

Univerza  
v Ljubljani

Fakulteta  
za gradbeništvo  
in geodezijo



*Katedra za metalne konstrukcije*

# JEKLENE KONSTRUKCIJE I

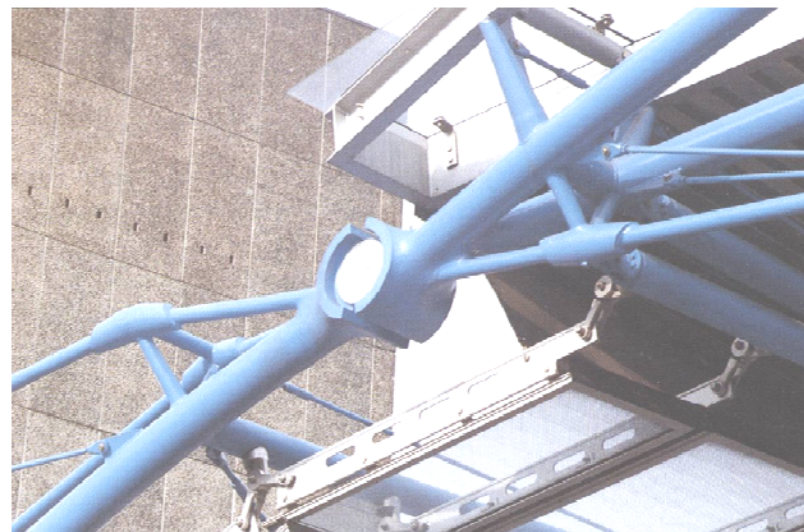
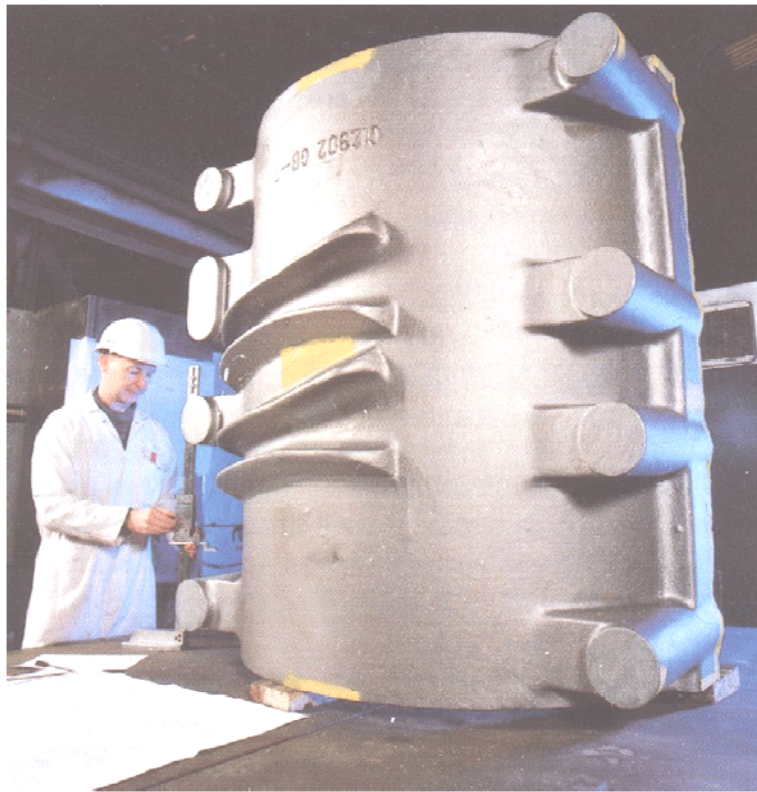
## 3.0 IZDELAVA in OBDELAVA

