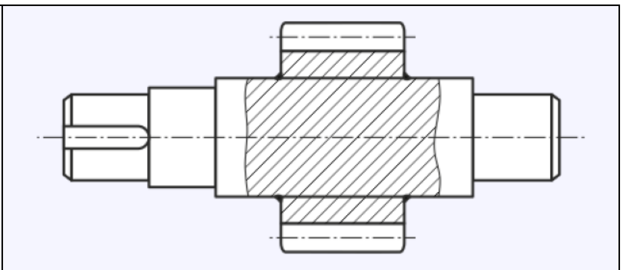
(b) modificirana akrilna *(ako zračnosti nisu prevelike)*,

(c) epoksidna *(maksimalna čvrstoća pri visokim temperaturama)*.

Nerastavljivi zavareni spojevi glavina s vratilima



Slika 10.06 Zupčanik i vratilo izrađeni iz jednog komada [Decker 2006, str. 437]



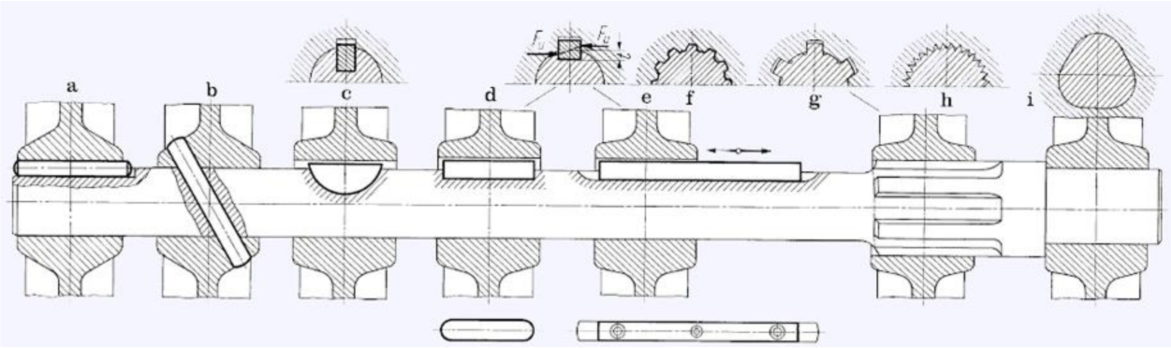
Slika 10.07 Glavina zupčanika zavarena na vratilo [Decker 2006, str. 437]

Kada je razlika promjera vratila i zupčanika mala mogu se vratilo i zupčanik izraditi iz jednog dijela *(**S 10.06**)*. Također je moguće i zavarivanje glavine na vratilo *(**S 10.07**)* koje se provodi prije obrada skidanjem strugotine *(uključivo ozubljenje)*. U odnosu na zupčanik i vratilo izrađeni iz jednog komada ovdje je postignuta značajna ušteda materijala i smanjenje vremena potrebnog za obradu skidanjem strugotine.

Rastavljivi spojevi glavina s vratilima

Pored profilnih u oblikovne spojeve spadaju i spojevi sa zaticima, svornjacima i perima, dok su spojevi s klinovima tarno-oblikovni.

Primjeri često korištenih oblikovnih spojeva glavine s vratilom prikazani su na **S 10.xx** [Niemann 2005, s. 839]:

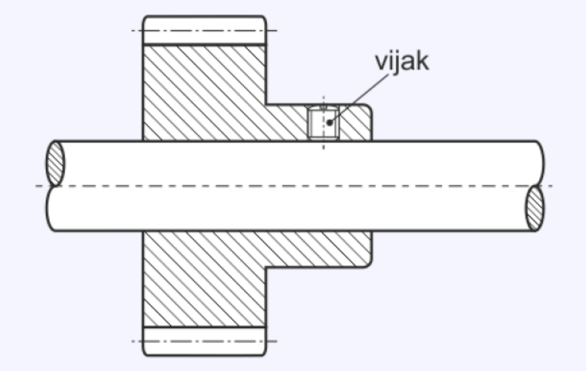
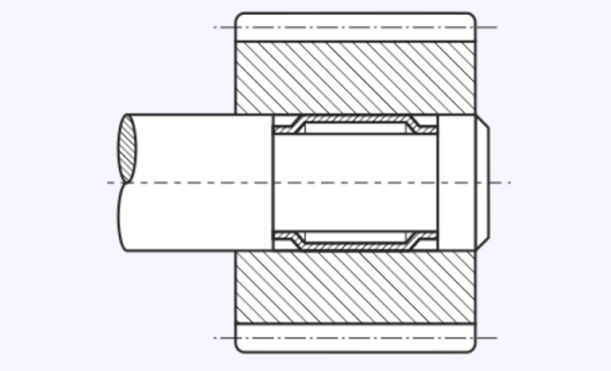


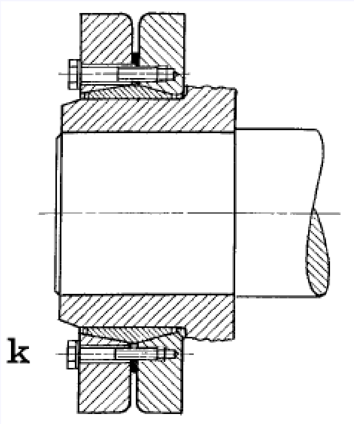
a Längsstift, b Querstift, c Scheibenfeder, d Paßfeder, e Gleitfeder, f Zahnwelle g Keilwelle, h Kerbzahnwelle, i Polygonwelle

(a) uzdužni zatik, (b) poprečni zatik, (c) segmentno pero, (d) dosjedno pero, (e) klizno pero, (f) zupčano vratilo, (g) klinasto vratilo (h) profilno vratilo s trokutastim zupcima (i) poligonalno vratilo

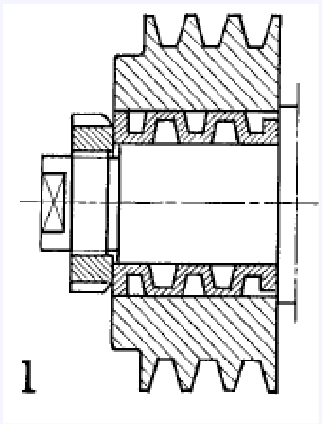
Slika 10.08 Primjeri oblikovnih spojeva glavine s vratilom

Rastavljivi tarni spojevi glavina s vratilima

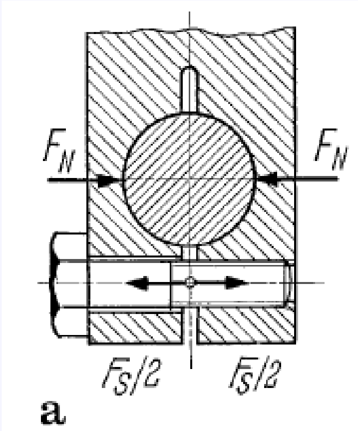
	
Slika 10.08 Podesivi tarni spoj glavine i vratila s učvrsnim vijkom [Childs 2004, str. 98]	**Slika 10.09** Tarni spoj glavine i vratila s tolerancijskom čahurom [Niemann 2005, str. 806]



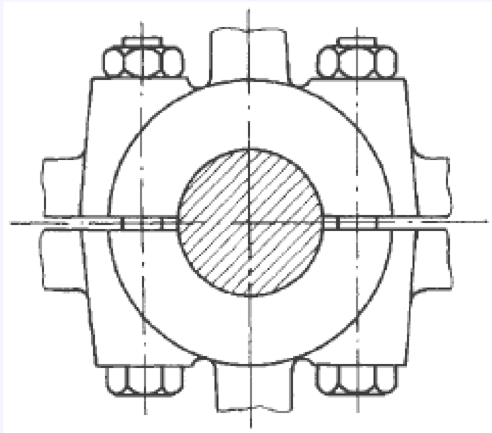
Slika 10.10 Tarni spoj glavine i vratila s tlačnom čahurom [Niemann 2005, str. 806]



Slika 10.11 Tarni spoj glavine i vratila s rebrastom tlačnom čahurom [Niemann 2005, str. 806]

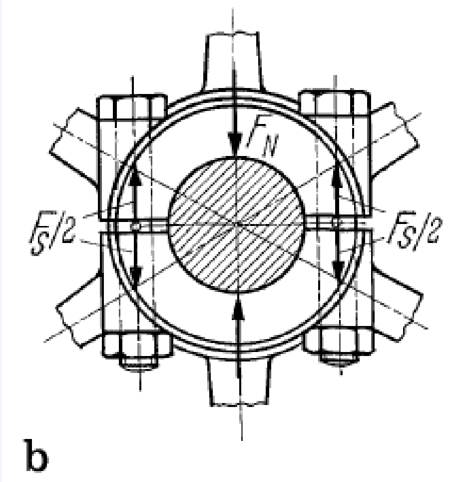


Slika 10.12 Stezni tarni spoj jednodijelne glavine i vratila [Niemann 2005, str. 806]

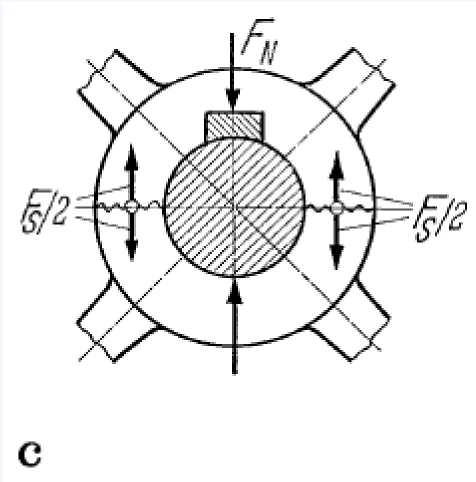


Slika 10.13 Stezni tarni spoj dvodijelne glavine i vratila [Böge 2011, str. I120]

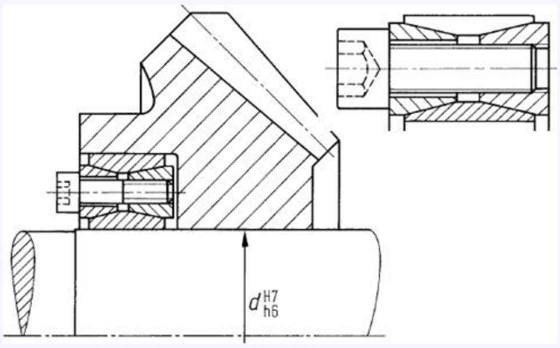
Cilindrični rastavljivi tarni spoj *(**S 10.12** i **S 10.12**)* lako se sastavlja i rastavlja. Moguće ga je aksijalno i radijalno podešavati. Koristi se za prijenos manjih okretnih momenata dok se za prijenos većih okretnih momenata osiguravaju perima ili tangencijalnim klinovima. Primjenjuje se za spajanje na glatka vratila: remenica i kolotura te ručica. Glavina može biti dvodijelna ili jednodijelna rasječena.



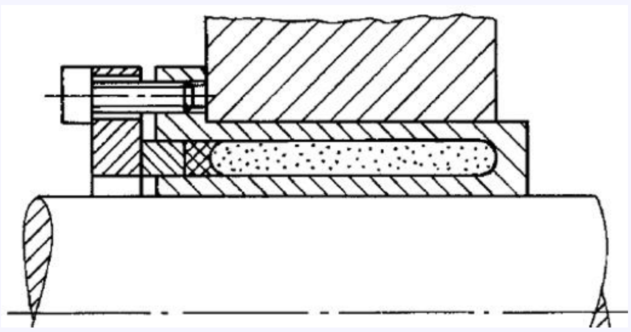
Slika 10.14 Stezni tarni spoj dvodijelne glavine i vratila [Niemann 2005, str. 806]



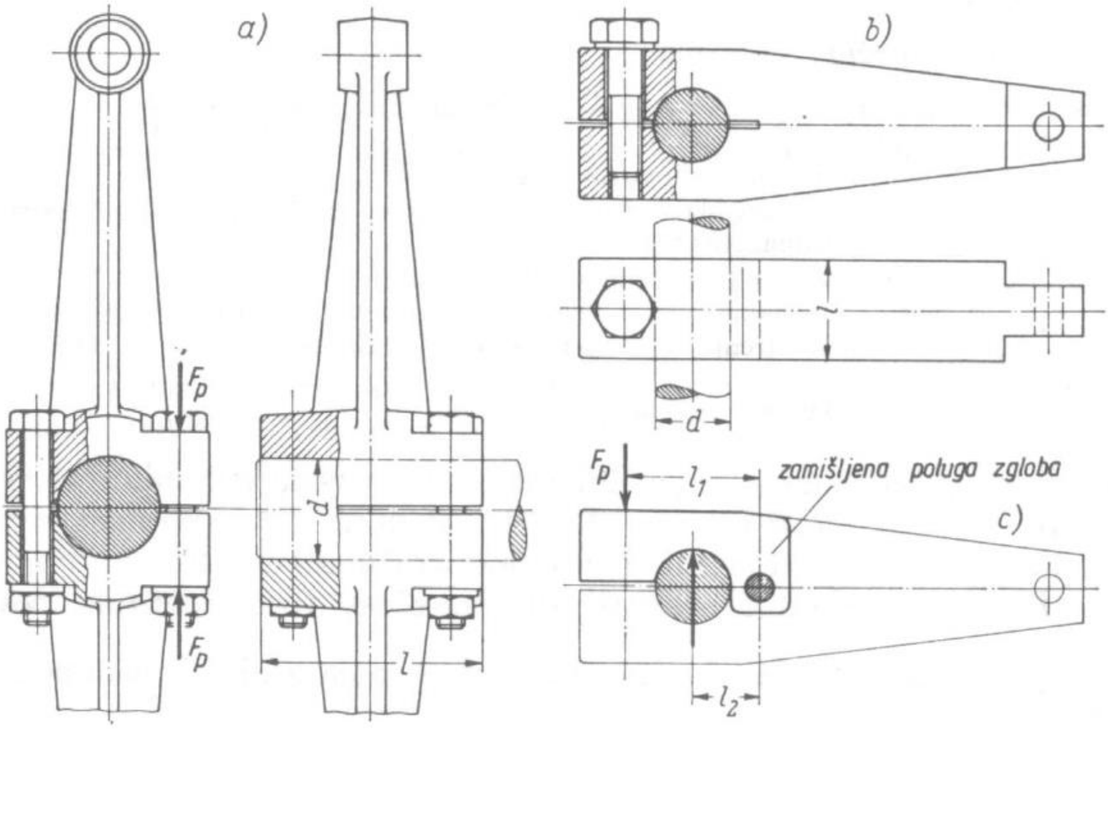
Slika 10.15 Stezni tarni spoj dvodijelne glavine s udubljenim klinom [Niemann 2005, str. 806]



Slika 10.16 Stezni tarni spoj s mehaničkomtlačnom [Niemann 2005, str. 837]

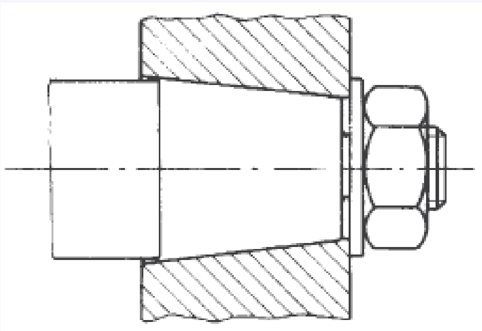
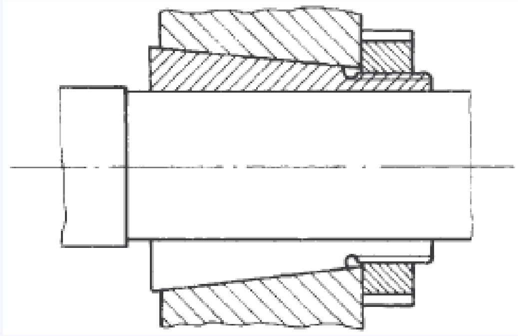


Slika 10.17 Stezni tarni spoj sa šupljom hidrauličkom čahurom [Niemann 2005, str. 806]

