MARINE CONSTRUCTION & WELDING

NA21003

Welding

- Introduction
- Welding Parameters
- Fusion Welding Methods
- Solid State Welding
- Residual Stress and Distortion
- Distortion Control and Mitigation
- Welding defects

Introduction

Introduction

Welding is a fabrication process used to join materials, usually metals or thermoplastics.

Generally done by fusion of the base metal, while other processes may also be used where melting is not involved.

A filler material may be added in the welded joint of the base material to make it stronger.

Power source

Generally electric energy is used in the form of an arc for welding.

Fusion welding is a **thermal** process. The joining takes place through melting of the joined edges.

The heat energy required can be derived from various sources:

oxyacetylene flame,
electrical energy in the form of arc,
laser beam,
solar energy, etc.

Power source

Classification of the power sources are based on their static volt-ampere characteristics:

- **Constant-potential** power sources usually have near constant voltage output.
- **Constant-current** sources have constant-current output.
- **Pulsed** power sources can provide power in pulses over a broad range of frequencies.

Welding Parameters

Welding Parameters

Weld quality and weld metal deposition rate both are influenced very much by the various welding parameters as well as the joint geometry.

- Welding current.
- Arc voltage.
- Welding speed.
- Electrode feed speed.
- Electrode extension (length of stickout).
- Electrode diameter.
- Electrode orientation.
- Electrode polarity.
- Shielding gas composition
- Marangoni convection.

Welding Current

Welding current is the most influential variable in a welding process.

It controls the electrode melting rate and hence the deposition rate, the depth of penetration, and the amount of base metal melted.

For too high current at a given welding speed, the depth of fusion or penetration will be too great. Too low current may result in lack of fusion or inadequate penetration.

For an electrode, melting rate is directly related to electrical energy supplied to the arc.

$$Q = I\,V \quad \text{J/s}, \qquad \text{or} \qquad Q = I^2 R_a \quad \text{J/s},$$

where,

Q = electrical energy consumed,

I = welding current,

V = arc voltage,

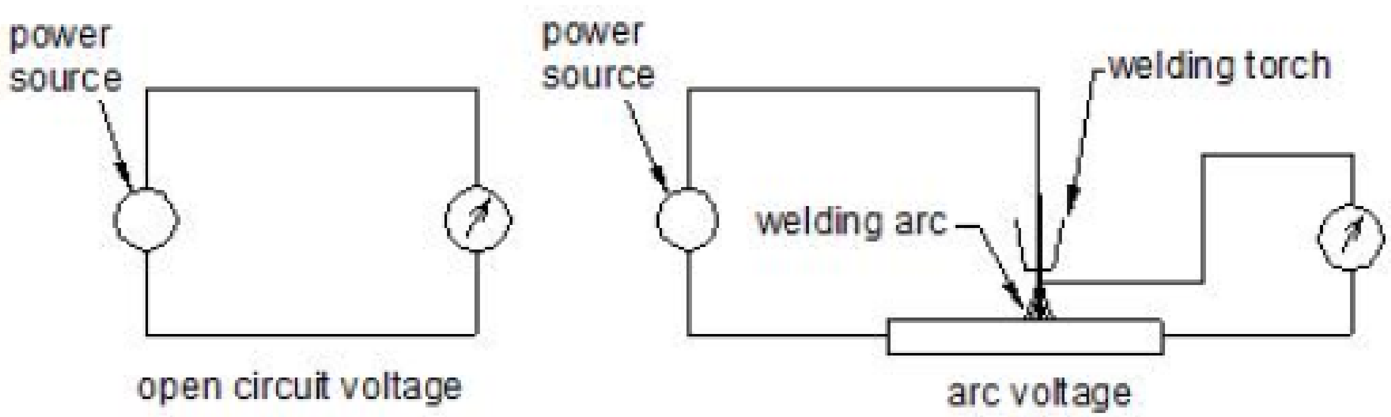
R_a = arc resistance.

Welding Arc Voltage

Arc voltage is the voltage between the electrode tip and the job during welding.

