Surface Coating Processes*

*** Processes of covering surfaces with new materials. This new materials can be metal, ceramic, organic based (like paints and plastics) or mixing of them (composite).**

Prof. Dr. Kerem Altuğ GÜLER

Hot dip coating

Hot dip coating of metals is the oldest, easiest and cheapest technique.

For hot dip coating:

- Coating metal must have low melting point. (Zn, Sn, Pb, Al)
- Properties of base metal must not change in bath temperature. Steel is the base metal for hot dip coating. Also, Sn coated Cu and Al coated Ti or Mo are used for special purposes.

Advantages of hot dip coating

- Edges, corners and complex shapes can be coated easily.
- Metallurgical bonding occurs between coating and base metal and it has resistance to mechanical damages.
- Corrosion resistance to against to many atmospheres.
- Maintenance free.
- Long service life. (~70 years)
- Easy to paint.

** The last three of them are especially for hot dip galvanizing.*

Hot dip galvanizing (Zinc coating)

It is a commonly used process to protect Fe based products against to atmospheric, underground and underwater corrosion.

<u>Zinc coating protects steel in three ways:</u>

1. Continuous zinc film separates steel from its environment.
2. In case of any discontinuity, zinc behave as a sacrifice anode for protect steel. (It is a kind of cathodic protection, Zn is more active than Fe in EMF series.)
3. Zinc provides high corrosion resistance in many atmospheres. In open air conditions, almost insoluble zinc carbonate layer [$3Zn(OH)_2.2ZnCO_3$] occurs on galvanized surfaces with time.

Process stages of hot dip galvanizing

- Surface cleaning of base metal.
- Fluxing.
- Galvanizing.
- Post galvanizing treatments.

Surface cleaning: Grease (oil) removing, shot or bead blasting, alkali cleaning (caustic) and acid cleaning (pickling).

Fluxing treatments:

Purpose of fluxing:

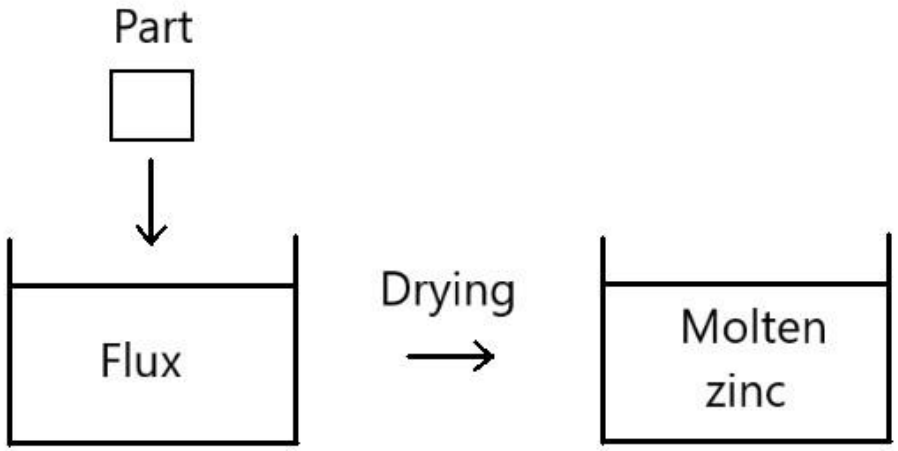
- Prevent oxidation of metal just before galvanizing (after cleaning).
- To activate metal surface for easy reaction.
- Provide wetting of molten metal to base metal surface.

Composition of flux: 87% $ZnCl_2$ + 13% NH_4Cl (solution)

- Fluxing in a different bath is called dry galvanizing.
- Fluxing combined with zinc coating is called wet galvanizing.

Dry galvanizing

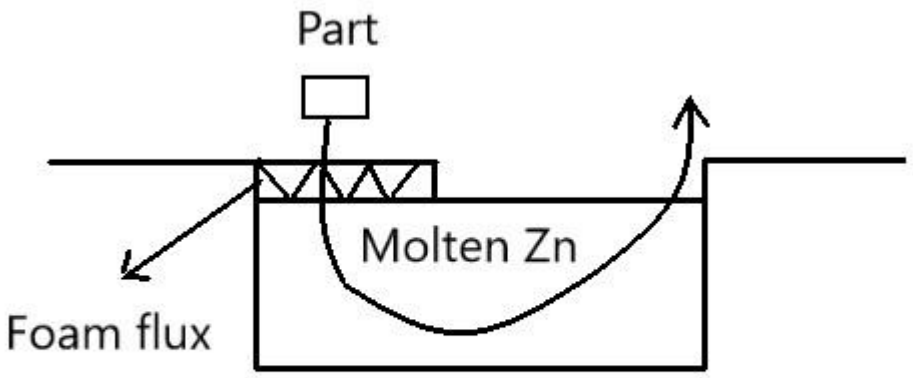
- After cleaning, part is dipped into flux solution then dried and dipped into molten zinc
- Separated fluxing is an easy controlling process.
- It gives more consistent results.
- Dry galvanizing is necessary if zinc bath includes Al.



