MANUFACTURING PROCESSES

WELDING INTRO

JOINING PROCESS

- Welding is a ***joining process***.
- Joining may be preferred for one or more of the following reasons:-
  - ***Product is impossible or uneconomical to manufacture as a single piece.***
  - ***The product is easier to manufacture in individual components, which are then assembled, then as a single piece.***

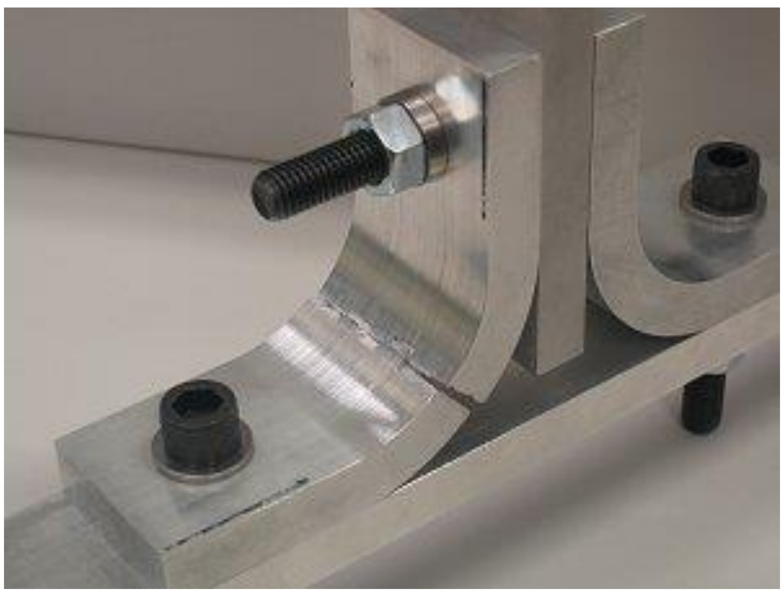
NEED FOR JOINING

- ***Different properties may be desirable for functional purpose of the product.***
- ***Transportation of the product in individual components are more economical than transporting it as a single piece***

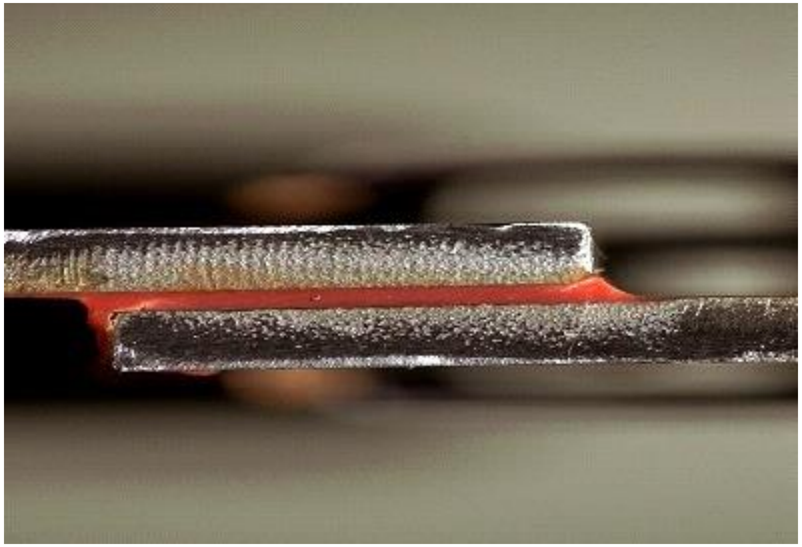
JOINING PROCESS

- Three joining techniques are commonly used.
  - ***Mechanical joints***
  - ***Adhesives***
  - ***Welding and allied processes***

MECHANICAL JOINTS



ADHISIVES



WELDING JOINTS

WELDING DEFINATION

- Welding is a process of ***permanent joining*** two materials (usually metals) through localised coalescence resulting from a suitable combination of ***temperature, pressure and metallurgical conditions.***
- Depending upon the combination of temperature and pressure from a high temperature with no pressure to a high pressure with low temperature, ***a wide range of welding processes has been developed.***

WELDING DEFINATION

- Welding is a fabrication process that joins materials, usually metals, by causing coalescence.
- This is often done by ***melting*** the workpieces and ***adding a filler*** material to form a pool of molten material (the weld pool) that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld.