prof. dr. Darko Beg  
Sodelavci: Blaž Čermelj

# Vlivanje

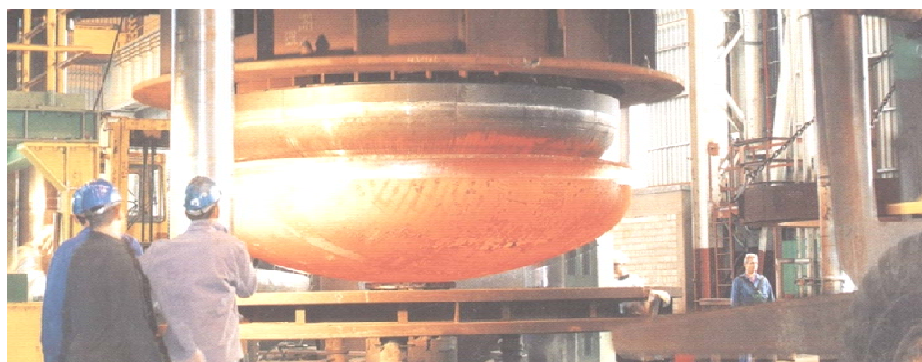


# Vlivanje





# Stiskanje

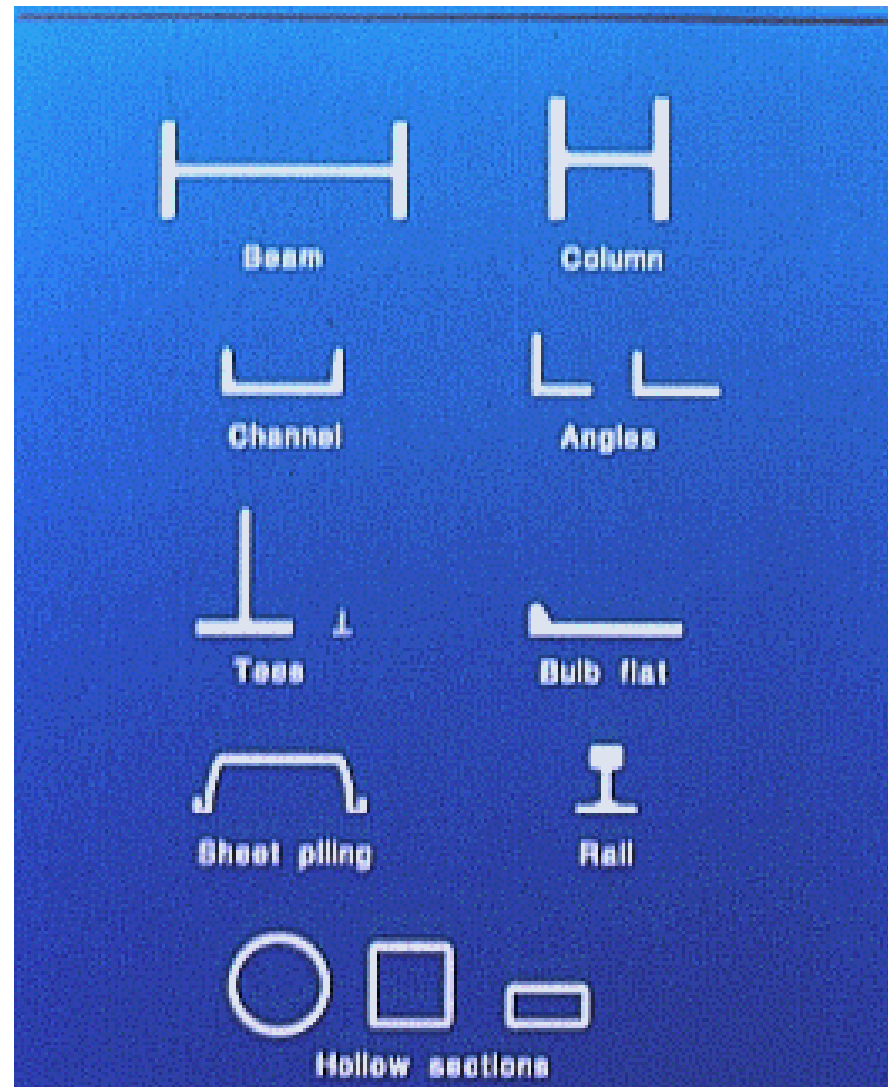




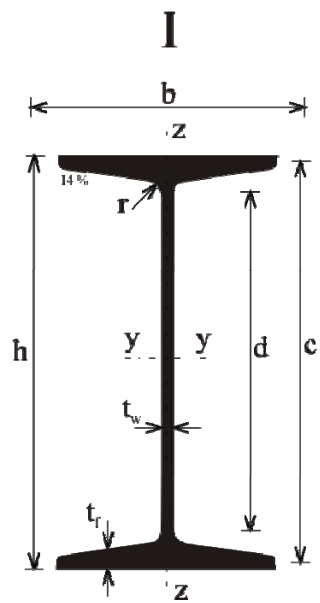
# Stiskanje



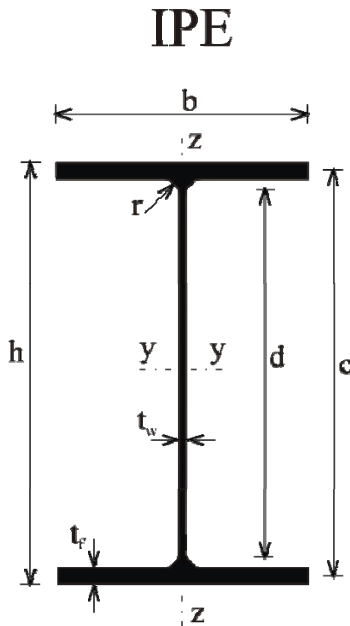
# Vroče valjanje



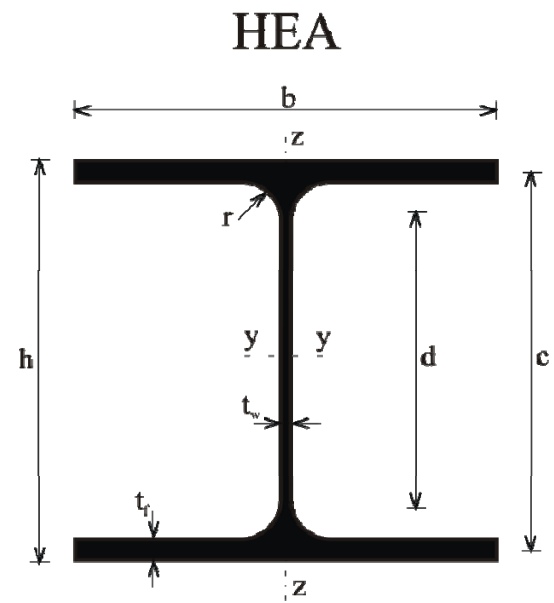
# Vročne valjanje - standardni profili



$80 \text{ mm} \leq h \leq 600 \text{ mm}$



$80 \text{ mm} \leq h \leq 600 \text{ mm}$

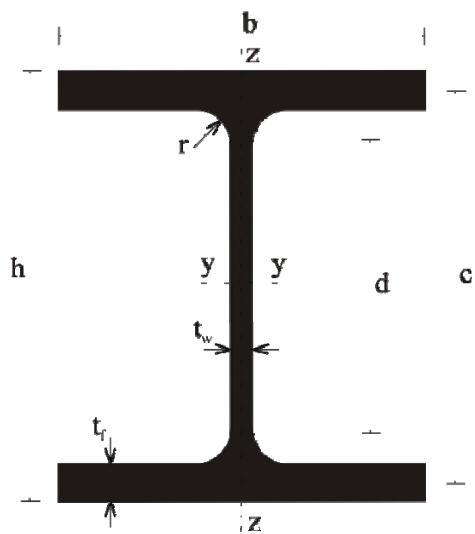


$100 \text{ mm} \leq h \leq 1000 \text{ mm}$

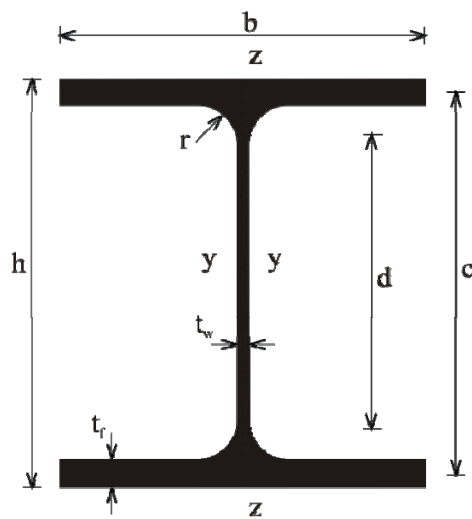


# Vroče valjanje - standardni profili

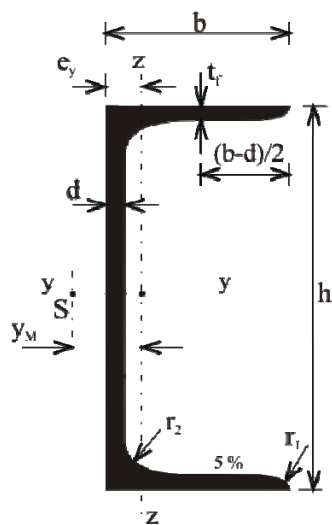
HEM



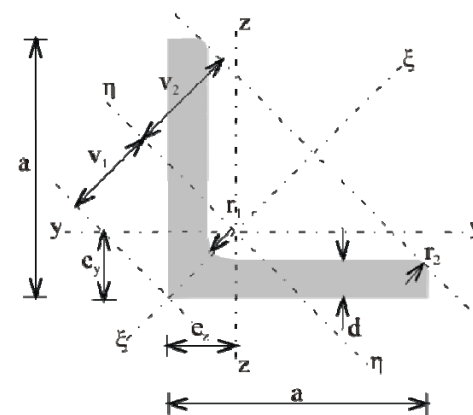
HEB



U



KOTNIK



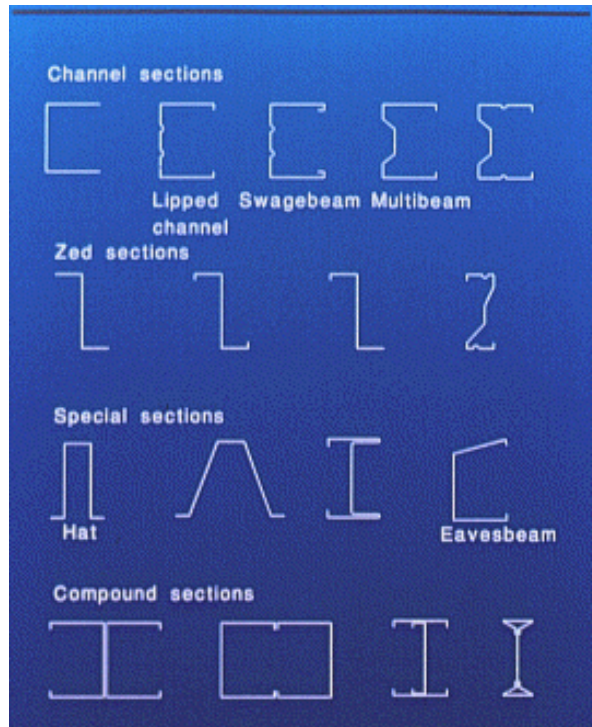






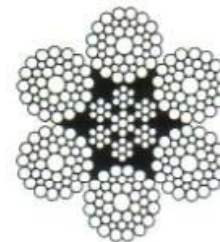
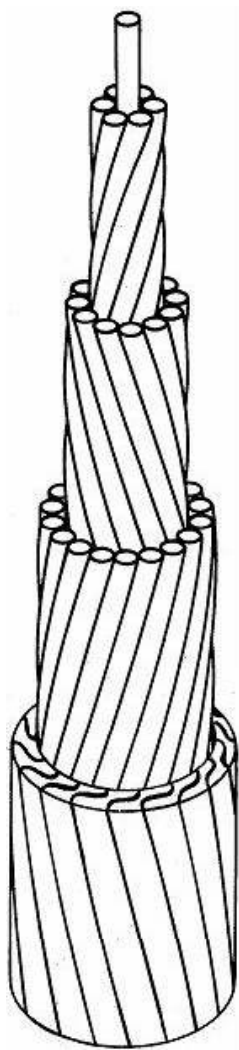
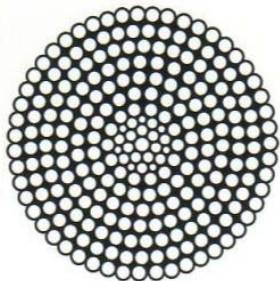


# Hladno valjanje



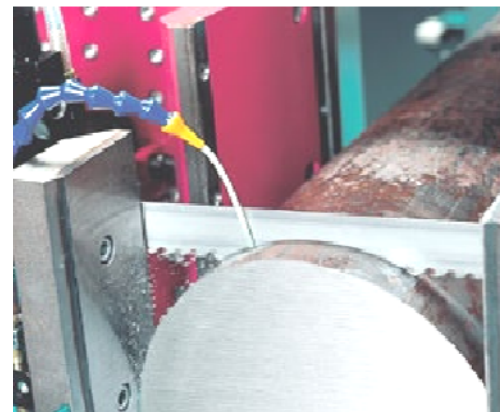
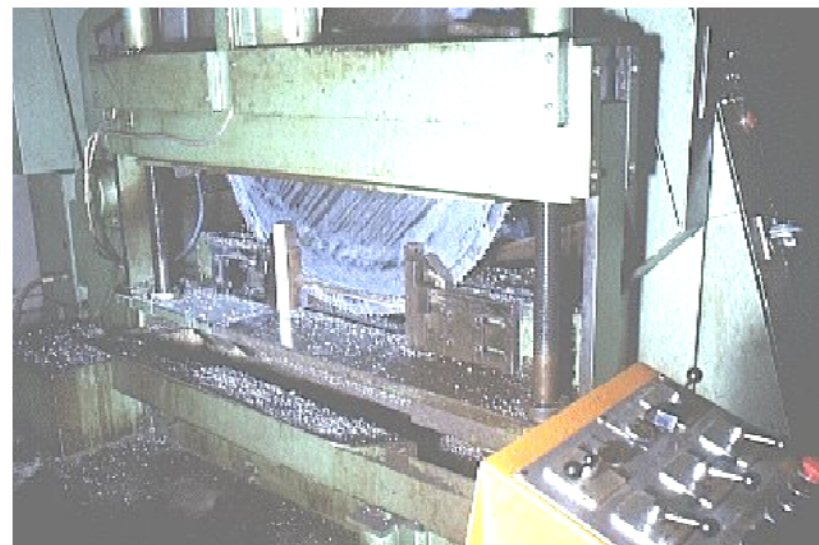


# Vlečenje – žice, vrvi, armaturne palice

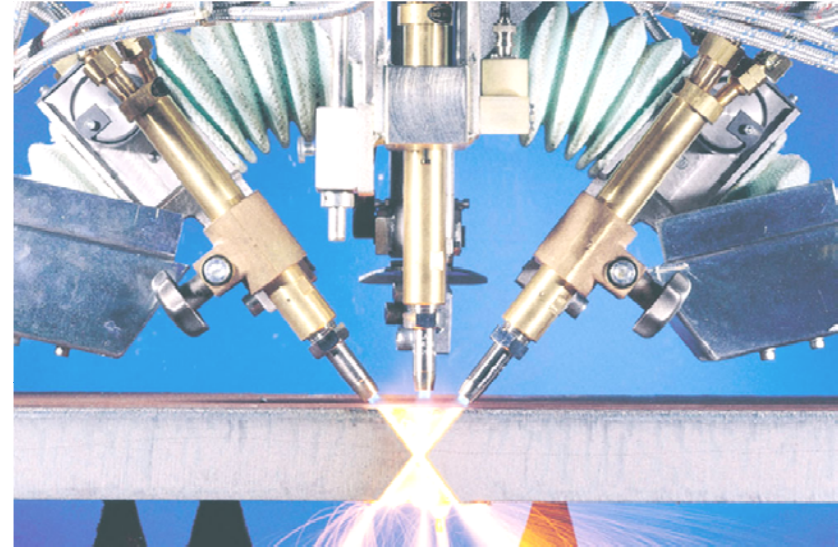
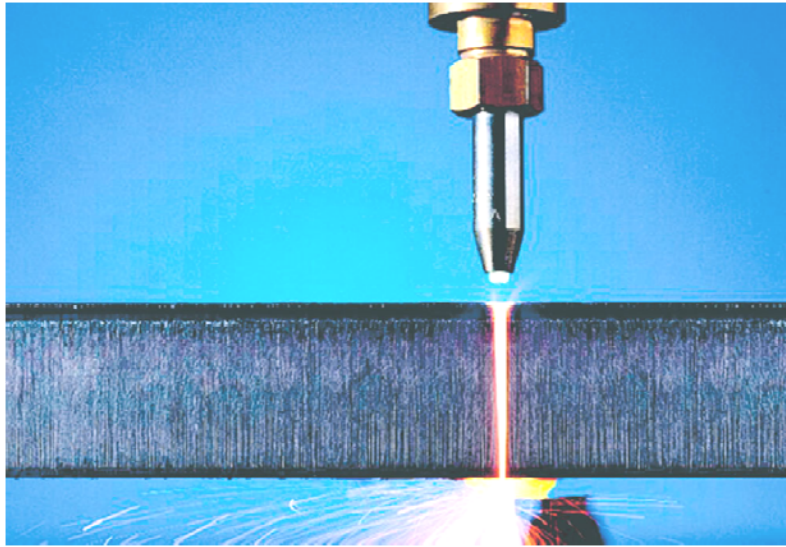




# Rezanje - žaga

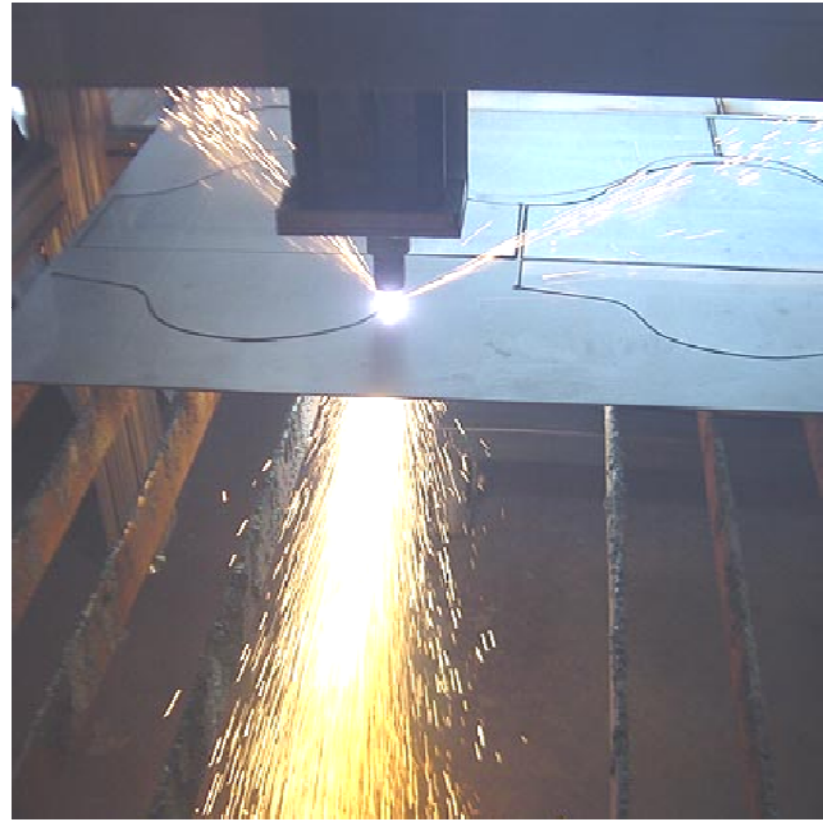


# Plamensko rezanje



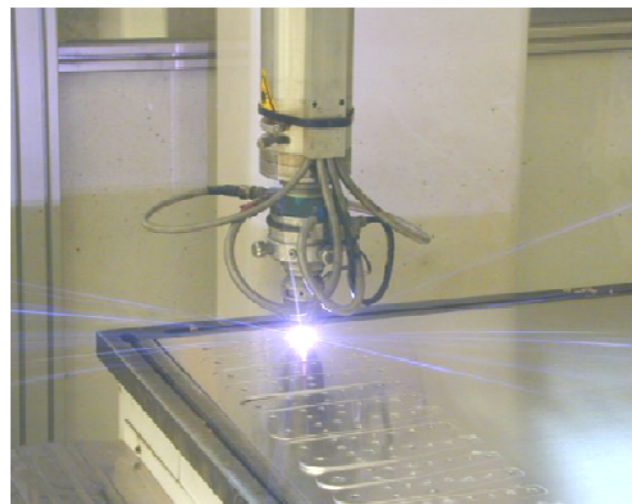
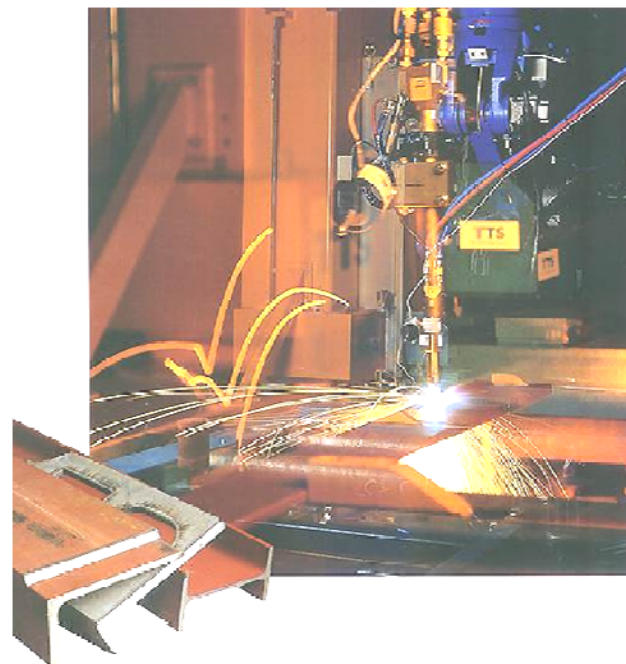
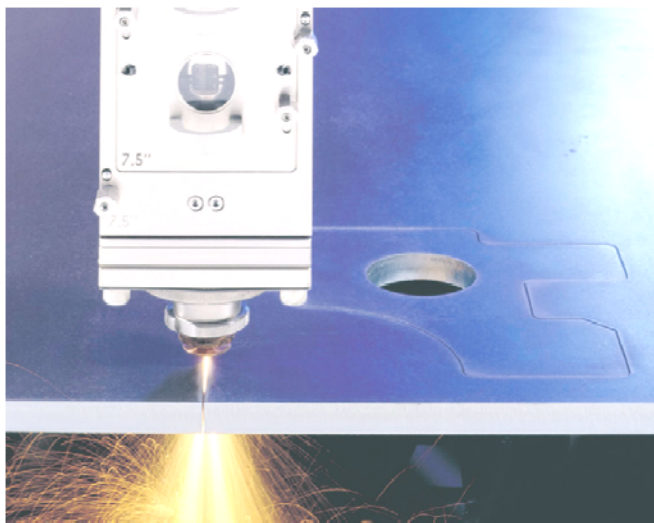


