Lectures #6

6 October 2020

Joining Processes

ADHESIVE BONDING

PROCESS

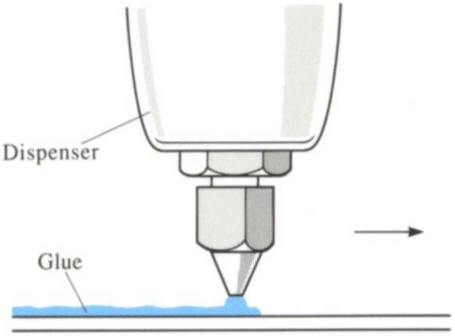
Gluing
Adhesive is applied to prepared surfaces which are then brought together. Heat may be applied to encourage adhesive setting.

SHAPE

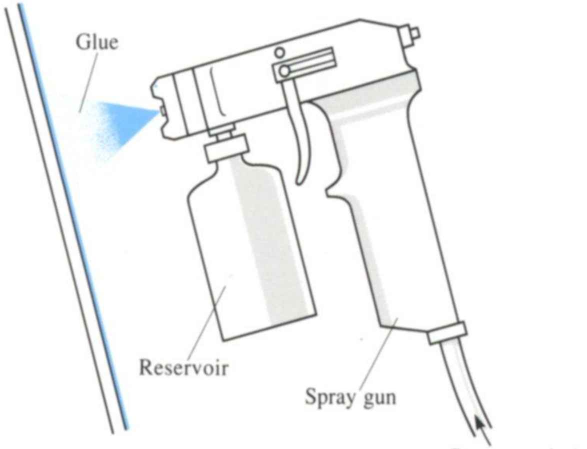
All shapes
Joints are usually designed to minimize service stresses.

MATERIALS

All materials
Adhesive must wet the substrate to ensure a good bond. Low surface energy materials need special surface treatments.



Small areas
Small area joints can be covered by automated dispensers. Ideal for hot melt and reactive polymeric glues.



Large areas
Large area joints can be covered using spraying techniques. Especially suitable for low room-temperature viscosity and solvent-based glues.

CYCLE TIME

Depends on the rate of adhesive solidication. Can be temperature dependent. Production rates increased by automated application methods.

RATING 2

QUALITY

Defects can be caused by inadequate wetting of the joint or gas evolution during setting.

RATING 3

FLEXIBILITY

Can be operated with no special equipment for mixing or application.

RATING 5

MATERIALS UTILIZATION

Can be 100% but reactive adhesive systems require surplus material to ensure adequate coverage of the joint.

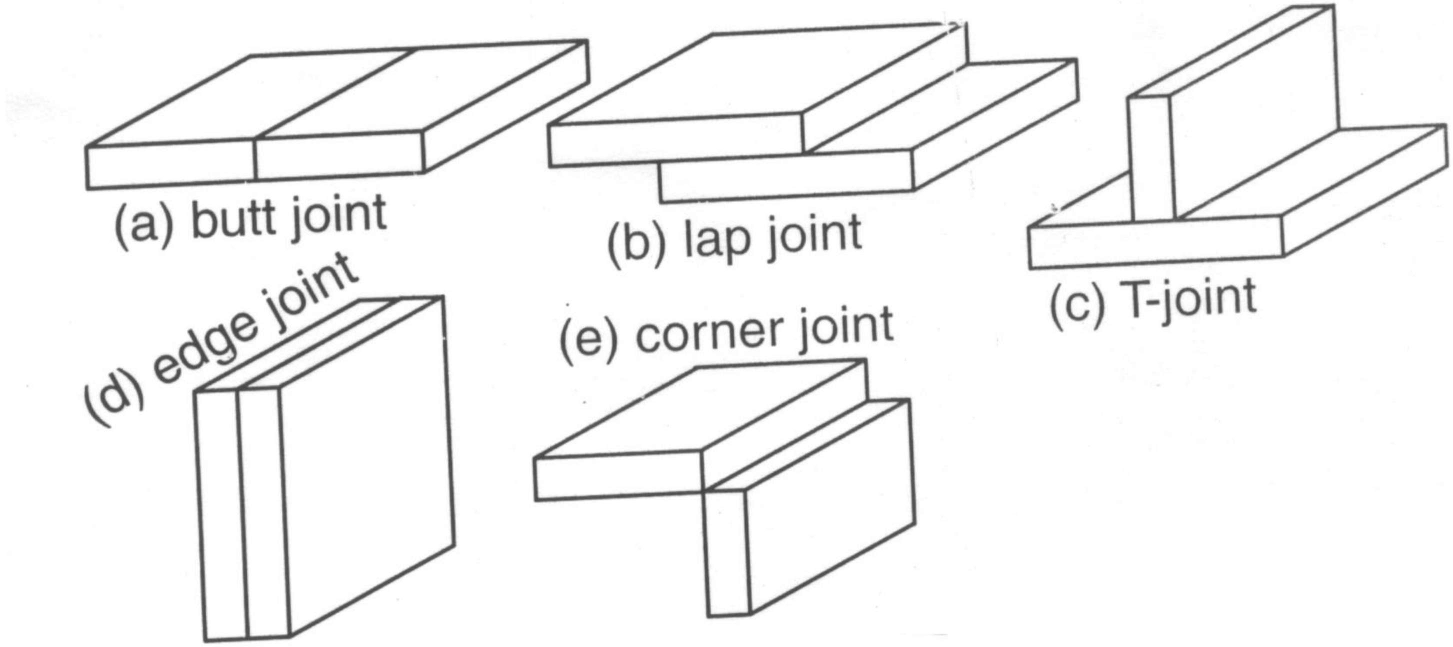
RATING 5

OPERATING COST

Minimal cost unless significant automation involved.

RATING 5

Types of Weld Joint



FUSION WELDING

PROCESS

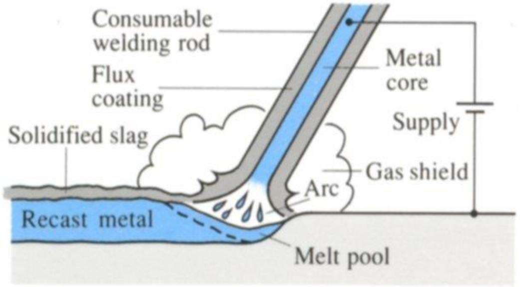
Fusion
Heat is applied to soften or melt material surface which then flows into the joint. Extra material (filler) may be required to fill the joint completely. Atmosphere excluded in some processes.

SHAPE

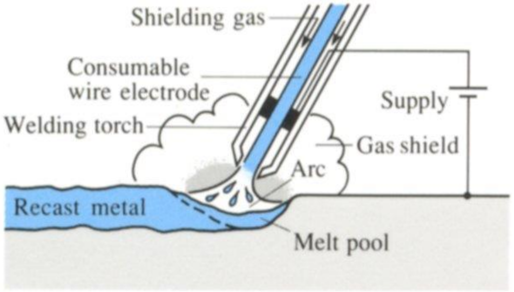
All shapes
All shapes possible.

MATERIALS

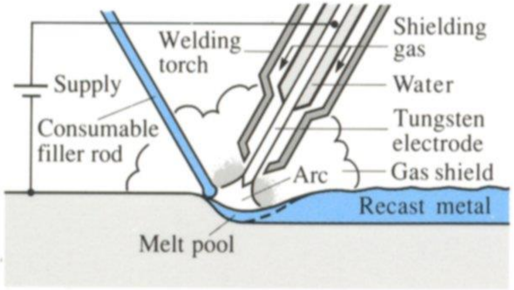
Metals, thermoplastics, glasses
Can be used for all materials that can be made to soften and flow without chemical degradation.



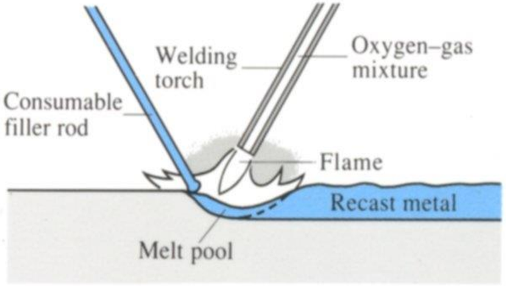
Flux shielded manual metal arc (MMA)
Welding rod is consumed. The metal core joins the melt pool and forms the cast metal. The flux forms both a gas shield and a protective solid slag layer on the recast metal.