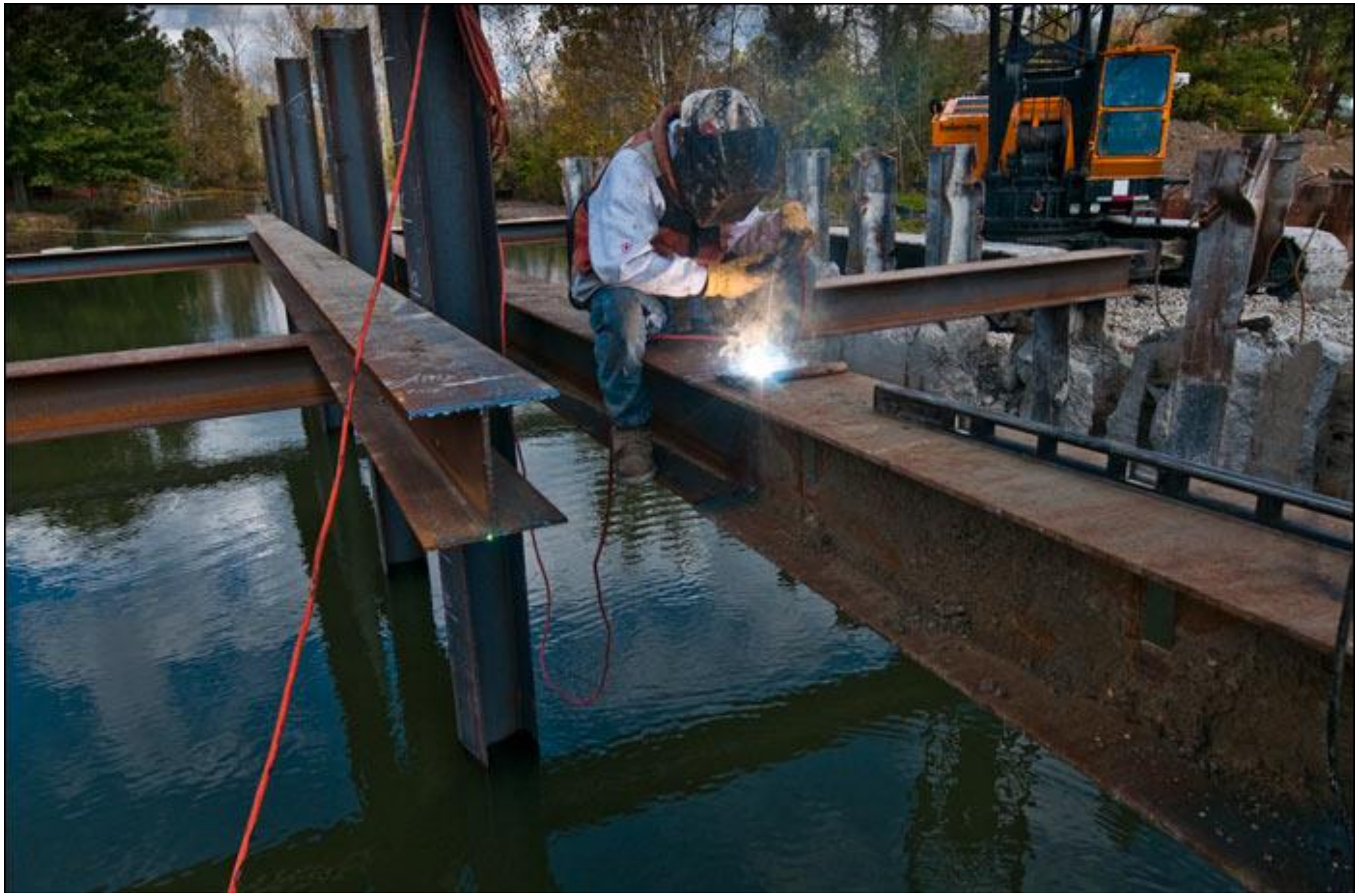
ADVANTAGES

- ***Strong*** and tight joining.
- ***Cost*** effectiveness.
- ***Simplicity*** of welded structures design.
- Welding processes may be mechanized and ***automated***.

DISADVANTAGES

- Internal stresses, distortions and changes of micro-structure in the weld region.
- Harmful effects: light, ultra violate radiation, fumes, high temperature.