Open circuit voltage, on the other hand, is the voltage generated by the power source when no welding is done.

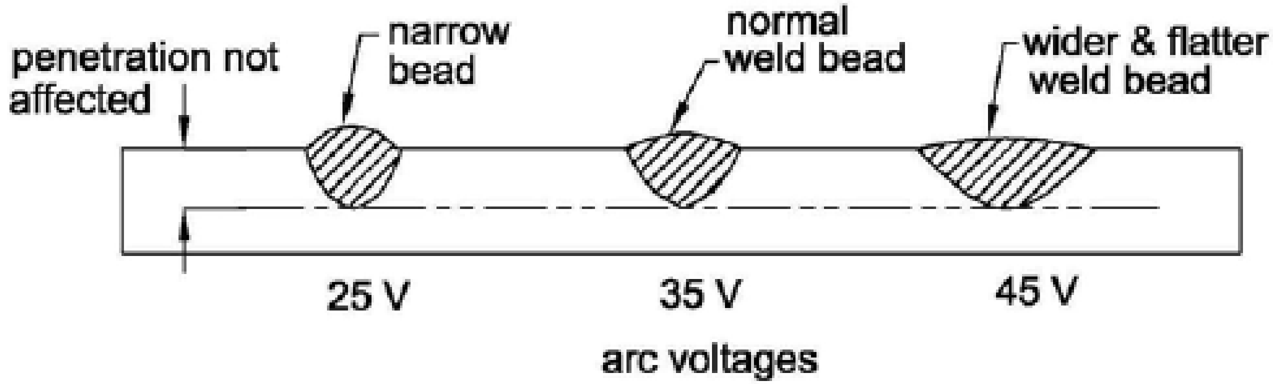
Arc voltage is the voltage drop across the arc column determined by arc length for any given electrode.



Arc voltage depends on the arc length and the type of electrode.

Welding Arc Voltage

Variation of arc voltage influences the fusion zone, and hence the shape of the weld bead.



Welding Speed

Welding speed is the linear rate at which the arc moves along a weld joint.

Welding speed controls the actual welding time having a direct effect on the production cost.

Increase of Welding Speed:

- Heat input per unit length of welded joint decreases
- Less filler metal is deposited, resulting in lack of weld deposition
- Reduction in distortion and residual stress

Decrease of Welding Speed

- Filler metal deposition rate increases
- Rate of heat input increases, weld beads become wider
- Increase in heat-affected zone (HAZ), residual stress and distortion

Electrode Feed Speed

The electrode feed speed determines the amount of metal deposited per unit length of weld or metal deposited per unit time.

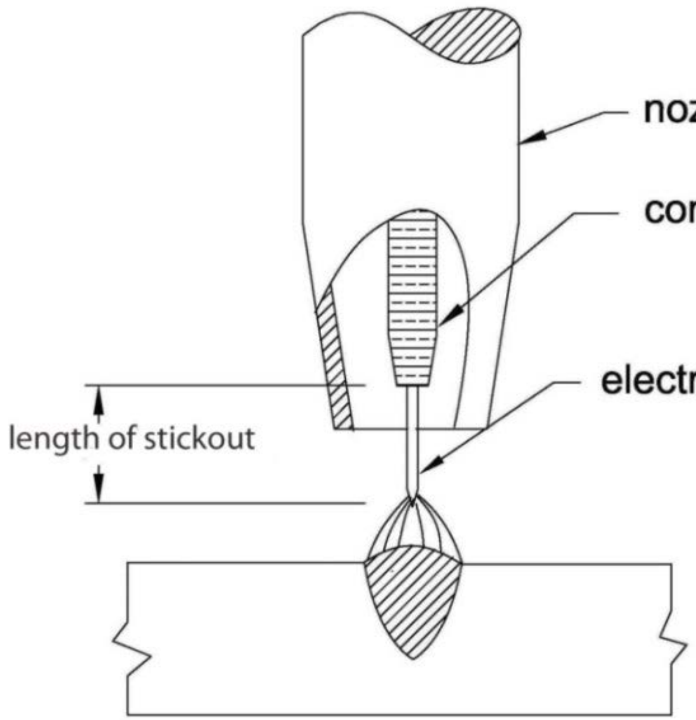
Increasing electrode feed speed automatically increases the arc current and vice versa.