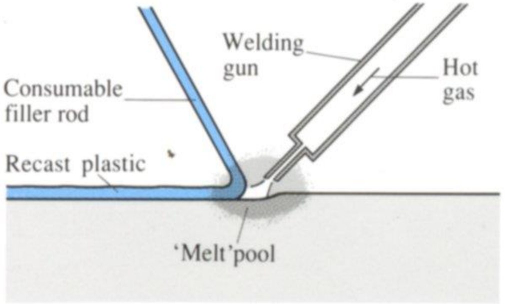
Metal arc gas shielded (MAGS/MIG)
The wire electrode is consumed. Shielding is provided by gas fed to the region of the melt pool by the welding torch.



Tungsten inert gas (TIG)
Melt pool is supplemented by filler rod if necessary.



Gas welding
Melt pool is supplemented by filler rod. Shielding provided by combustion gases.



Hot gas welding
Used for welding thermoplastics. A force is usually applied to the joint to encourage mixing of the softened material.

CYCLE TIME

Depends on size of joint. In small joints may be limited by time taken to align components.

QUALITY

All casting defects may occur in weld. Heat affected zone (HAZ) always produced.

FLEXIBILITY

Extremely flexible. Tooling limited to clamping jigs and fixtures.

MATERIALS UTILIZATION

Scrap is only produced when welds are built up above the level of the surface and must be ground back.

OPERATING COST

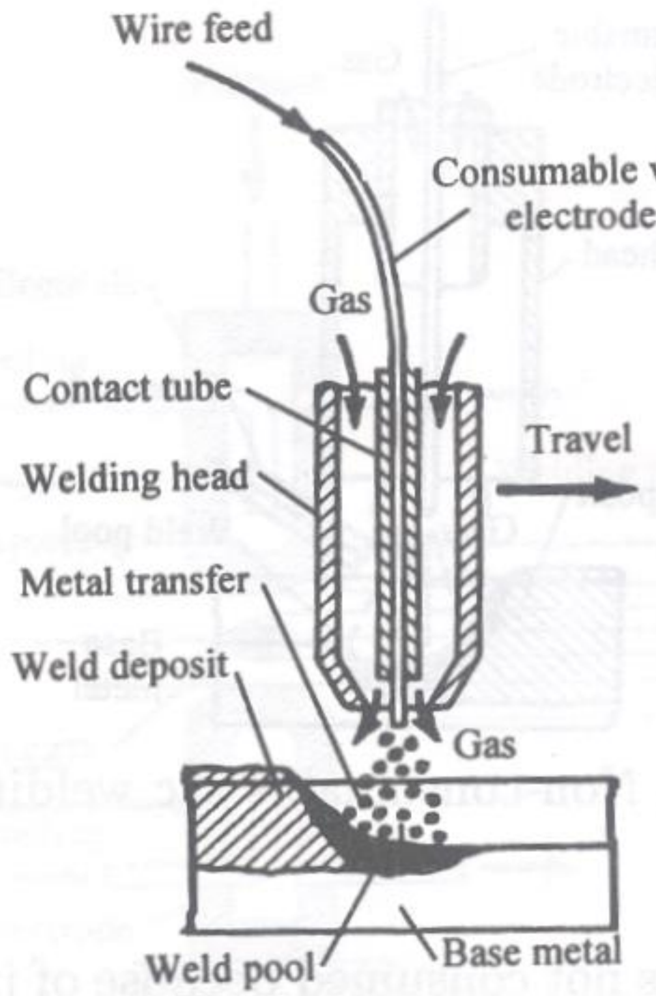
Setting up and running costs for most processes very low. Costs increase with dedication to a product range and the sophistication of heating and shielding methods.

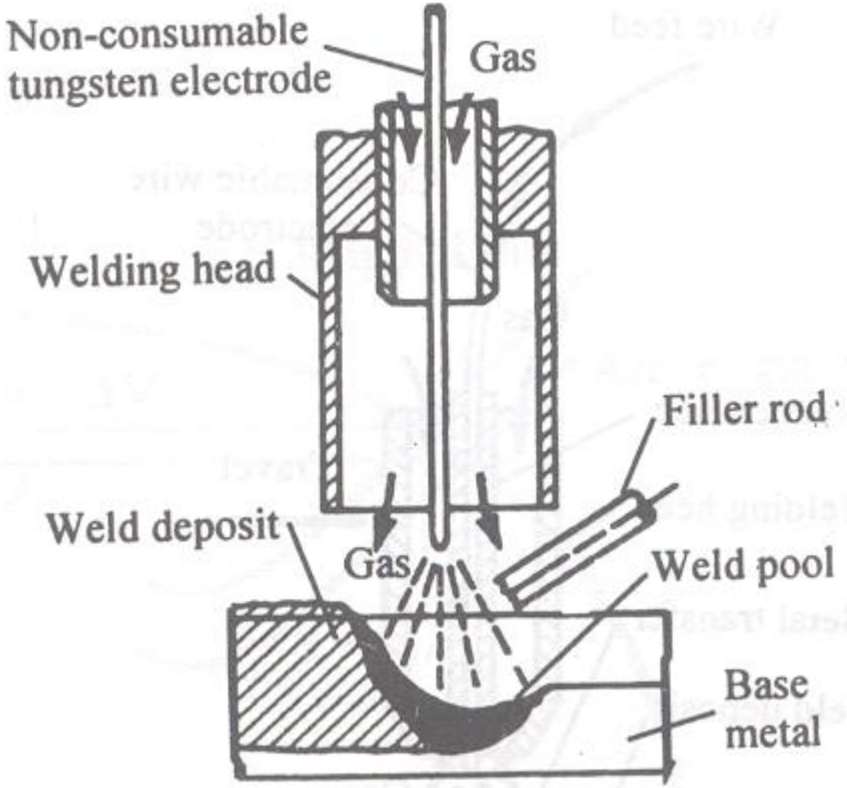
GMAW/MIG

Gas –Metal Arc Welding
or Metal Inert Gas Welding

GTAW/TIG

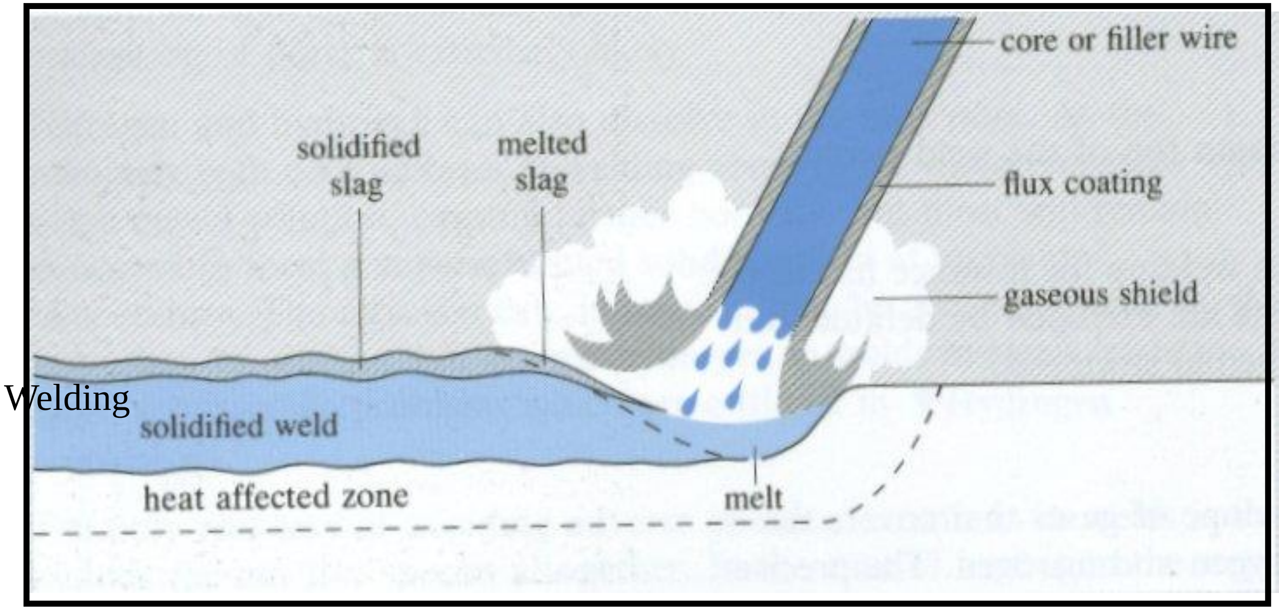
Gas –Tungsten Arc Welding
or Tungsten Inert Gas Welding