BUILDINGS AND BRIDGES STRUCTURES



AUTOMOTIVE, SHIP AND AIRCRAFT CONSTRUCTIONS

PIPE LINES

TANKS AND VESSELS

RAILROADS

MACHINERY ELEMENTS

CLASSIFICATION

- There are two groups of welding processes according to the state of the base material during the welding process:
  a) Liquid-state welding (fusion welding)
  b) Solid-state welding.

a. Liquid-state (fusion welding)

- ***Fusion welding*** is defined as the ***melting*** together and joining of materials by means of ***heat***, usually supplied by ***chemical or electrical*** means; ***filler*** metals ***may or may not*** be used.
- Fusion welding is composed of ***consumable and non consumable-electrode*** arc welding and high-energy-beam welding processes.
- Fusion welding is by far the more ***important category.***

a. Liquid-state (fusion welding)

- The fusion category includes the most widely used welding processes, which can be organized into the following general groups
  - ***Arc welding***
  - ***Resistance Welding (also Solid-state welding)***
  - ***Oxyfuel gas welding***
  - ***Other fusion welding (Electron beam & Laser beam)***

b. Solid-state welding

- ***Solid-state*** welding refers to joining processes in which joining results from application of ***pressure*** alone ***or a combination*** of ***heat*** and pressure.
- Joining takes place ***without fusion***; consequently, there is ***no liquid*** (molten) ***phase*** in the joint.
- If heat is used, the temperature in the process is below the melting point of the metals being welded.
- ***No filler*** metal is utilized.

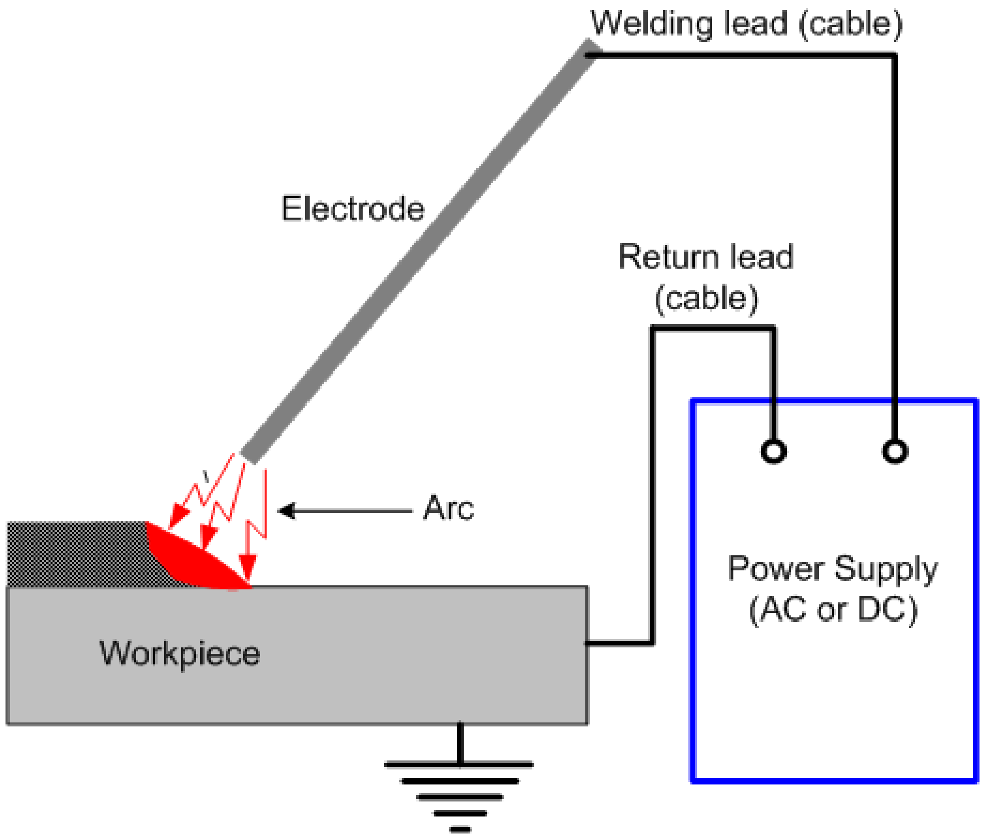
b. Solid-state welding

- Representative welding processes in this group include:
  - ***Friction welding***
  - ***Diffusion welding***
  - ***Ultrasonic welding***
  - ***Resistance Welding (also fusion welding)***

