

Advances in Welding and Joining Technologies

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Module 8

Metal Transfer in Welding and Metal Printing

- ✓ Fundamentals of metal transfer in arc welding
- ✓ Cold metal transfer (CMT)
- ✓ Introduction to metal printing

Introduction

Metal transfer in arc welding

GMAW, SMAW, SAW

GTAW

Metal addition in laser welding – metal printing

GMAW has also been used to develop low-cost 3D metal printer

Mode of metal transfer in GMAW

Continuous mode / Pulse mode

GMAW – CMT

Cold metal transfer (CMT) is new form of gas metal arc welding (GMAW). It's not exactly cold.

It is in lower temperature than regular GMAW process

Modes of metal transfer - GMAW

Transfer of molten metal from consumable electrode to the weld pool

Secondary Factors

Shielding gas, composition of the electrode, diameter of the electrode

Current, Voltage, arc gap

Types of metal transfer

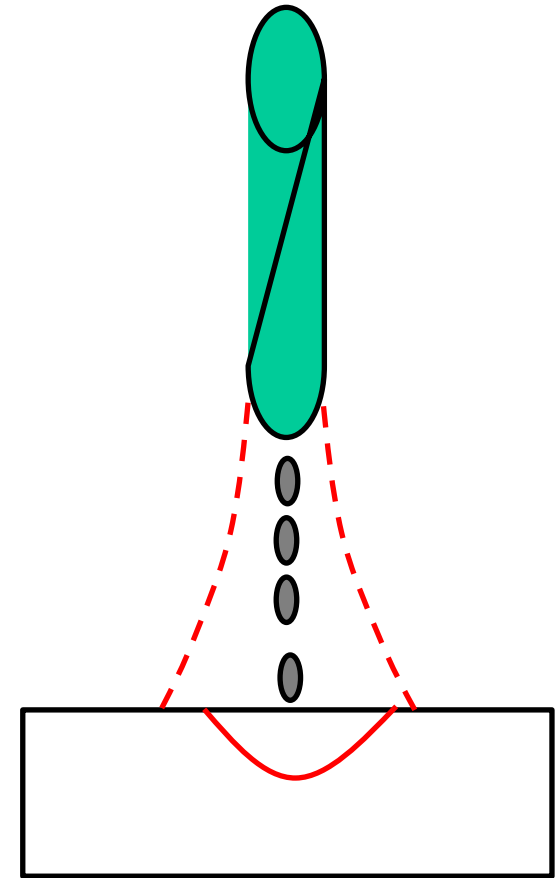
- Short Circuit Transfer
- Globular Transfer
- Spray Transfer

Modes of Metal transfer – Globular transfer

- ✓ Welding current is low (more than short circuit transfer) and arc gap is large - droplet can grow slowly
- ✓ Droplets continues to grow until gravitational force exceeds the surface tension force
- ✓ As soon as drop attains large size enough and so gravitational force becomes more than other drop-holding-forces
- ✓ Drop separates from the electrode tip and is transferred to the weld pool
- ✓ The droplet transfer occurs when it attains size larger than the electrode diameter
- ✓ May not suitable for printing

Modes of Metal transfer – Spray transfer

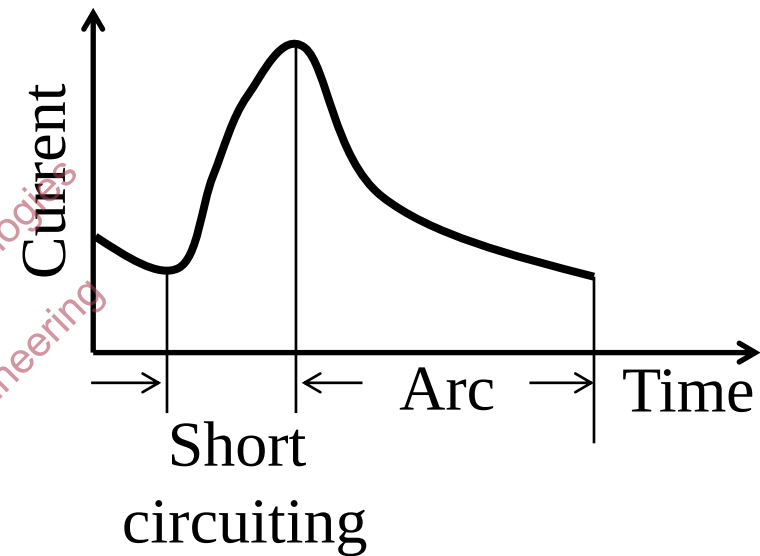
- ✓ Welding current density is higher than globular transfer
- ✓ High welding current density results in high melting rate and greater pinch force
- ✓ Droplets are formed rapidly and pinched off quickly by high pinch force
- ✓ Droplets are of very small in size
- ✓ High welding current increases temperature that lowers the surface tension force
- ✓ Decreases the resistance to detachment of drops