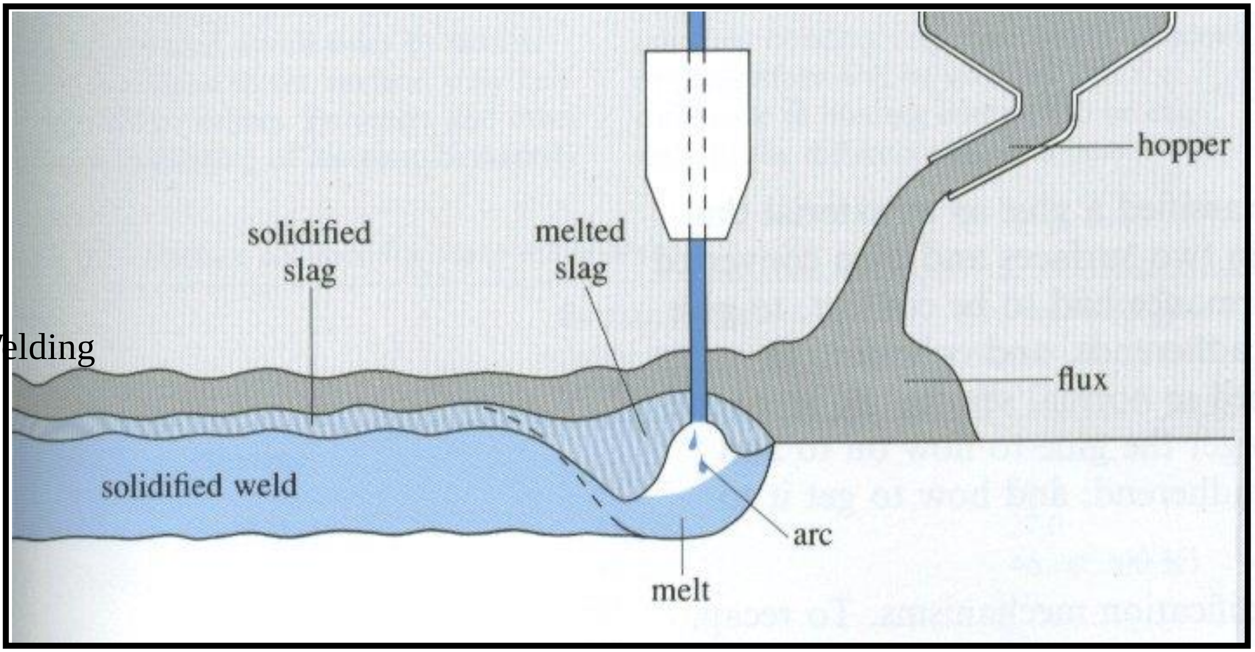
MMAW

Manual Metal Arc Welding



SAW

Submerged Arc Welding



FRICTION WELDING

PROCESS

Solid state

One component is rotated at high speed against another, generating heat. Once sufficiently hot, rotation ceases and the joint is forged.

SHAPE

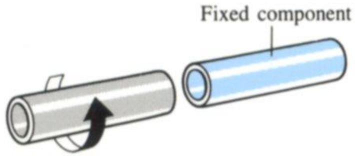
All shapes

At least one component must have circular symmetry.

MATERIALS

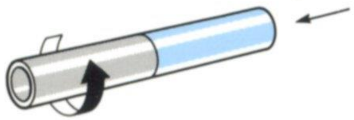
All materials

One component must be ductile when hot to allow deformation during forging. Widely used for joining dissimilar materials.



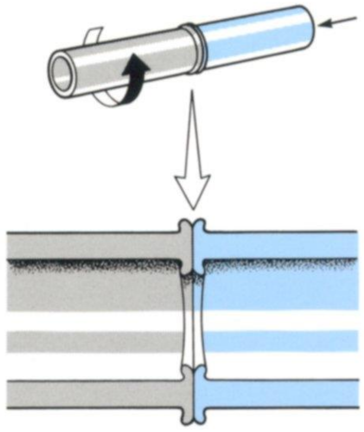
Pre-weld stage

Components with square surfaces to be joined are inserted into machine. One component is held stationary and the other is rotated.



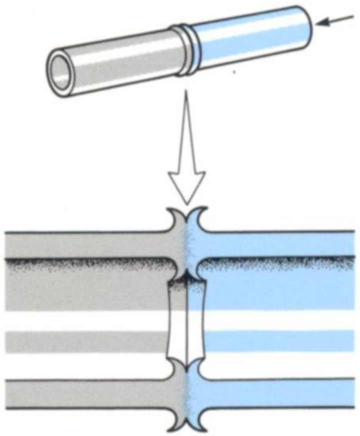
First friction stage

The components are pushed together with a low pressure to clean and prepare the surfaces.



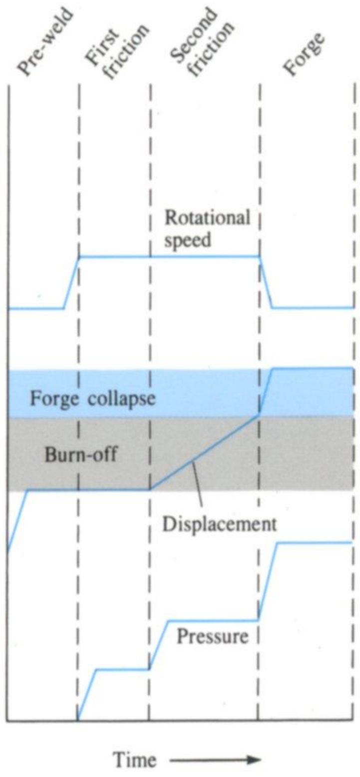
Second friction stage

Pressure is increased and temperature increases so that plasticity, and possibly some melting, occurs at rotating surfaces.



Forge stage

Rotation is stopped and pressure increased rapidly. Any molten metal is squeezed out and a 'forged' joint is produced.



Friction welding cycles

CYCLE TIME

Depends on size of components and materials but can be short if process automated.

QUALITY

Generally good but component positioning critical to production of a sound weld.

FLEXIBILITY

Clamping tooling generally dedicated. Machines can cope with a wide spread of component size.

MATERIALS UTILIZATION

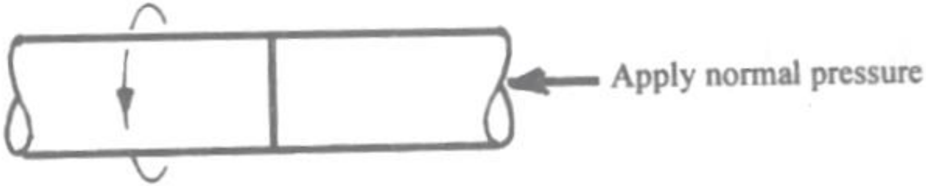
Formation of an upset crucial to the process although this may be incorporated into the component design giving minimal scrap.

OPERATING COST

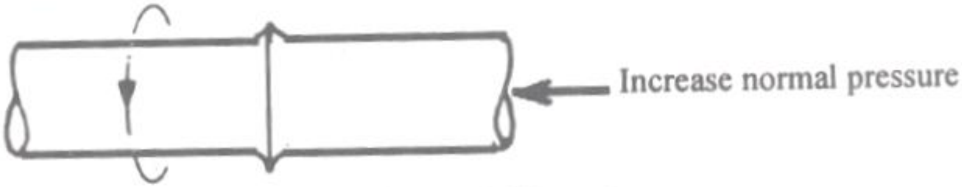
Machines expensive. Tooling costs relatively low.

Friction Welding

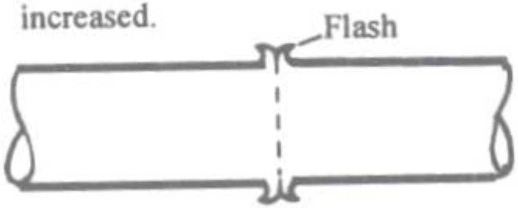
(a) Rotate left part at high speed.