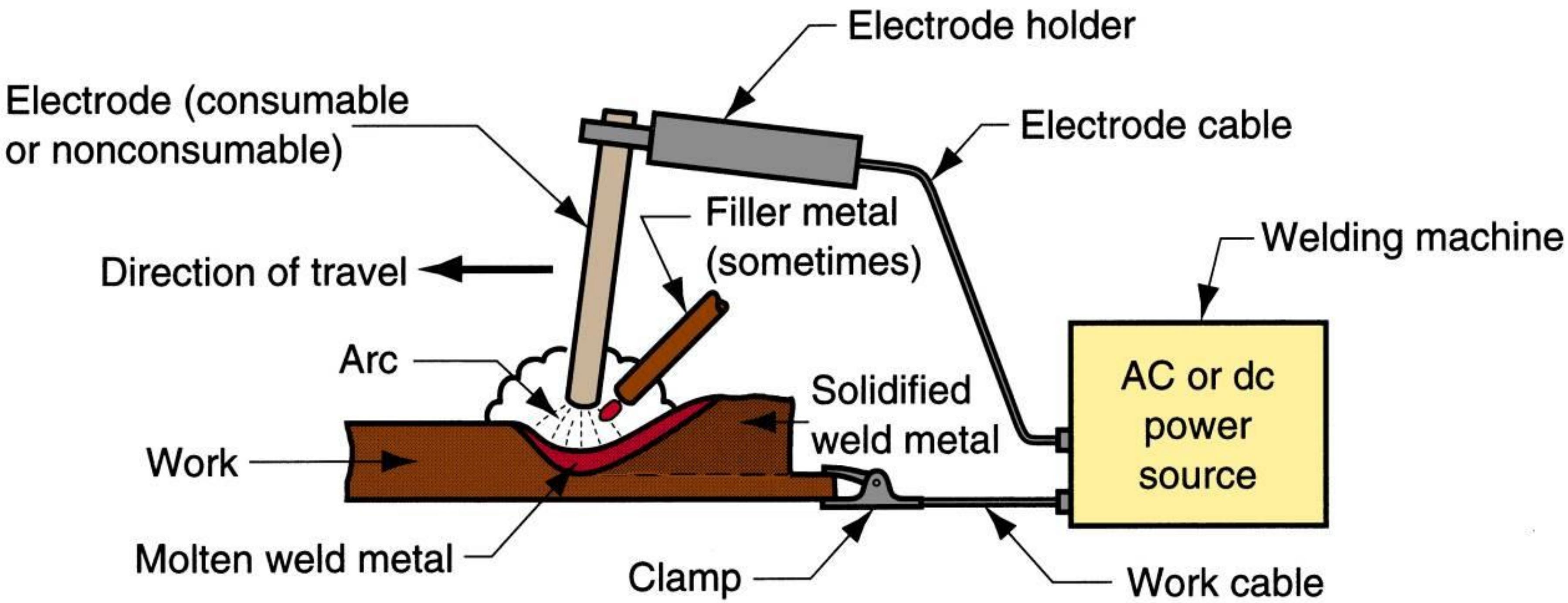
1. Arc Welding

- **Arc welding** is a fusion-welding process, in which heat is generated by an **electric arc** struck between an electrode and the work piece.
- Any arc welding method is based on an electric circuit consisting of the following parts:
  - *Power supply (AC or DC);*
  - *Welding electrode;*
  - *Work piece;*
  - *Welding leads (electric cables) connecting the electrode and work piece to the power supply.*

1. Arc Welding



1. Arc Welding



The basic configuration and electrical circuit of an arc-welding process.

1. Arc Welding

- ***Electric arc*** between the electrode and work piece closes the electric circuit.
- An ***electric arc*** is a discharge of electric current across a gap in a circuit.
- It is sustained by the presence of a thermally ionized column of gas (called a ***plasma***) through which current flows.
- The arc temperature may reach ***5500°C***, which is sufficient for fusion the work piece edges and joining them.

1. Arc Welding

- A ***pool*** of molten metal, consisting of base metal(s) and filler metal (if one is used) is formed near the tip of the electrode.
- In most arc-welding processes, ***filler metal*** is added during the operation to increase the volume and strength of the weld joint.
- Chemical compositions of filler metal is ***similar*** to that of work piece.

1. Arc Welding - ELECTRODES

- ***CONSUMABLE*** electrodes - are used in SMAW, SAW & GMAW.

- ***NON-CONSUMABLE*** electrodes – are used in GTAW.

1. Arc Welding - ELECTRODES

- ***CONSUMABLE*** electrodes provide the source of the filler metal in arc welding.
- These electrodes are available in two principal forms:
  - **rods (also called sticks) and**
  - **wire.**
- Welding ***rods*** are typically 225 to 450 long and 9.5 mm or less in diameter.

1. Arc Welding - ELECTRODES

- The ***problem*** with consumable welding ***RODS***, at least in production welding operations, is that they must be ***changed periodically***, reducing arc time of the welder.
- Consumable weld ***WIRE*** has the ***advantage*** that it can be ***continuously fed*** into the weld pool from spools containing long lengths of wire, thus avoiding the frequent interruptions that occur when using welding sticks.