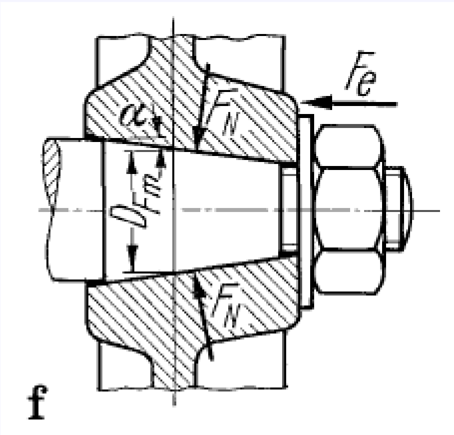
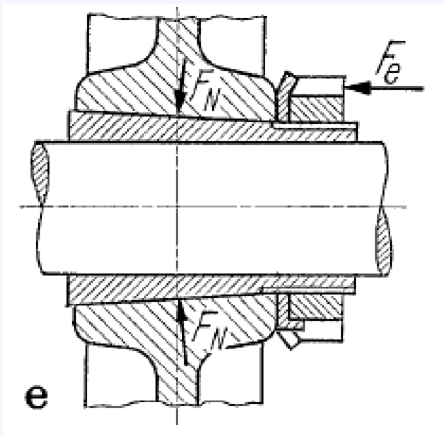


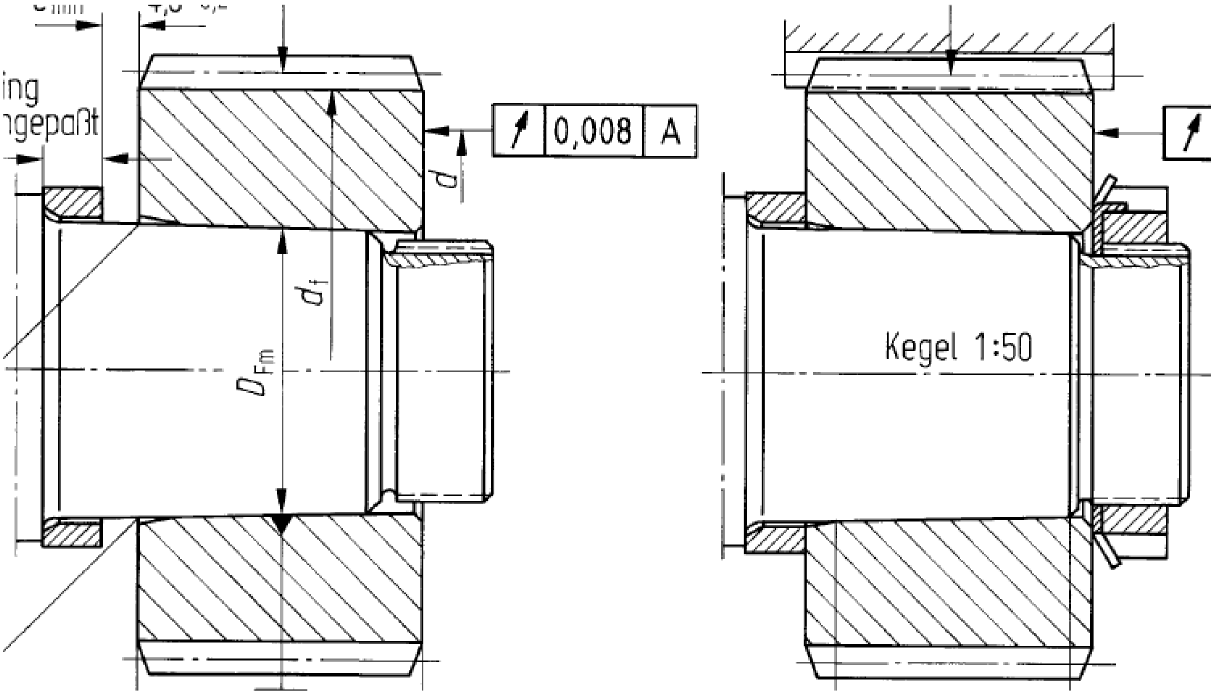
a) dvodijelna – rasječena glavina, b) jednodijelna – zasiječena glavina
c) zamišljena poluga zasječene glavine

Slika 10.18 Stezni spojevi [Decker 2006, str. 156]

	
Slika 10.19 Konusni tarni spoj glavine i vratila [Böge 2011, str. I120]	**Slika 10.20** Konusni rastavljivi tarni spoj [Böge 2011, str. I120]

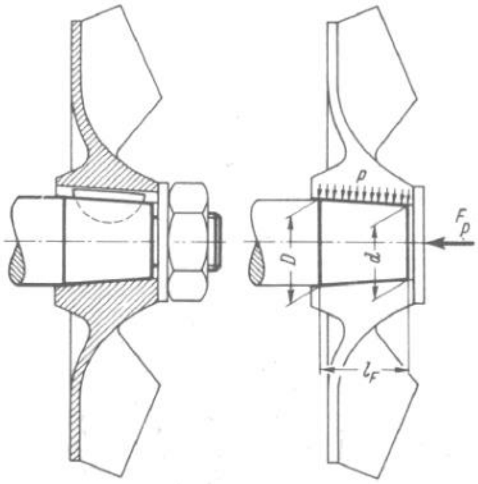
Konusni rastavljivi tarni spoj *(**S 10.03**, **S 10.04**)* lako se rastavlja i sastavlja. Moguće ga je radijalno podešavati. Koristi se za prijenos većih, promjenljivih i udarnih okretnih momenata. Primjenjuje se za spajanje na vratila: remenica, zupčanika, spojki, zamašnjaka većih strojeva te alata kod alatnih strojeva i ležajeva. Glavinu pritiska vijak ili matica te aksijalna sila koja se javlja u alatu pti obradi odvajanjem strugotine *(npr. bušenje)*. Konusni tuljak je najčešće ***(S 10.04)*** rasječen.

	
Slika 10.21 Konusni tarni spoj glavine i vratila [Niemann 2005, str. 806]	**Slika 10.22** Tarni spoj glavine i vratila s konusnom čahurom [Niemann 2005, str. 806]

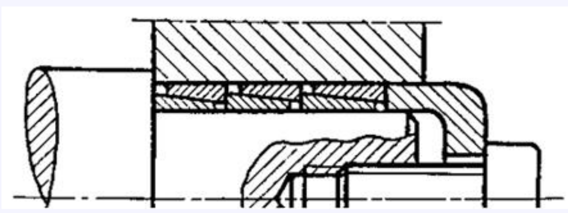
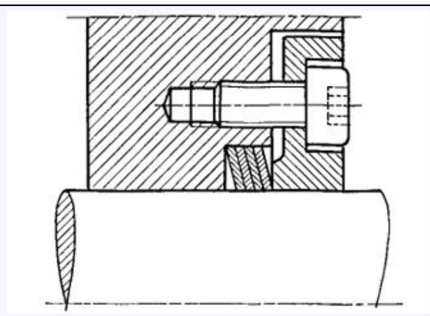


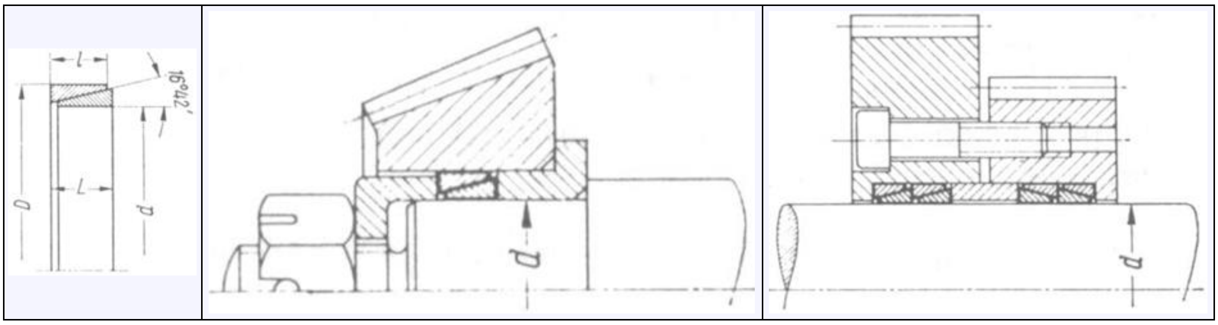
spoj prije stezanja, b) spoj sa stegnutom maticom i savijenim osiguračem

Slika 10.23 Konusni tarni spoj s određenim putom stezanja [Niemann 2005, str. 832]

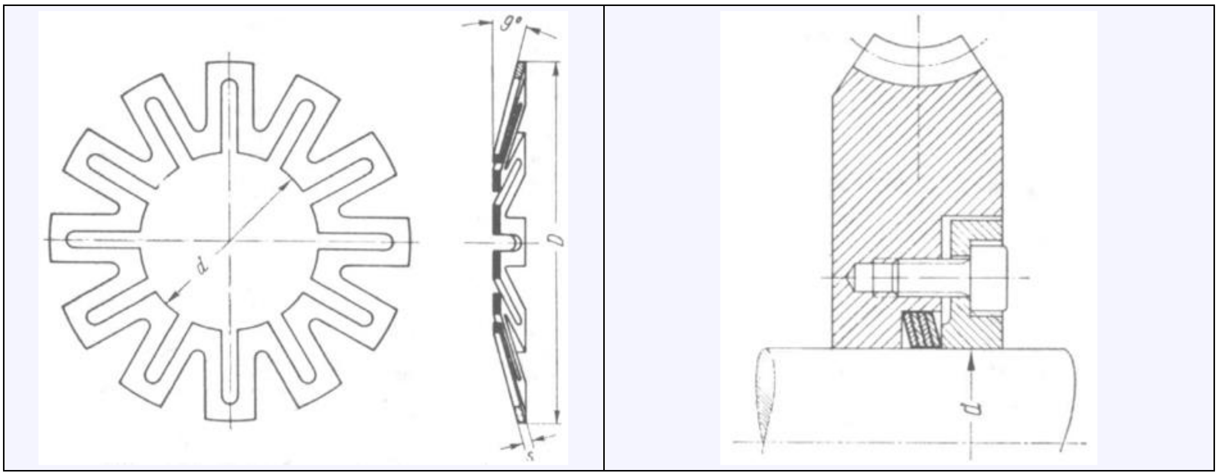


Slika 10.24 Konusni tarni spoj glavine propelera s vratilom [Decker 2006, str. 155]

	
Slika 10.25 Tarni spoj s tlačnim prstenastim oprugama [Niemann 2005, str. 806]	**Slika 10.26** Tarni spoj s tlačnim zvjezdastim pločicama [Niemann 2005, str. 806]

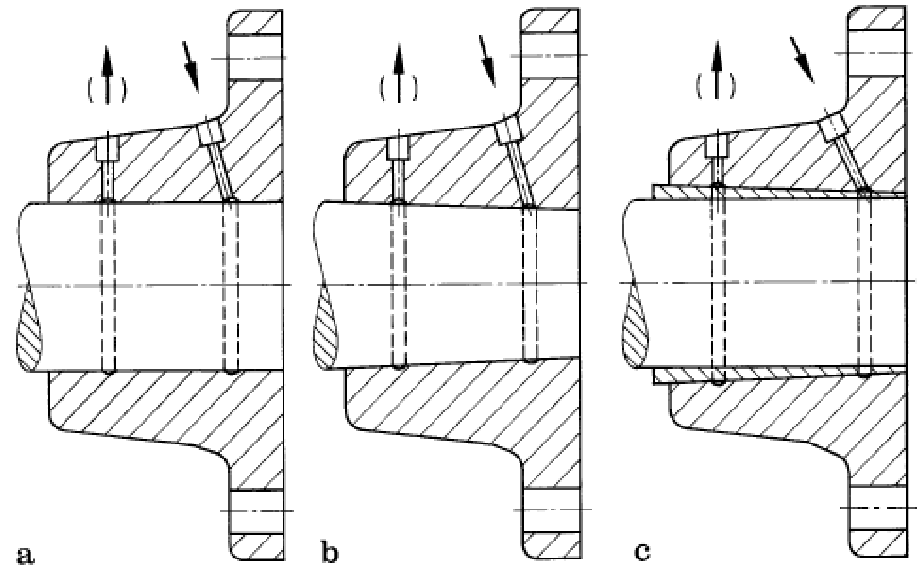


Slika 10.27 Tarni spoj s tlačnim prstenastim oprugama [Decker 2006, str. 158]



Slika 10.28 Tarni spoj s tlačnim zvjezdastim plocicama [Decker 2006, str. 161]

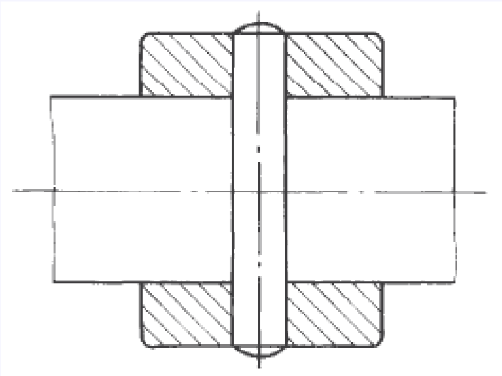
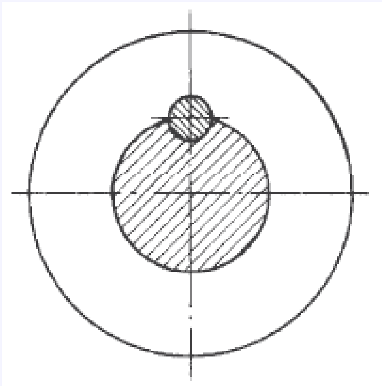
Rastavljanje tarnih spojeva se olakšava tlačenjem ulja kroz provrte glavine.



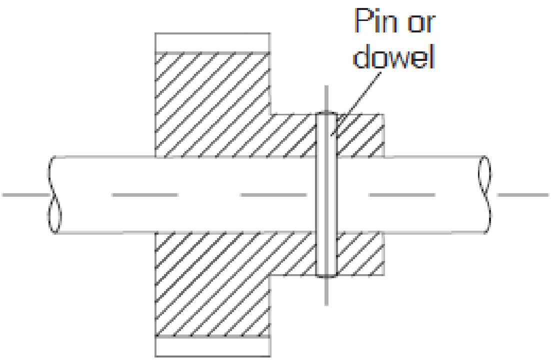
a cilindrični tarni spoj, b konični tarni spoj,
c tarni spoj s koničnom čahurom

Slika 10.29 Rastavljanje tarnih spojeva [Niemann 2005, 828]

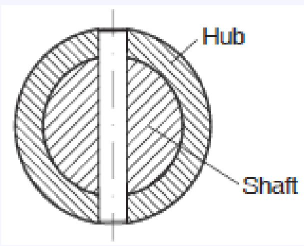
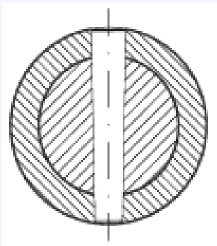
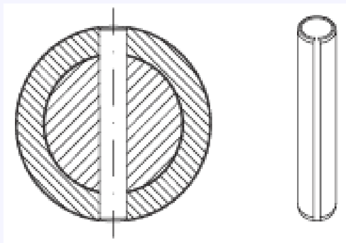
Rastavljivi oblikovni spojevi glavina s vratilima

	
Slika 10.30 Rastavljivi oblikovni spoj s radijalnim zatikom Böge2011/I121	**Slika 10.31** Rastavljivi oblikovni spoj s aksijalnim zatikom Böge2011/I121

Rastavljivi oblikovni spoj sa zatikom *(**S 10.30**, **S 10.31**)* se koristi za prijenos manjih okretnih momenata nepromjenljivog smjera. Primjenjuje se za spajanje na vratila: graničnika, prstena za podešavanje, kotača, ručica i tuljaka. Koriste se konusni zatici *(DIN EN 22339)* nagiba 1 : 50, cilindrični zatici *(DIN EN ISO 2338)* a za veća opterećenja otvrdnuti cilindrični zatik *(DIN EN ISO 8734)*, te zasječeni i naponski zatici.