(b) Bring right part in contact and apply axial force.

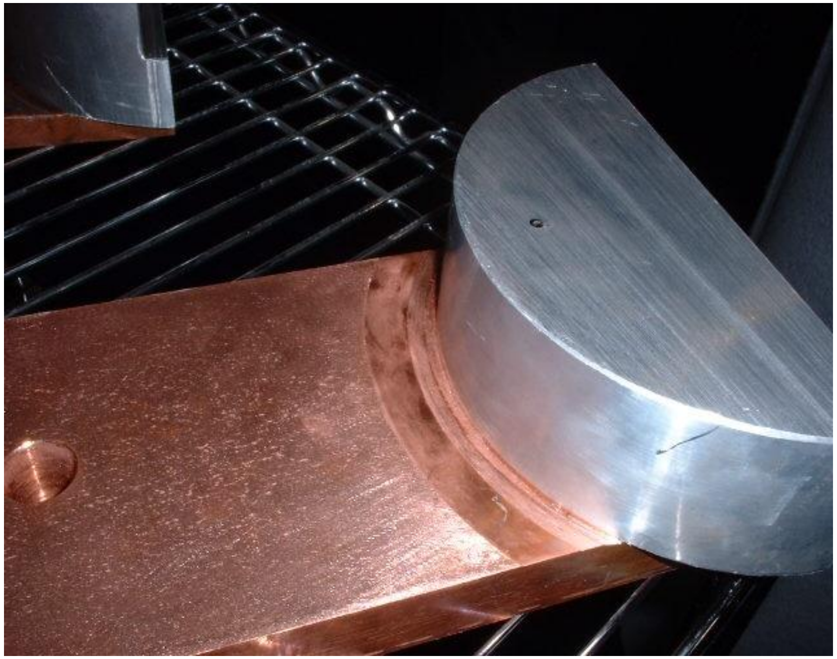


(c) Flash begins to form when axial force is increased.

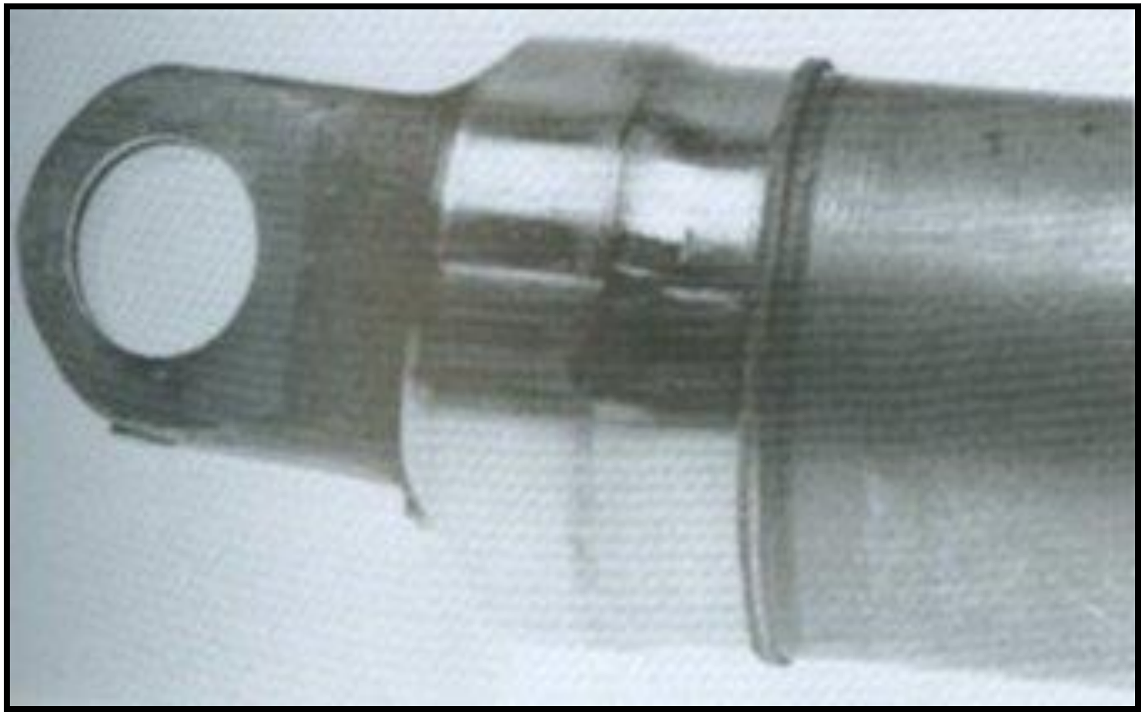


(d) Stop rotating left part when flash is formed.