Electrode extension

The **electrode extension** (length of stickout) is the distance between the end of the contact tube to the electrode tip.

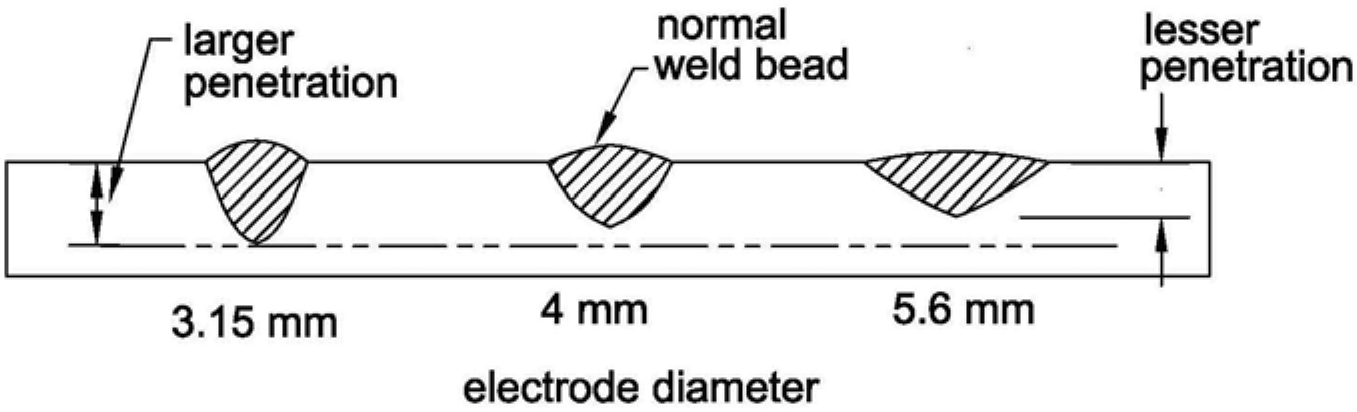
Increase in the length of stickout increases electrical resistance of the electrode as well as the welding circuit causing decrease in arc voltage.

Greater extension also gives rise to additional heat generation and increases the electrode melting rate, and more metal deposition.



Electrode diameter

The **electrode diameter** influences the weld bead configuration.



At a given current level, a smaller diameter electrode will have a higher current density causing greater weld penetration than a larger diameter electrode.

However electrodes of different diameter will have a limiting current density, beyond which the welding arc becomes unstable and erratic.

Hence, the electrode diameter should be increased with increasing current in order to increase deposition rate.

Electrode orientation

The **electrode orientation** with respect to the weld joint affects the weld bead shape as well as weld penetration.