Slika 10.32 Rastavljivi oblikovni spoj sa zatikom [Childs 2004, 98]

<table>
<tr><td>
</td><td></td><td></td></tr>
<tr><td>ravni okrugli zatik</td><td>konični okrugli zatik</td><td>rasječeni cijevni zatik</td></tr>
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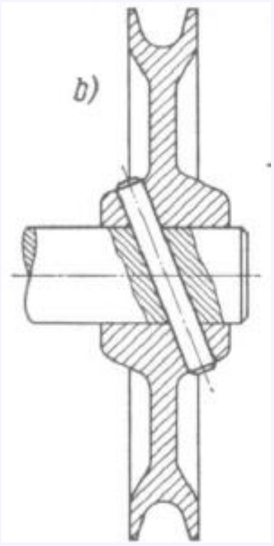
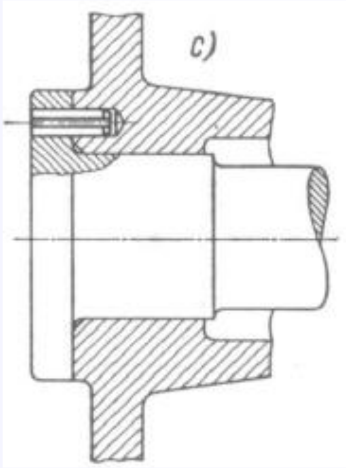
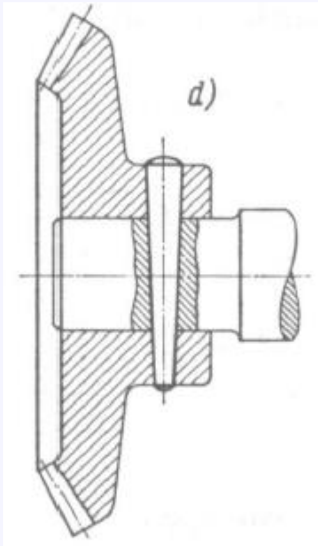
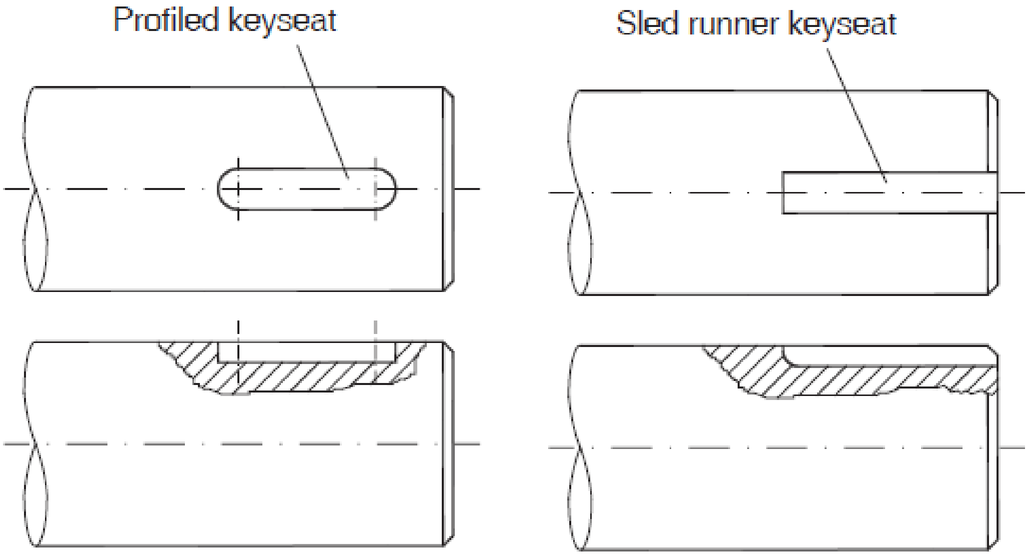
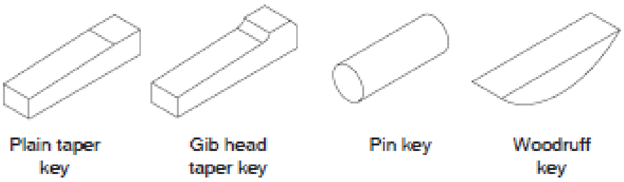
Slika 10.33 Rastavljivi oblikovni spoj sa zatikom [Childs 2004, 99]

		
cilindrični zatik h8 kao spojni zatik	tlačni zatik kao osigurač spoja	konični zatik za spajanje i učvršćivanje

Slika 10.33 Rastavljivi oblikovni spoj sa zatikom [Decker 2006, 167]



Childs2004/98



Childs2004/98

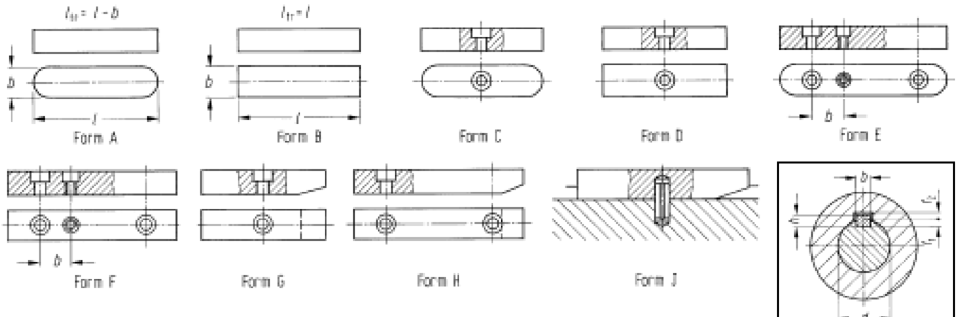


Abb. 18.45. Paßfedern, Nennmaße nach DIN 6885

Niemann2005/859

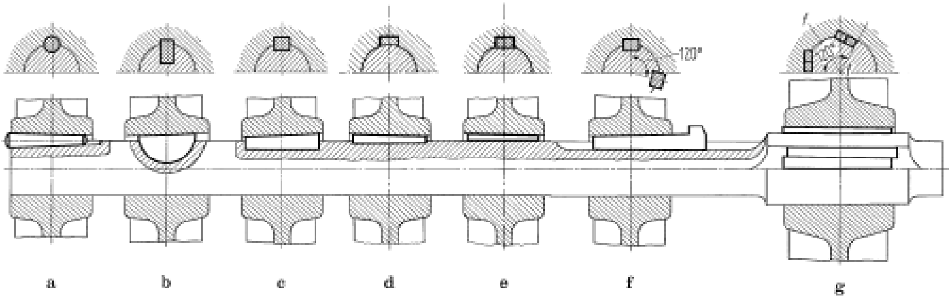
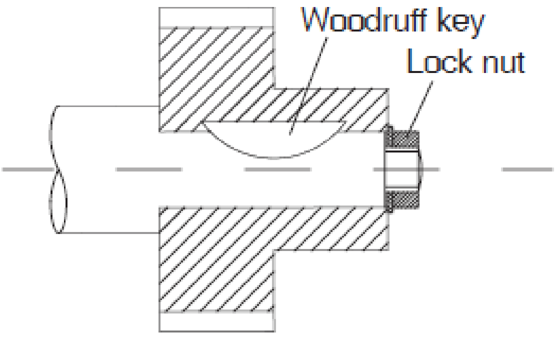
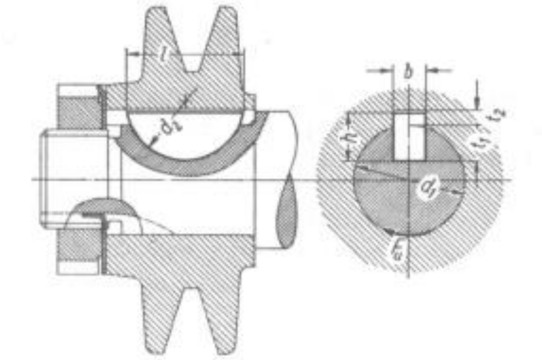


Abb. 18.49a–g. Vorgespannte Formschlußverbindung **a** Rundkeil (Stirnkeil), **b** Scheibenkeil, **c** Einlegekeil, **d** Hohlkeil, **e** Flachkeil, **f** Treibkeil ohne bzw. mit Nase (bei 2 Stück um 120° versetzt), **g** Tangentenkeile (f–f = Lage der Teilfuge, wenn die Nabe geteilt ist)

Niemann2005/863

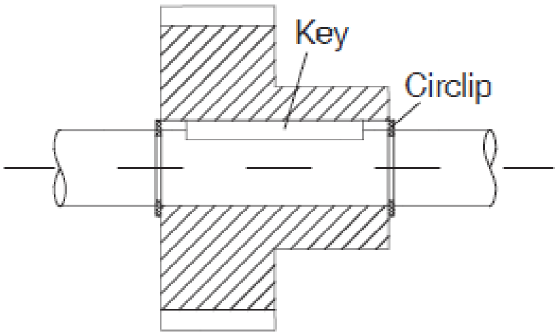


Childs2004/98



Slika 125. Spojevi segmentnim perom prema DIN 6888
(JUS M.C2.050)

Decker1987/114



Childs2004/98

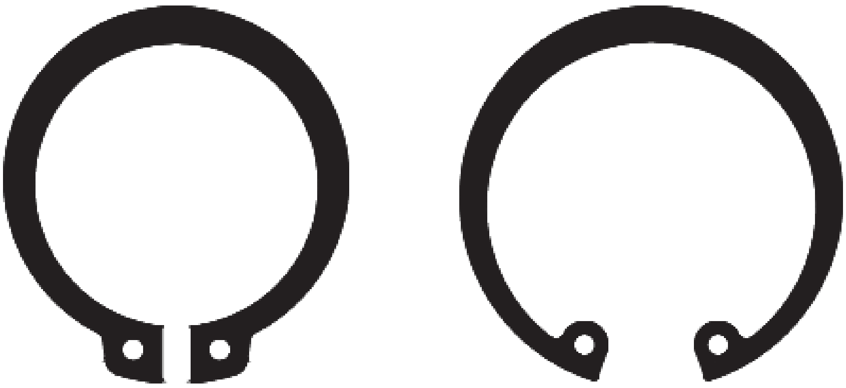
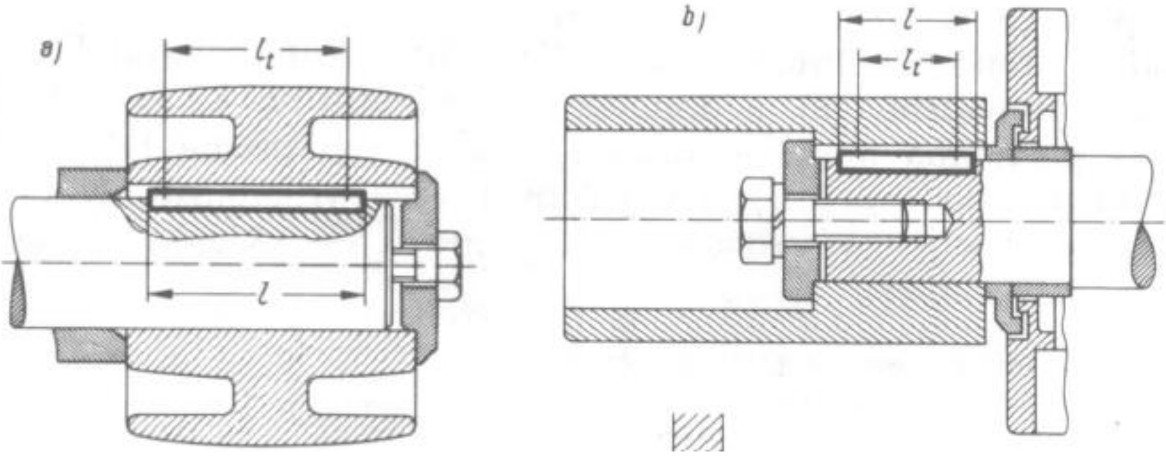
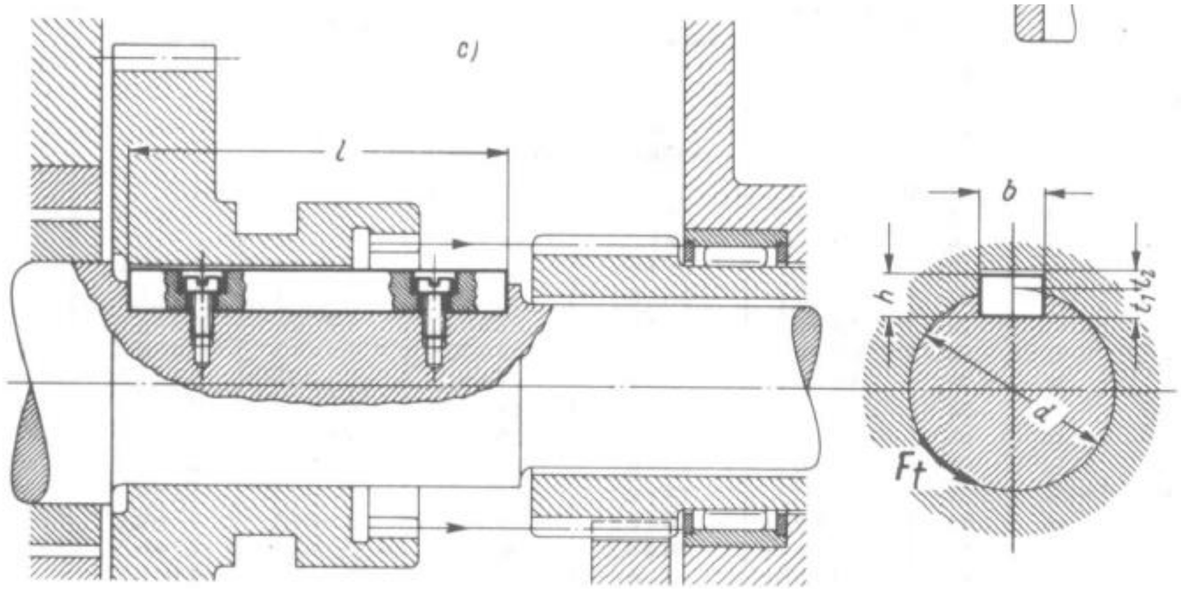


Figure 5.9 Snap rings or circlips.

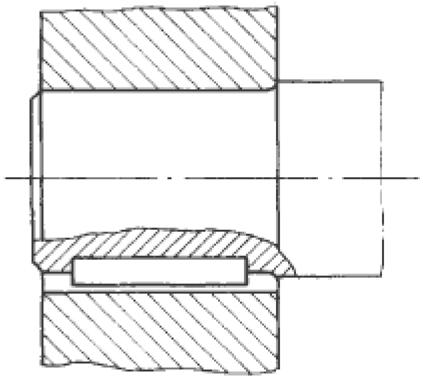
Childs2004/98



Decker1987/112



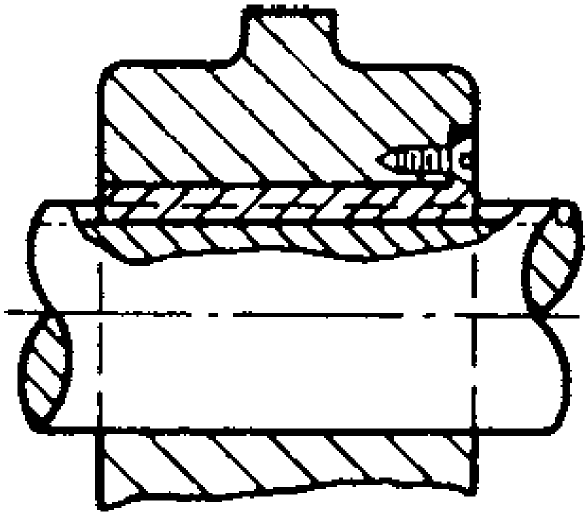
Decker1987/112



Böge2011/I121

Slika 10.05 Rastavljivi oblikovni spoj s perom

Rastavljivi oblikovni spoj s perom *(**S 10.05**)* lako se sastavlja i rastavlja. Koristi se za prijenos okretnih momenata nepromjenljivog smjera. Moguća su aksijalna pomicanja koja se ograničavaju graničnicima i sigurnosnim prstenima. Primjenjuje se za spajanje na vratila: remenica, spojki, zupčanika *(aksijalno pomični zupčanici mjenjača motornih vozila)*.