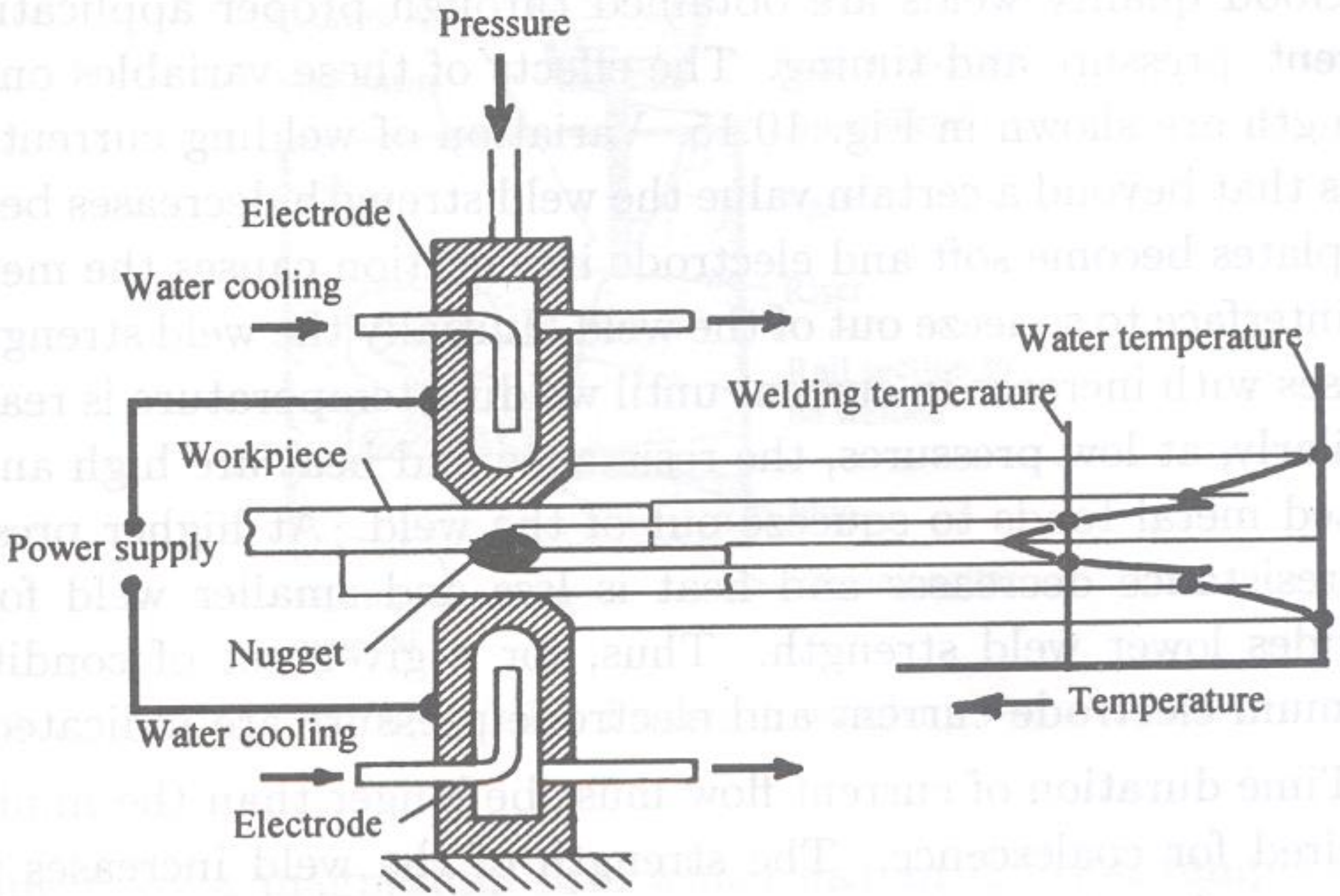
Friction Welded Components



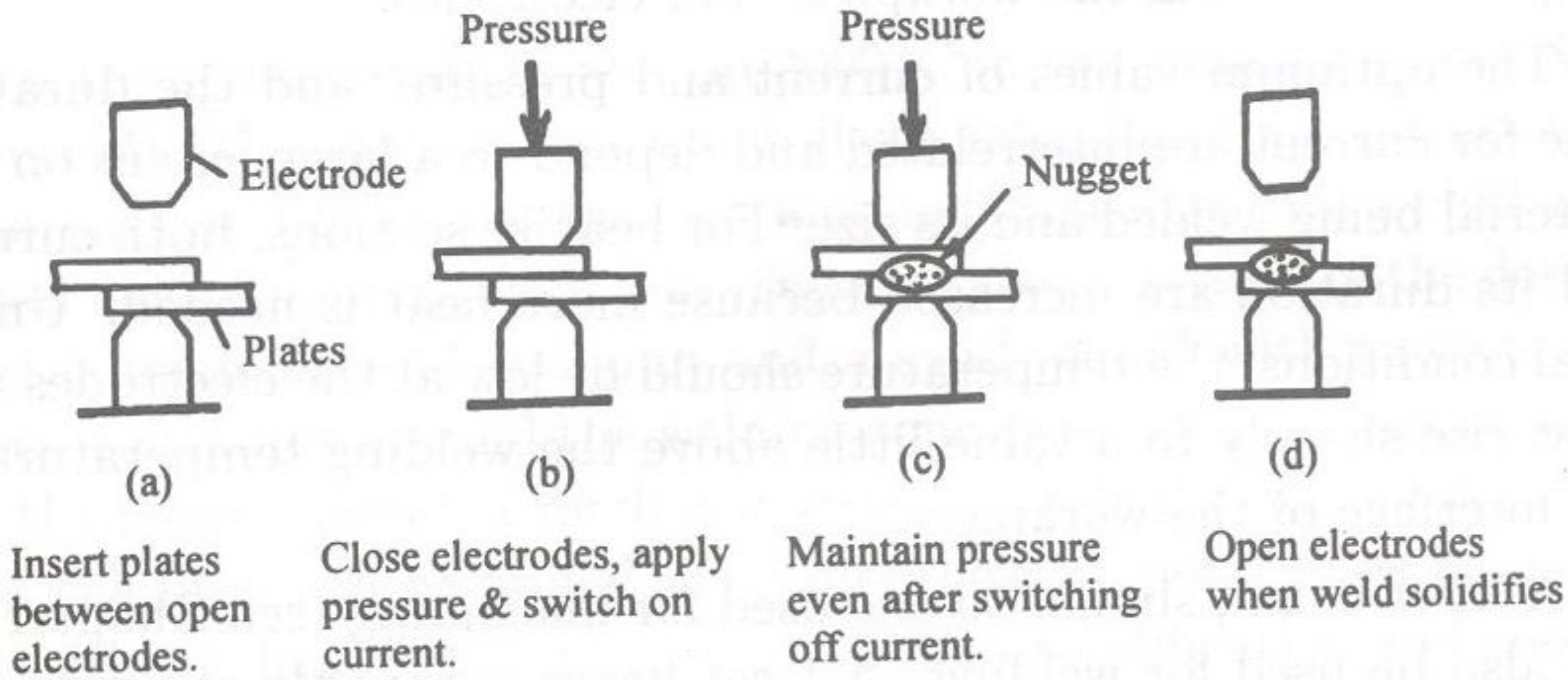
friction welded automotive component



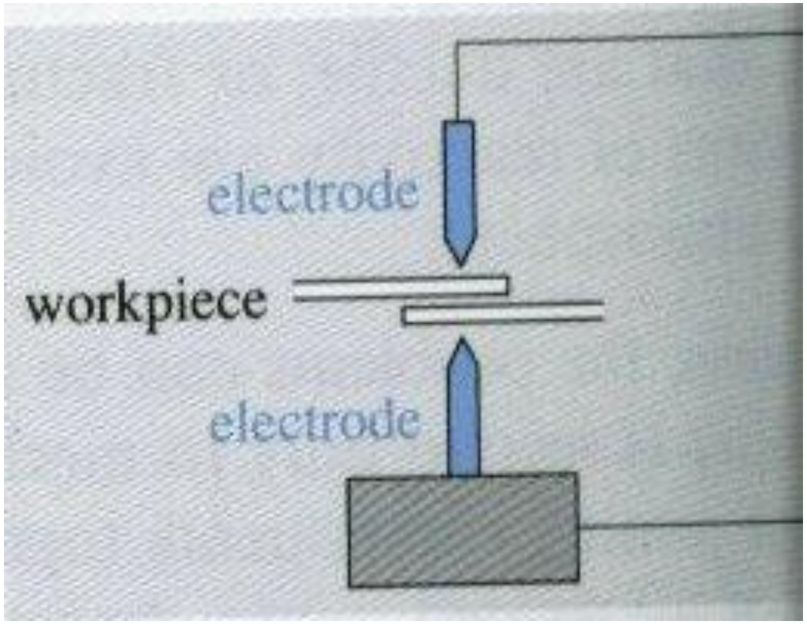
Resistance Welding/Spot Welding/Resistance Spot Welding