1. Arc Welding - ELECTRODES

- ***Non-consumable*** electrodes are made of tungsten (or carbon, rarely), which resists melting by the arc.
- Despite its name, a ***non-consumable*** electrode is gradually depleted during the welding process (vaporization is the principal mechanism), analogous to the gradual wearing of a cutting tool in a machining operation.

1. Arc Welding - ELECTRODES

- For arc welding processes that utilize ***non-consumable*** electrodes, any filler metal used in the operation must be supplied by means of a separate wire that is fed into the weld pool.
- If no filler rod is used with non-consumable electrode then the process is called ***Autogenous***.

1. Arc Welding - ARC SHIELDING

- At the high temperatures in arc welding, the metals being joined are ***chemically reactive*** to ***oxygen , nitrogen , and hydrogen*** in the air.
- The mechanical properties of the weld joint can be seriously ***degraded*** by these reactions.
- Thus, some means to ***shield*** the arc from the surrounding air is provided in nearly all arc welding processes.

1. Arc Welding - ARC SHIELDING

- Arc shielding is accomplished by covering the electrode tip, arc, and molten weld pool with a blanket of ***gas or flux***, or both, which inhibit exposure of the weld metal to air.
- Common shielding gases include ***argon*** and ***helium***, both of which are inert.
- In the welding of ferrous metals with certain Arc Welding processes, ***oxygen*** and ***carbon dioxide*** are used, usually in combination with Ar and/or He.

1. Arc Welding - FLUX

- A ***flux*** is a substance used to ***prevent*** the formation of oxides and other unwanted contaminants, or to dissolve them and facilitate removal.
- During welding, the flux melts and becomes a liquid ***slag***, covering the operation and protecting the molten weld metal.
- The slag hardens upon cooling and ***must be removed*** later by chipping or brushing.

1. Arc Welding - FLUX

- Flux is usually formulated to serve several additional functions:
  - *provide a **protective atmosphere** for welding,*
  - ***stabilize** the arc,*
  - *provide a **protective slag** coating to accumulate impurities, prevent oxidation, and slow the cooling of the weld metal,*
  - *affect **arc penetration** (the depth of melting in the workpiece)*
  - *add **alloying elements** to the weld,*
  - *to **reduce spatter**.*

1. Arc Welding - FLUX

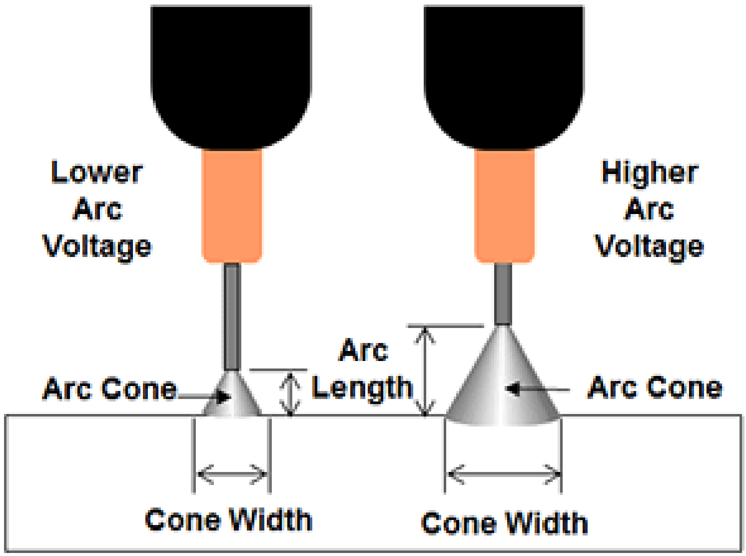
- The method of flux application differs for each process. The delivery techniques include

1. pouring ***granular flux*** onto the welding operation,
2. using a stick electrode ***coated*** with flux material in which the coating melts during welding to cover the operation, and
3. using ***tubular electrodes (flux cored)*** in which flux is contained in the core and released as the electrode is consumed.