# Rezanje - plazma

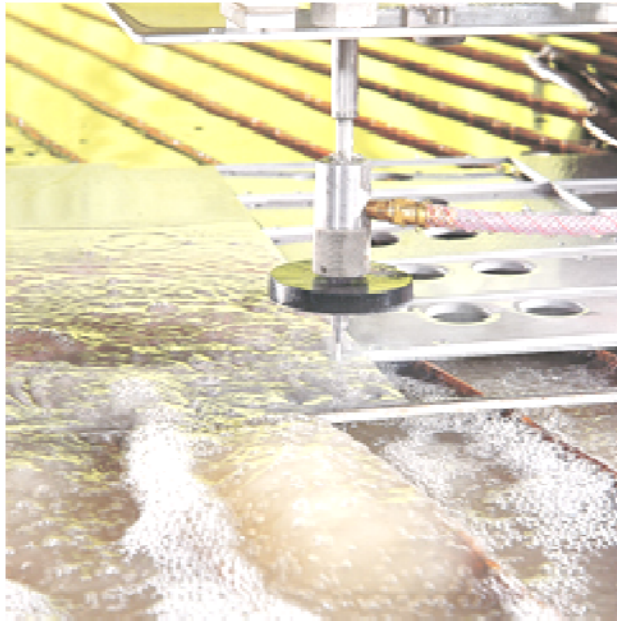




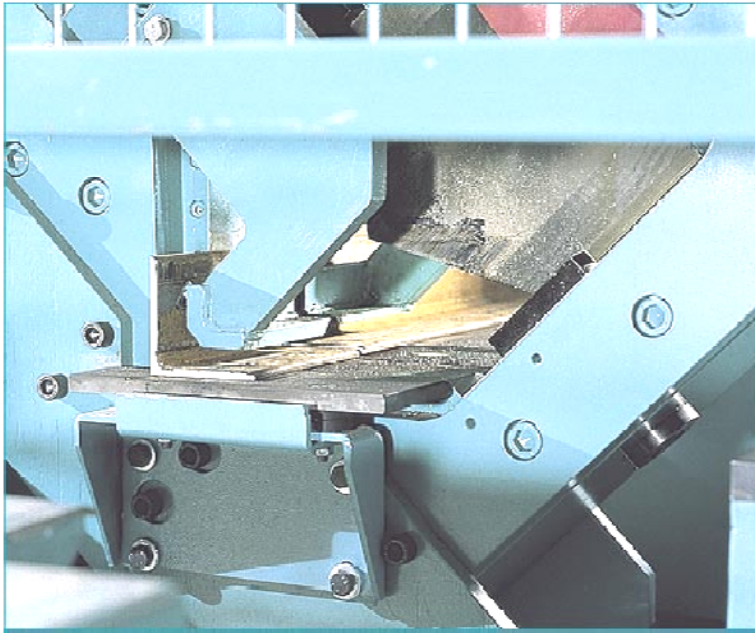
# Rezanje - laser



# Abrasivno vodno rezanje

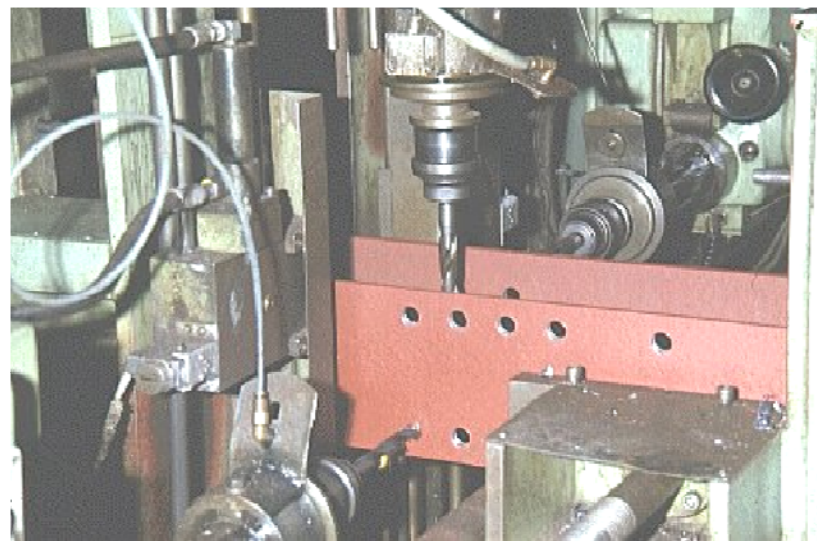


# Rezanje - škarje



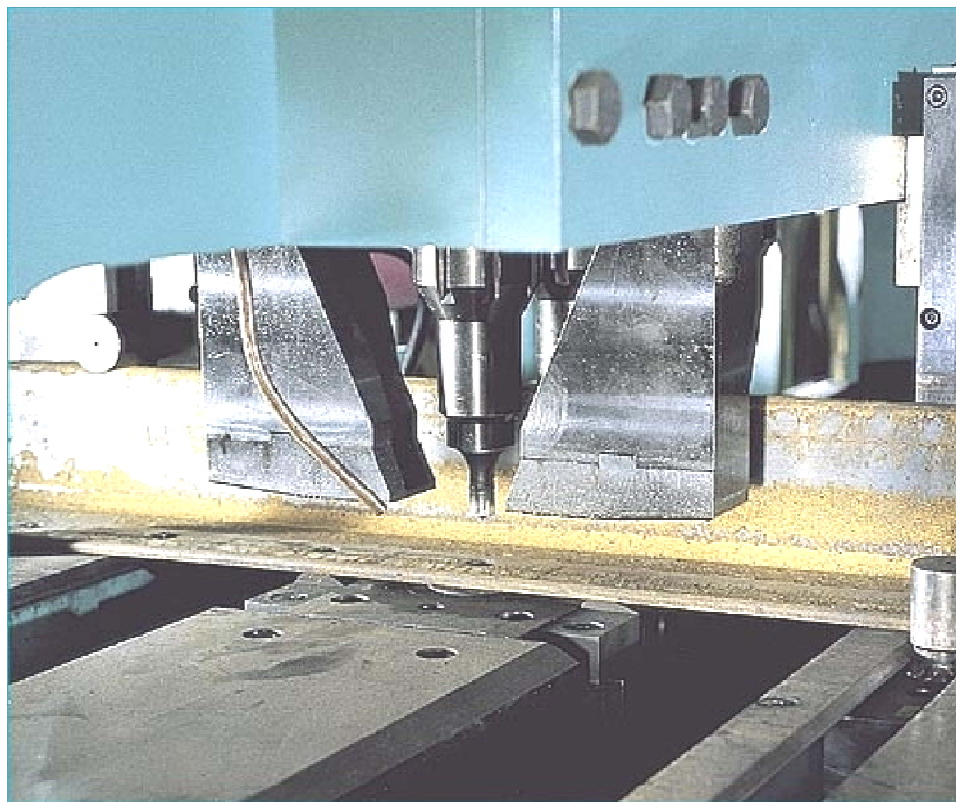


# Vrtanje





# Luknjanje - preboj pločevine



# Krivljenje

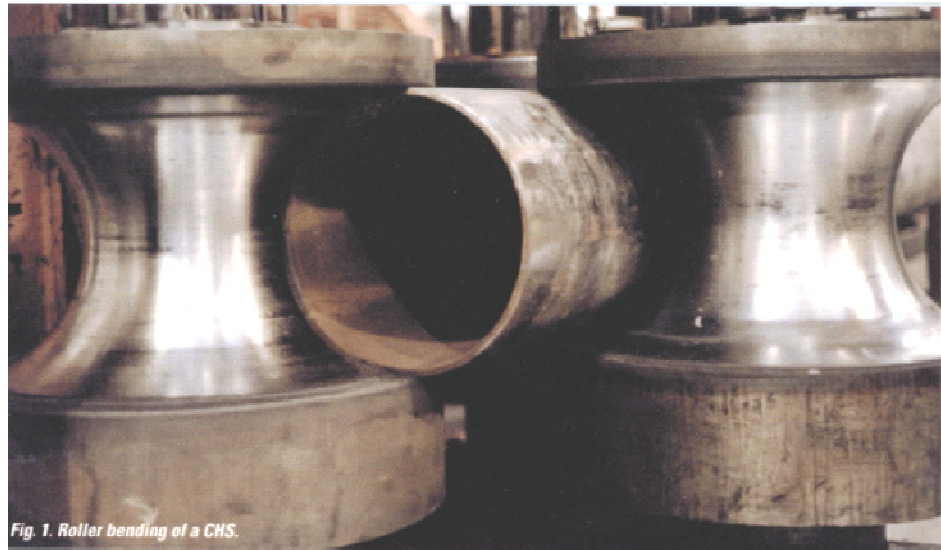
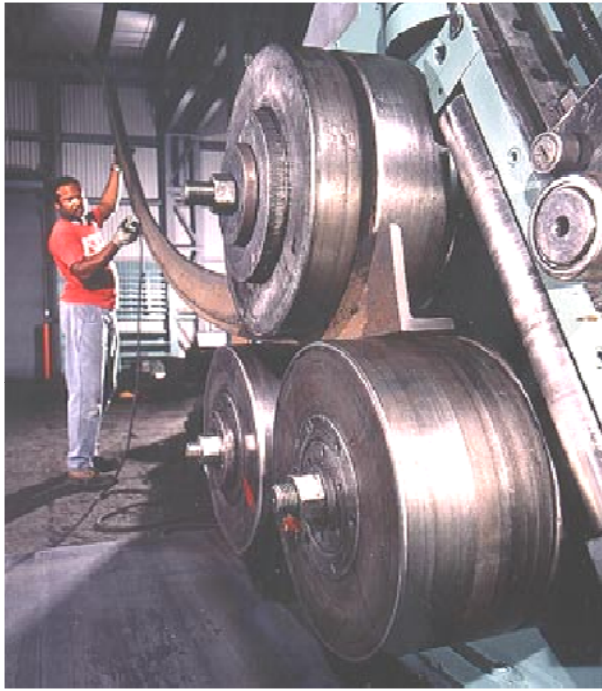
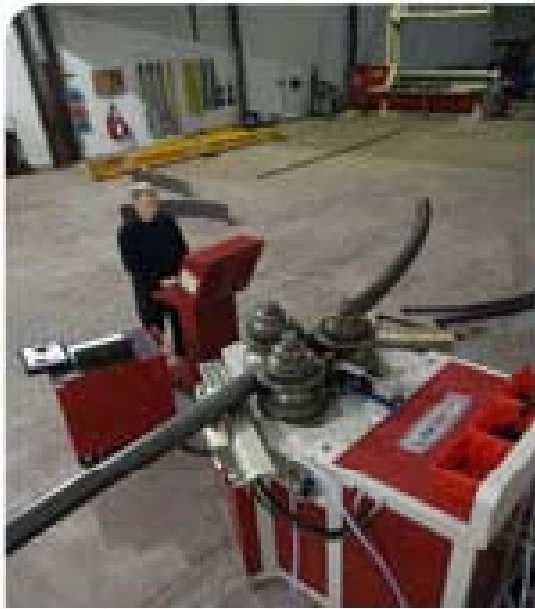


Fig. 1. Roller bending of a CHS.