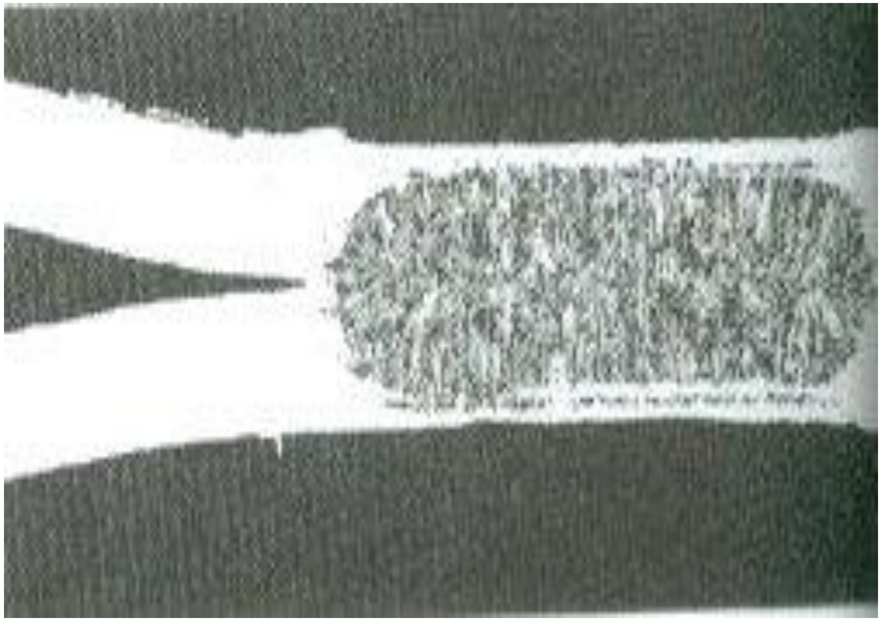


Resistance Welding/Spot Welding/Resistance Spot Welding

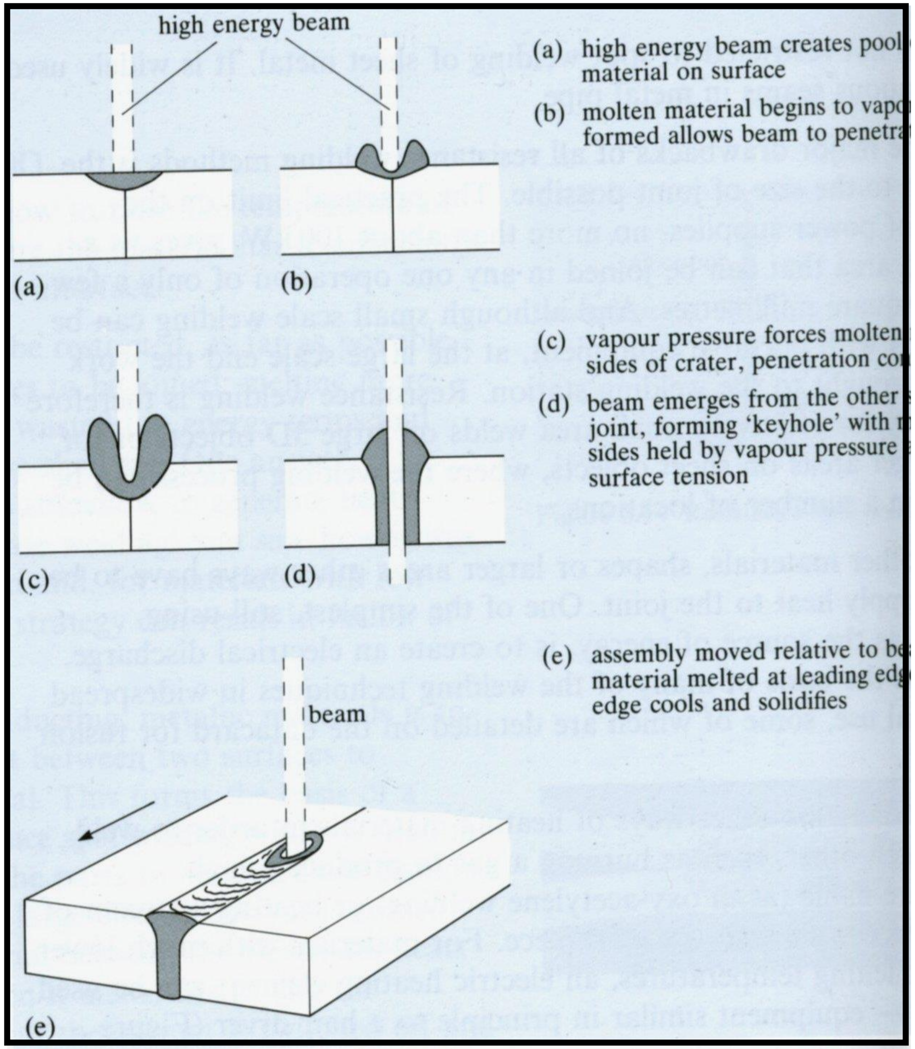


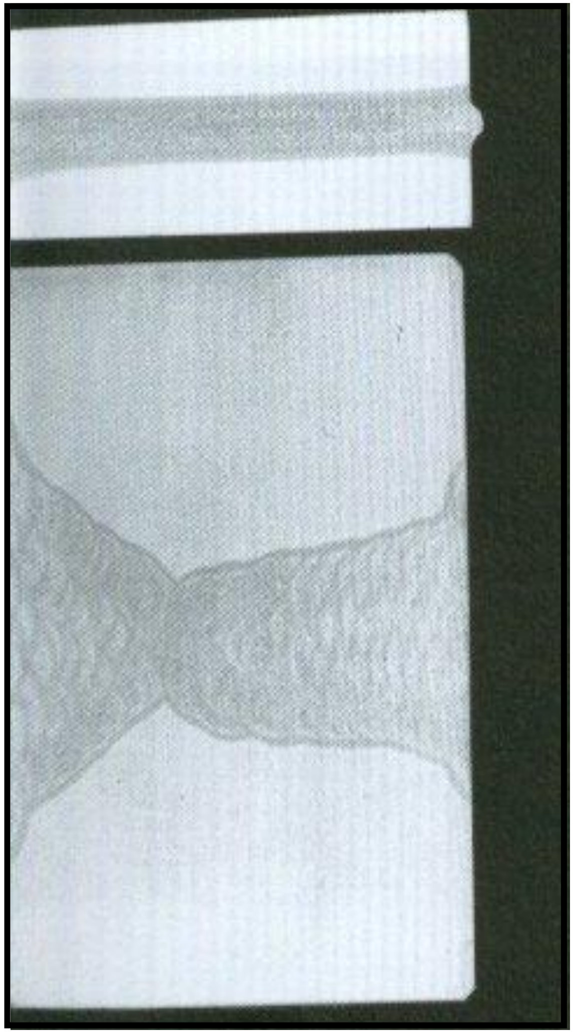
spot welding





Electron-Beam Welding (EBW)
Laser Beam Welding (LBW)