Avallone2006/667

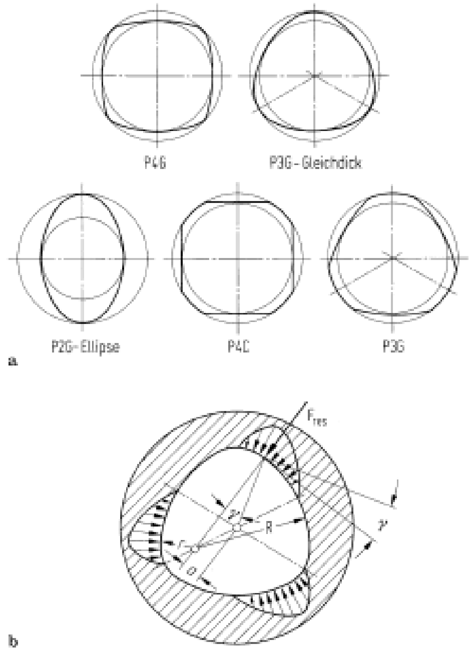
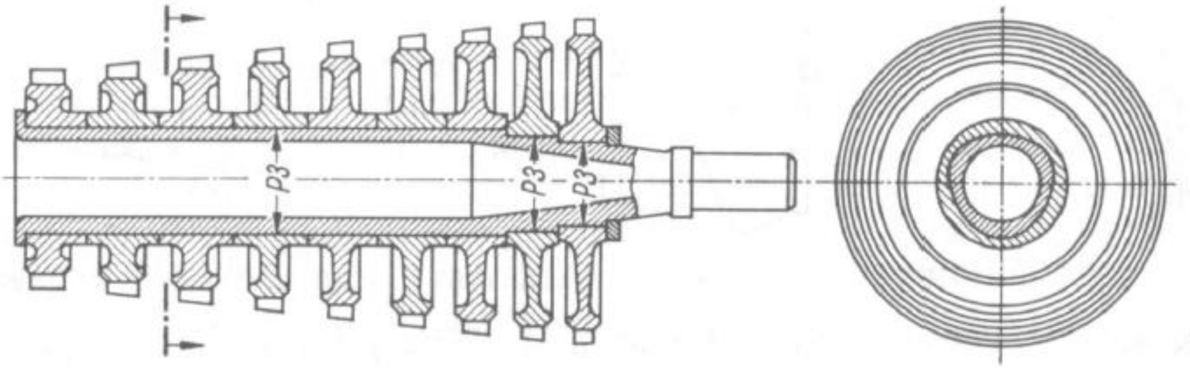


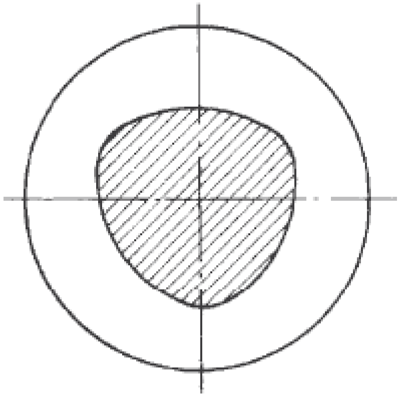
Abb. 18.43. a Polygonwellen-Profile, b Beanspruchung des P3G-Profils

Niemann2005/855



Slika 132. Poligonim profilima P3 povezane lopatice duhaljke

Decker1987/120



Böge2011/I121

Slika 10.04 Rastavljivi oblikovni poligonalni spoj

Profilewellenverbindungen sind Formschlussverbindungen für hohe und höchste Belastungen. Das *Polygonprofil* (P3G-Profil) ist im Duchmesser ein sogenanntes „Gleichdick“ und nach DIN 32711 genormt. Unter Last zentriert es sich zwangsläufig selbst.

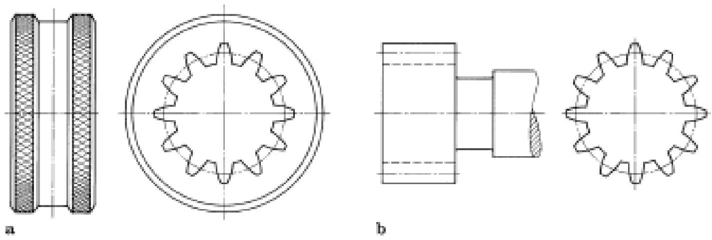
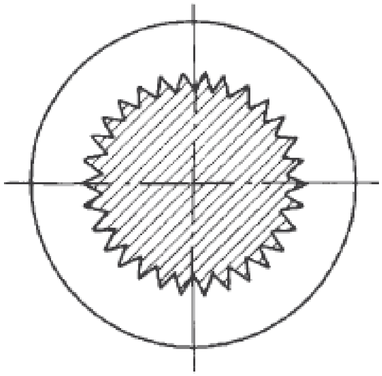


Abb. 18.29a, b. Vollverzahnte Lehren für Zahnwellen, a Gutlehrring, b Gutlehrdorn; DIN 5480 Bl. 15

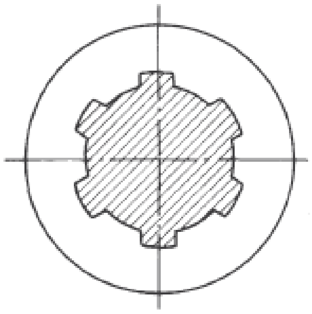
Niemann2005/828



Böge2011/I121

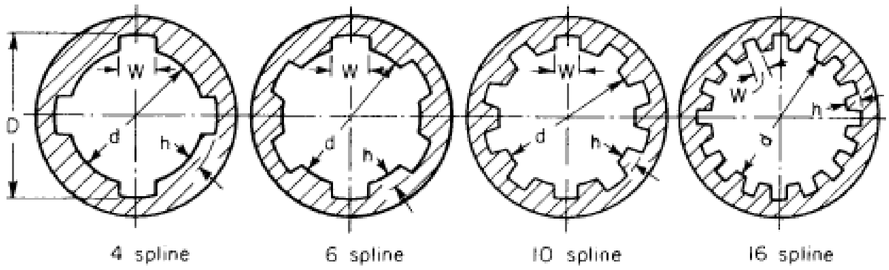
Slika 10.04 Rastavljivi oblikovni trokutasto zupčasti spoj

Das Kerbzahnprofil ist nach DIN 5481 genormt. Die Verbindung ist leicht lösbar und feinverstellbar. Verwendung zum Beispiel bei Achsschenkeln und Drehstabfedern an Kraftfahrzeugen. Ein Sonderfall ist die Stirnverzahnung (Hirthverzahnung) als Plan- Kerbverzahnung. Hersteller: A. Hirth AG, Stuttgart-Zuffenhausen.



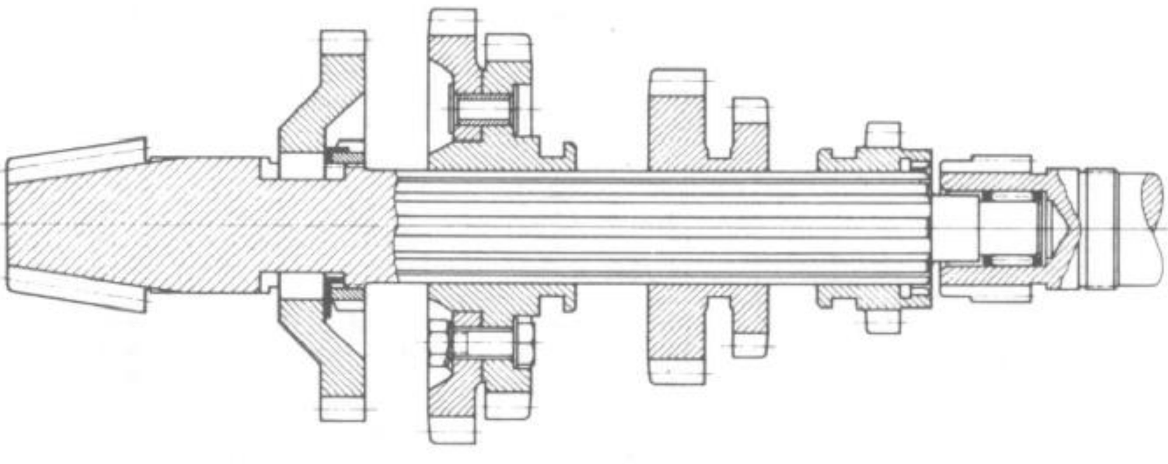
Böge2011/I121

Slika 10.04 Rastavljivi oblikovni klinasti spoj



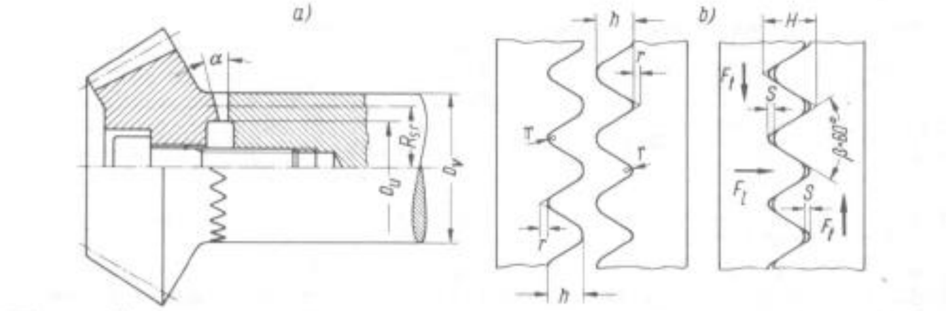
Avallone2006/668

Das Vielnutprofil ist als „Keilwellenprofil" genormt. Die Bezeichnung „Keilwellenprofil" ist irreführend, weil die Wirkungsweise der Passfederverbindung (Formschluss) entspricht, nicht aber der Keilverbindung. Die Verbindung ist leicht lösbar und verschiebbar. Verwendung zum Beispiel bei Verschieberädergetrieben, bei Kraftfahrzeugkupplungen und Antriebswellen von Fahrzeugen.



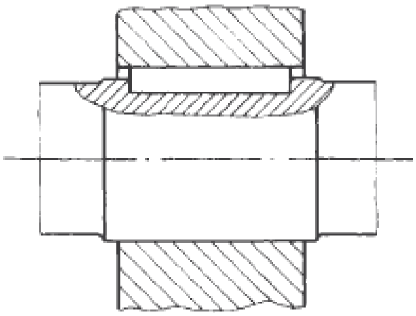
Slika 127. Klinasto vratilo kao vratilo prijenosnika

Decker1987/115



Slika 141. Čeono ozubljenje: a) stožnik spojen s vratilom; b) oblik zuba na vanjskom obodu Decker1987/128

Rastavljivi spojevi glavina i vratila s klinom



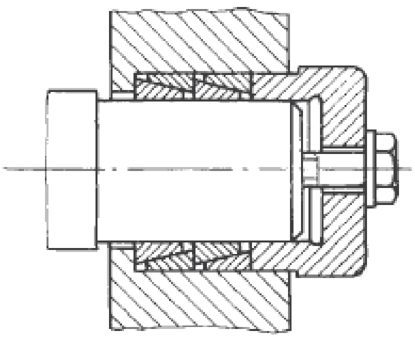
Böge2011/I120

Slika 10.04 Rastavljivi tarno-oblikovni spoj s klinom

Lösbare Verbindung zur Aufnahme wechselnder Drehmomente. Kleinere Drehmomentenaufnahme beim Flach- und Hohlkeil, große und stoßartige Drehmomentenaufnahme beim Tangentkeil. Die Keilneigung beträgt meistens 1 : 100.

Verbindungsbeispiele: Schwere Scheiben, Räder und Kupplungen im Bagger- und Landmaschinenbau, insgesamt bei schwererem und rauem Betrieb.

Die Verbindung mit dem Hohlkeil ist nachstellbar.



Böge2011/I120

Slika 10.04 Rastavljivi tarno-oblikovni spoj s prstenima klinastog presjeka

Leicht lösbare und in Längs- und Drehrichtung nachstellbare Verbindung zur Aufnahme großer, wechselnder und stoßartiger Drehmomente.

Das übertragbare Drehmoment ist abhängig von der Anzahl der Spannelemente. Hierzu sind die Angaben der Herstellerfirmen zu beachten, zum Beispiel Fa. Ringfeder GmbH, Krefeld-Uerdingen.

Power transmitting components such as gears, pulleys and sprockets need to be mounted on shafts securely and located axially with respect to mating components. In addition, a method of transmitting torque between the shaft and the component must be supplied.The portion of the component in contact with the shaft is called the hub and can be attached to, or driven by, the shaft by keys, pins, setscrews, press and shrink fits, splines and taper bushes. Table 5.1 identifies the merits of various connection methods. Alternatively the component can be formed as an integral part of a shaft as, for example, the cam on an automotive cam-shaft. Childs2004/97

Figure 5.6 illustrates the practical implementation of several shaft hub connection methods. Gears, for example, can be gripped axially between a shoulder on a shaft and a spacer with the torque transmitted through a key. Various configurations of keys exist including square, flat and round keys as shown in Figure 5.7. The grooves in the shaft and hub into which the key fits are called keyways or keyseats. A simpler and less expensive method for transmitting light loads is to use pins, and various pin types are illustrated in Figure 5.8. An inexpensive method of providing axial location of hubs and bearings on shafts is to use circlips as shown in Figures 5.2 and 5.9. One of the simplest hub–shaft attachments is to use an interference fit, where the hub bore is slightly smaller than the shaft diameter. Assembly is achieved by press fitting, or thermal expansion of the outer ring by heating and thermal contraction of the inner by use of liquid nitrogen. The design of interference fits is covered in greater detail in Section 15.2.2. Mating splines, as shown in Figure 5.10, comprise teeth cut into both the shaft and the hub and provide one of the strongest methods of transmitting torque. Both splines and keys can be designed to allow axial sliding along the shaft. Childs2004/97,99

Childs2004/98

Table 5.1 Merits of various shaft–hub connections (after Hurst, 1994)

	Pin	Grub screw	Clamp	Press fit	Shrink fit	Spline	Key	Taper bush
High torque capacity	✔	✔	✘	✔	✘	✘	✘	✘
Large axial loads	✘	✔	✘	✔	✘	✔	✔	✘
Axially compact	✔	✔	✔	✘	✘	✘	✘	✘
Axial location provision	✘	✘	✘	✘	✘	✔	✔	✘
Easy hub replacement	✔	✘	✘	✔	✔	✘	✘	✘
Fatigue	✔	✔	✘	✘	✘	✔	✔	✘
Accurate angular positioning	✘	✔	✔	✔	✔	✘	✘	✘
Easy position adjustment	✔	✘	✘	✔	✔	✔	✔	✘

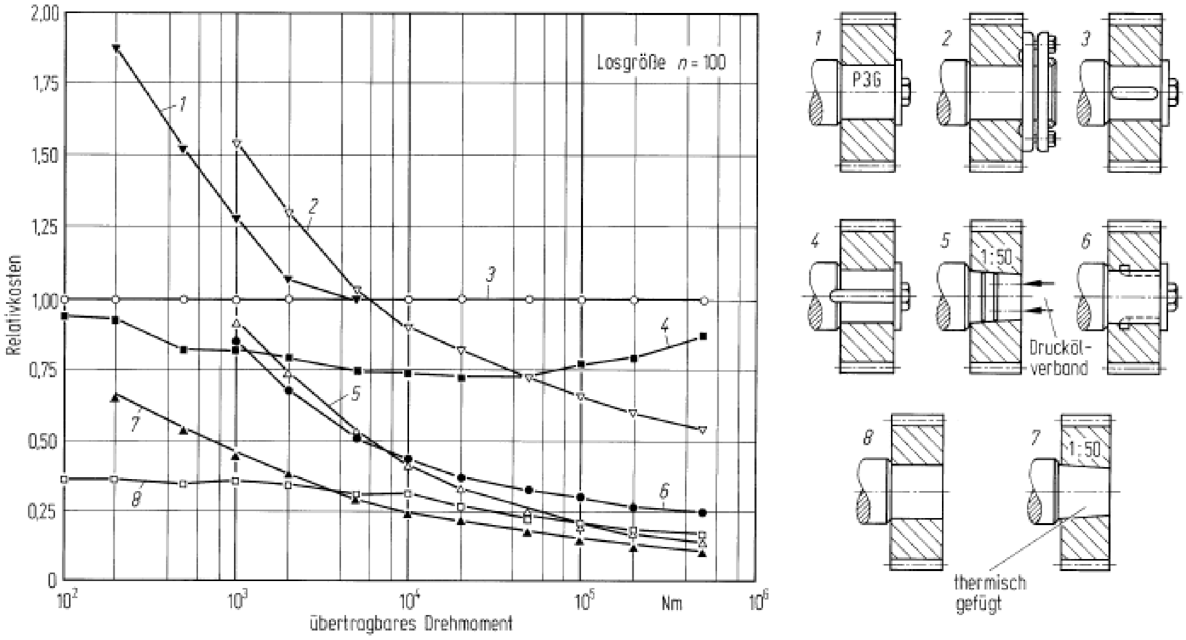


Abb. 18.60. Relativkosten verschiedener Welle-Nabe-Verbindungen [18.3-25]

Niemann2005/876

Smjernice za izbor pogodnog načina spajanja glavine i vratila su date u **T 10.01** [Niemann 2005, str. 778].