1. Arc Welding – POWER SOURCES

- Two types:
    a) ***Constant Current (Drooping)***
    b) ***Constant Voltage***

- Before discussing the question of CC vs. CV, we must first understand the effects of both current and voltage with arc welding. Current effects the melt-off rate or consumption rate of the electrode, whether it be a stick electrode or wire electrode. The higher the current level, the faster the electrode melts or the higher the melt-off rate, measured in pounds per hour (lbs/hr) or kilograms per hour (kg/hr). The lower the current, the lower the electrode's melt-off rate becomes. Voltage controls the length of the welding arc, and resulting width and volume of the arc cone. As voltage increases, the arc length gets longer (and arc cone broader), while as it decreases, the arc length gets shorter (and arc cone narrower). **Figure 2** illustrates the effect of voltage in the arc.



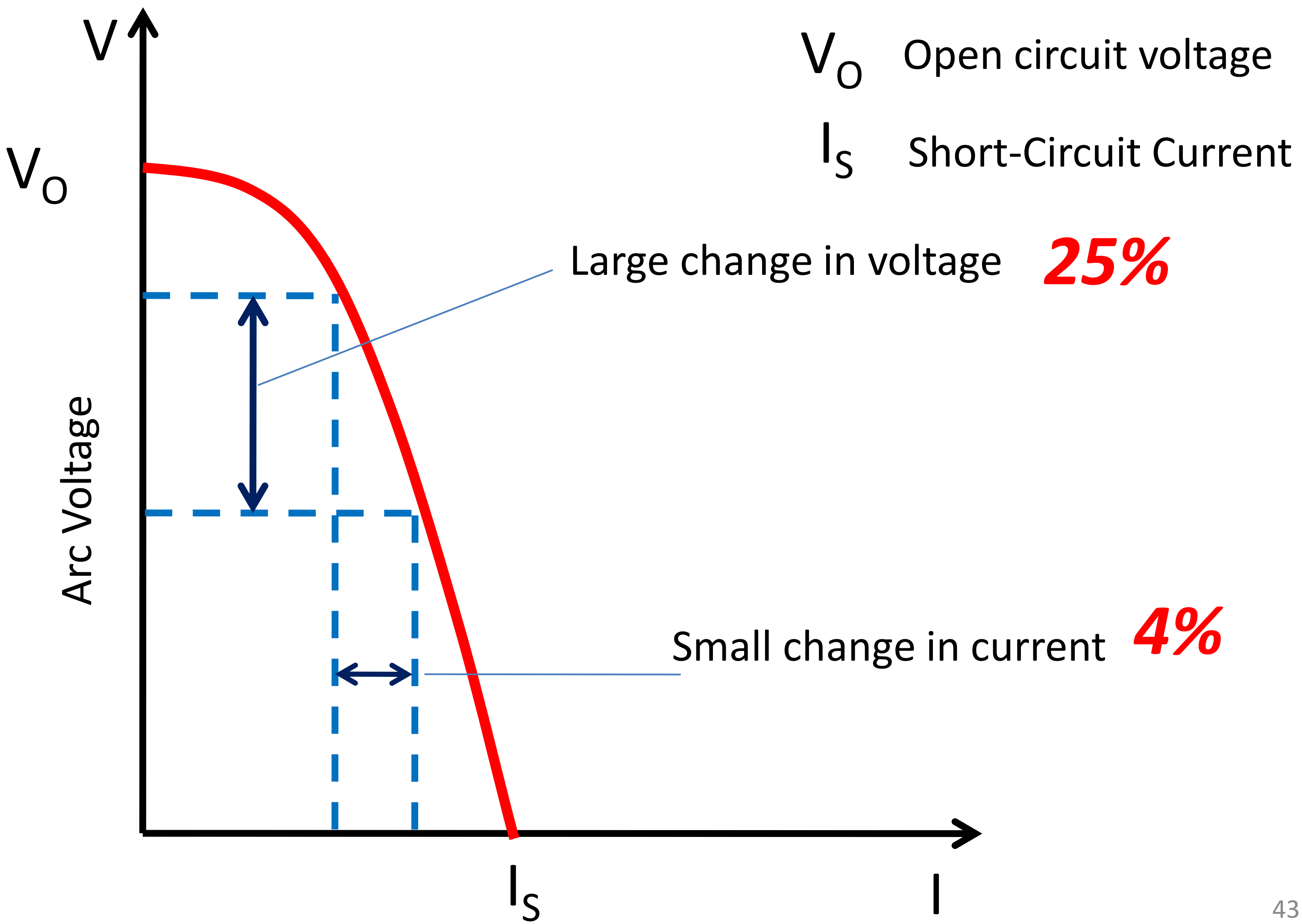
- Now the type of welding process you are using, and its associated level of automation, determines which type of welding output is most stable and thus preferred. The Shielded Metal Arc Welding (SMAW) process (aka MMAW or stick) and the Gas Tungsten Arc Welding (GTAW) process (aka TIG) are both generally considered manual processes. This means you control all welding variables by hand. You hold the electrode holder or TIG torch in your hand and control travel angle, work angle, travel speed, arc length and the rate in which the electrode is fed into the joint all by hand. With the SMAW and GTAW processes (i.e. the manual processes), CC is the preferred type of output from the power source.
- onversely, the Gas Metal Arc Welding (GMAW) process (aka MIG) and the Flux Cored Arc Welding (FCAW) process (aka flux core) are both generally considered semi-automatic processes. This means that you still hold the welding gun in your hand and control travel angle, work angle, travel speed and contact tip to work distance (CTWD)) by hand. However, the rate in which the electrode is fed into the joint (known as wire feed speed (WFS)) is controlled automatically with a constant speed wire feeder. With the GMAW and FCAW processes (i.e. the semi-automatic processes), CV is the preferred output.

