Marine Construction & Welding

NA21003

Autumn 2020

Construction Materials

Design Aspects

From the designer's point of view, the material selection is based on the mechanical responses:

- Strength and stiffness (ultimate strength, yield strength, modulus of elasticity)

- Time-dependent material behavior(eg. Fatigue, corrosion)

Manufacturing Aspects

- Ductility/Formability
- Machining and Welding capability
- Resistance to corrosion
- Maintainability

Economic & Environmental Aspects

Material selection based on economic viability

Materials should have the least environmental impact during production, operation and decommissioning phase of the product.

Materials

Metallic materials:

- Structural Steel*
- Aluminium and its alloys*
- Other non-ferrous alloys (Cu-Ni, Al or Mn bronze etc.)
- Titanium (marine riser joints & submersibles)

Non-metallic materials:

- Wood (early shipbuilding)
- Cement & Concrete (gravity based offshore structures)
- Thermoplastics (polymers moulded into various shapes)
- Composites*
- Buoyancy materials (Foams, used in marine risers, buoys etc.)

Steel

Steels are widely used as the material for ship construction

- Good mechanical properties
- Relatively low cost
- Ease of fabrication by welding

Steel

The properties of steel depends on-

- Chemical composition
- Melting practice
- Deoxidation
- Special processing
- Grain refining
- Rolling procedure
- Heat treatment

Aluminium

- Light in weight
- Some alloys have strengths exceeding that of mild steel
- High strength to weight ratio
- Low rigidity: Elastic modulus 70 GPA (Steel 210 GPA)
- High resistance to atmospheric corrosion
- Not toxic
- High thermal conductivity (as compared to steel)
- Necessitates a high rate of heat input for fusion welding
- Aluminum and its alloys develop oxide film when exposed to air

Aluminium

Applications:

Used as pure Al or as an alloy with Cu, Mn, Si, Mg etc.

- Filler alloys for welding
- Hull, superstructures, and stiffeners for weight sensitive vessels
- Tanks in LNG carriers
- Offshore structures exposed to humidity

Fibre Reinforced Composites

Commonly known as GFRP or CFRP, i.e. glass fibre reinforced plastic or carbon fibre reinforced plastic.

The plastic or the polymer material forms the matrix and the glass or the carbon fibres act as the reinforcements.

- Weight reduction
- Corrosion resistance
- Design flexibility
- Low maintenance costs
- Easy reproduction of complicated designs

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Fibre Reinforced Composites

High Specific Strength - Fiber reinforced composites have substantially high strength-to-weight ratios. However its stiffness is rather poor, which limits its applicability as construction material

Enhanced Fatigue Life - Most composites are considered to be more resistant to fatigue.

Corrosion Resistance - Composites do not rust and corrode. Composite material components can be used gainfully where standard metallic components incur high maintenance costs due to corrosion.

Fibre Reinforced Composites

Controllable Thermal Properties

FRP composites exhibit different coefficients of thermal expansion in the fiber direction and perpendicular to the fiber direction, i.e. along the laminate thickness. FRP composites have low thermal conductivity, making them typically good thermal insulators.

Parts Integration

Large and complex structural parts can be fabricated in one operation

Fibre Reinforced Composites

Tailored Properties
Composite material can be engineered to obtain mechanical properties as specifically required in different directions thereby improving efficiency and economy.

Non-Magnetic Properties
GFRP and CFRP composites being non-magnetic, they are effectively used as hull structural material where non-magnetic property is required, e.g. mine sweeper.

Lower Life-Cycle Costs
Composites having high resistance to marine corrosion requires less maintenance resulting in lower overall life-cycle costs.

Fibre Reinforced Composites

Source: http://www.sintesfiberglass.com/

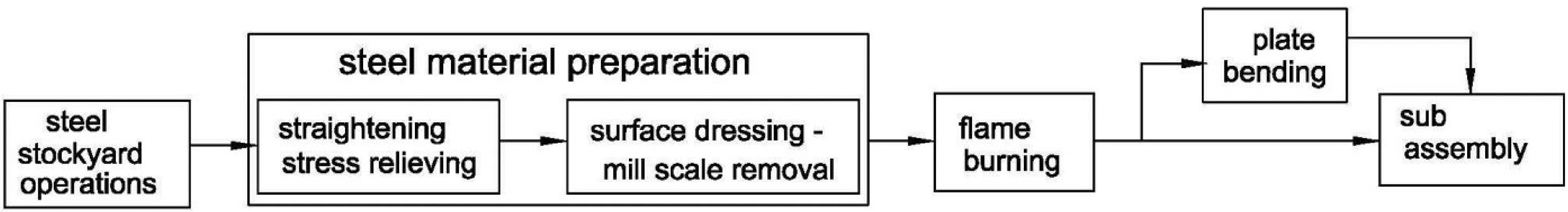
Fibre Reinforced Composites

Composite propeller blade fabrication process by A.I.R., Germany ***(Chen et al., 2009)***
Carbon fiber layers are stacked with resin