Tablica 10.01 Preporuke za izbor spojeva glavina s vratilima

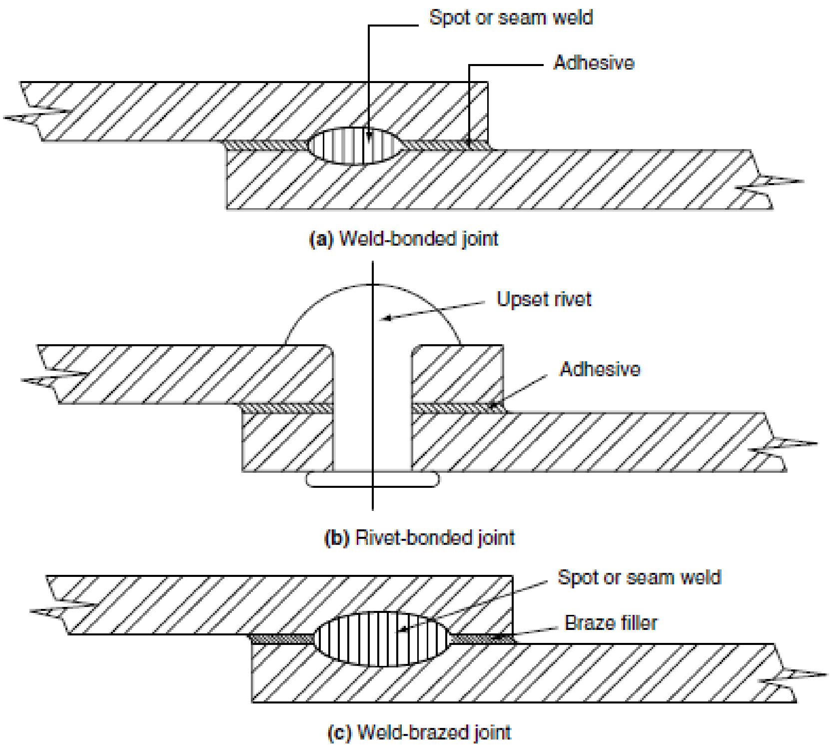
	Spojevi			
	tarni	oblikovni	tarno-oblikovni	materijalni
Manji momenti	stezni, udubljeni klin, tolerantni prsten	poprečni zatik, segmentno pero	–	zalijepljeno klizno pero, zalemljeni
Momenti nepromjenljivog i promjenljivog smjera	preklop, stezni, udubljeni klin, tolerantni prsten	poprečni zatik, pero	–	preklop s ljepilom
Veliki momenti promjenljivog smjera smjera i udarni momenti	preklop	–	profilno vratilo s preklopom, tangencijalni klin	zavar
Kratka glavina i veliki momenti	preklop s silicijkarbidnim prahom	profilno vratilo	–	zavar, preklop s ljepilom
Uzdužno klizne glavine i vratila	–	klizno pero, klinasto vratilo	–	–
Glavina s lakom demontažom	stezni, konični,	pero, profilno vratilo	klin s nosom	
Naknadna montaža glavine na glatko vratilo		–	–	–
Glavina podesiva u smjeru vrtnje		profilno vratilo s trokutastim zupcima	–	–
Glavina s tankim zidom	preklopni profilni prsten	profilno vratilo s trokutastim zupci-	navoj	

		ma		

10.4.2 Kombinirani spojevi

Messler2004,

There are some hybrid joining processes in which two different fundamental processes are combined to create a new process with extended capability. Sometimes the resulting hybrid simply combines the characteristics or attributes of both of the parent processes, hoping to obtain the best of both. Some would say braze welding is an example, although it is contended here that braze welding is a variant of welding or of brazing, not a hybrid. At other times the hybrid exhibits unique benefits as the result of synergy between the two parent processes. This should be the goal, in fact. Three examples of hybrid processes are (1) rivet-bonding, (2) weld-bonding, and (3) weldbrazing. Not every combination of basic joining processes necessarily results in a useful hybrid, no more than every attempt at interbreeding different animal or plant species results in a better hybrid animal or plant. In fact, there are some process combinations that can cause problems. [Messler2004, 514]

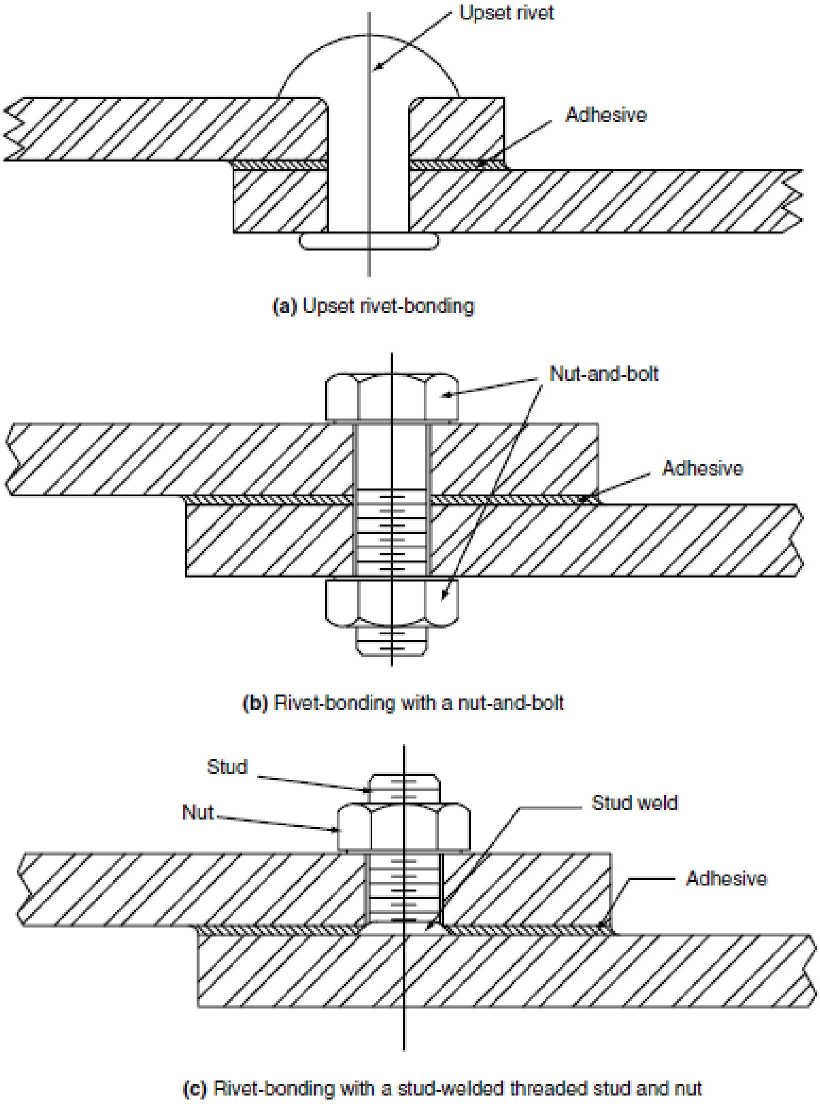


(a) weld-bonding, (b) rivet-bonding, and (c) weld-brazing.

Slika 10.04 Tri najčešće sretana postupka hibridnog spajanja

Zakovice s lijepljenjem

Rivet-bonding is a hybrid of adhesive bonding and mechanical joining employing rivets as fasteners. Shown schematically in Figure 10.9, the combination of rivets driven and set though structural adhesive has been used to considerable advantage in helicopter manufacturing, as an example. The rivets tend to carry any transient out-of-plane loads (whether anticipated or unexpected) to protect the adhesive from failing in peel. On the other hand, the adhesive acts to spread loading and soften stress concentrations around the rivets, thereby improving fatigue resistance. Another particular advantage in helicopters is vibration damping. (Without adhesive, these would be riveted-only joints, with only the friction at joint faying surfaces acting to damp vibrations.) Last but not least, a major consideration in the use of rivets with structural adhesives has been the mutual self-fixturing that results. Rivets hold adhesive-bonded structures together under pressure until the adhesive fully cures. On the other hand, quick-setting (especially pressure-sensitive ‘‘contact’’) adhesives can be used to tack structures together while riveting is being performed.



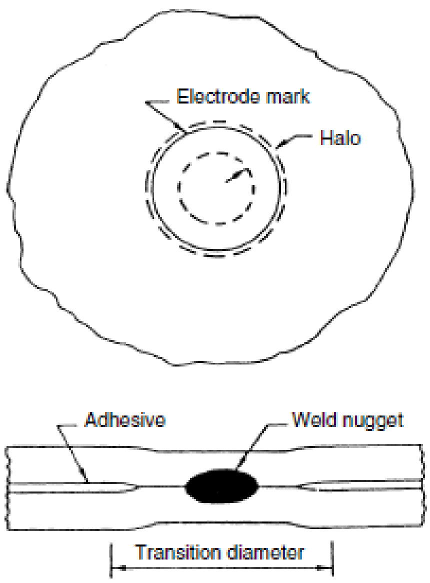
Slika 10.04 Schematic illustration of rivet-bonding in a lap joint using an actual upset rivet (a), a nut and bolt (b), or a stud-arc or percussion-welded threaded stud and nut (c).

Note that rivets and bolts are virtually always inserted after adhesive bonding.

Zavarivanje s lijepljenjem

Weld-bonding, also called ‘‘spot-weld adhesive bonding’’ for reasons that will soon become clear, is a hybrid method of fabricating that uses both welding and adhesivebonding techniques. In its most common form, a layer of adhesive, in either paste or film form, is applied to one of the metal members to be joined. The other metal member is placed on top, forming a lap-type joint, and the assembly is then clamped to maintain part alignment. The two metal members are then joined by resistance welding through the adhesive using a spot welder mounted on a common C-frame (as widely used in the aerospace industry), or as a portable unit attached to the working end of a robot arm (as widely used in the automobile industry). Spot welds are typically spaced 2.5–5.0 cm (1–2 in.) apart, center to center. It is also possible, in another variation of the process, to spot weld first and then back-infiltrate the gap between the joint element faying surfaces with a thinned adhesive, relying on capillary action to cause flow and fill.

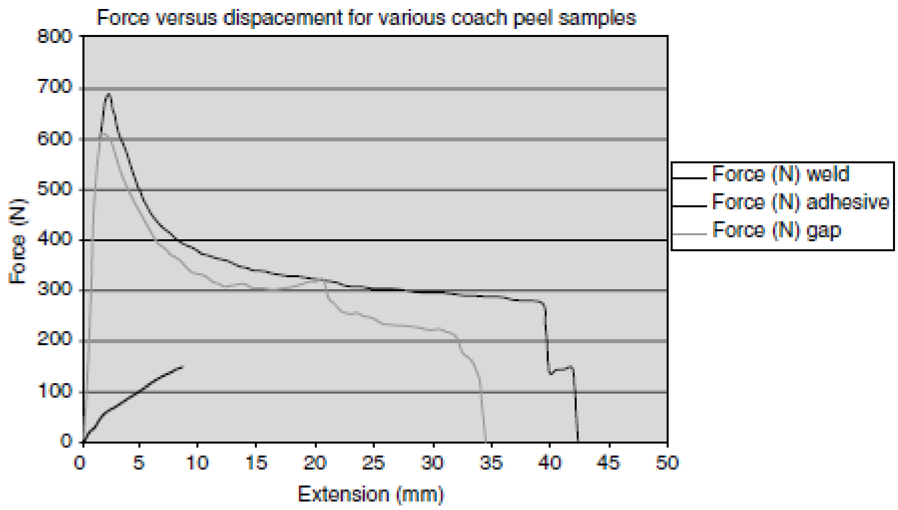
Figure 10.10 schematically illustrates a resistance spot weld in a single-lap weldbonded joint. Spot-welding pressure and heat displace the adhesive from the immediate area where the weld is to be made and allow metal fusion to occur, forming a nugget. A visible mark on the face surface of the metal sandwich (or lap joint) sheet denotes the weld location. The inner circle outlines the weld nugget. The area between the two dashed circles in the figure, known as the ‘‘halo,’’ is effectively unbonded because of the near total displacement of the adhesive and heating effects (e.g., adhesive softening and squeezing away, or adhesive thermal decomposition). Beyond the halo is a region of transition to full adhesive bond line thickness and adhesive bond strength.



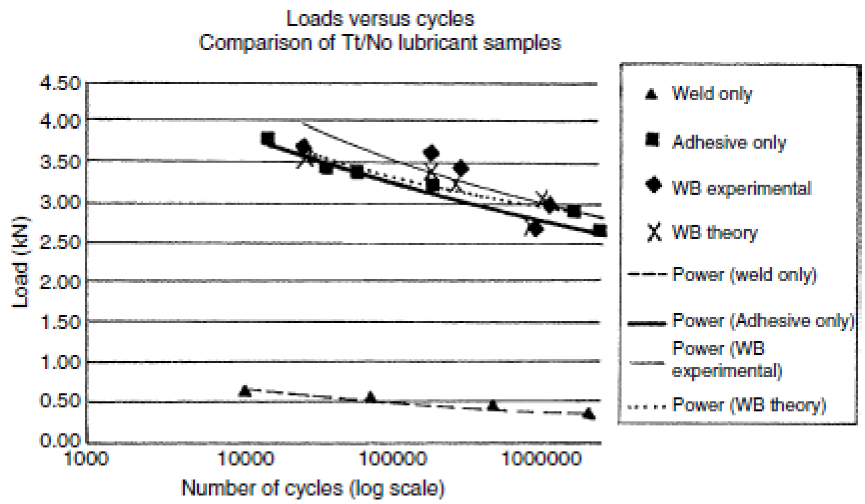
Slika 10.04 Schematic illustration of weld-bonding in single-overlap joints showing the so-called ‘‘halo’’ around the weld nugget, where there has been upsetting but no fusion by the resistance spot welding electrodes.