- With the two manual processes, SMAW and GTAW, you are controlling all variables by hand (which is why they are the two most operator skill intensive processes). You need to have the electrode melt at a consistent rate, so that you can feed it into the joint at a consistent rate. To do this, the welding output needs to maintain current at a constant level (i.e., CC), so that the resulting melt-off rate is consistent. Voltage is a less controlling variable. With manual processes, it is very difficult to consistently maintain the same arc length because you are also constantly feeding the electrode into the joint. Voltage varies as a result of changes in arc length. With CC output, current is your preset, controlling variable and voltage is simply measured (typically as an average value) while welding.
- If you tried to weld with the SMAW process for example using CV output, current, and the resulting melt-off rate, would vary too much. As you were traveling along the joint (trying to be consistent with all other welding variables), the electrode would melt at a faster rate, then a slower rate, then a faster rate, etc. You would constantly need to change the rate in which you fed the electrode into the joint. This is an impracticable condition, thus making CV output undesirable.
- When you switch to a semi-automatic process, such as GMAW or FCAW, something changes. While you are still controlling many of the welding variables by hand, the electrode is being fed into the joint at a constant speed (based on the particular WFS you have set on the wire feeder). Now you want the arc length to be consistent. To do this, the welding output needs to maintain voltage at a constant level (i.e., CV), so that the resulting arc length is consistent. Current is a less controlling variable. It is proportional to, or a result of, the WFS. As WFS increases, so does current and vice versa. With CV output, voltage and WFS are your preset, controlling variables and current is simply measured while welding.
- If you tried to weld with the GMAW or FCAW processes using CC output, voltage, and the resulting arc length, would vary too much. As voltage decreased, arc length would become very short and the electrode would stub into the plate. Then as voltage increased, arc length would become very long and the electrode would burn back towards the contact tip. The electrode would be constantly stubbing into the plate, then burning back towards the tip, then stubbing into the plate, etc. This is an impracticable condition, thus making CC output undesirable

a). CONSTANT CURRENT POWER SOURCE

- In ***Constant Current*** [***CC***] power source, variation in welding current with arc voltage (due to fluctuations in arc length) is very small.
- ***welding current*** remains more or less ***constant*** in spite of fluctuations in arc voltage/length.
- ***suitable for*** those welding processes where large fluctuation in arc length is observed like in *Manual Metal Arc Welding* (***MMAW***) ***and*** *Tungsten Inert Gas* ***TIG welding***.

a). CONSTANT CURRENT POWER SOURCE



a). CONSTANT CURRENT POWER SOURCE

- The constant current (CC) welding machine is called a ***drooper*** because of this curve.
- A ***25%*** change in voltage results in only a ***4%*** change in amperage.
- The current change is so ***slight*** that the current is considered constant.

a). CONSTANT CURRENT POWER SOURCE

- Following points should be kept in mind regarding CC power source:
  - It has ***high OCV*** (open circuit voltage:- the voltage when the welding is not being performed).
  - High OCV ensure ***easy initiation*** and ***maintenance of arc.***
  - ***Low short circuit current.***