Not suitable for printing

Modes of metal transfer - Short Circuit Transfer

- ✓ **Low welding current** - droplet grows slowly
- ✓ When drop touches weld pool, short-circuiting takes place
- ✓ Due to narrow arc gap, molten drop does not attain a size big enough to fall under gravitational force
- ✓ After short circuit - welding current flow increases abruptly and results in excessive heat generation
- ✓ The molten metal of droplet becomes thinner (low surface tension)
- ✓ Molten metal is transferred to the weld pool
- ✓ An arc gap is established that increases arc voltage abruptly



Arc
Short circuiting
Pinching

Finally, re-ignites arc and flow of current starts

Repeated over cycle

Cold metal transfer (CMT)

- ✓ CMT is actually a part of GMAW
- ✓ In principle, it works at **reduced welding current** and **retracting** the weld wire at a short circuit condition
- ✓ Ensure a drop-by-drop deposit of weld material.
- ✓ First developed for **thin materials** with strict control of weld parameters
- Now-a-days, the welding of dissimilar metals and thicker materials along with improved weld bead aesthetics are developed.
- It is one of the option of metal printing technology development.
- CMT process is developed by Fronius of Austria in 2004.
- This process differs from GMAW in terms of mechanical droplet dethatching method

Difference of CMT from GMAW process

The main difference is in terms of wire feed

In GMAW – wire continuously moving forward into the weld pool

- ✓ In CMT - the wire is retracted the instant current flows
- ✓ It breaks the arc. The metal droplet detaches from the filler and fuses with the – still molten - base metal.
- ✓ Again, the wire moves forward to create another arc.
- ✓ All these phenomena happens several times in each second
- CMT provides a controlled method of material deposition by sophisticated wire feed system at low thermal input
- In effect, it needs high-speed digital control technology.

Cold metal transfer (CMT)

Main features of the CMT process

- ✓ Short circuit occurs with **low current** corresponding to a low heat input
- ✓ Short circuit occurs in a **stable controlled** manner
- ✓ During metal transfer, the **current drops to near-zero** and thereby any spatter generation is avoided
- ✓ As soon as the metal transfer is completed, the arc is re-ignited and the wire is fed forward once more with welding current reflow

Cold metal transfer (CMT)

CMT welding electrical signal cycle consists of three phases

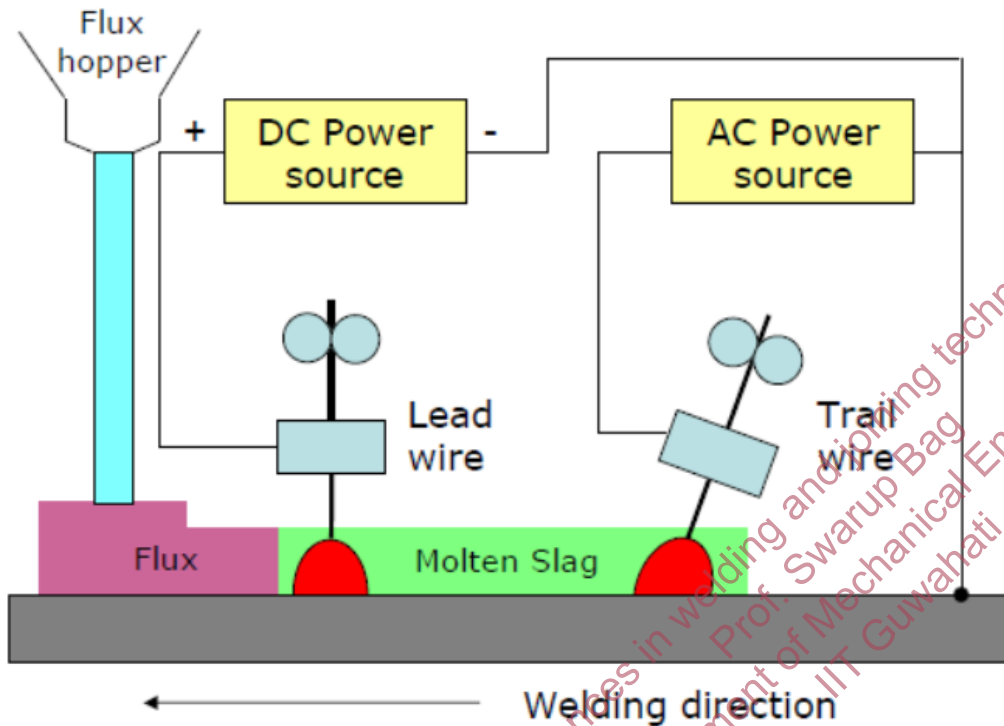
- ✓ **Peak current:** Constant arc voltage corresponding with high pulse current