Material Preparation

Steel Material Preparation

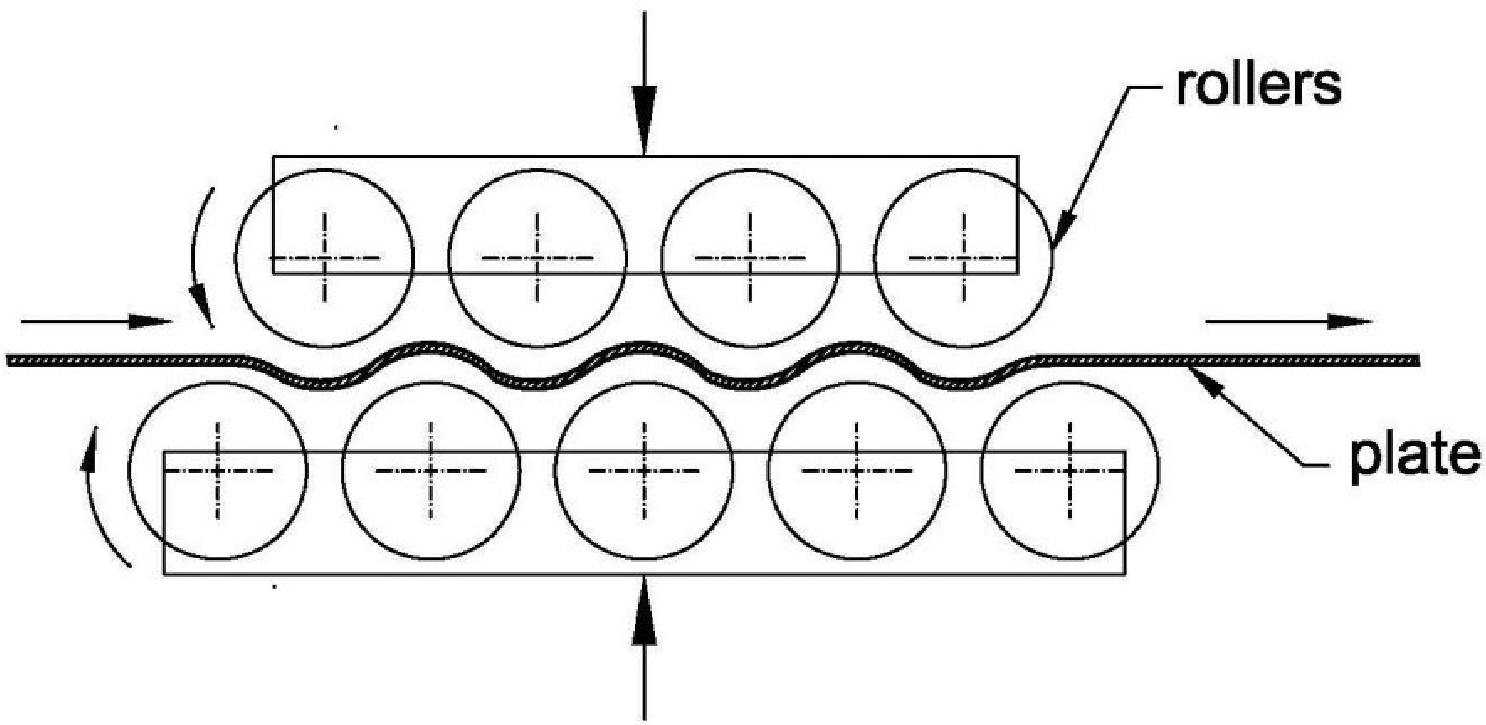
Production workflow from steel stockyard to the fabrication of assemblies:



Straightening and Stress relieving

The steel plates are passed through a machine consisting of multiple rollers

Straightening and residual stress relieving is done by the reversal of plastic bending



Mill scale removal

Mill scale is a layer of ferric and ferrous oxides formed on the plate surface during the hot rolling operation of the steel plates in steel rolling mills.

The scale layer peels out with time in contact with the environment. If not removed the scale would peel off with the paint coating over the hull surface.

Mill scale removal is also necessary to avoid defects in welding during the fabrication process.