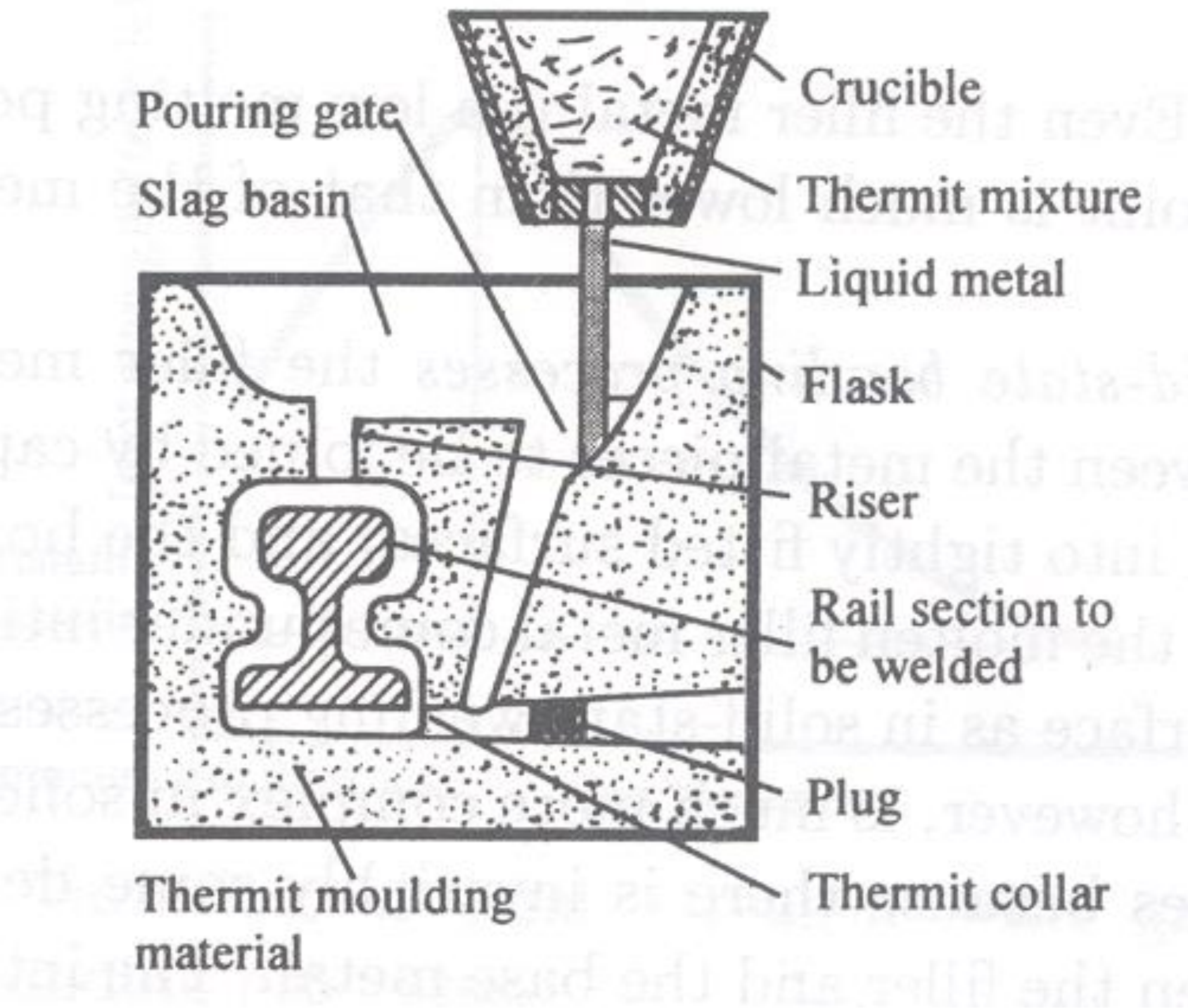




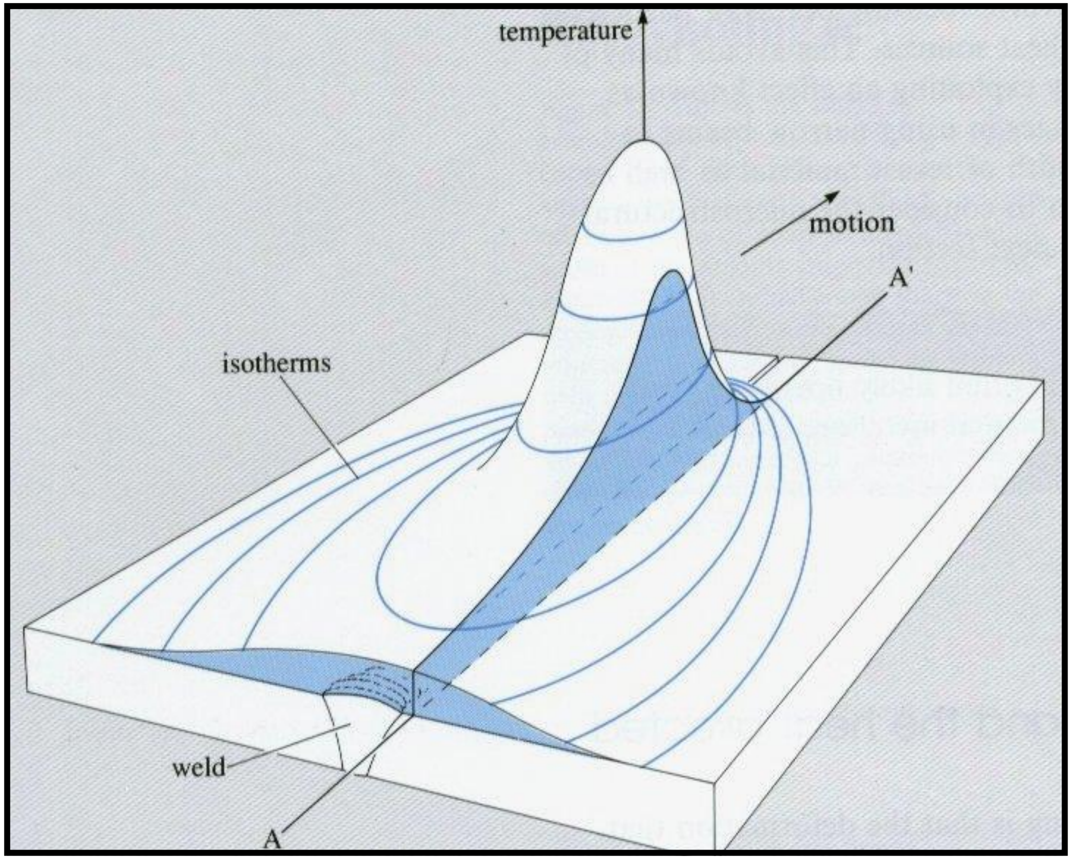
Features: Single pass welding; very fast process; for high thickness:width ratios; Minimal Heat-Affected Zone (HAZ)

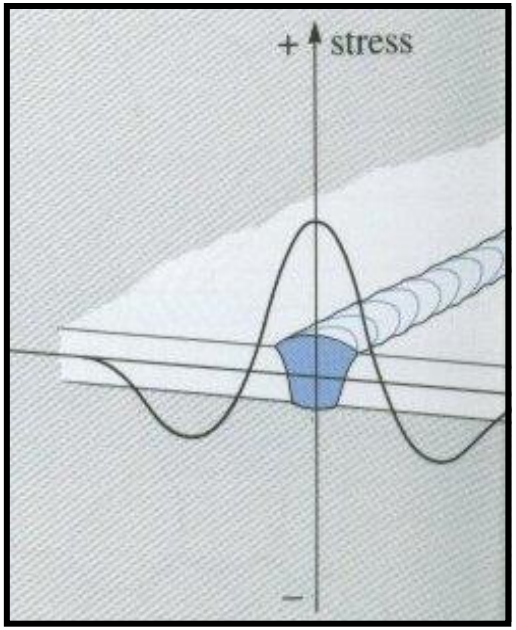
In EBW, the whole setup is maintained under very high vacuum (~10^{-6} torr), whereas LBW done in normal atmosphere

Thermit Welding



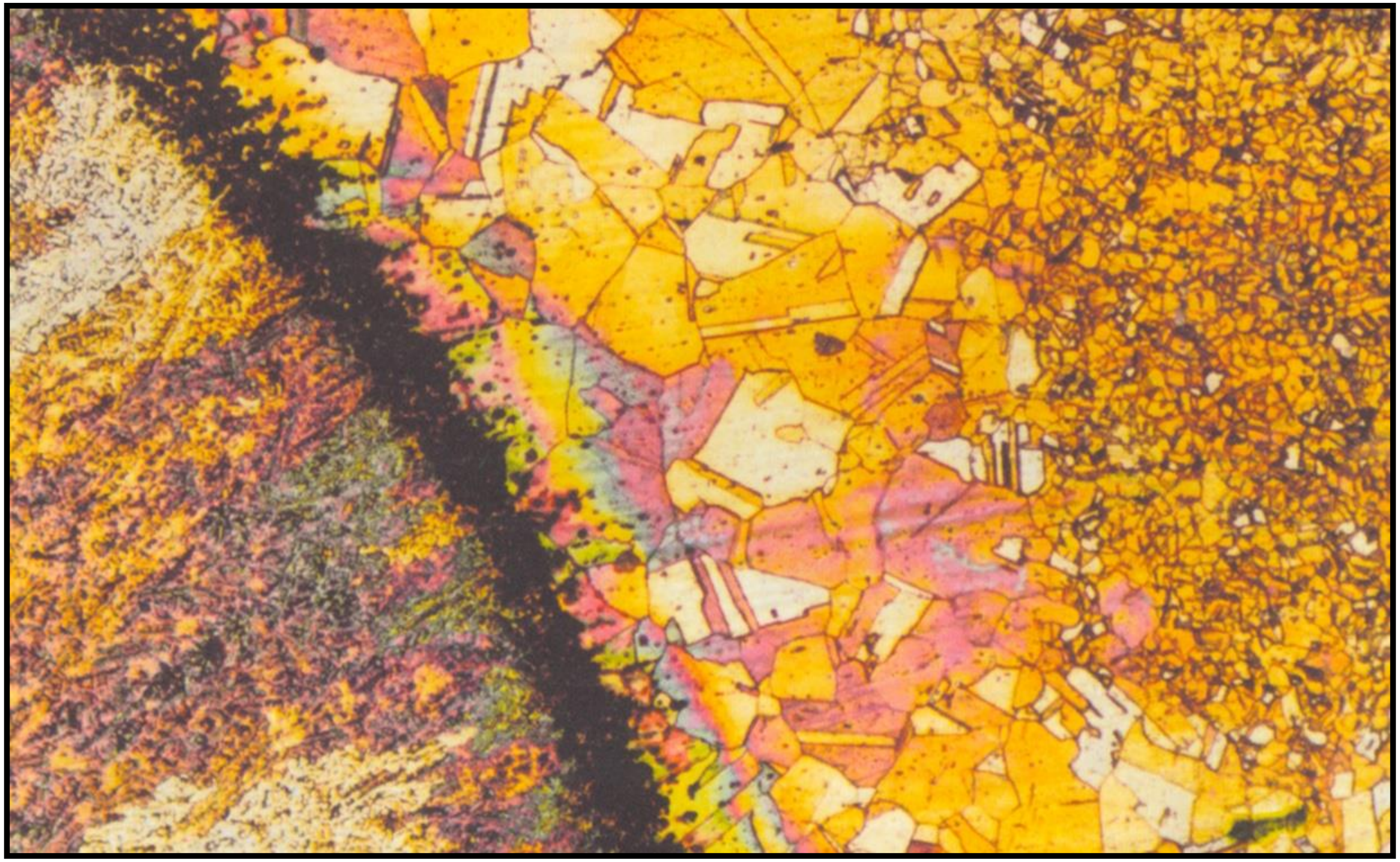
Temperature distribution around a typical weld





Residual stress in simple butt weld

Weld Zone Structure of Stainless Steel
-Effect of Heating



Optical micrograph of a butt weld joint in a stainless steel (grade SS321) showing weldment, fusion zone, heat-affected zone, and parent metal. The picture shows marked grain growth at the HAZ which can lead to failure in the welded structure. This picture was awarded the Ist prizein the Optical Microscopy category during the metallography contest held during NMD-ATM2004.