Ignition of the welding arc easily and form droplets

- ✓ **Background current:** Lower current level
Prevents the globular transfer of little liquid droplet, continues until short circuiting occurs.

- ✓ **Short-circuiting:** arc voltage is zero
wire is given back-drawing force - liquid fracture occurs and transfer of material into the welding pool

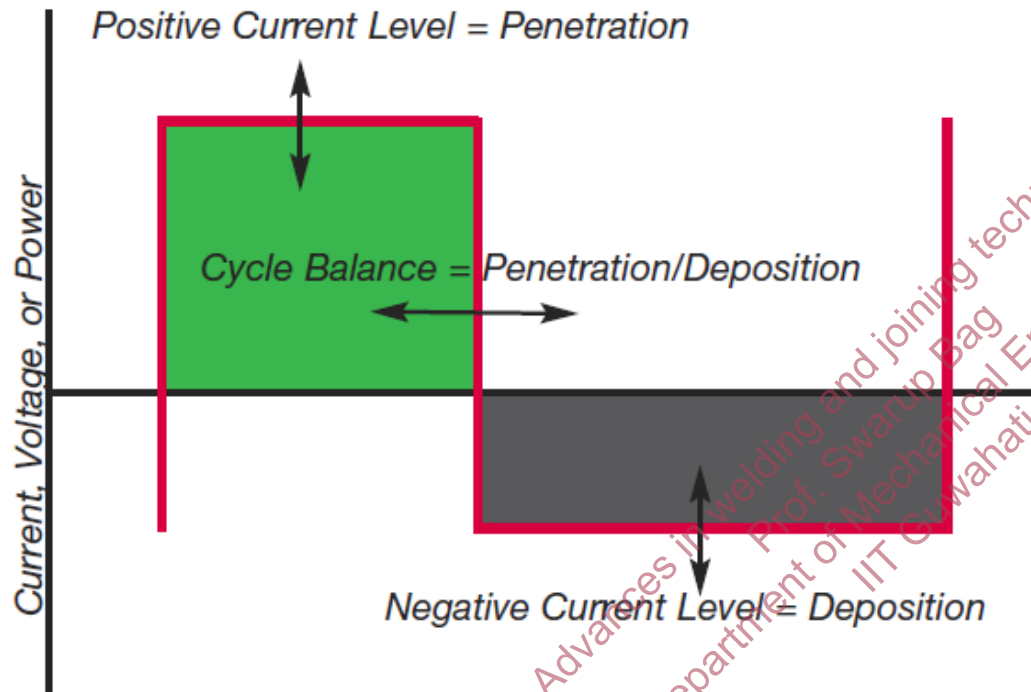
Metal transfer in SAW



Two Wire Tandem SAW Process

- ✓ Two arcs and electrode wires are independently controlled by two separate power sources, which may be interfaced.
- ✓ Offers high deposition rate
- ✓ Applications in shipbuilding, pipelines and infrastructures.