Mill scale removal

Several surface dressing methods can be used to remove mill scales:

- Flame treatment
- Manual wire brushing
- Sand blasting
- Shot blasting*
- Chemical pickling*

Shot Blasting

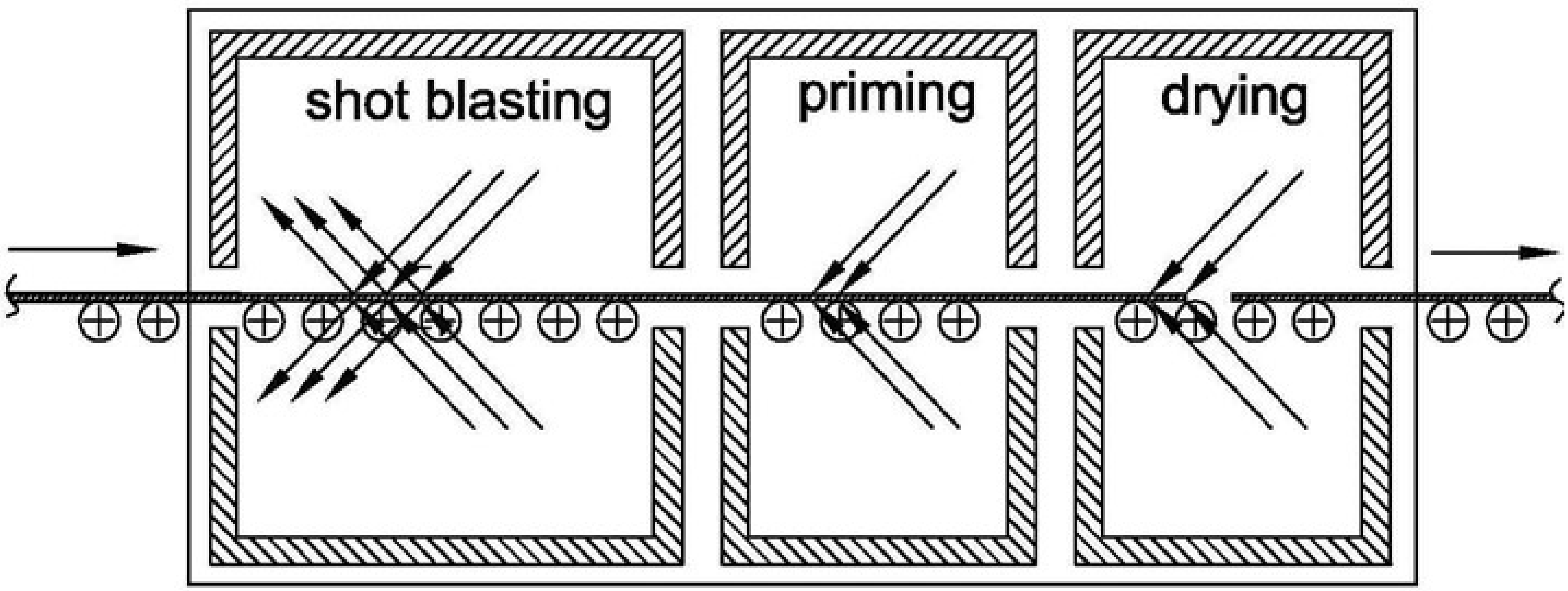
A very effective method in removing mill scale from steel plates.

Shot blasting- Tiny metal shots are fired on the metal surface from both sides. They chip off the mill scale with it exposing the bare steel plate.

Priming- In the priming chamber, the plate is given a coat of primer paint, generally rich in zinc, to protect it from atmospheric corrosion forming rust.

Drying- In the drying chamber, the plate is subjected to hot air jet for drying of the primer paint

Shot Blasting



The size, velocity, and angle of the shots must be controlled to achieve effective scale removal without damaging the plate

Shot Blasting

Merits:

- Completely removal can be obtained by proper controlling of parameters.
- No dust or noise pollution is caused as the process is carried out in a noise and dust insulated chamber.
- The efficiency of this process is generally very high- about 100 to 200 m^2/hr.

Shot Blasting

Demerits:

- Lesser thickness plates upto 6 mm may get deformed.
- When the shots strike the plate, locally the stress may exceed the yield stress at that leading to formation of cracks.
- Improper selection of process parameters may cause the shots to chip off part of the metal along with the mill scale or cause incomplete removal of mill scale.

Acid pickling

The mill scale is removed through chemical reaction.