The weld-bonding process offers some important advantages over simple mechanical fastening as well as over simple adhesive bonding. Compared to a mechanically fastened structure, a similar weld-bonded structure offers (1) increased static pure tensile and/or tensile shear strength (by increasing the total area of joining from just the area of the fasteners to the area of the welds and the surrounding adhesive); (2) increased fatigue life (by spreading the loading through the adhesive and minimizing stress concentrations around points of discrete spot welding or fastening); (3) gas-tight and/or fluid-tight joints (through the sealing action of the adhesive, whether a structural type or simply a sealant); (4) increased structural rigidity or stiffness, especially against torsion in automobile frames, for example (by preventing slip at fasteners or buckling between points of fastening or welding); (5) improved resistance to corrosion (through sealing); (6) inexpensive tooling (as tack welds or ‘‘holding’’ adhesives can be used); (7) weight savings (compared to fasteners); (8) smooth, hermetically sealed inner and outer surfaces (for aerodynamics); (9) enhanced energy absorption (due to the added energy needed to open the bonded plus welded or fastened joint area), which improves both the crashworthiness of automobiles and their ride quality (through vibration damping and noise abatement) and (10) complete interface bonding to improve load transfer.

While not always used with structural (as opposed to non-structural) adhesives applied for other purposes, some of the most interesting property improvements are realized with structural adhesives. Compared to pure adhesive bonding, weld-bonding dramatically increases resistance to peel and/or cleavage failure by having welds carry out-of-plane loads. It absolutely increases resistance to buckling in compression, and seemingly even increases static pure tensile and tensile shear strength. The ability of joints, and thus joined structures, to absorb impact energy is absolutely increased, often quite dramatically, by the added energy that must go into tearing open the adhesive. This improvement can be shown with the increased area under the tensile stress-strain curve for T-peel tests, as shown in Figure 10.11. There is considerable evidence that fatigue strength is higher for any needed life, or that fatigue life is increased for any design stress, seemingly from the softening of stress concentrations around discrete spot welds (or fasteners in rivet-bonded joints). What is more, the improvement in fatigue life is more than would be expected from simply adding the expected life or strength from adhesive alone or welds alone. This effect is shown in Figure 10.12.



Slika 10.04 Plot of weld-bonded versus welded-only and bonded-only energy absorption in T-tension or ‘‘coach-peel’’ tests, with area under the curve corresponding to the amount of energy absorbed to failure.



Slika 10.04 Plot of weld-bonded versus welded-only and bonded-only fatigue strength in laser-beam weld-bonded AA5754. Note that actual, experimental data points would fall above the points predicted by theory, if combining the two processes produced simply additive versus synergistic effects.

Weld-bonding is competitive in static strength with titanium fasteners in sheet titanium up to 4mm (0.156 in.) thick. Beyond this point, spot-welding limitations and static strength capacity make weld-bonds less desirable. Epoxy and polyimide adhesives are typically used for titanium, often using fillers of silica (7 wt.%), strontium chloride (3 wt.%) for corrosion resistance, and metal powder. Aluminum alloys are also weld-bonded using epoxy, modified epoxy, or elastomeric urethane adhesives, sometimes with fillers. When conductive metal-filled adhesives are used, welding parameters are nearly the same as those used for welding without an adhesive.

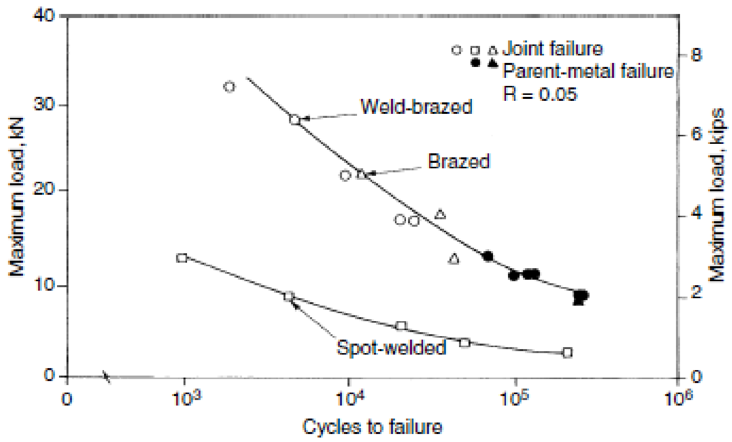
Resistance spot welding through an adhesive causes a high percentage of irregularly shaped nuggets, but the strength of the joints is not adversely affected. There is, however, also a tendency for a higher percentage of spot welds to exhibit ‘‘expulsion’’ or ‘‘spitting,’’ in which molten metal from within the nugget is blown out from between the squeezed, overlapped joint elements due to thermally induced pressure. Such expulsion absolutely results in lower quality and lower strength welds. This has proven to be a particular challenge as automobile manufacturers have considered using laser welding instead of resistance welding to spot weld-bond aluminum alloy-intensive vehicles. The approach of welding first and then back-infiltrating with a low-viscosity (or thinned) adhesive, or of welding through prepunched openings in preplaced film adhesive, as well as some other techniques of applying localized pressure during welding, opens up new possibilities of laser-beam weld-bonding.

Use of weld-bonding has probably grown most rapidly in the automobile industry, with continuing needs and efforts to reduce vehicle weight to improve fuel economy without compromising safety or comfort (ride harshness). The increased use of aluminum alloys in vehicle bodies has provided an additional driving force for further development, with impressive demonstrations in special test and prototype vehicles. [Messler2004, 521]

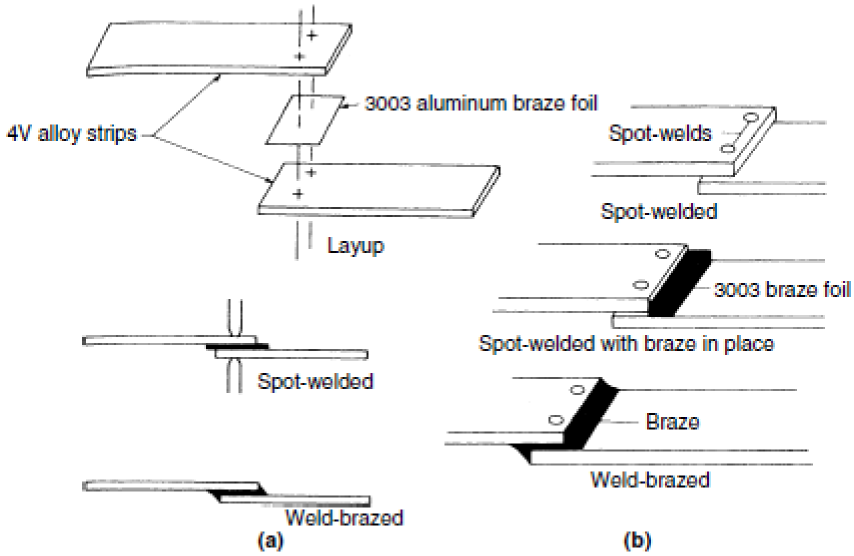
Zavarivanje s lemljenjem

The National Aeronautics and Space Administration (NASA) and the U.S. Air Force developed the hybrid joining process of weld-brazing, in which molten braze filler was back-infiltrated between overlapped joint elements that had been spot-welded (see Figure 10.13a). Braze alloy preforms have also been used in which there are prepunched holes through which spot welds are first made, and then the braze filler is melted to flow throughout the joint, as shown in Figure 10.13b. In either variation, the process is called weld-brazing.

Two materials that have been weld-brazed to advantage are titanium and aluminum alloys, both using aluminum alloy braze filler (i.e., a BAlSi type). The process of weld-brazing results in demonstrable improvements in static shear and, especially, peel and fatigue strength. There is not much evidence of a synergistic effect in weld-brazing, however. Static shear strength seems to improve in a simple additive fashion, and there appears to be no gain in weld-brazed over brazed-only joints (Figure 10.14). Strength-at-temperature, on the other hand, is improved somewhat, mostly by extending service temperatures slightly beyond those for brazing alloys alone. This isclearly due to the welds carrying most of the load to lower the stress in the braze filler. Figure 10.15a shows the tensile shear strength as a function of test temperature, while Figure 10.15b shows stress-rupture behavior, both for single-overlap specimens.



Slika 10.04 Schematic illustration of alternative approaches to weld-brazing.



Slika 10.04 Plot of fatigue strength for weld-brazed versus brazed-only and welded-only joints.

Hibridno zavarivanje

Just as it is possible to combine two fundamental joining processes to create new, hybrid joining processes (such as weld-bonding), it is possible to combine two different welding processes to create a new hybrid welding process. This is usually done to create a hybrid that combines the best characteristics of each parent welding process, hopefully offering some synergistic benefit(s) as well. Five examples of hybrid welding processes have received some attention, but less use: (1) laser–GTA welding, (2) laser– GMA welding, (3) plasma–GMA welding, (4) plasma–GMA welding, and (5) laser– assisted FSW. These are addressed very briefly in the following paragraphs. [Messler2004, 522]

10.4.3 Radionički spojevi

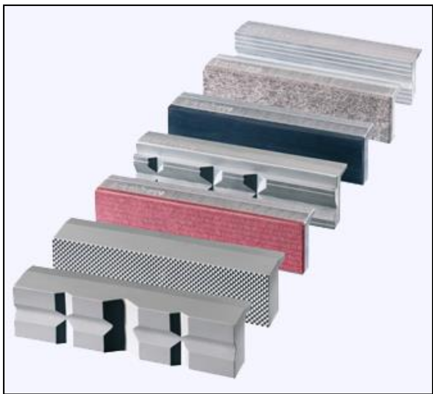
Radionički spojevi obuhvaćaju primjere učvršćivanja ručno ili strojno obrađivanog komada postupcima strojarske tehnologije.

Škripac

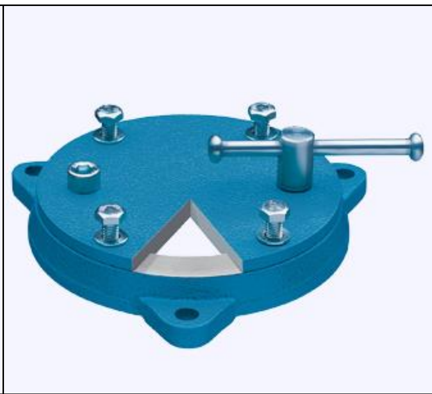
Slika 10.131 Suvremeni radionički škripac s isječcima *(za opis funkcioniranja)*

Slika 10.132 Radionički škripac sa izmjenjivim pločicama

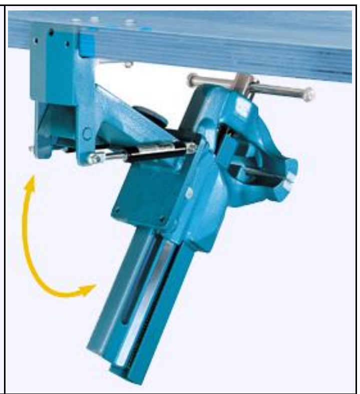
Ispod steznog dijela za ravne površine, bez zamjenljivih steznih pločica ***(S 10.131)*** ili sa pločicama ***(S 10.132)*** nalazi se dio oblikovan za stezanje cijevi. Na stranici njemačkog proizvođača škripaca – Brockhaus-Heuer GmbH *(http://www.brockhaus-heuer.de)*, nalaze se podloge za izbor pogodnog škripca s više zanimljivih rješenja ***(S 10.133 ÷ S 10.138)***.



Slika 10.133 Zamjenjive pločice *(npr: aluminij, guma, filc)*



Slika 10.134 Okretna ploča s isječkom *(za opis funkcioniranja)*



Slika 10.135 Naprava za uklanjanje s radnog stola

Slika 10.136 Stolna naprava za dizanje

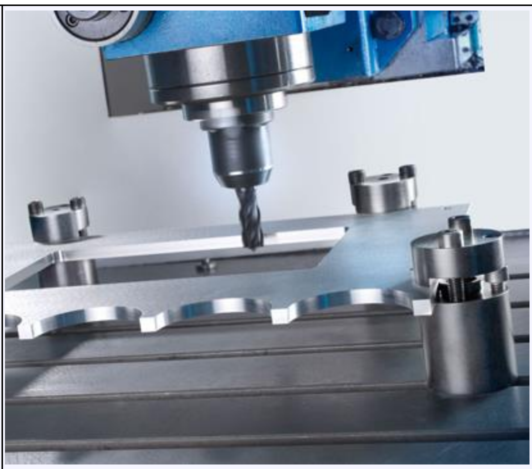
Slika 10.137 Stolna naprava za dizanje bez škripca

Slika 10.138 Stolna naprava za dizanje sa škripcem

Stega za radne stolove alatnih strojeva

Na stranicama proizvođača Brockhaus-Heuer GmbH nalazi se i stega ***(S 10.139 ÷ S 10.141)*** za radne stolove strojeva za obradu odvajanjem strugotine *(npr. bušilica, glodalica)*.

Slika 10.136 Stega za radne stolove



Slika 10.137 Primjer primjene stega za radne stolove alatnih strojeva

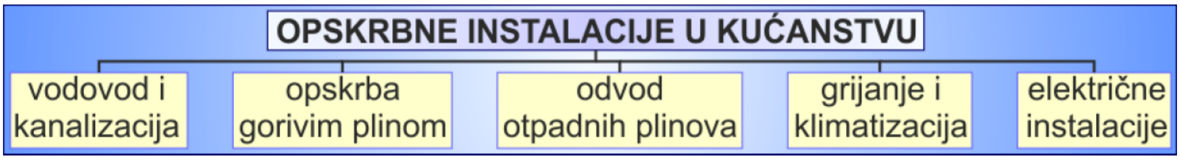
Slika 10.138 Adapteri različitih dimenzija

10.4.4 Spojevi opreme kućanstva

Opskrbne instalacije

Antaki2003, Avallone2006/793÷810,1041÷1045,1238÷1239, Bickford1997, Dickenson1999, Hicks2004/188÷306,664÷790,988÷997,1041÷1077, Lee1999, Muscroft2007, Parisher2002, Pritchard1998, Prestly2008, Wang2000, Woodson2009,

Opskrbne instalacije u kućanstvu obuhvaćaju:



Spojevi opskrbnih instalacija ovise o:

1. svojstvima transportiranog medija,
2. radnim uvjetima i
3. odabranom materijalu.

Vodovodne instalacije opskrbe pitkom vodom

Sastav pitke vode propisan je zakonom, a potrebne količine su date u građevinarskim podlogama. U izvedbi se koriste cijevi od:

- toplo pocinkovanog čelika i
- polietilena.

Vodovodne instalacije od toplo pocinkovanog čelika

Cijevi

Verzinkt, ohne Gewinde und Muffen				
Artikelnummer	NW	Zoll	ä. D. x Wand (mm)	kg/mtr.
2440VGGL025	8	1/4"	13,5 x 2,35	0,68
2440VGGL038	10	3/8"	17,2 x 2,35	0,89
2440VGGL050	15	1/2"	21,3 x 2,65	1,27
2440VGGL075	20	3/4"	26,9 x 2,65	1,65
2440VGGL100	25	1"	33,7 x 3,25	2,55
2440VGGL125	32	1 1/4"	42,4 x 3,25	3,28
2440VGGL150	40	1 1/2"	48,3 x 3,25	3,77
2440VGGL200	50	2"	60,3 x 3,65	5,33
2440VGGL250	65	2 1/2"	76,1 x 3,65	6,80
2400VGGL300	80	3"	88,9 x 4,05	8,85
2440VGGL400	100	4"	114,3 x 4,50	12,60

Vodovodne instalacije opskrbe toplom pitkom vodom

Sastav pitke vode propisan je zakonom, a potrebne količine su date u građevinarskim podlogama. U izvedbi se koriste cijevi od:

- toplo pocinkovanog čelika,

- polipropilena i
- bakra.

Kanalizacija kućanskih otpadnih voda

Sastav i količine kućanskih otpadnih voda dati su u građevinarskim podlogama. U izvedbi se koriste cijevi od:

- polivinil klorida i
- keramike.

Odvodnja oborinskih voda

Količine oborinskih voda date su u građevinarskim podlogama. U izvedbi se koriste cijevi od:

- pocinčanog lima ,
- bakra i
- keramike.

Opskrba gorivim plinom

Potrebne količine gorivog plina su određene u termoenergetskim podlogama. U izvedbi se koriste cijevi od:

- čelika i
- bakra.

Odvod produkata izgaranja

Sastavi i količine produkata izgaranja su određene u termoenergetskim podlogama. U izvedbi se koriste cijevi od:

- čelika.