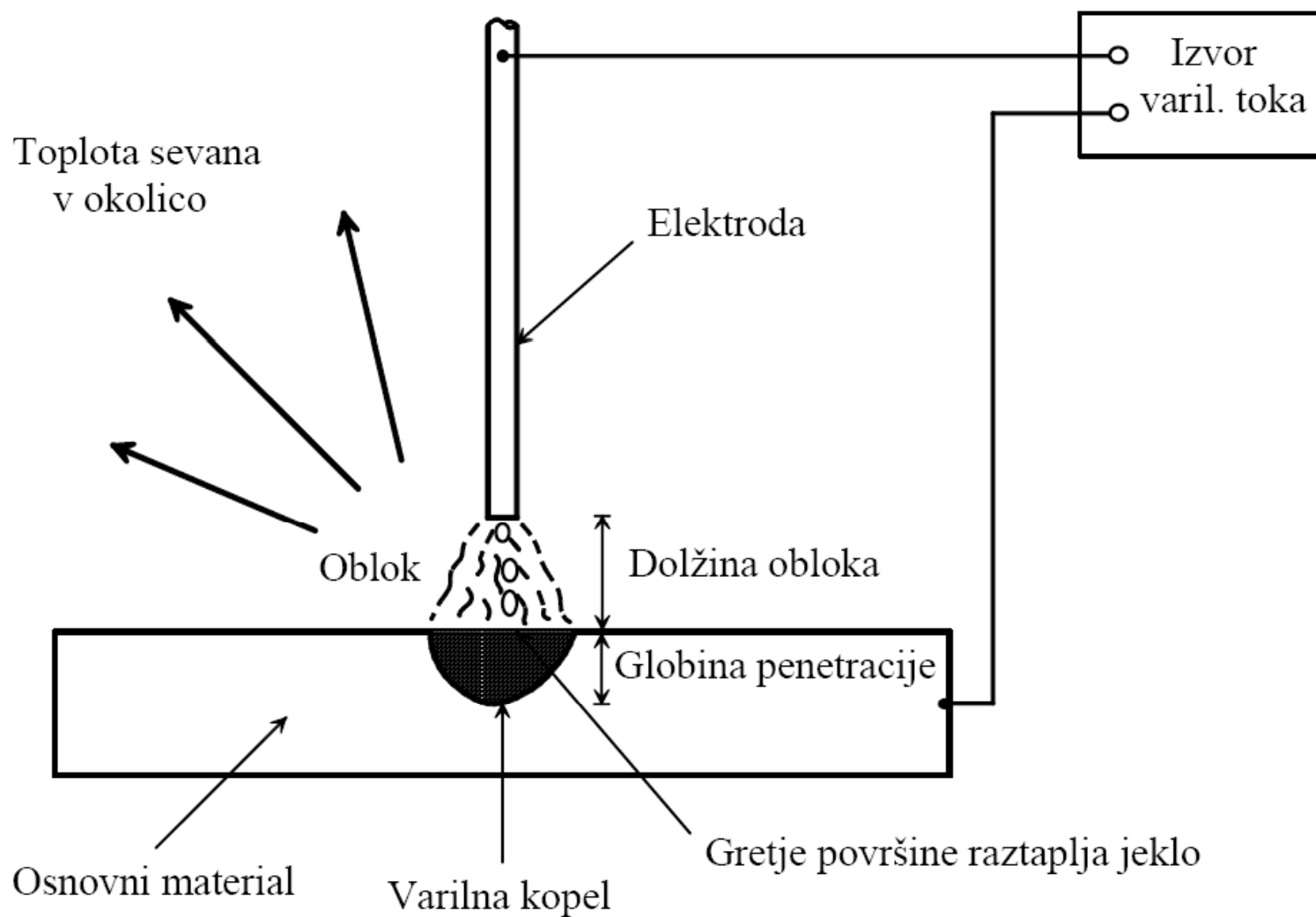


# Vrste varjenja, ki se najpogosteje uporabljajo pri izdelavi konstrukcij

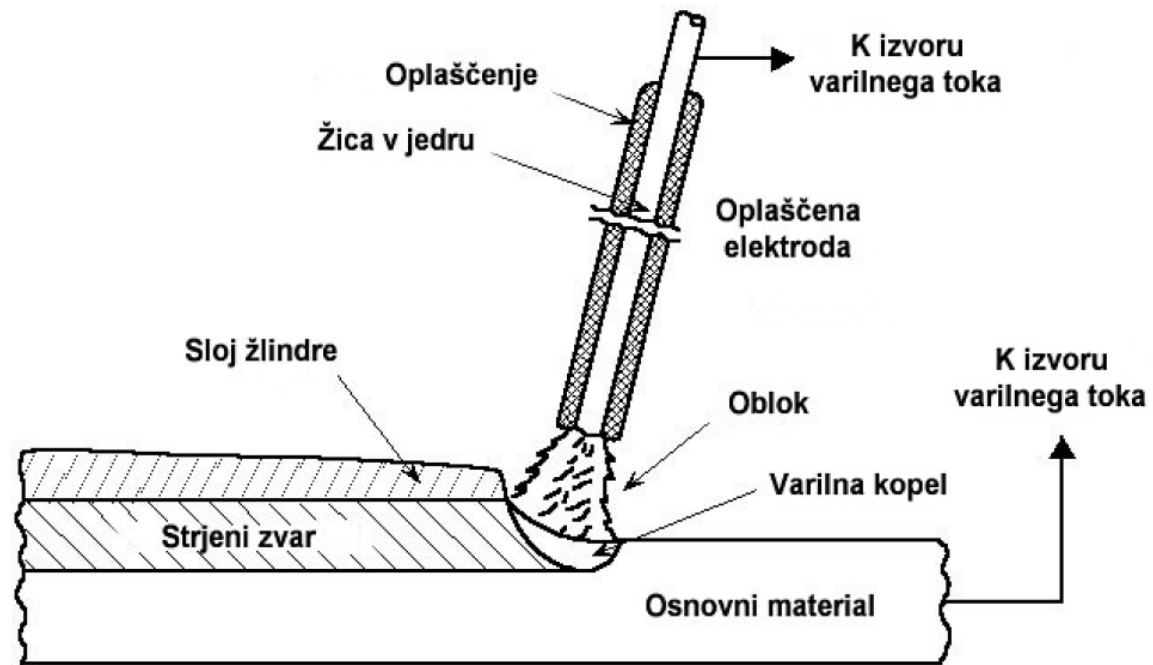
- Elektroobločna varjenja:
  - ročno varjenje z oplaščeno elektrodo;
  - polavtomatsko varjenje v zaščiti CO<sub>2</sub>;
  - avtomatsko varjenje pod praškom.
- Uporovno varjenje čepov za sovprežne konstrukcije.
- Avtogeno varjenje.



# Varjenje



Princip elektroobločnega varjenja

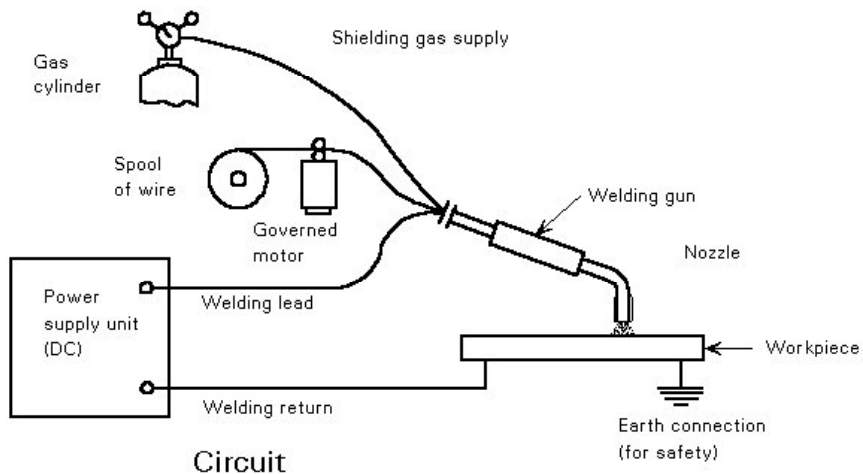


Ročno varjenje z oplaščeno elektrodo

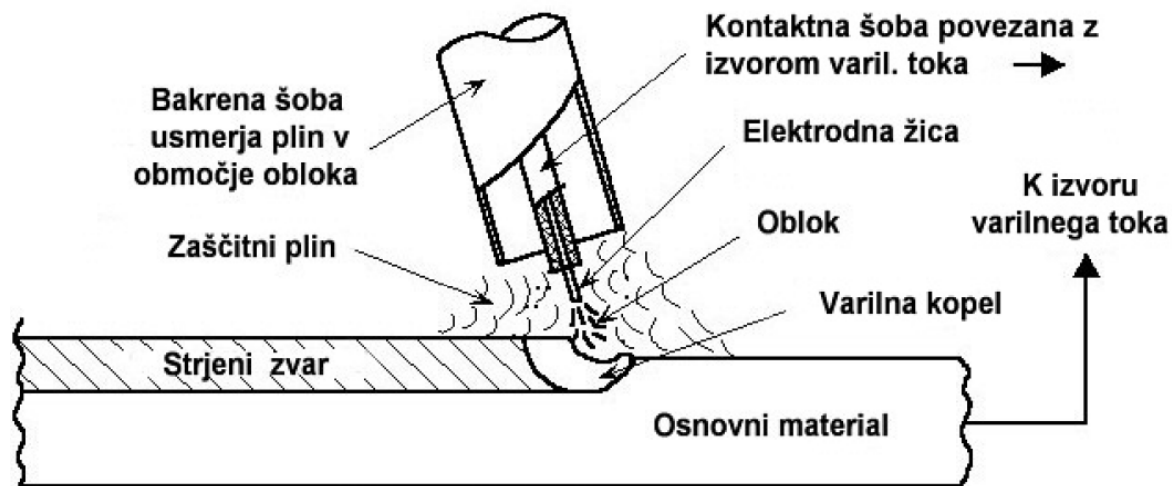
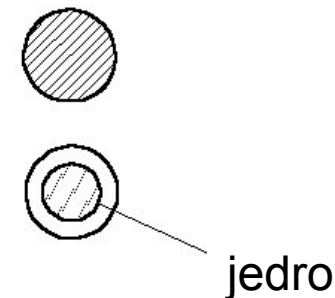