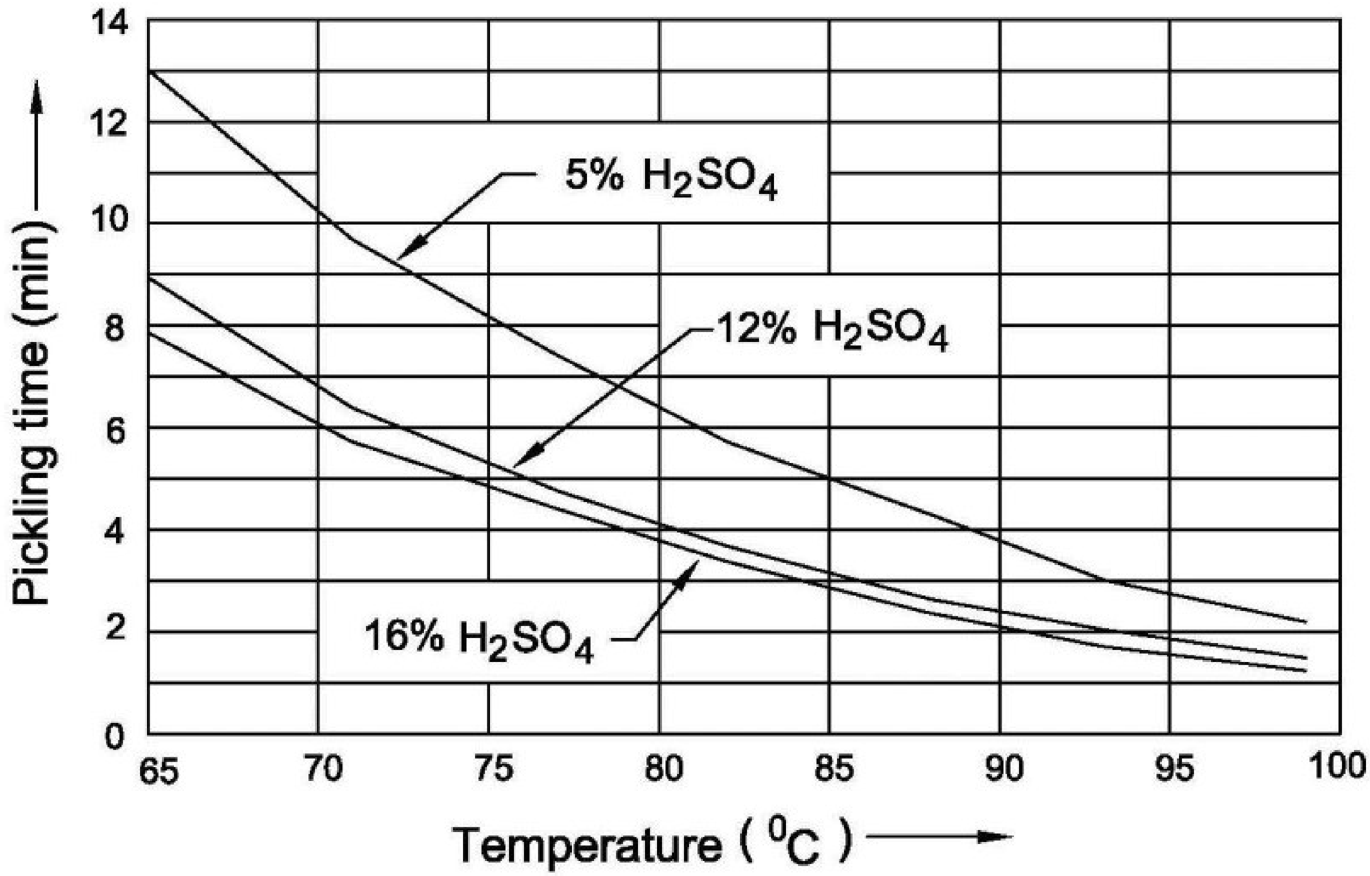
The mill scale is dissolved from the steel surface using an acid. Generally HCL or $H2SO_4$.

The pickling time decreases with increase in temperature as well as acid concentration.

For effective pickling adequate agitation of the acid bath is done.

A water bath is next used followed by an alkali wash to removes the acid from the plates.

Acid pickling



Pickling time decreases with increase in temperature and acid concentration

Acid pickling

Merits:

- Work hardening does not occur.
- Thin plates are not deformed
- Noise free method.

Acid pickling

Demerits:

- Using chemicals (acids and alkali) may be hazardous.
- Water requirement is high
- Acid fumes may cause damage to equipment