Odvod plinova iz kuhinje i zahoda

Protoci plinova iz kuhinja i zahoda su određeni u građevinarskim podlogama. U izvedbi se koriste cijevi od:

- polivinil-klorida.

Topla voda centraliziranog grijanja

Sastav i protoci tople vode za centralizirano grijanje određuju se na temelju termoenergetskih podloga. U izvedbi se koriste cijevi od:

- čelika i
- bakra.

Rashladni medij klimatizacije

Mediji i njihovi protoci između vanjske i unutarnje jedinice određeni su u termoenergetskim podlogama.

U izvedbi se koriste cijevi od:

- bakra.

Antaki2003, Avallone2006/793÷810,1041÷1045,1238÷1239, Bickford1997, Dickenson1999, Hicks2004/188÷306,664÷790,988÷997,1041÷1077, Lee1999, Muscroft2007, Parisher2002, Pritchard1998, Prestly2008, Wang2000, Woodson2009,

Bijela tehnika

Bijela tehnika obuhvaća:

hladnjake štednjake perilice grijače klimatizere

hladnjak štednjak perilicu suđa perilicu rublja grijač vode grijač zraka klimatizer

Kalweit2006, Sobey2006,

Rashladni uređaji

Hladnjak

Zamrzivač

Štednjak

Električni štednjak

Plinski štednjak

Strojevi za pranje

Stroj za pranje rublja

Stroj za pranje posuđa

Grijači vode

Električni grijač vode

Plinski grijač vode

Elektronička oprema

Alfirevic1996/145÷165,

Telefon

Mobitel

Televizor

Računalo

DVD uređaji

Namještaj

Nagyszalanczy2006, Timings2000/353, Kalweit2006,

10.4.5 Spojevi vozila, plovila

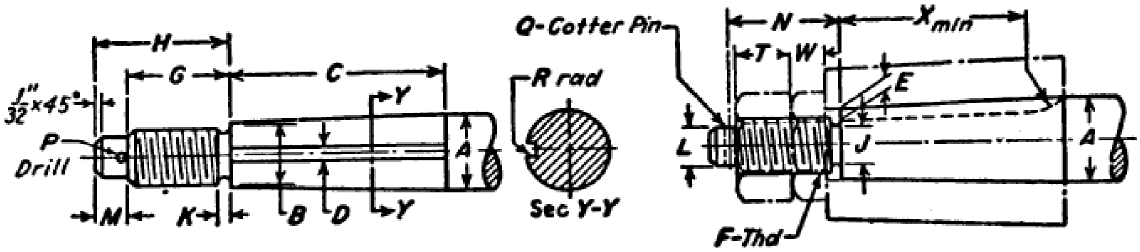
Spojevi vozila

Avallone2006/1061÷1176, Garrett2000, Trzesniowski2010, Kirchner2007, Braess2007, Sobey2009,

Spojevi plovila

Naujok2009, Gerr2008, Esterle2009, Evridge2009,

Gerr2008,28



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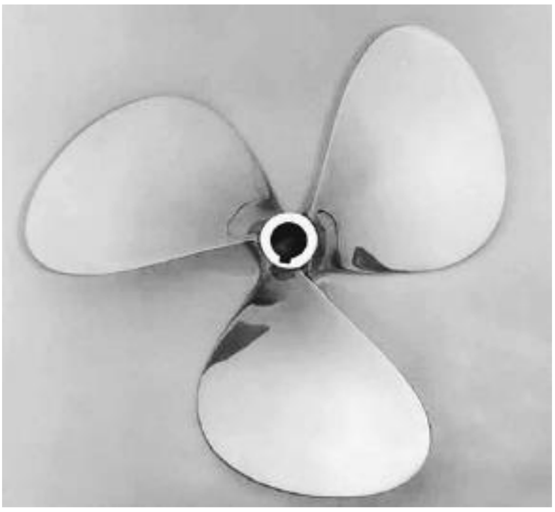

Dodaci

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10.1 Posebni spojevi
10.1.1 Spojevi glavina s vratilima
Avallone2006/498,665,669÷671,6769÷685,1416,1440÷1441,772÷811,1197÷1207, Böge2011/I119÷I137, Childs2004/97÷99, Niemann2005/802÷888,
10.1.2 Materijali i spojevi
Ashby2002/193÷293, Ashby2005/187÷214,224,577, Ashby2007/260÷261,414, Kalweit2006, Messler2006, Messler2004,
10.1.3 Kombinirani spojevi
Messler2004, Kulak1987, Whitney2004,
10.2 Spojevi opreme kućanstva
10.2.1 Opskrbne instalacije
Antaki2003, Avallone2006/793÷810,1041÷1045,1238÷1239, Bickford1997, Dickenson1999, Hicks2004/188÷306,664÷790,988÷997,1041÷1077, Lee1999, Muscroft2007, Parisher2002, Pritchard1998, Prestly2008, Wang2000, Woodson2009,
10.2.2 Bijela tehnika (kućanski aparati)
Kalweit2006, Sobey2006,
10.2.3 Namještaj
Nagyszalanczy2006, Timings2000/353, Kalweit2006,
10.2.4 Elektronička oprema
Alfirevic1996/145÷165,
10.3 Spojevi vozila, plovila i radionički spojevi
10.3.1 Spojevi vozila
Avallone2006/1061÷1176, Garrett2000, Trzesniowski2010, Kirchner2007, Braess2007, Sobey2009,
10.3.2 Spojevi plovila
Avallone2006/1098÷1116, Spectre1997, Naujok2009, Gerr2008, Esterle2009, Evridge2009,
10.3.3 Radionički spojevi
Timings2000/288÷296,
Dodaci
Literatura

Internet

Norme

Oznake

Rječnik

hrvatski	engleski	njemački
vratilo	shaft	Welle
glavina	hub	Nabe
kućanski aparati	household appliances	Haushaltsgeräte
klin	taper key	Keile
klin s nosom	gib head taper key	Nasenkeile
pero	key	Passfeder
segmentno pero	Woodruff key	Scheibenfeder
zatik	pin	Stift
svornjak	knuckle pin	Bolzen
škripac	vise	Schraubstock

Podloge

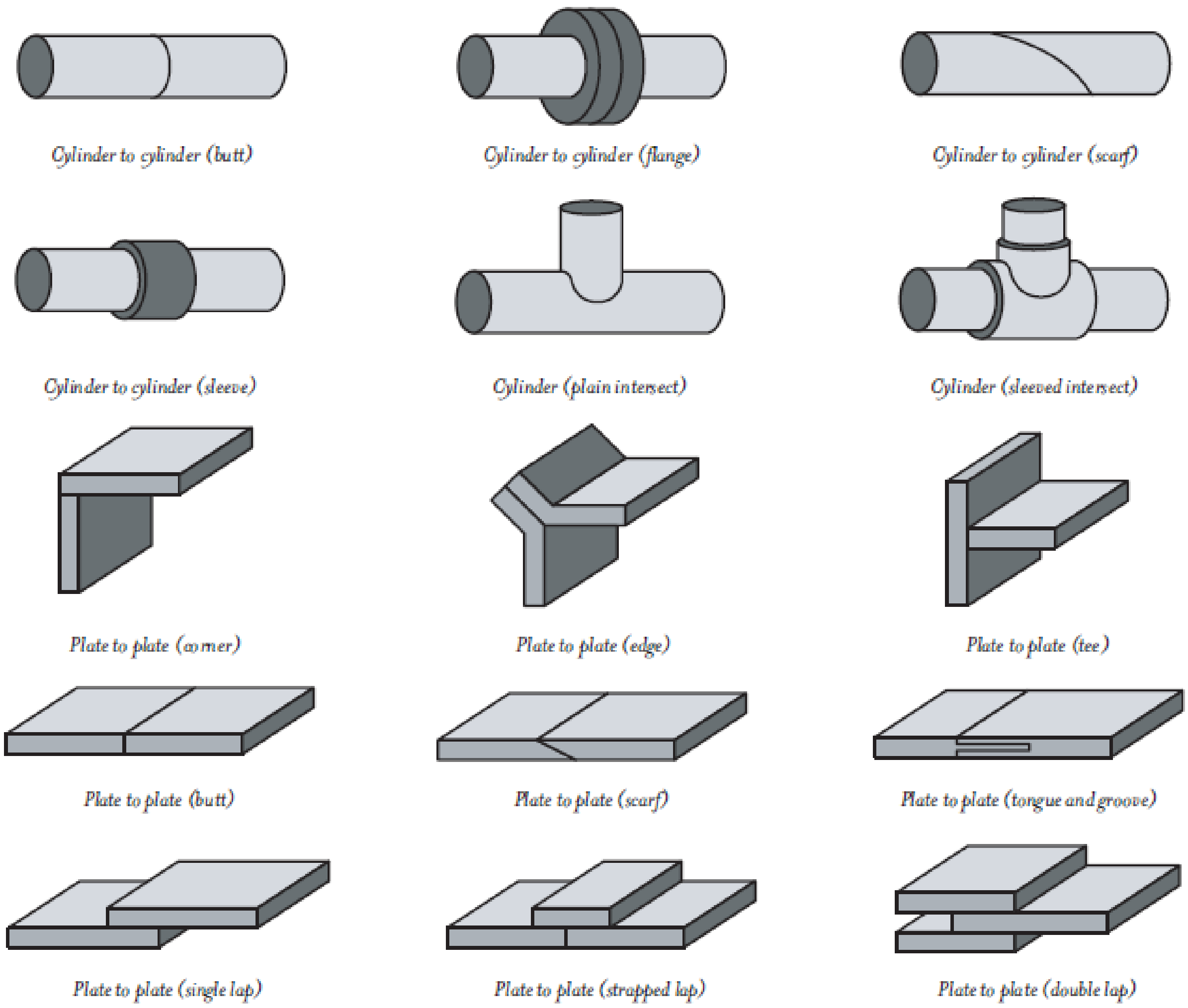
Niemann2005/885÷888

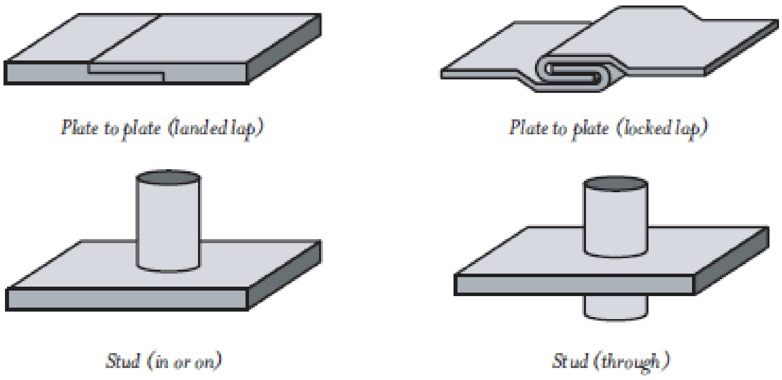
Razno

Materijali i spojevi

Kalweit2006, Ashby2005/187÷214,224÷225,577, Ashby2007/260÷261,414÷416, Messler2006, Messler2004,

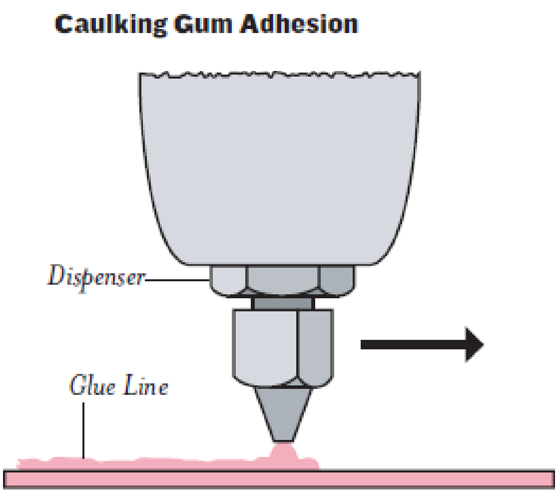
Vrste spojeva [Ashby 2002, 260]:

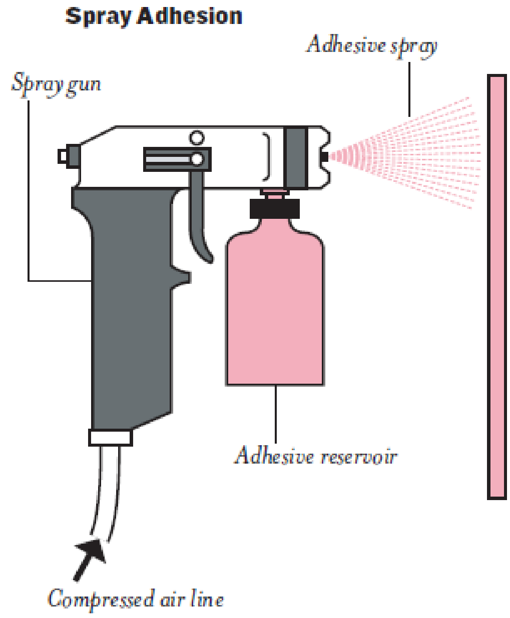




Lijepljenje [Ashby 2002, 262]

Adhesives have a number of features that allow great design freedom: almost any material or combination of materials can be adhesively bonded; they can be of very different thickness (thin foils can be bonded to massive sections); the processing temperatures are low, seldom exceeding 180 c; the flexibility of some adhesives tolerates differential thermal expansion on either side of the joint; adhesive joints are usually lighter than the equivalent mechanical fasteners; and adhesives can give joints that are impermeable to water and air. The main disadvantages are the limited service temperatures (most adhesives are unstable above 190 c, though some are usable up to 260 c), the uncertain long-term stability and the unpleasant solvents that some contain.





Good ventilation is essential wherever adhesives are used. Competing Processes Mechanical fasteners – although these generally require holes with associated stress concentrations.

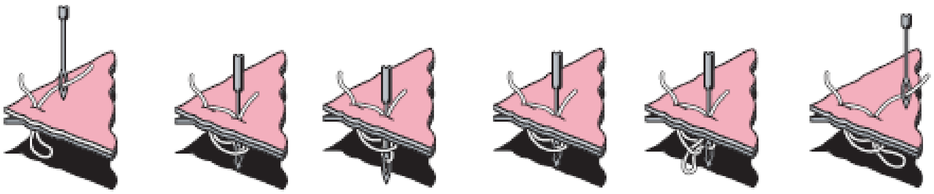
[Ashby 2002, 263]

	Metals	Wood	Polymers	Elastomers	Ceramics	Fiber-Composites	Textiles
Metals	Acrylic, CA, Epoxy, PU, Phenolic, Silicone						
Wood	Acrylic, Epoxy, Phenolic, Hot-melt	Epoxy, Phenolic, PVA					
Polymers	Acrylic, CA, Epoxy, Phenolic	Epoxy, PU, Phenolic, PVA	Acrylic, CA, Epoxy, Phenolic				
Elastomers	CA, Epoxy, Silicone	Acrylic, Phenolic, Silicone	CA, Epoxy, Phenolic, Silicone	PU, Silicone			
Ceramics	Acrylic, CA, Epoxy, Ceram	CA, Epoxy, PVA,Ceram	Acrylic, Epoxy, PU, PVA, Ceram	Acrylic, Epoxy, PU, PVA, Silicone	Acrylic, CA, Epoxy, Ceram		
Fiber-Composites	Acrylic, CA, Epoxy, Imide	Acrylic, CA, Epoxy, PVA	Acrylic, Epoxy, PVA, Silicone	Epoxy, PU, Silicone	CA, Epoxy, Silicone	Epoxy, Imide, PES, Phenolic	
Textiles	PU, Hot-melt	Acrylic, PVA, Hot-melt	Acrylic, PVA	Acrylic, PU, PVA	Acrylic, PU, PVA, Hot-melt	Acrylic, PU, PVA	PVA, Hot-melt

Key
Polyurethane = PU
Thermoplastic = Hot-melt
Cyanoacrylate = CA
Polyester = PES
Polyvinylacetate = PVA
Ceramic-based = Ceram

Šivenje [Ashby 2002, 266]

Dissimilar materials can be joined. The threads used for conventional sewing are the natural fibers cotton, silk and flax, the cellulose derivative (rayon or viscose), and drawn polymer fibers made from polyethylene, polyester, polyamide (nylons) or aramids (such as Kevlar). It is also possible to sew with metal threads. The joining thread or fibre must be sufficiently strong and flexible to tolerate the tensions and curvatures involved in making a stitch. All fabrics, paper, cardboard, leather, and polymer films can be sewn. Sewing can also be used to join fabric and film to metal, glass or composite if eye-holes for the threads are molded or cut into these. There are many possible joint configurations, some involving simple through-stitching of a single lap or zigzag stitching across a simple butt, others requiring folding to give locked-lap and butt configurations.