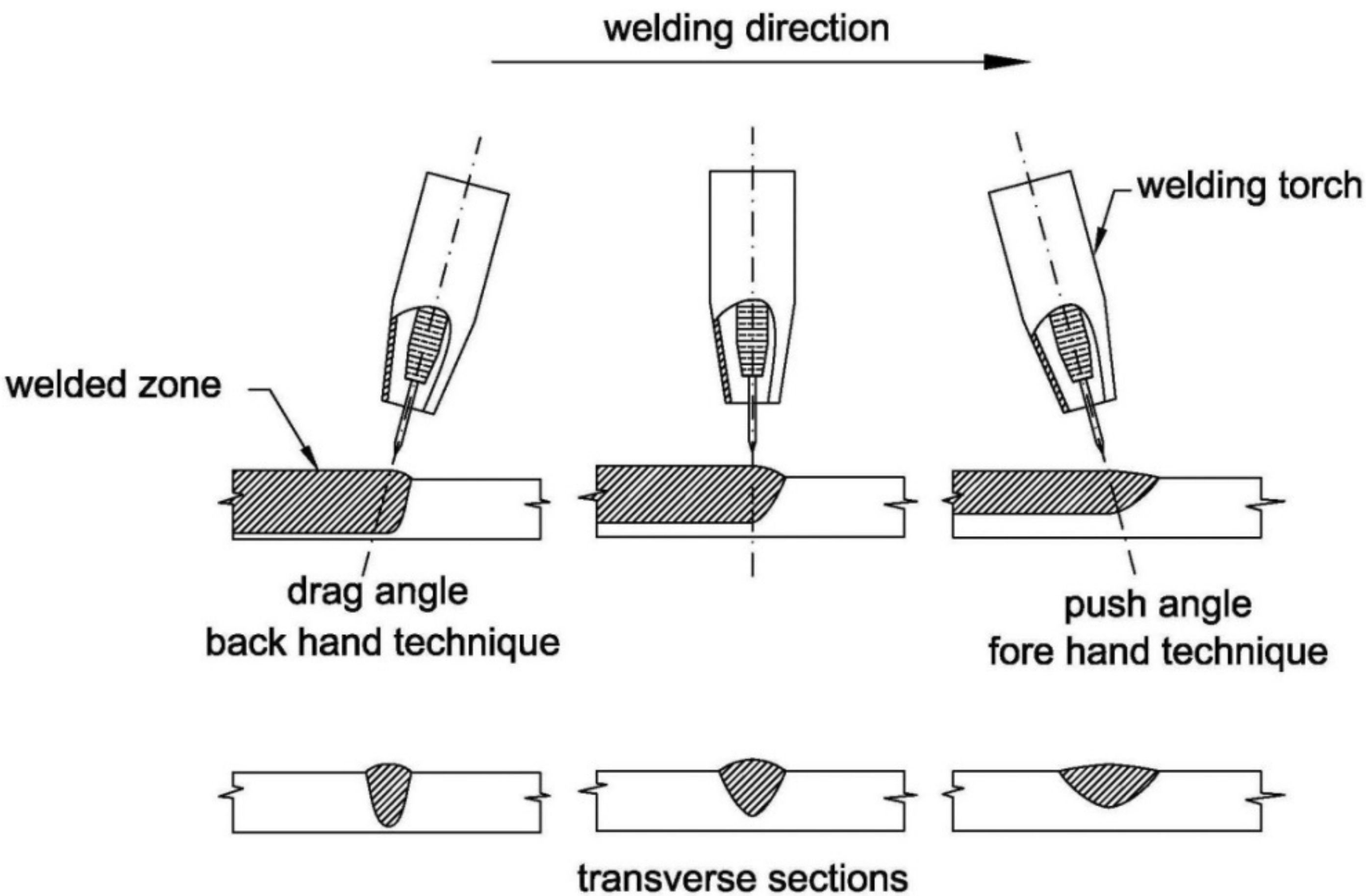
Travel angle: Angle between electrode axis and the direction of travel

Work angle: Angle between the electrode axis and the adjacent work surface.

Backhand technique: Electrode axis inclined in the direction of welding
(Weld penetration more, bead narrow, more spatter)

Forehand technique: Electrode axis inclined against the direction of welding
(Less weld penetration, bead wider, less spatter)

Electrode orientation



Electrodde polarity

The polarity of the electrode plays an important role only in DC power supply.

Shielding gas composition:

Main function: To protect the arc and the molten weld pool from atmospheric oxygen and nitrogen. If not properly protected it forms oxides and nitrides and also results in weld defect such as porosity and weld embrittlement.