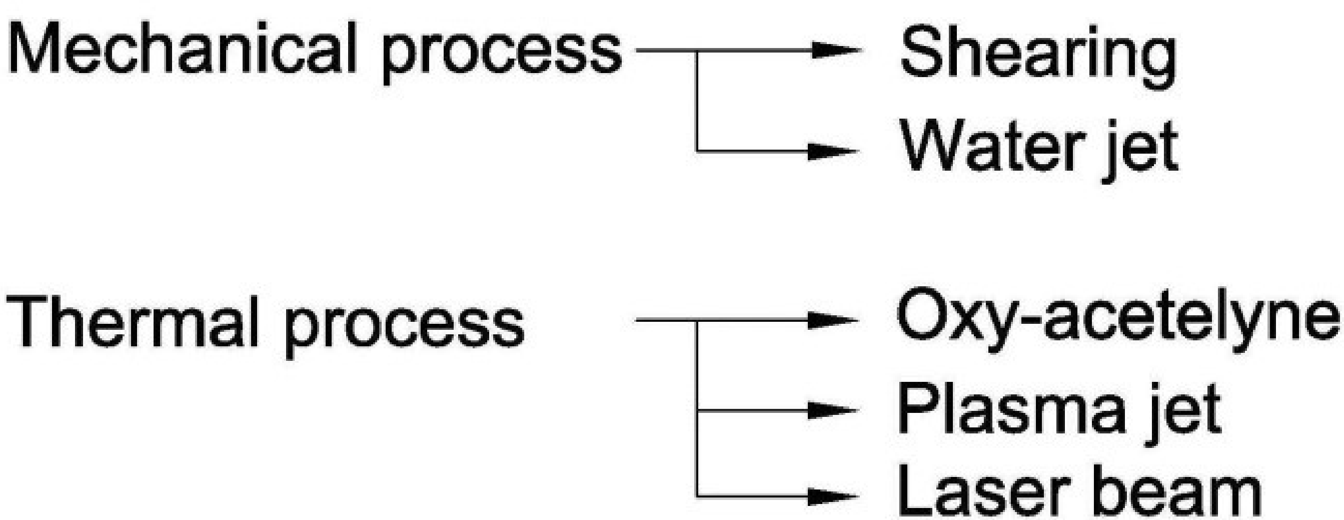
Plate Cutting

Plate Cutting

Plate cutting is a very important activity in a shipyard.

Cutting processes may vary from manually operated gas torch to numerically operated systems.

Classification of cutting methods:



Mechanical Shearing

Mechanical cutting by shearing is done by the action of two blades, one fixed at the bottom and one moving vertically above.

The moving blade has an inclined edge.

Waterjet Cutting

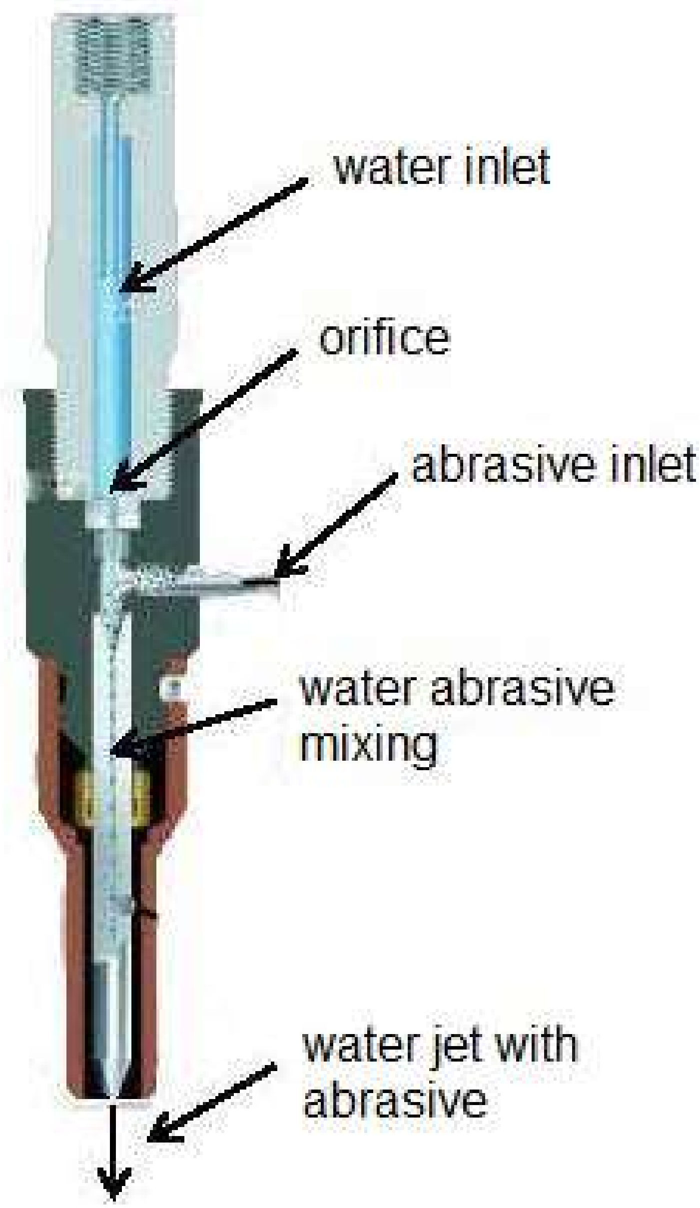
A jet of water is forced through a small orifice, under extremely high pressure (1300 to 6200 bar).

The thin stream of water leaves the orifice at very high velocity, and a separate line feeds fine abrasive particles to the water jet.

Waterjet Cutting

The abrasive particles mix with the water in the mixing tube.

They are then accelerated through the orifice by the water jet and cuts through the metals.



Thermal Cutting

- Oxy-fuel flame cutting
- Plasma cutting
- Laser cutting

Oxy-fuel flame cutting

A process of cutting through **oxidation** (burning)

A fuel gas is burnt in presence of oxygen to generate the required heat.