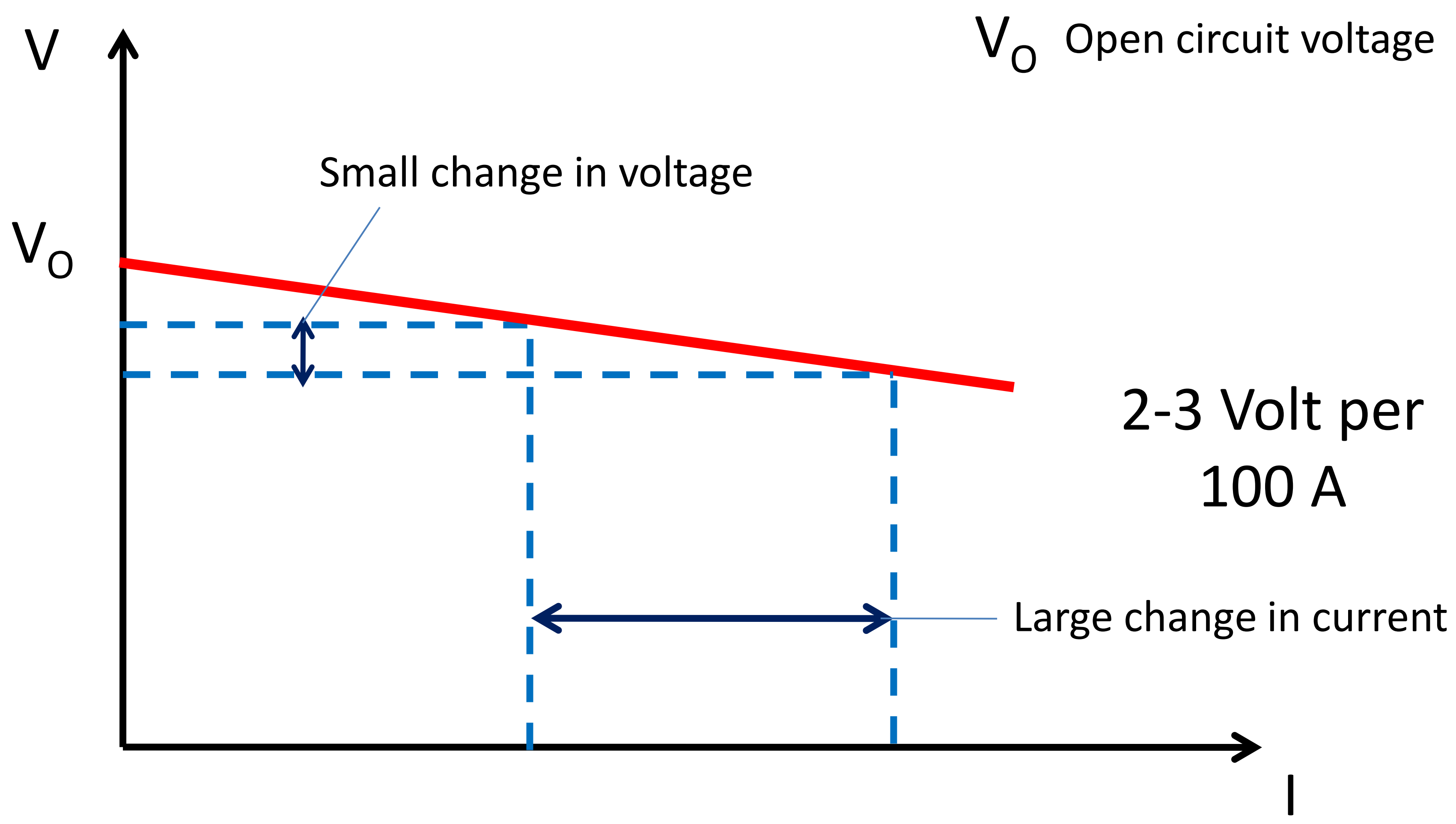
b). CONSTANT VOLTAGE POWER SOURCE

- In CV power source, very small variation in arc voltage (due to fluctuation in arc length) causes significant change in welding current.
- Since ***arc voltage*** remains almost ***constant*** therefore this type of power sources are called constant voltage power source.
- Constant voltage power source does not have true constant voltage output. It has ***slightly*** downward or ***negative slope***.

b). CONSTANT VOLTAGE POWER SOURCE

- ***suitable for*** all those welding processes where small fluctuations in arc length can take place, like in semiautomatic welding processes ***MIG & SAW*** .

b). CONSTANT VOLTAGE POWER SOURCE



b). CONSTANT CURRENT POWER SOURCE

- Following points should be kept in mind regarding CV power source:
  - It has slightly ***low OCV*** as compared to CC power source.
  - ***High short circuit current.***

1. Arc Welding- TYPES

A. Shielded/Manual Metal Arc Welding ***(SMAW)(MMAW)***

B. Submerged Arc Welding ***(SAW)***

C. Tungsten Inert Gas Arc Welding ***(TIG, GTAW)***

D. Metal Inert Gas Welding ***(MIG, GMAW)***