Metal transfer in SAW



**Effects of wave
controlled trailing
arc on penetration**

Control penetration and bead width independently
for the same heat input

Additive manufacturing

- ✓ Layer by layer deposition - one layer at a time
- ✓ 3D printing and additive manufacturing are synonyms
- ✓ 3D printing/additive manufacturing is the process - rapid prototyping is the end result

Common methods for producing layers in 3D printing

SLA or SL: Stereolithography

FDM: Fused deposition modeling

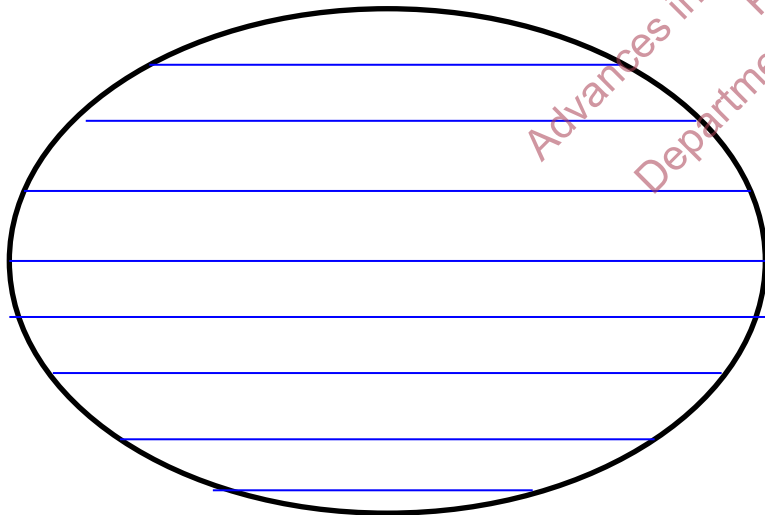
SLM: Selective laser melting

SLS: Selective laser sintering

DMD: Direct metal deposition

Additive manufacturing/3D printing

- Layer by layer manufacturing process
- Creates 3D objectives - not by subtractive methods
- It is additive method – Effective utilization of materials
- Creates object according to 3D models
- Computer interface is required
- Surface roughness – post processing is required



Is this optimum layer thickness?

Additive manufacturing of metallic components

- ✓ Powder Bed Fusion
- ✓ Wire Feed Directed Energy Deposition
- ✓ Powder Feed Directed Energy Deposition
- Fusion of successive layers of metal using a focused heat source - Laser or electron beam
- A well defined pre-programmed path
- Layer thickness, surface roughness and material deposition rate
 - Focused beam diameter
 - Scanning speed
 - Powder particle size
 - Powder flow rate
 - Shielding gas type (Nitrogen/Argon)
 - Shielding gas flow rate
 - Solidification

Additive manufacturing of metallic components

- Consists of many complex physical processes
Melting/solidification, solidification shrinkage, absorption, vaporization, wetting, sintering

Application to metallic materials

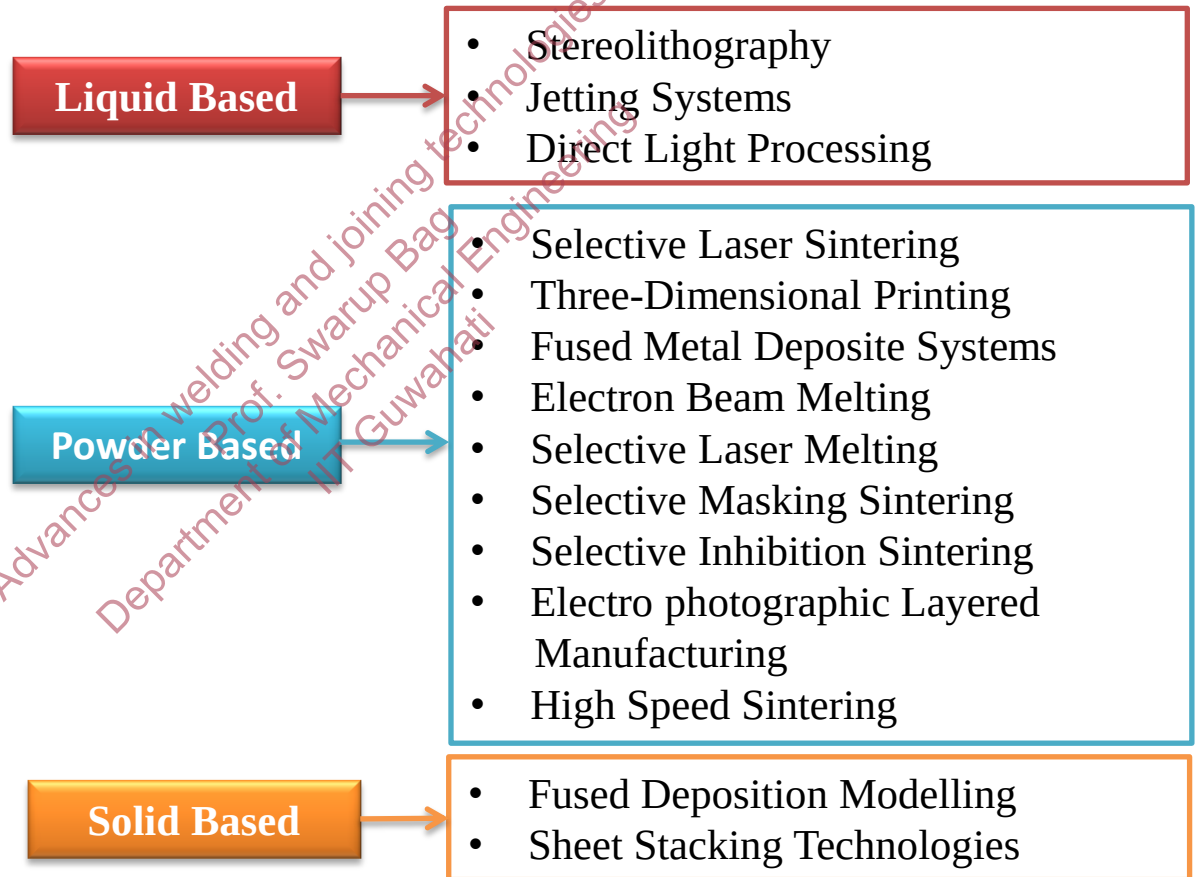
- ✓ Stainless steel – medical grade (316L)
- ✓ Maraging steel