Oxy-fuel flame cutting

For shipyard applications, generally in acetylene gas is used as the fuel because of its higher calorific value of 18,890 kJ/m3.

The material is brought to the ignition temperature, about 1000°C for steel, by an oxy-acetylene flame and is then burnt by supplying additional oxygen to the heated zone.
The oxide in the molten state is blown off by the gas jet.

Oxy-fuel flame cutting

CONDITIONS:

- The ignition temperature (oxidation) of the material has to be lower than its melting temperature, otherwise the metal will melt and cutting cannot be done.

- The melting temperature of the oxides has to be lower than the melting temperature of the material.

- The ignition temperature has to be continuously maintained by the gas flame due to the heat losses by way of conduction and convection.

- The oxidation reaction between the oxygen jet and the metal must be an exothermic one to maintain a positive heat balance.

Only **steel** and **titanium** satisfy these conditions and therefore oxy-acetylene cutting is possible for these metals.

Oxy-fuel flame cutting

Adverse Effects:

- Carbonisation (increase in carbon content) may occur at the cut edge. This results in hardening of the flame cut surface.

- The cooling rate of the plate increases with an increase in plate thickness. The increase in cooling rate leads to increase in grain size. This along with carbonisation of the cut surface results in increase in hardness of the flame cut surface.
To prevent higher cooling rate in thicker plates, preheating is done.

- Heat induced shrinkage of the cut edges may cause alignment problems in structural fabrication. Thermal stresses may also cause buckling of plate edges.

Plasma arc cutting

A process of cutting through **fusion**

In very high temperature, high velocity ionised gas jet (plasma) is used to melt the plate and the molten metal is blown off.

When steam is energized, the gases that make up the steam get ionised. Some electrons break away from their atoms in the steam. These free electrons make the resulting ionised gas (steam) electrically conductive. This state of the electrically conductive ionized gas is referred to as **plasma.**

Plasma arc Cutting

Merits:

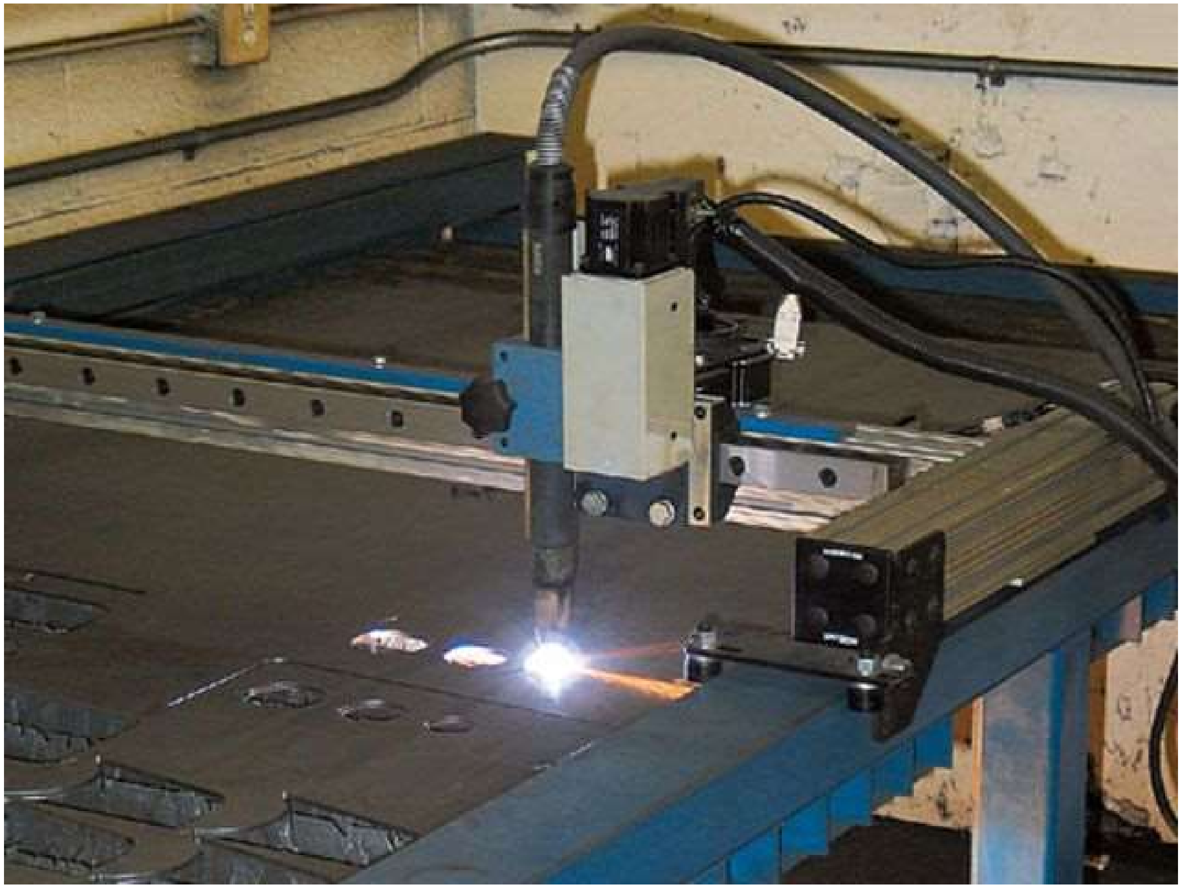
- It can cut all metals.
- Higher cutting speed compared to oxy-acetylene cutting, especially on steels less than 25 mm thick.
- Heat affected zone and heat induced deformation are minimised.
- Carbonisation of cut edge does not take place.
- Hazardous or explosive gases are not used.