Other Functions:

- Forms the arc plasma
- Stabilizes the arc on the material surface
- Ensures smooth transfer of molten metal droplets from the wire to weld pool

Marangoni Convection

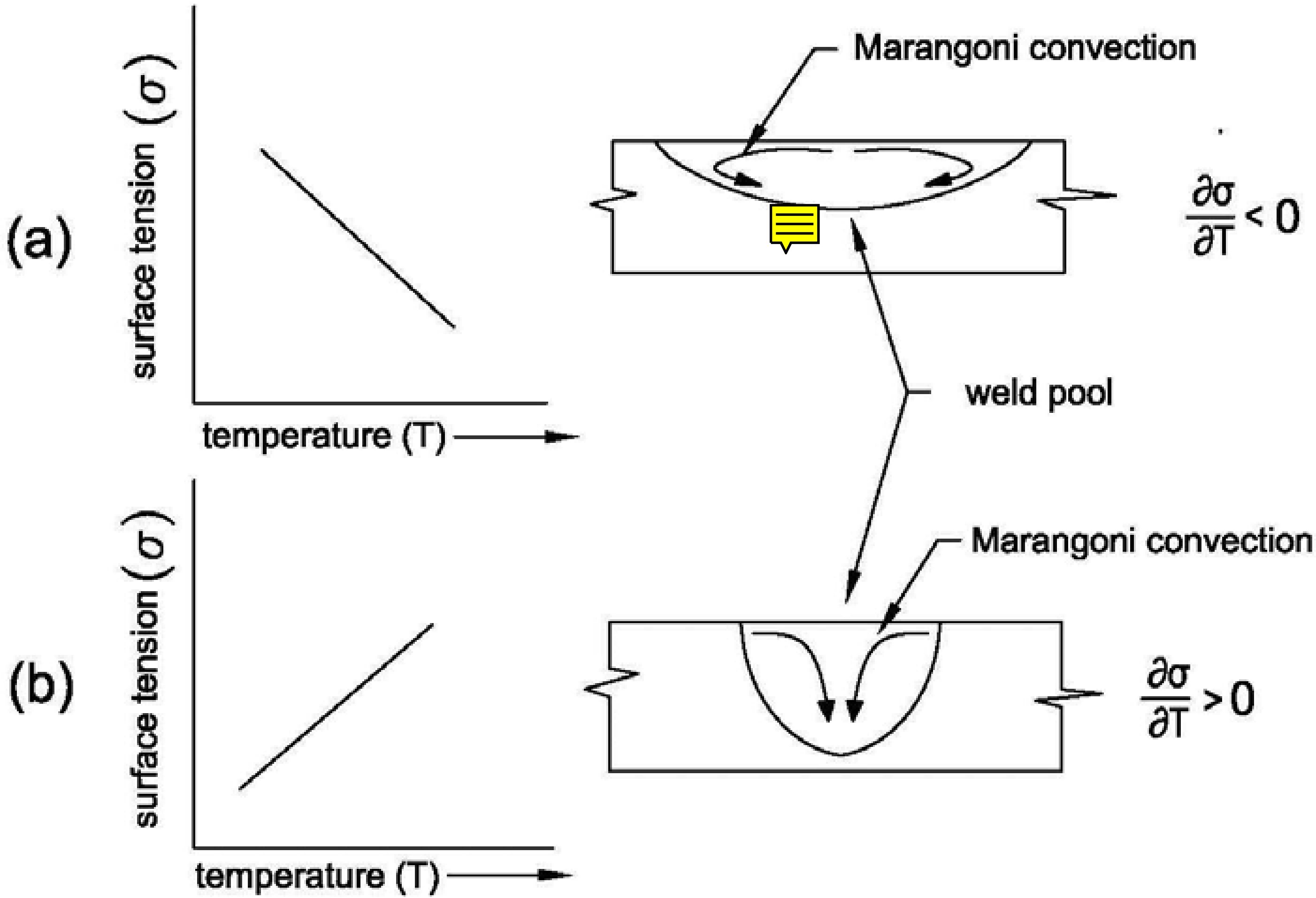
Weld penetration in a welding process is driven by electromagnetic force, surface tension gradient, buoyancy force and impinging force of arc plasma.

High temperature gradients in the molten weld pool surface causes variation of the surface tension over the weld pool surface.

This surface tension gradient influences the convection mode of the molten metal in the weld pool called **Marangoni convection**.