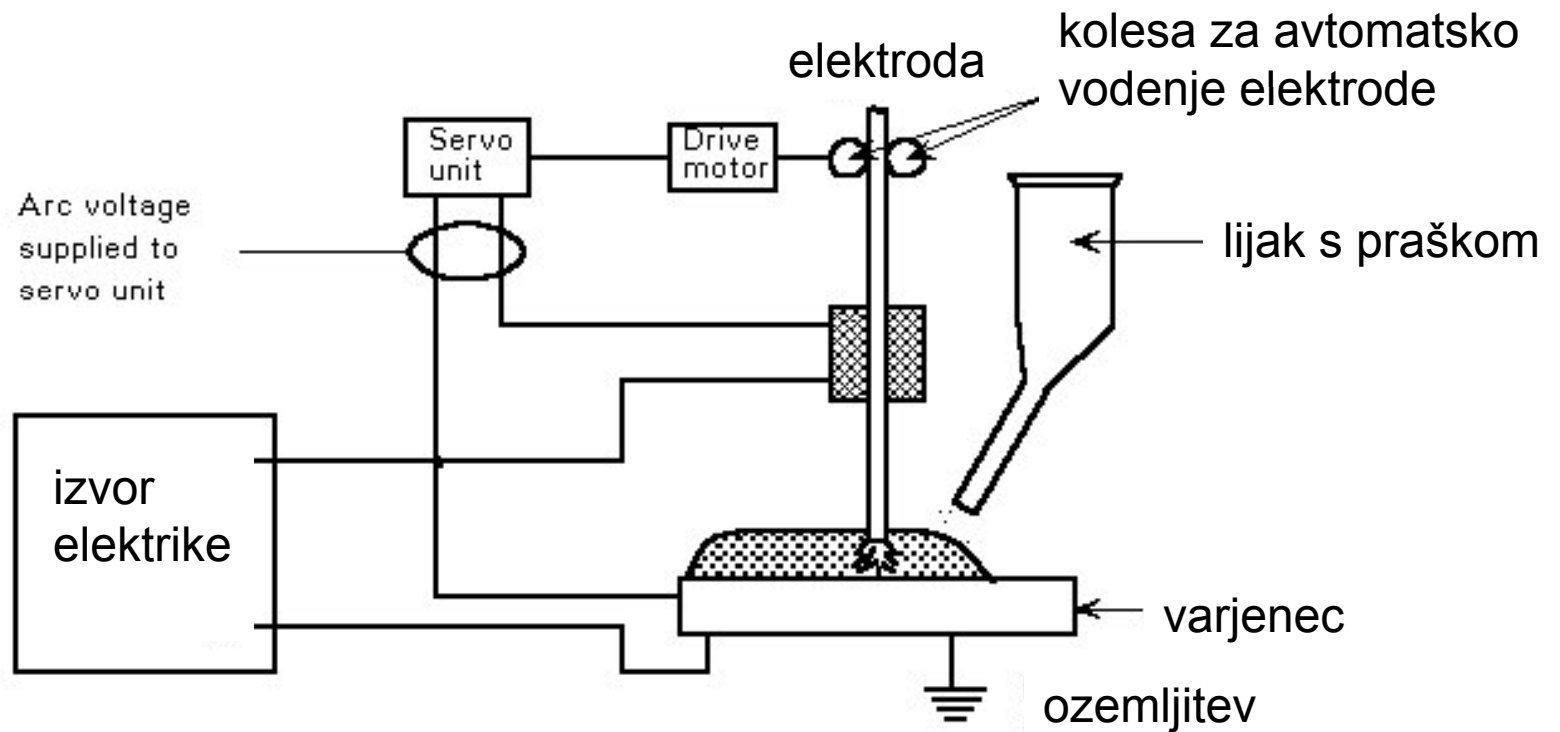




## Elektrode za varjenje



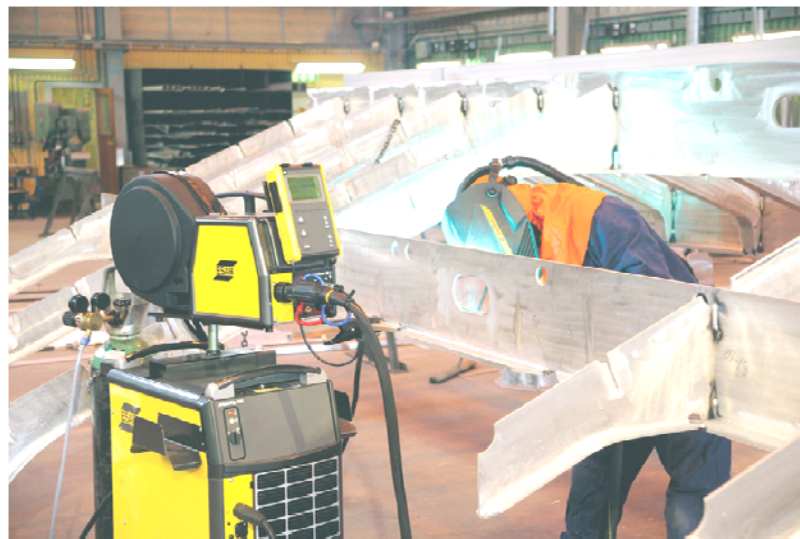
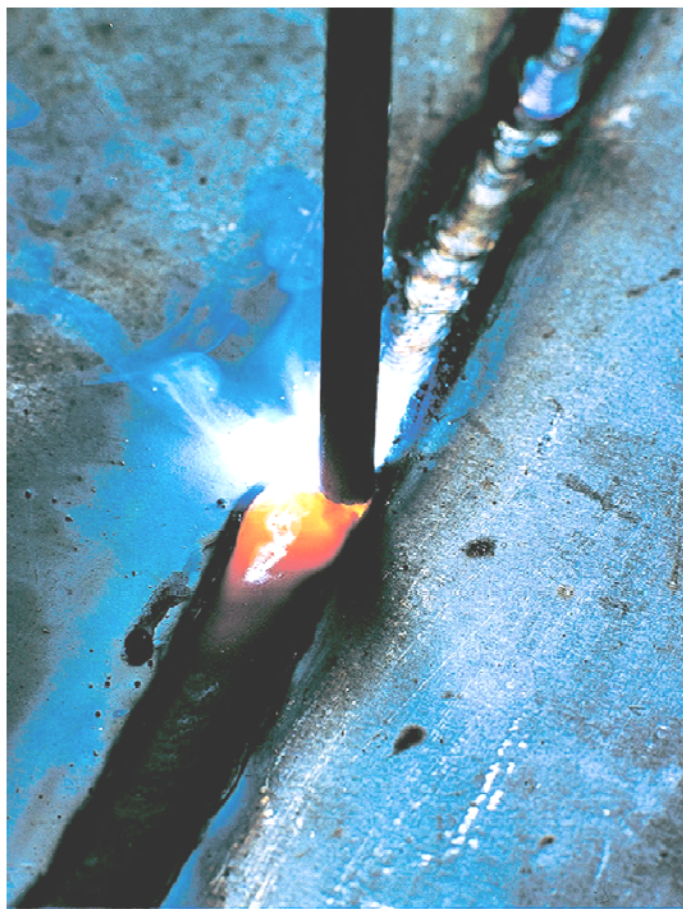
## Polavtomatsko varjenje v zaščiti CO<sub>2</sub> (MAG)



Avtomatsko varjenje pod praškom



# Ročno in polavtomatsko varjenje

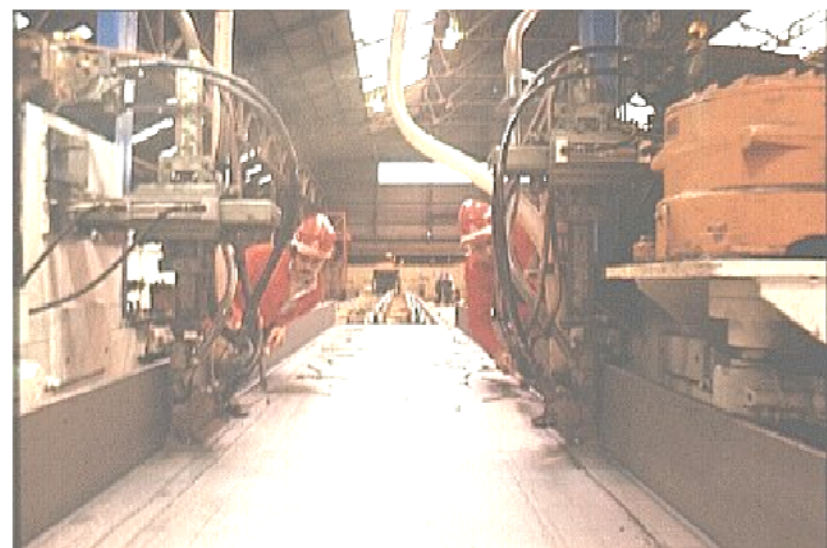
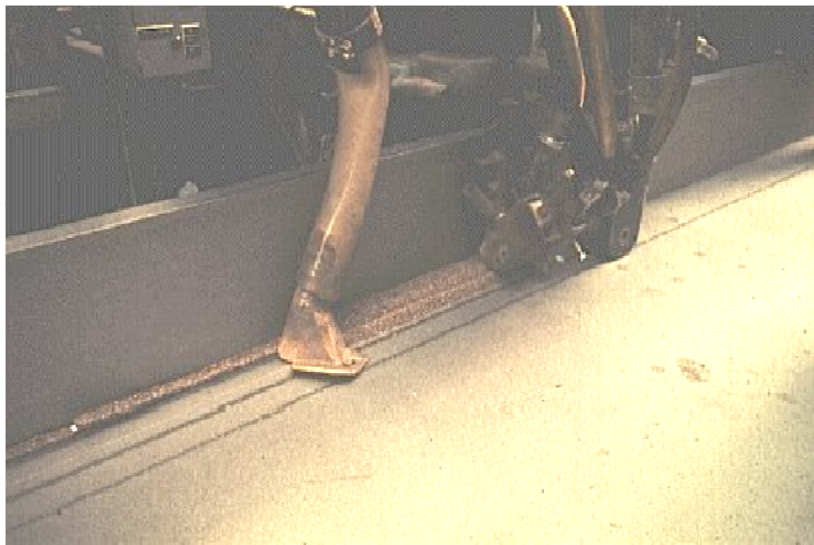


# Avtomatsko varjenje pod praškom

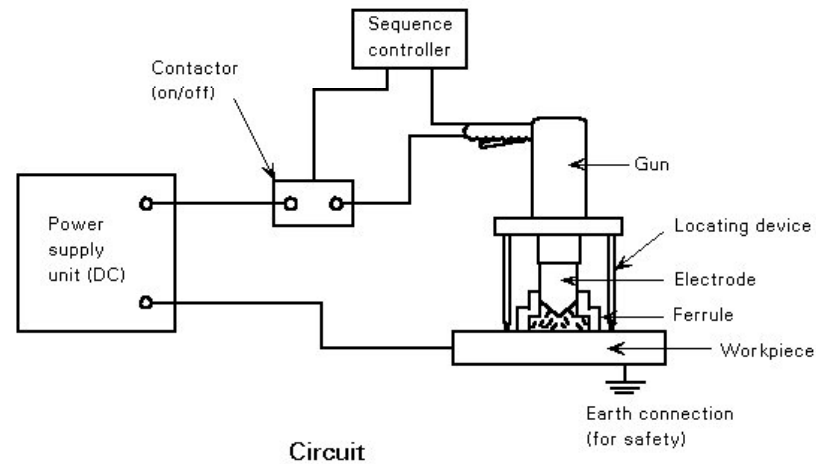




# Avtomatsko varjenje pod praškom








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Electrode : Studs with ends prepared for welding by manufacturer

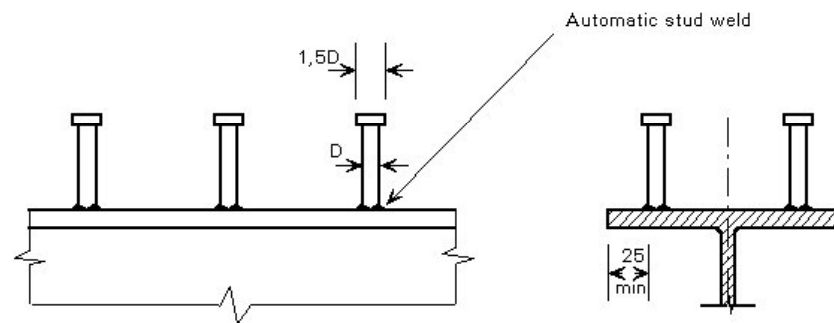
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Ceramic ferrules : shaped to suit stud profile

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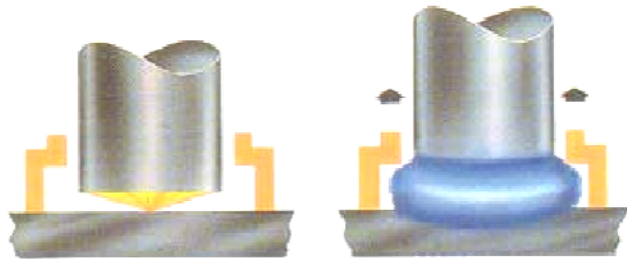
Controls : Current - preset at power supply unit  
 Voltage - vary during welding in a sequence  
 Electrode feed - determined by the control unit  
 Location - controlled by operator

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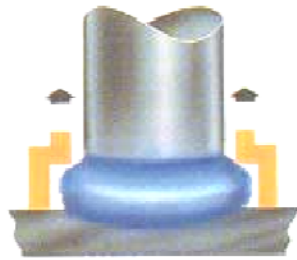