Plasma arc Cutting

There are many methods of plasma arc cutting.

Two general methods are:

- Plasma cutting with transferred arc
- Plasma cutting with non-transferred arc

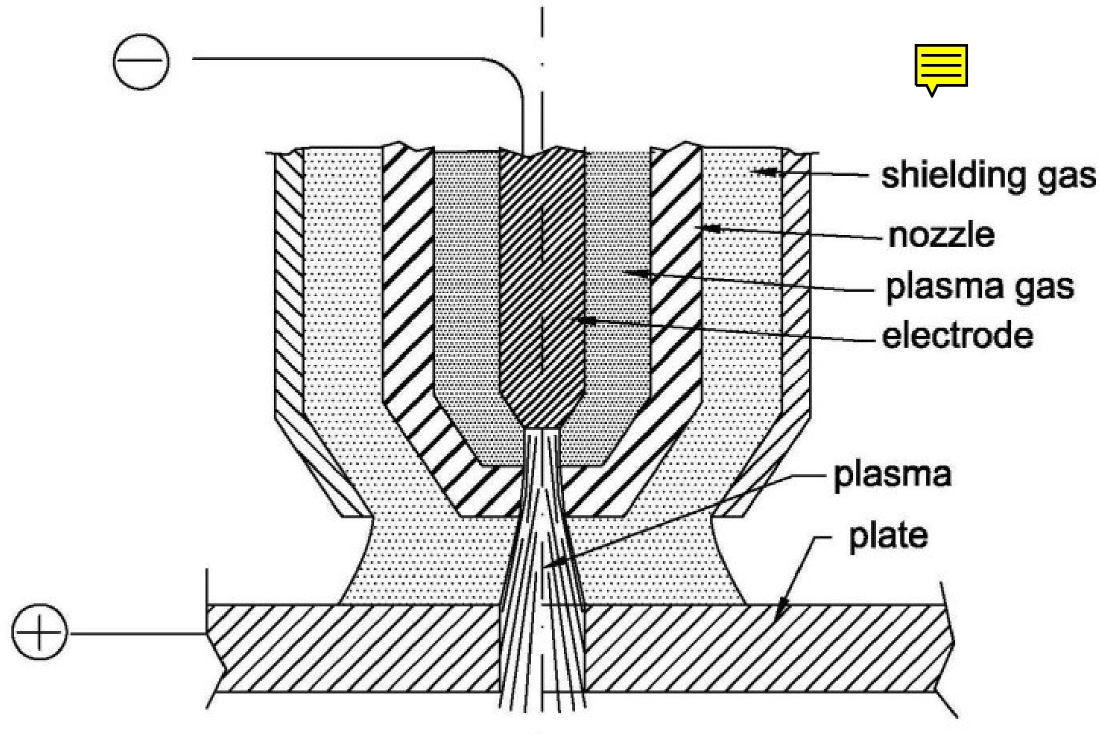


Plasma arc Cutting with transferred arc

The arc is between the plasma torch electrode (cathode) and the workpiece (anode)

Only electrically conductive materials can be cut by this method.

Additional gas is supplied to the plasma arc torch for shielding the plasma jet as well as to cool the torch.