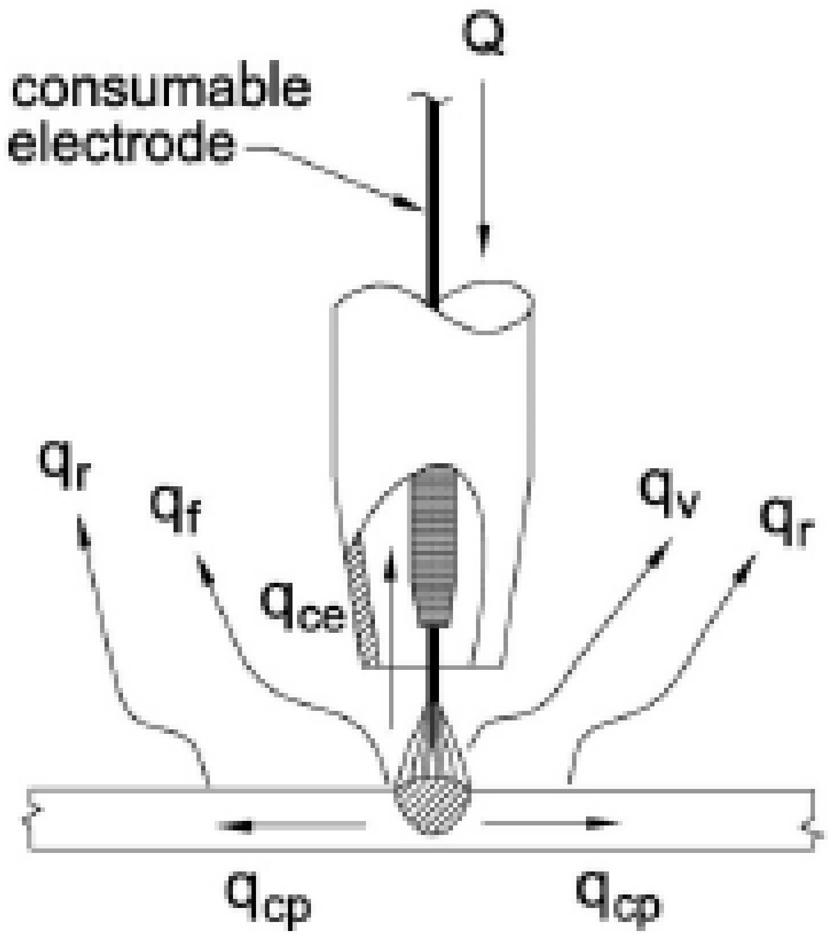
However oxygen, sulfur, and selenium, known as surface active elements can change the temperature coefficient of surface tension from negative to positive.

Marangoni convection



Marangoni convection due to surface tension gradient in the weld pool

Heat Balance in Welding



q_{cp}/q_{ce}: Heat lost by conduction
q_v: Heat lost by convection
q_r: Heat lost by radiation
q_f: Heat used for melting

Heat Balance in Welding

In electric arc welding, the heat input (Q) in J/s is given by:

$$Q = VI \quad \text{J/s}$$

Where, V = arc voltage (V)
I = Welding current (A)

The actual heat available to the weld joint depends on the weld speed v (mm/s), and is given by,

$$H = \frac{Q}{v} \quad \text{J/mm}$$

Because of some heat loss due to various factors the actual heat (Hnet) that goes into a welded joint is determined using a heat transfer efficiency (η)

$$H_{net} = \eta\, H = \eta\, \frac{VI}{v} \quad \text{J/mm}$$

Heat Balance in Welding

The entire 'net heat' reaching the weld joint is not used for melting, since part of it would be lost due to conduction.

The net heat that is actually utilized for melting can be obtained using another efficiency factor (η_m)

$$\eta_m = \frac{Heat\ required\ to\ melt\ the\ joint}{net\ heat\ supplied}$$

Heat Affected Zone (HAZ)

The **HAZ** is defined as that region where due to the welding heat microstructural transformations may take place.

It is important to estimate the extent of the HAZ as adverse microstructural transformations may take place in the welded region.

It is preferable to choose such welding parameters which also keep the HAZ to a minimum.