## Uporovno varjenje moznikov

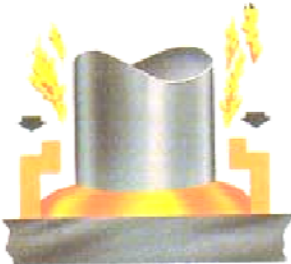
# Uporovno varjenje – varjenje čepov



1. Stud & ceramic ferrule against the work plate.



2. Stud lifts and arc is drawn.



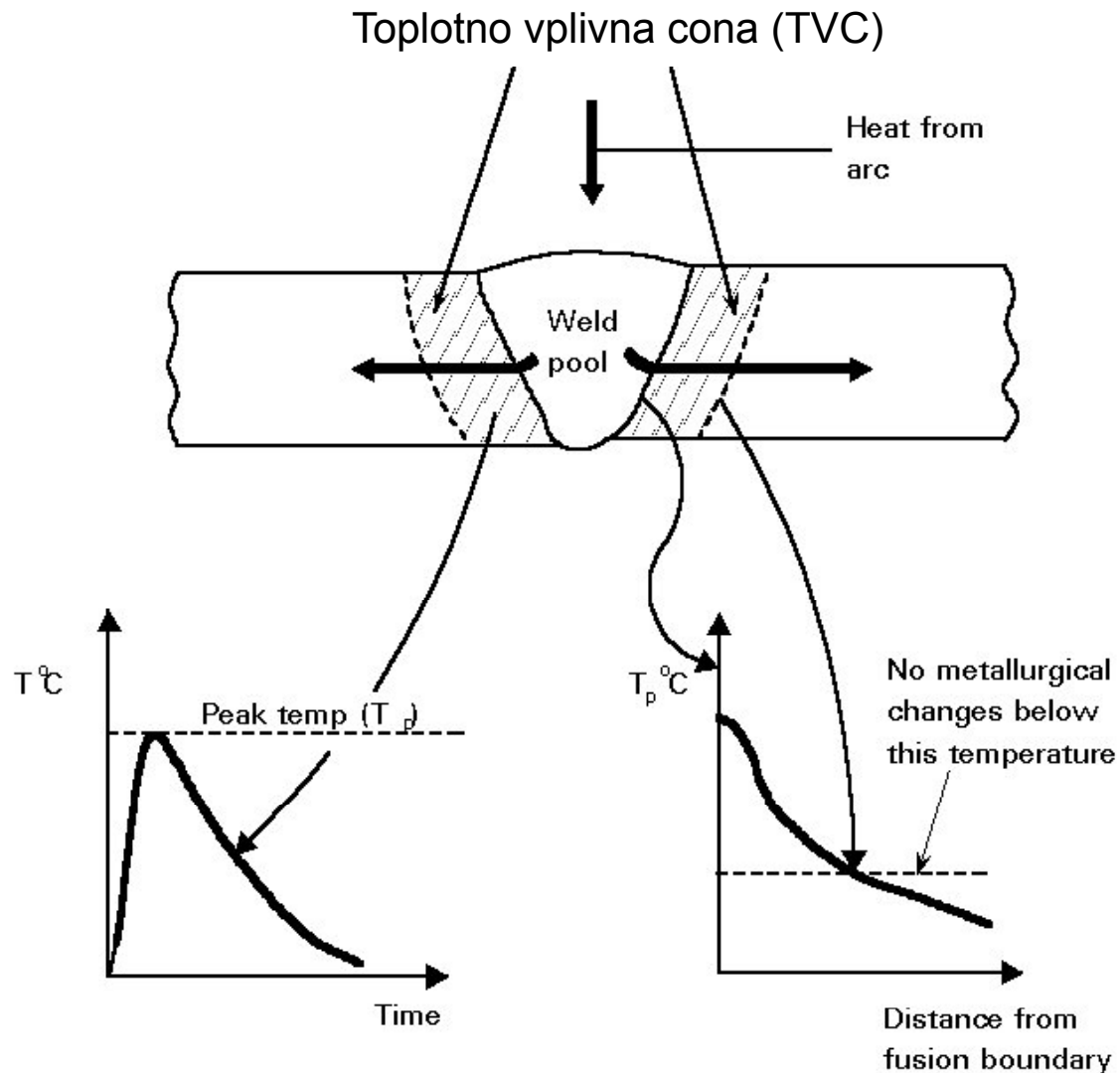
3. Control times out and stud plunges into molten steel.



4. Metal solidifies and weld is completed in milliseconds.



# Razvoj toplotno vplivne cone

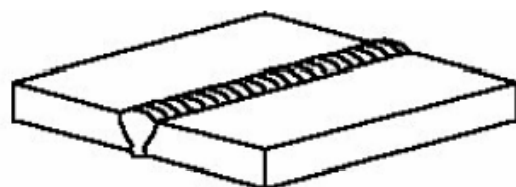


Segrevanje in ohlajevanje v TVC

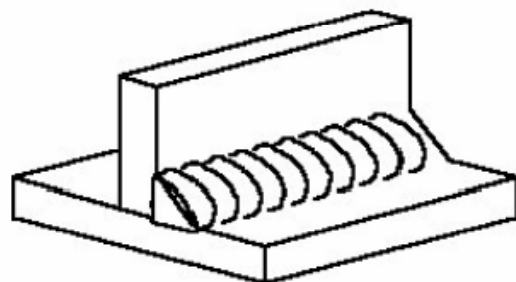
Sprememba temperature v TVC



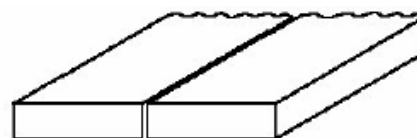
# Vrste spojev



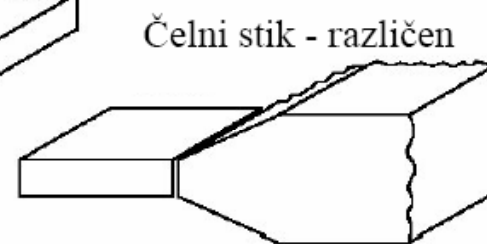
čelni zvar



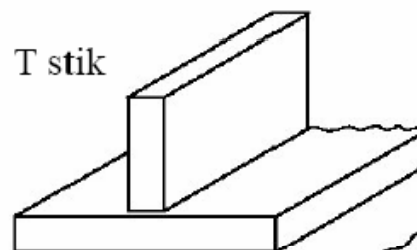
kotni zvar



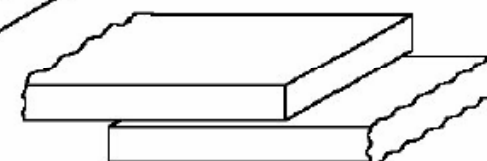
Čelni stik - enak



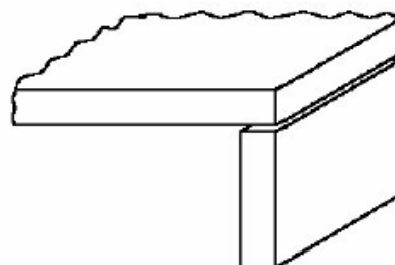
Čelni stik - različen



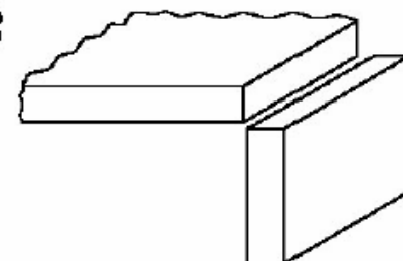
T stik



preklopni stik

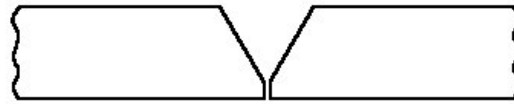


vogalni stik - zaprt



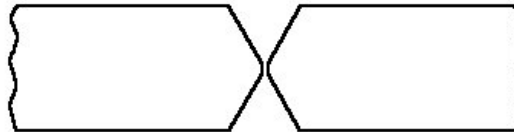
vogalni stik - odprt

# Priprava žleba za čelni zvar



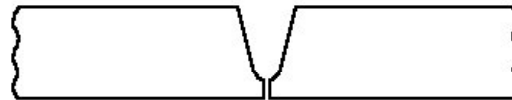
Single Vee

Tanjše pločevine

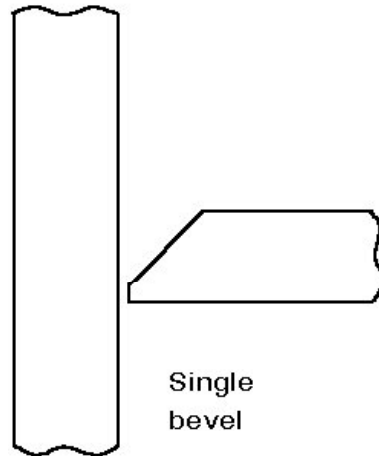


Double Vee

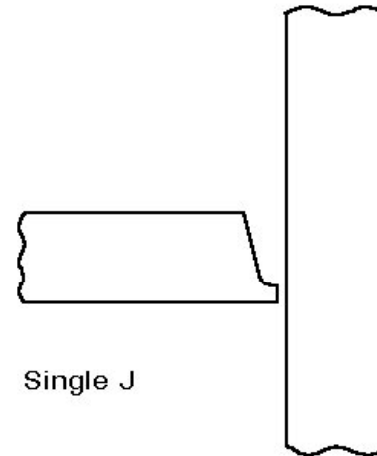
Debelejše pločevine



Single U

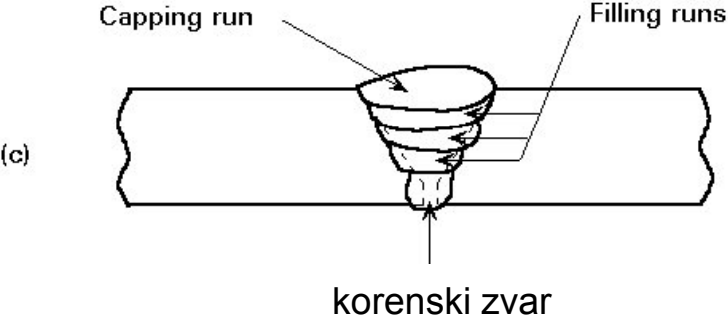
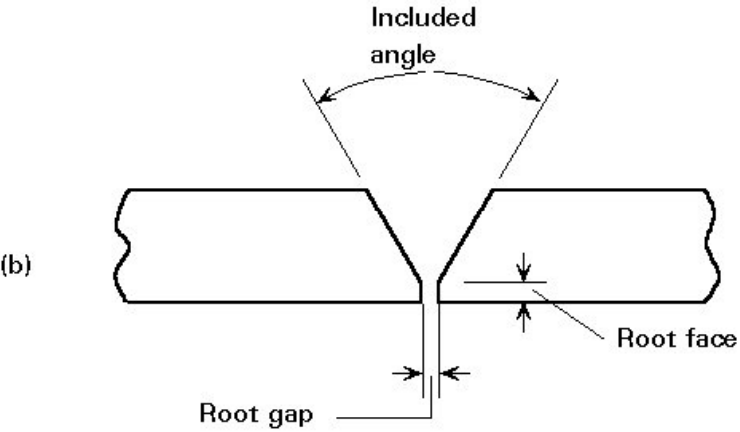
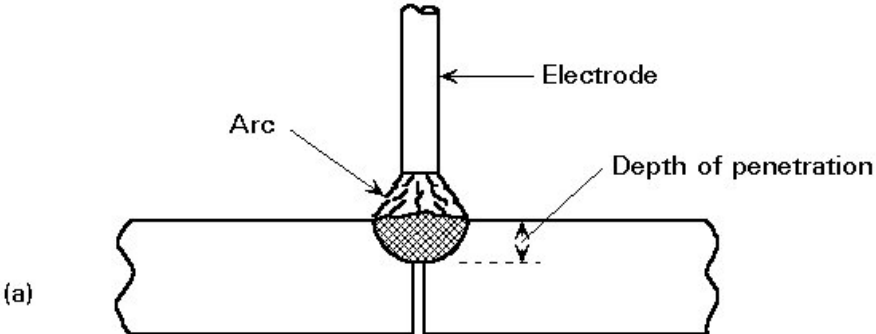


Single  
bevel



Single J

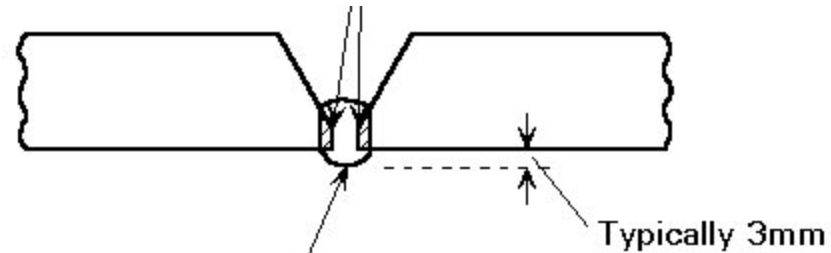
# Izvedba zvarov pri obločnem varjenju



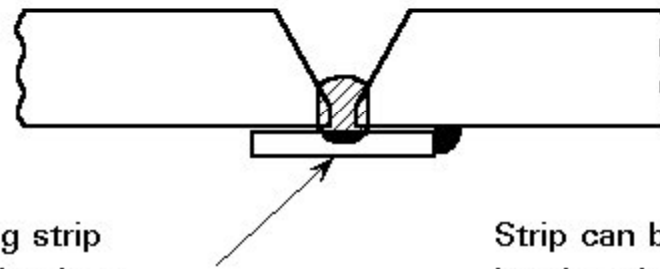


# Izvedba korenskega zvara

Koren zapolnjen z zvarom

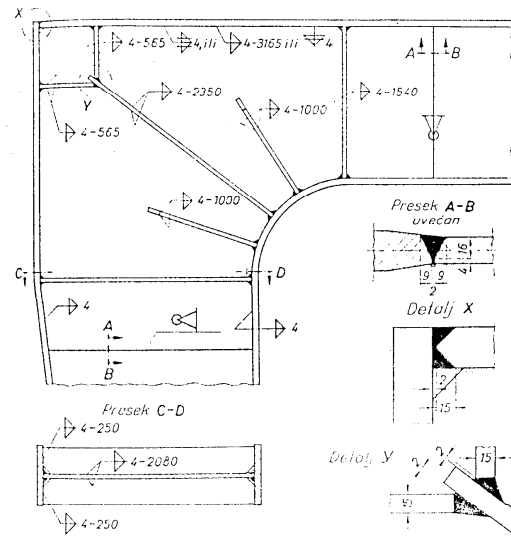


Penetration bead must not be too wide, otherwise weld pool will collapse

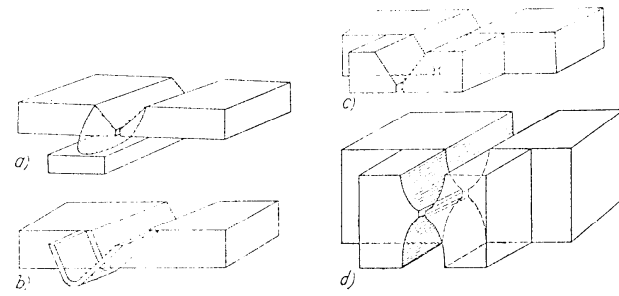


Steel backing strip may be left in place or removed after welding (depends on code)