Source: IIM Metal News, v. 8, n. 4, Aug 2005

Iron Pillar

location: New Delhi, India

fabricated in: 375 - 414 A.D.

dimensions:

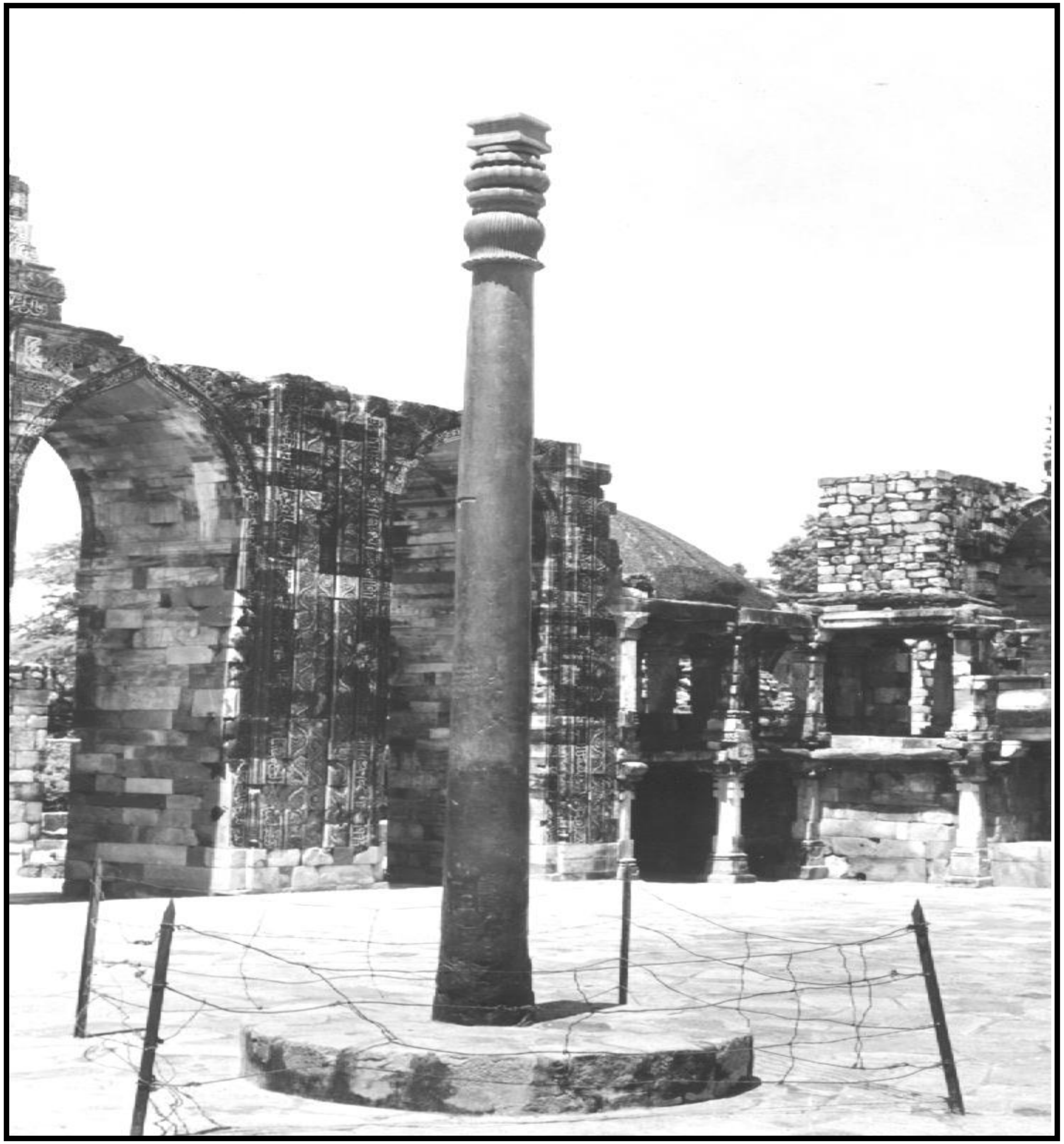
length:	26 ft 6 in
diameter:	1 ft - top
	2 ft - bottom

weight: ~ 6000 kg

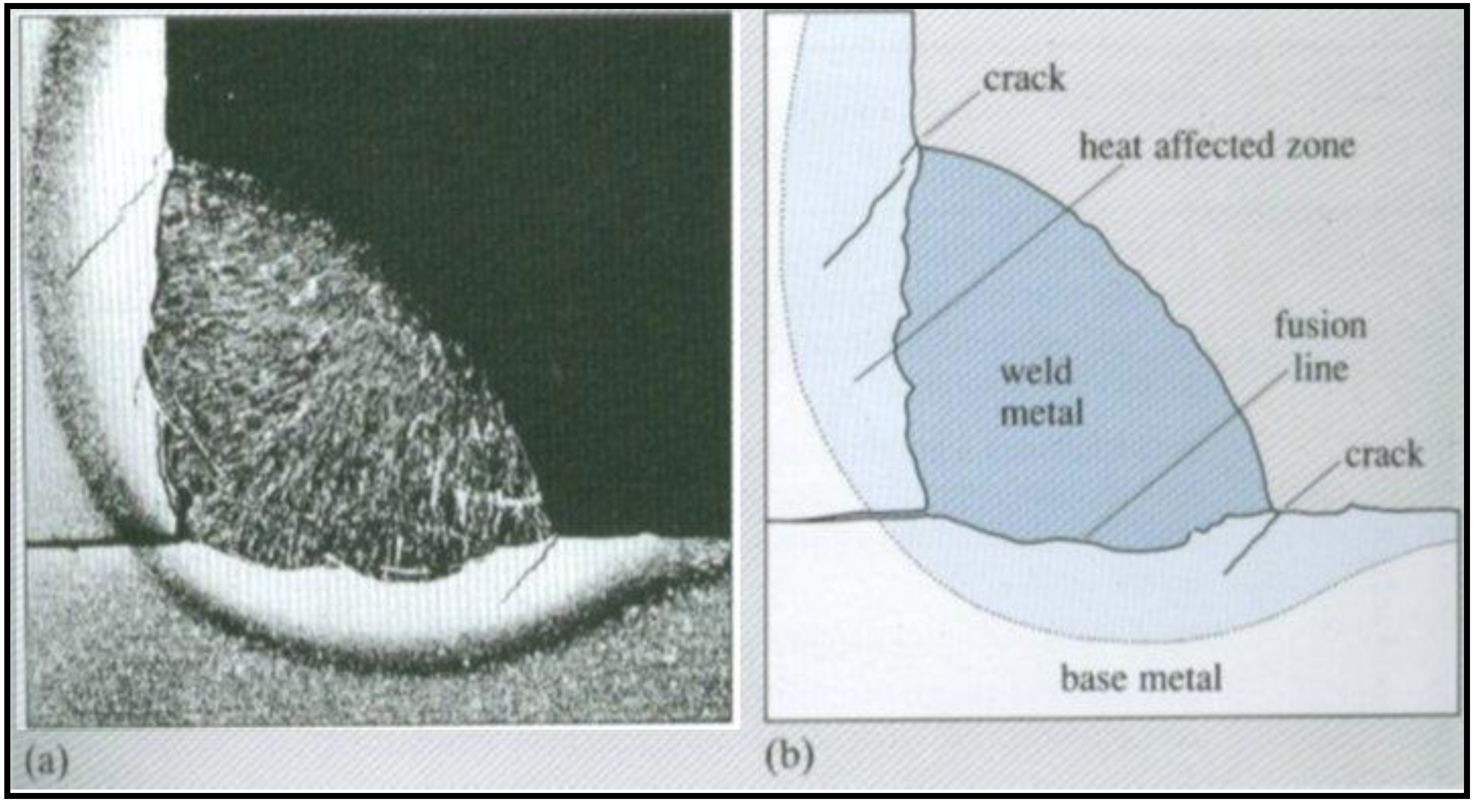
composition (wt.%): **Fe-0.15C-0.25P-0.05Si-0.05Ni-0.05Mn-0.03Cu-0.02N-0.005S**

processing route: **forge welding**

Iron Pillar



Steel joint welded using gas/oxygen heat source



- **hydrogen cracking**

- **lamellar tearing**