Difficult for steel having high percentage of carbon

- ✓ Nickel and nickel alloy (Inconel)
- ✓ Aluminum and aluminum alloy
- ✓ Titanium alloy

Additive Manufacturing

Major AM processes based on Hopkinson and Dickens' classification



Stereolithography (SLA or SL)

- is widely recognized as the first 3D printing process
 - is a laser-based process that works with photopolymer resins
- It reacts with the laser and cures to form a solid
 - It is generally accepted as being one of the most accurate 3D printing processes with excellent surface finish

Limiting factors:

- post-processing steps required
- stability of the materials over time – may be more brittle

3D metal printing

- ✓ 3D geometry of object - computer-aided design (CAD) files
 - ✓ Slicing with layers – decide the layer thickness
 - ✓ CAD file - converted to a format usually .STL format
 - ✓ All data fed to 3D printer
 - ✓ Path of melted/solidified metal – controlled by XYZ movement of table or movement of laser source
-
- Most of the metal 3D printing technologies – **SLM**
 - Transformation of powdered metal into a solid metallic object

3D metal printing

Selective laser sintering (SLS)

- ✓ Use laser as the power source to sinter powdered material (mainly polymer)
- ✓ Bind the material together to create a solid structure
- ✓ mainly been used for rapid prototyping and for low-volume production of component parts
- ✓ Similar to direct metal laser sintering (**DMLS**)
- ✓ Same concept but differ in technical details

Selective laser melting (SLM)

- ✓ Material is fully melted rather than sintered – allow different properties
- ✓ Based on powder bed system

3D metal printing

Fused deposition modeling (FDM)

- ✓ Use a continuous filament of a material
- ✓ This is fed from a large coil
- ✓ Molten material is forced out of the print head's nozzle
- ✓ It is deposited on new layer

Direct Metal Deposition (DMD)

- ✓ Use a laser to melt metallic powder
- ✓ It is not based on a powder bed
- ✓ Powders are projected through nozzle
- ✓ Powders are fused by focused laser beam
- ✓ Concept is similar to FDM, but powder is used here

3D metal printing

- ✓ In laser based metal 3D printing technologies - DMD is the only one not based on a powder bed
- ✓ In SLM and DMLS, the unfused metallic powder is used as support material and can be reused
- ✓ In DMD, supports can be required to maintain the building object
- ✓ In DMD almost all the powder is transformed into solid
- ✓ DMD technology also has the ability to comply with a freeform substrate
- ✓ Cooling times can be considerable for laser sintering
- ✓ Porosity of may be an issue for laser sintering
- ✓ Metal sintering requires much higher powered laser than plastic

**Thank you
for your kind attention**

End of Module 8

Metal Transfer in Welding and Metal Printing