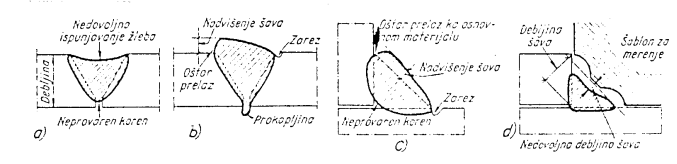
Strip can be held in place by short lengths of fillet weld



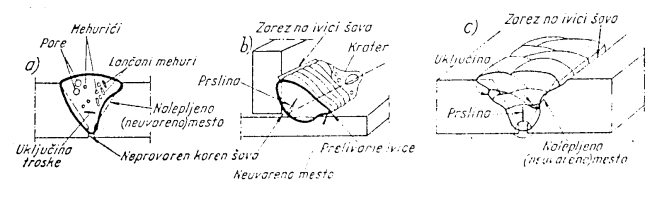
31. 54



31. 55

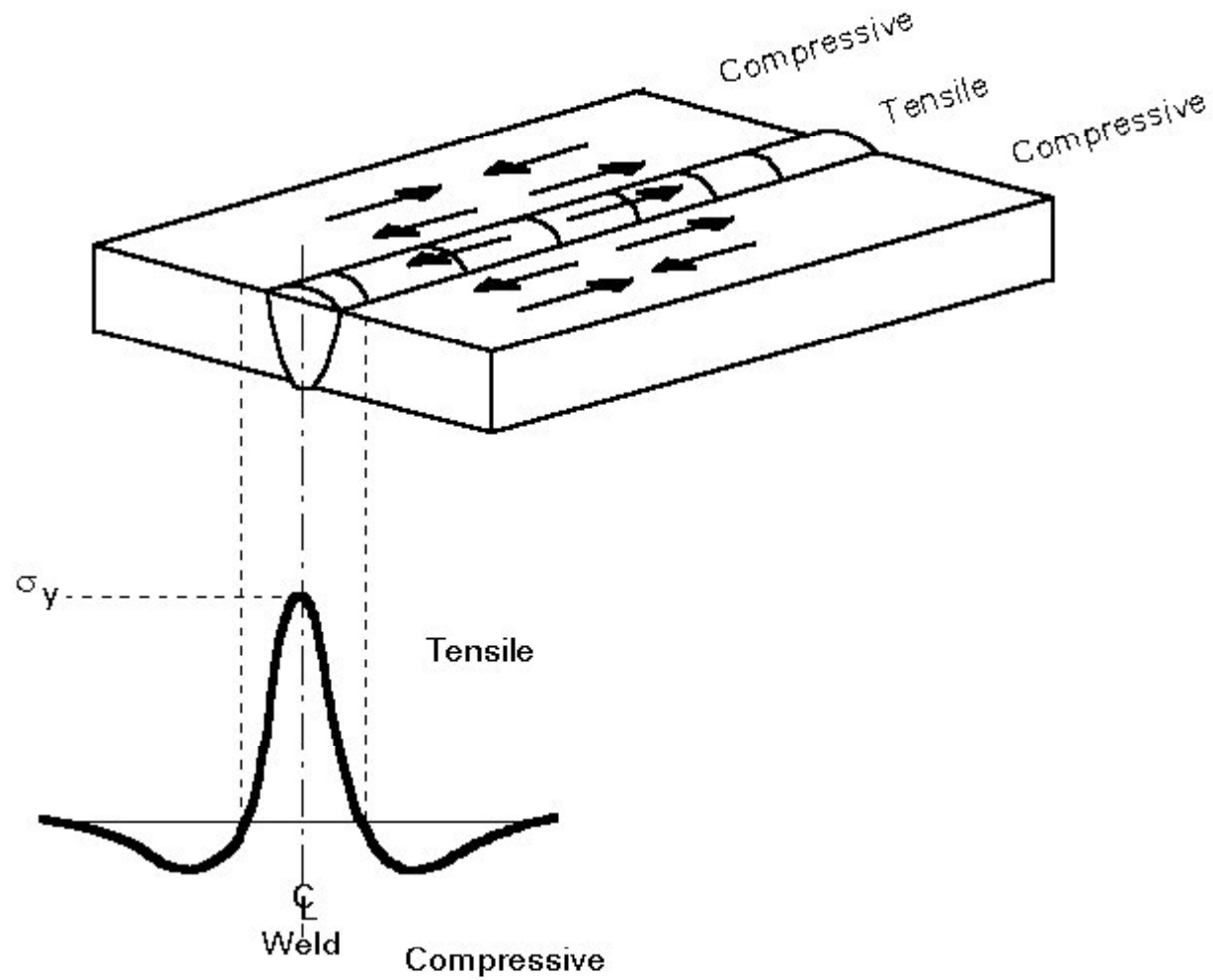


31. 56



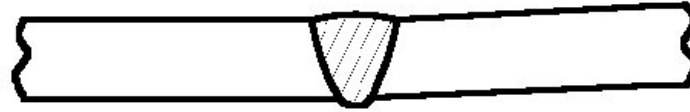
31. 57

# Zaostale napetosti

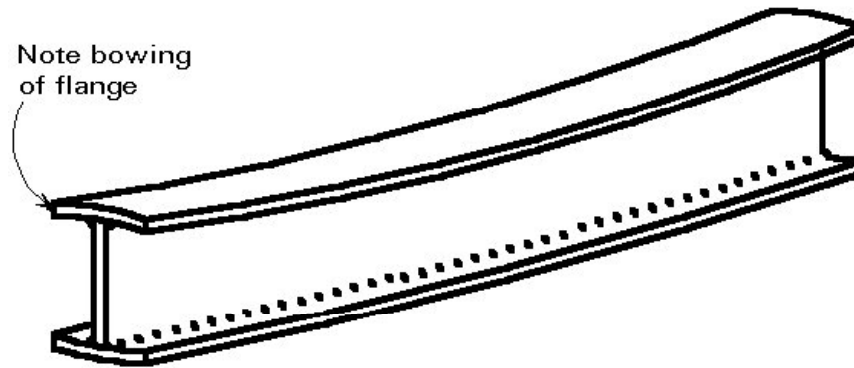




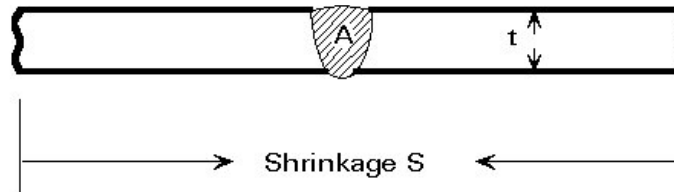
# Deformacija pločevine zaradi varjenja



Angular distortion in single vee butt



Longitudinal bowing in welded beam



$$S = \frac{kA}{t}$$

k = Empirical factor  
(0,1 to 0,17)

A = Cross-section of  
weld

t = Thickness of plate

# Pravilni potek varjenja brez deformacije pločevine

Angular distortion

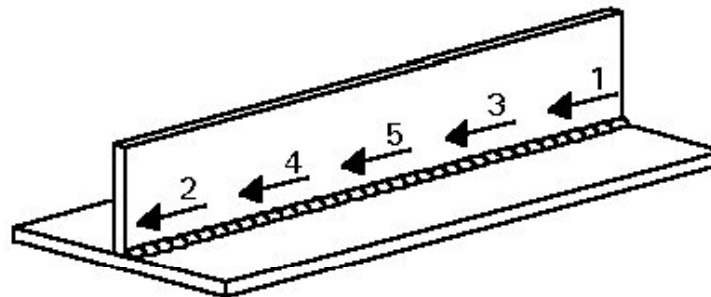


Double vee better than single vee



Single u better than single vee

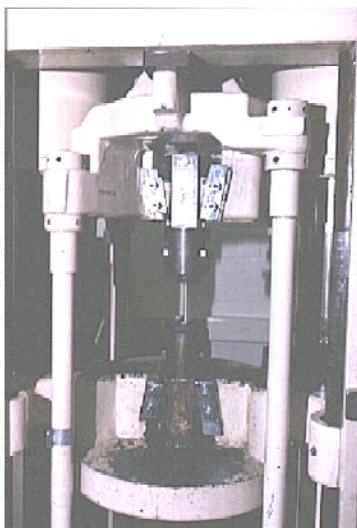
Longitudinal bowing



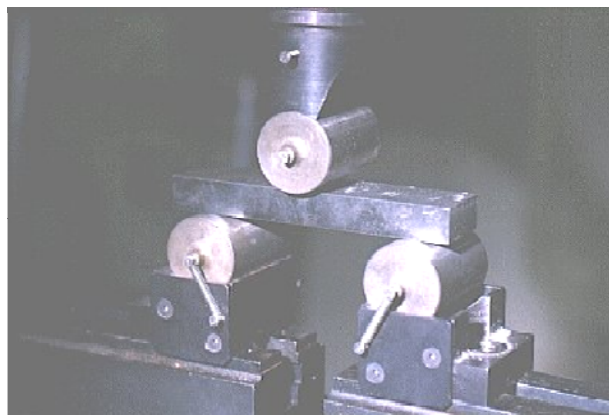
Welding in short lengths reduces longitudinal bowing but increases welding costs

# Kontrola zvarov - porušne kontrole; kontrola varilcev, varilne opreme in varilnih postopkov

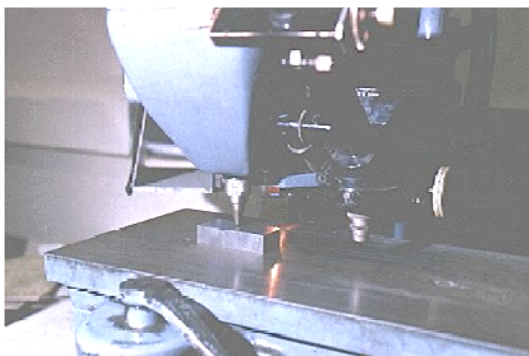
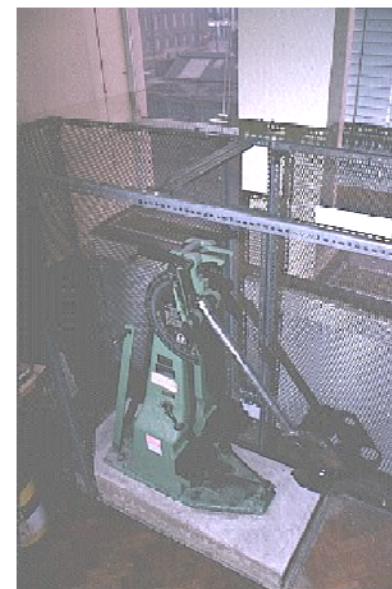
Natezni test



Upogibni test



Charpy-jev test  
(lomna žilavost)