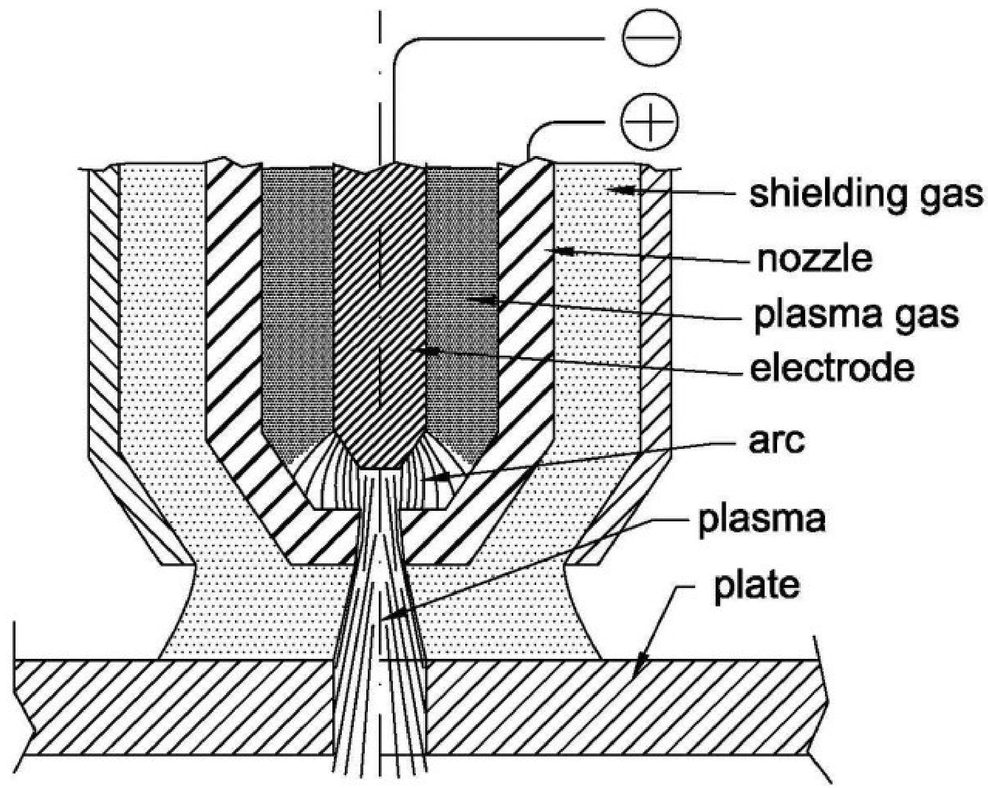


Plasma arc Cutting with non-transferred arc

The arc is present inside the nozzle between the electrode and the nozzle body

The hot stream of plasma jet comes out of the nozzle orifice in the form of flame.

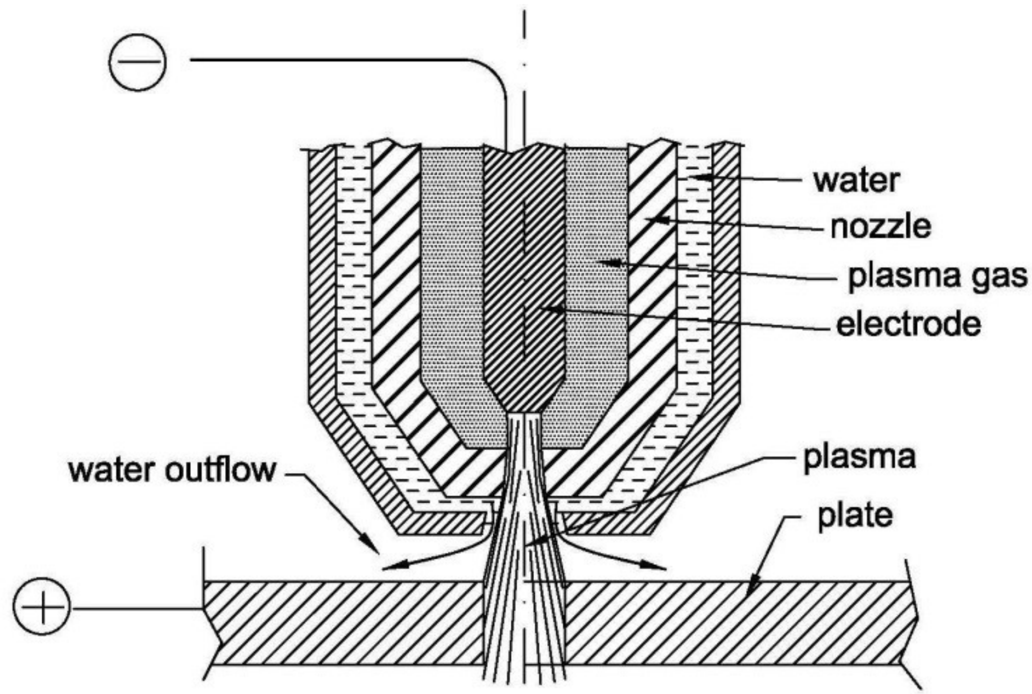
Can be used to cut electrically non-conducting materials.



Plasma arc Cutting with transferred arc & water injection

Here, water is injected, leading to greater constriction of the plasma jet and higher temperatures.

Better cut quality and higher speed obtained. Reduction in nozzle erosion increases its usable life.



Laser cutting

A process of cutting using **laser** as the heat source.

Using a lens, a high intensity laser beam is focused on a small area of the plate, which melts instantaneously.