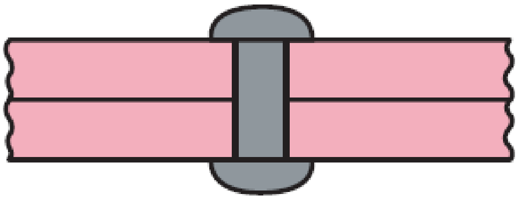


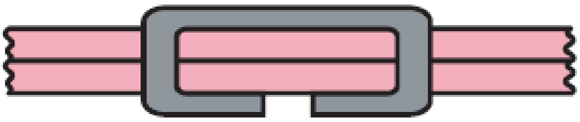
Sewing is the principal joining process used by the clothing industry. It is important in tent and sail making, shoe construction, and book-binding. It is used to join polymer sheet to make wallets, pockets, cases and travel gear.

The thimble was devised to protect the finger from puncture when sewing. This minor risk aside, sewing offers no threat to health or safety, and is environmentally benign. Competing Processes Adhesives; threaded fasteners.

Zakovice [Ashby 2002, 267]

Both rivets and staples can be used to join similar materials, but they can also be used to join one material to another even when there is a large difference in their strengths – leather or polymer to steel or aluminum for instance. Both allow great flexibility of design although a stress concentration where the fastener penetrates the material should be allowed for. Rivets should have heads that are 2.5–3 times the shank diameter; when one material is soft, it is best to put a washer under the head on that side to avoid pull-out. Staples are good when materials are thin; when metal is stapled, the maximum thickness is about 1mm, when nonmetallic it can be up to 10 mm.



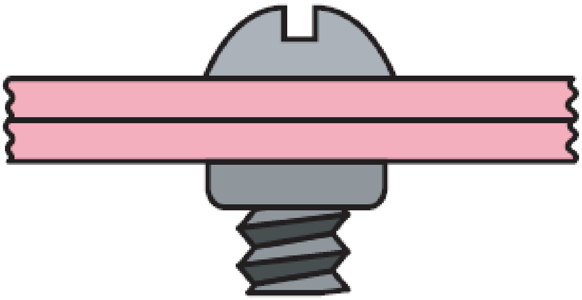


Rivets and staples are usually metallic: steel, aluminum and copper are common. Polymeric rivets and staples are possible: they are clinched by using heat as well as pressure. Almost any material, in the form of sheet, mesh or weave, can be joined by these methods; stapling also allows wire to be joined to sheet.

Stapling: joining of paper, leather, cloth, fiberboard. Rivets are extensively used in aerospace, automotive and marine applications, but have much wider potential: think of the riveting of the leather label to the denim of jeans. The sound of the shipyard is that of riveting – it can be very loud. Over-enthusiastic staplers have been known to staple themselves. These aside, both processes are environmentally benign. Competing Processes Adhesives; sewing; threaded fasteners.

Vijčani spojevi [Ashby 2002, 267]

Threaded fasteners are the most versatile of mechanical fasteners, with all the advantages they offer: they do not involve heat, they can join dissimilar materials of very different thickness and they can be disassembled.

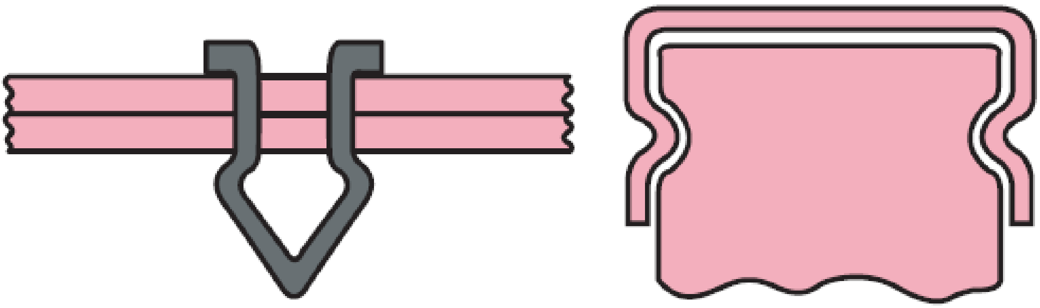


Threaded fasteners are commonly made of carbon steel, stainless steel, nylon or other rigid polymers. Stainless steel and nickel alloy screws can be used at high temperatures and in corrosive environments. Tightening is critical: too little, and the fastener will loosen; too much, and both the fastener and the components it fastens may be damaged – torque wrenches overcome the problem.

Competing Processes Snap fits, rivets and stapes, adhesives, sewing.

Snap spojevi [Ashby 2002, 269]

Snap fits, like other mechanical fastenings, involve no heat, they join dissimilar materials, they are fast and cheap and – if designed to do so – they can be disassembled. It is essential that the snap can tolerate the relatively large elastic deflection required for assembly or disassembly. Polymers, particularly, meet this requirement, though springy metals, too, make good snap fits.



Snap fits allow components of every different shape, material, color and texture to be locked together, or to be attached while allowing rotation in one or more direction (snap hinges). The snap fit can be permanent or allow disassembly, depending on the detailed shape of the mating components. The process allows great flexibility in design and aesthetic variety.

The best choices are materials with large yield strains (yield strain = yield strength/elastic modulus) and with moduli that are high enough to ensure good registration and positive locking. Polymers (particularly san, nylons, polyethylenes and polypropylenes) have much larger values of yield strain than metals. Elastomers have the largest of all materials, but their low modulus means that the assembly will be too flexible and pop apart easily. Among metals, those used to make springs (spring steel, copper beryllium alloys and cold worked brass) are the best choices, for the same reasons.

Snap spojevi se sve više koriste zbog velikog stupnja slobode koje omogućavaju glede oblika spajanih elemenata i materijala od kojih su oni izvedeni. Tipična im je primjena spajanje malih i srednje velikih elemenata od plastičnih masa, metalnih kućišta te metalnih limova i traka. Lako se sastavljaju i rastavljaju, čime omogućavaju jednostavnu reciklažu te nisu štetna po okolinu. Konkurentni su postupci lijepljenje, šivenje, spojke i spajanje vijcima/maticama.

Zavarivanje vrelim plinom [Ashby 2002, 270]

Zavarivanje vrelom polugom [Ashby 2002, 271]

Zavarivanje vrelom pločom [Ashby 2002, 272]

Hot plate welding can be used to form joints of large area – for example, the joining of large polyethylene gas and water pipes. The process is relatively slow, requiring weld times between 10 seconds for small components and 1 hour for very large. Hot plate welding can join almost all thermoplastics except nylons, where problems of oxidation lead to poor weld quality. The joint strength is usually equal to that of the parent material but joint design is limited to butt configurations. If the joint has a curved or angled profile, shaped heating tools can be used. Precise temperature control of the hot plate is important for good joints. The plate temperature is generally between 190–290 c depending on the polymer that is to be joined. Pressure is applied hydraulically or pneumatically. Most thermoplastic components can be welded by the hot-plate method, but it is most effective for joining large components made from polyethylene, polypropylene or highly plasticized pvc. It creates a strong bond, impermeable to gas or water. [Ashby 2002, 272]

Ultrazvučno zavarivanje [Ashby 2002, 273]

Zavarivanje laserskim zrakama [Ashby 2002, 274]

Electron and laser beams are the stuff of death-rays – invisible, deadly accurate, and clean – no smoke, no fumes, no mess. Both are used to weld metals; lasers can weld polymers too. It is possible to laser weld thin, semi-transparent or opaque polymer films by simply scanning the beam across them, melting them right through, but this is not the best way to use lasers. The trick in welding polymers is to arrange that the beam is absorbed where it is most useful – at the joint interface. For transparent polymers this can be achieved by spraying a thin film of ir or uv-absorbing dye, invisible to the human eye, onto the surface where the weld is wanted; the laser beam passes through the transparent upper sheet (which can be thick – up to 10 mm) without much energy loss. But when it hits the dye at the interface it is strongly absorbed, melting the polymer there and creating a weld whilst leaving most of the rest of the material cold. Scanning the beam or tracking the work piece gives a line weld up to 10 mm wide. Welding polymers (particularly transparent polymers) without an interfacial dye is limited to the joining of thin thermoplastic film and sheet. Welding with a dye give more control and allows thicker sections. Dissimilar materials can be joined, although their melting temperatures must be comparable. The main feature of the process is that it is noncontact, and exceptionally clean and fast. [Ashby 2002, 274]

Tvrdo lemljenje [Ashby 2002, 276]

Meko lemljenje [Ashby 2002, 277]

Zavarivanje električnim lukom – MAG postupak [Ashby 2002, 278]

Zavarivanje električnim lukom – MIG postupak [Ashby 2002, 279]

Zavarivanje električnim lukom – TIG postupak [Ashby 2002, 280]

Elektrotporno zavarivanje [Ashby 2002, 281]

Zavarivanje trenjem [Ashby 2002, 282]

Difuzno spajanje i spajanje glazura [Ashby 2002, 283]

Joints in long-fiber composite materials are sources of weakness because the fibers do not bridge the joint. Two or more laminates are usually joined using adhesives and, to ensure adequate bonding, an overlap length of 25 mm for single- and double-lap joints or 40–50 mm for strap, step and scarf joints is necessary. Holes in laminates dramatically reduce the failure strength making joining with fasteners difficult. Composite manufacture is labor intensive. It is difficult to predict the final strength and failure mode because defects are easy to create and hard to detect or repair. [Ashby 2002, 183]

Nickeliron alloys have low thermal expansion – good for glasstometal joints. [Ashby 2002, 222]

Table 10.5 List of Hybrid Welding Processes and Their Advantages

Laser–GTA Welding
• Dramatically enhanced laser coupling versus LBW alone
• Increased GTAW penetration
• Improved arc (especially low current) stability for the GTAW process
Laser–GMA Welding
• Increased arc (especially low current) stability for the GMAW process
• Increased molten metal deposition rate versus GMAW alone
• 3-D shape welding is practical into molds
Plasma–Laser Welding
• Enhanced plasma stability
• Superb metal deposition control
• 3-D shape welding is practical into molds or freeform
Plasma–GMA Welding
• At low currents, a fine, narrow arc allows higher welding speed in sheet gauges or deeper penetration in plate gauges
• At higher currents (above some transition value), molten metal deposition occurs with a swirling arc to produce a flat, shallow deposit with very low heat input
Laser–Assisted Friction Stir Welding (FSW)
• Reduced power required to operate the friction stir welding tool tip
• Increased tool tip life
• Improved stirring action

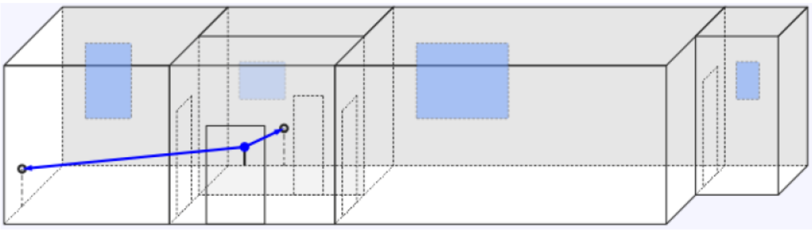
Provjera znanja

Pitanja

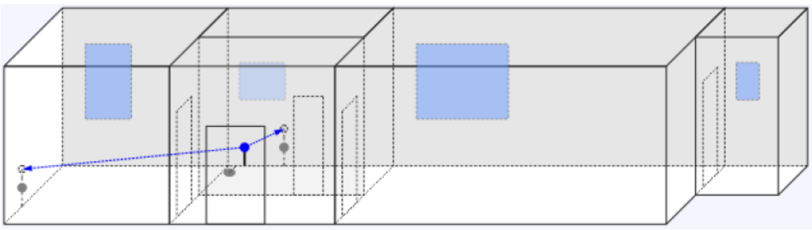
1. Nerastavljivi tarni cilindrični spoj glavine i vratila *(S+O(MPO+M/D)**[1]
2. Rastavljivi tarno/oblikovni cilindrični spoj glavine i vratila s klinom *(S+O(MPO+M/D)*
3. Rastavljivi tarni konusni spoj glavine i vratila sa segmentnim perom *(S+O(MPO+M/D)*
4. Rastavljivi oblikovni aksijalno klizni spoj glavine i vratila s perom *(S+O(MPO+M/D)*
5. Rastavljivi oblikovni zupčani aksijalno klizni spoj glavine i vratila *(S+O(MPO+M/D)*

*[1] *(S+O(MPO+M/D)* – skicirati, opisati mehanizam prijenosa opterećenja i montažu/demontažu

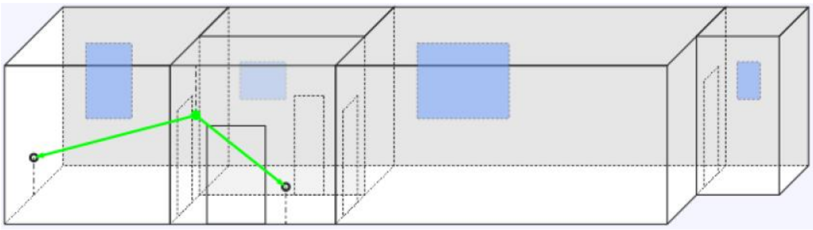
6. Instalacija za opskrbu pitkom vodom – jedan ulaz, dva izlaza *(S+L,M/D)**[2]



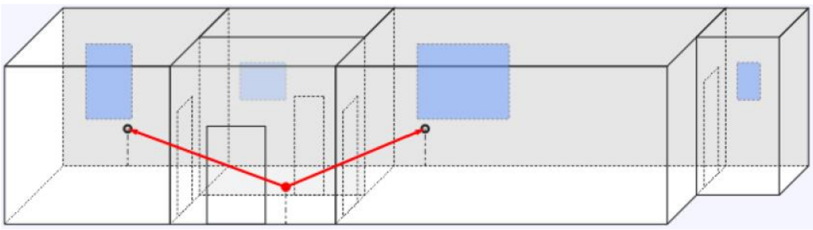
7. Instalaciju za kanalizaciju otpadnih voda – dva ulaza, jedan izlaz *(S+L,M/D)*



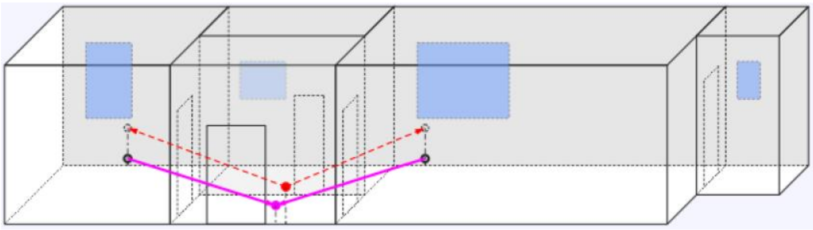
8. Instalaciju za opskrbu zemnim plinom – jedan ulaz, dva izlaza *(S+L,M/D)*



9. Instalaciju za centralno grijanje – potis iz grijača do dva grijna tijela *(S+L,M/D)*



10. Instalaciju za centralno grijanje – povrat iz dva grijna tijela do grijača *(S+L,M/D)*



*[2] *(S+L,M/D)* – nacrtati skicu s legendom, opisati montažu/demontažu

11. Opisati sklapanje prikazanog dijela perilice rublja ***(SPZ 10.01)***

Zadaci

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