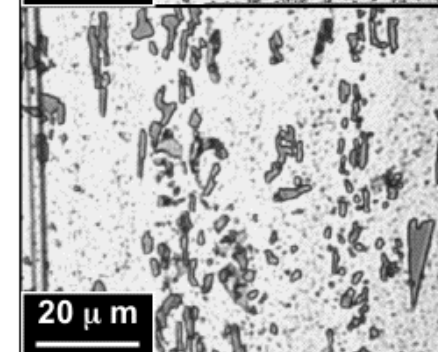
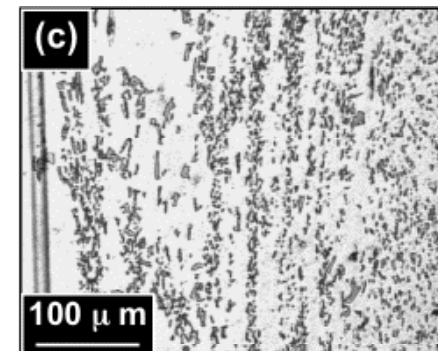
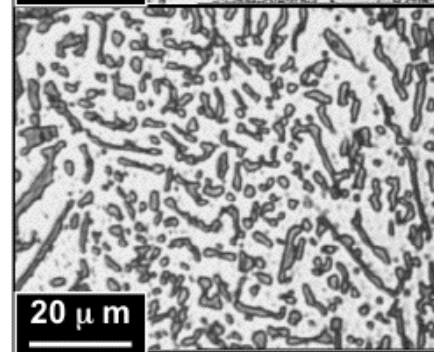
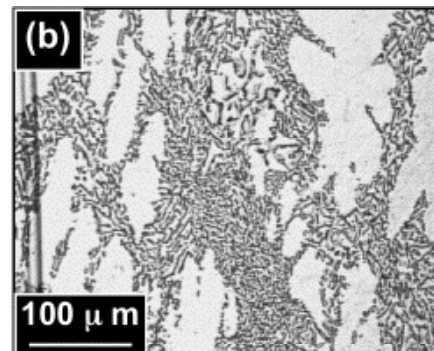
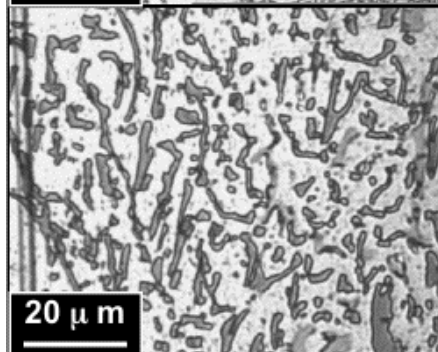
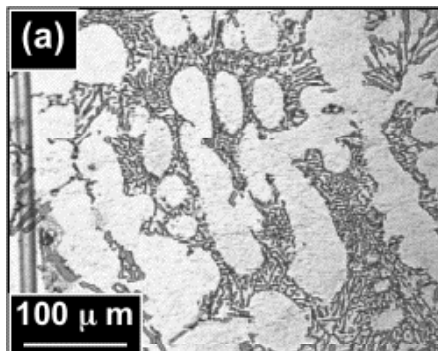
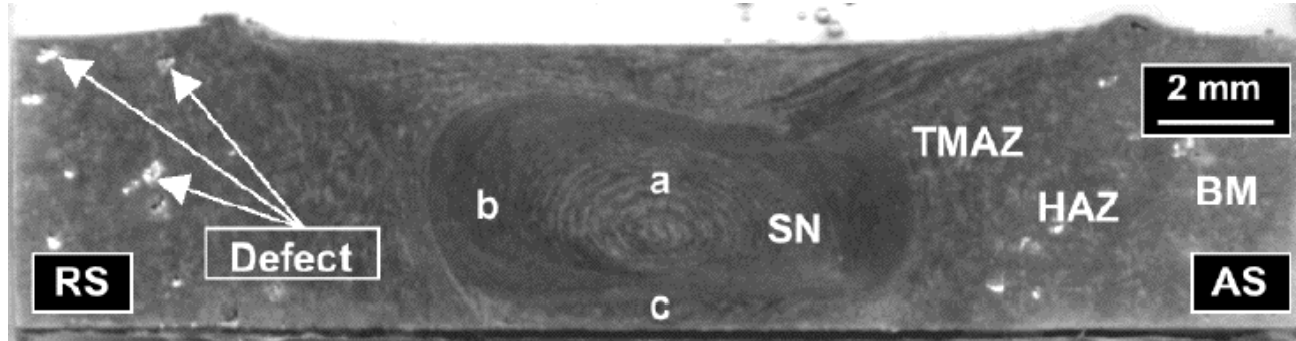


Test za določitev  
trdote



# Zvar in toplotno vplivna cona (HAZ)

- metalografski vzorec





# Kontrola zvarov

- Neporušne metode se uporabljajo za kontrolo zvarov v konstrukciji:
  - vizualna kontrola;
  - kontrola s penetracijo;
  - magnetna kontrola;
  - kontrola z ultrazvokom;
  - kontrola z rentgenom.

# Kontrola zvarov - neporušne metode

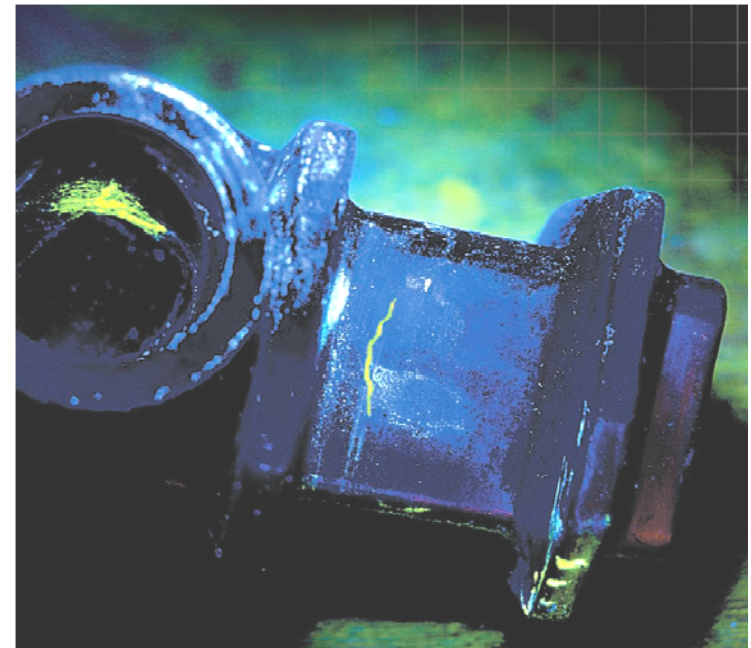
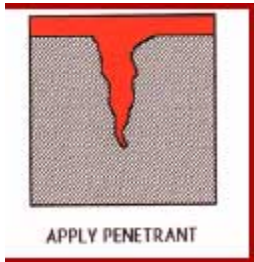
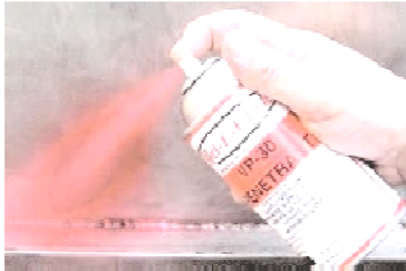


Vizualna kontrola zvarov - orodje za kontrolo dimenzij zvarov.

Ugotovimo, če je zvar sploh izdelan, če je izdelana prava vrsta zvara, preverimo geometrijo in površinske napake.

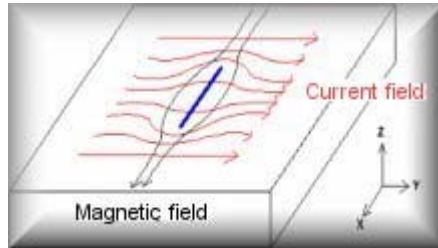
Vizualna kontrola se izvede za vse zware najmanj 16 ur po zaključku varjenja

# Kontrola zvarov - neporušne kontrole

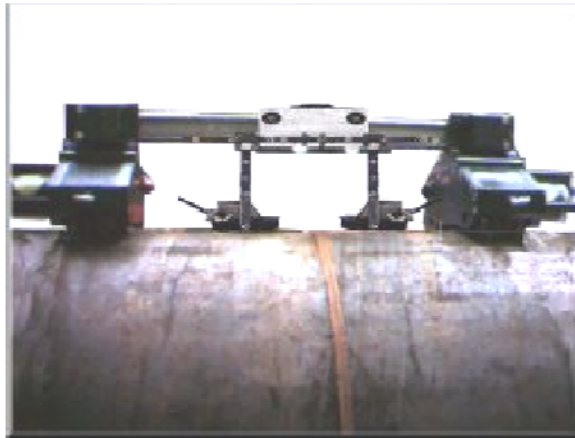


Odkrivanje razpok s penetracijo

# Kontrola zvarov - neporušne kontrole



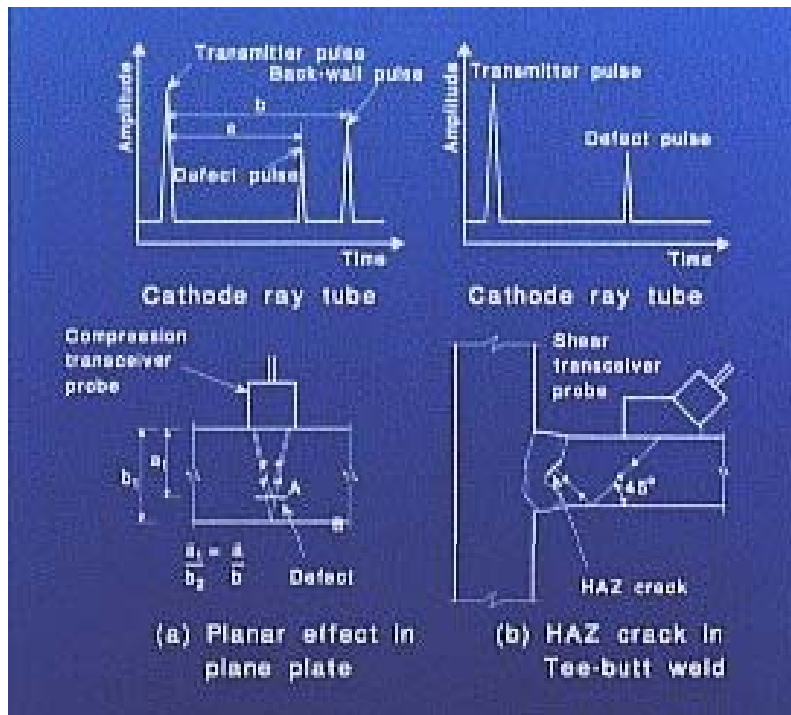
Magnetno polje



Magnetna kontrola

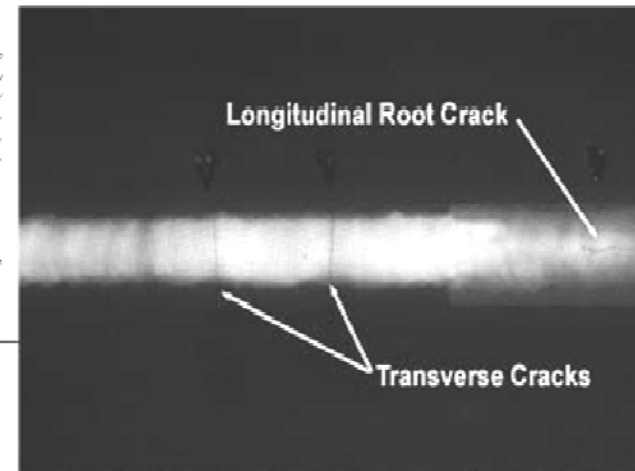
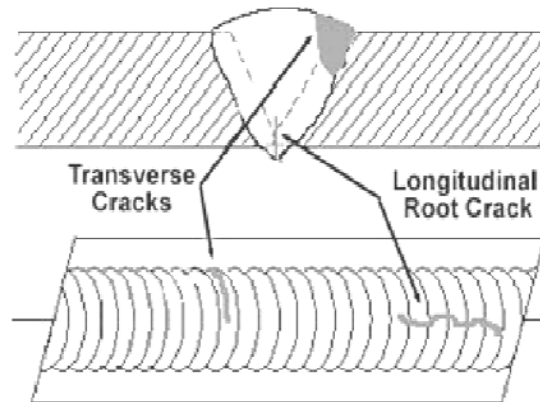
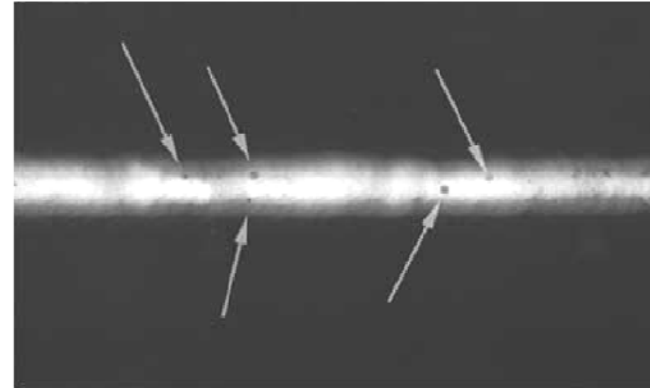
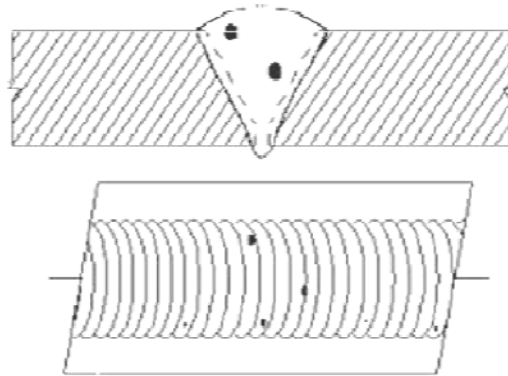


# Kontrola zvarov - neporušne kontrole



Kontrola z ultrazvokom

# Kontrola zvarov - neporušne kontrole



Kontrola z rentgenom