Dry galvanizing

Wet galvanizing

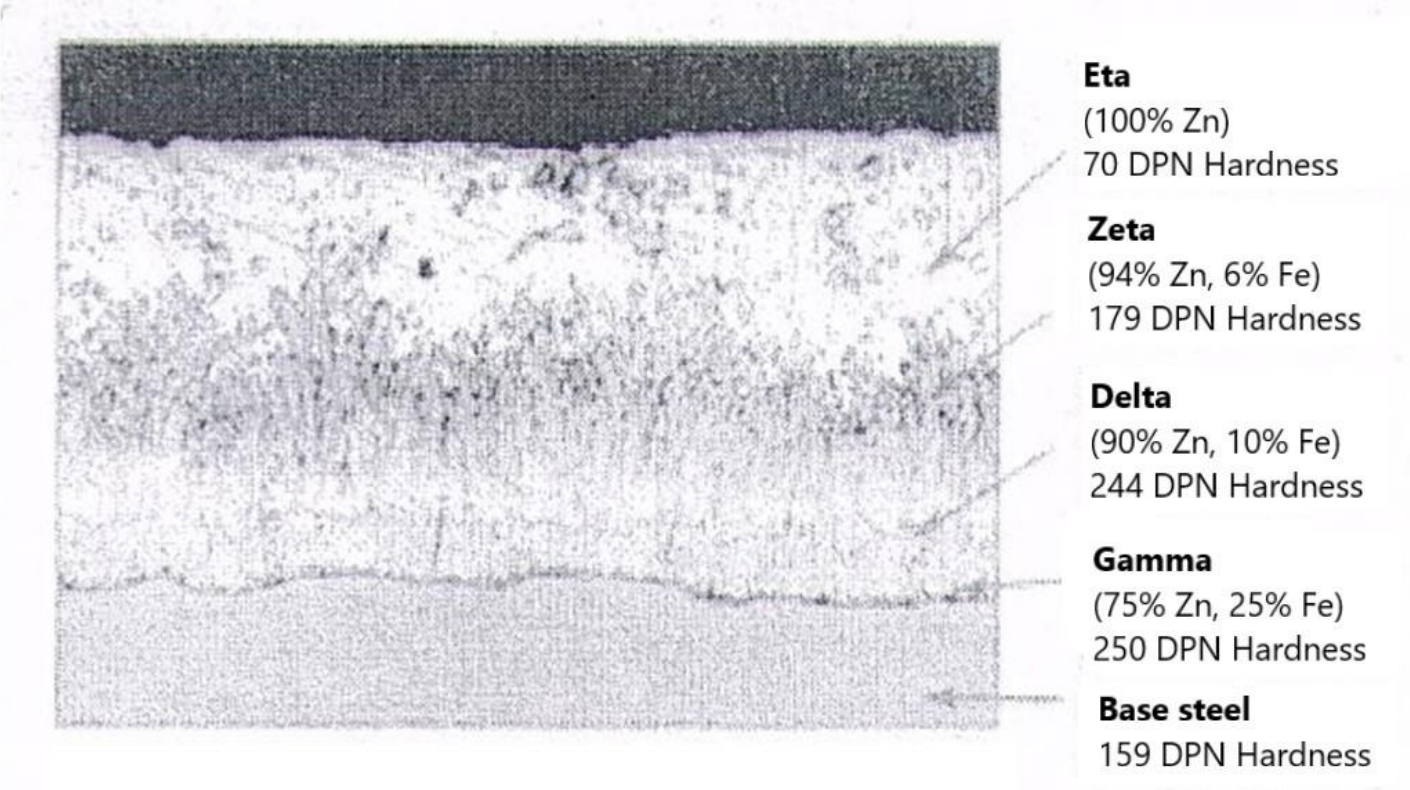
- Cleaned part is directly dipped into molten zinc.
- Zinc bath is divided into two parts.
- Foamy flux layer is placed on the first part. Metal is dipped from this part and got out from second part.
- It provides clean and bubble free coating surfaces.



Wet galvanizing

Galvanizing process features

- Tm Zinc: 420 °C
- Molten zinc bath temperature: 445-465 °C
- An alloy layer forms between steel and molten zinc.



Nature and thickness of these alloy layers depend on; **steel composition, bath composition, bath temperature and dipping time.**

1. Steel composition

Si content of the steel is so important. (0.02-0.20 %)

High Si content causes thick and brittle coating layers.

2. Bath composition (for ordinary galvanizing)

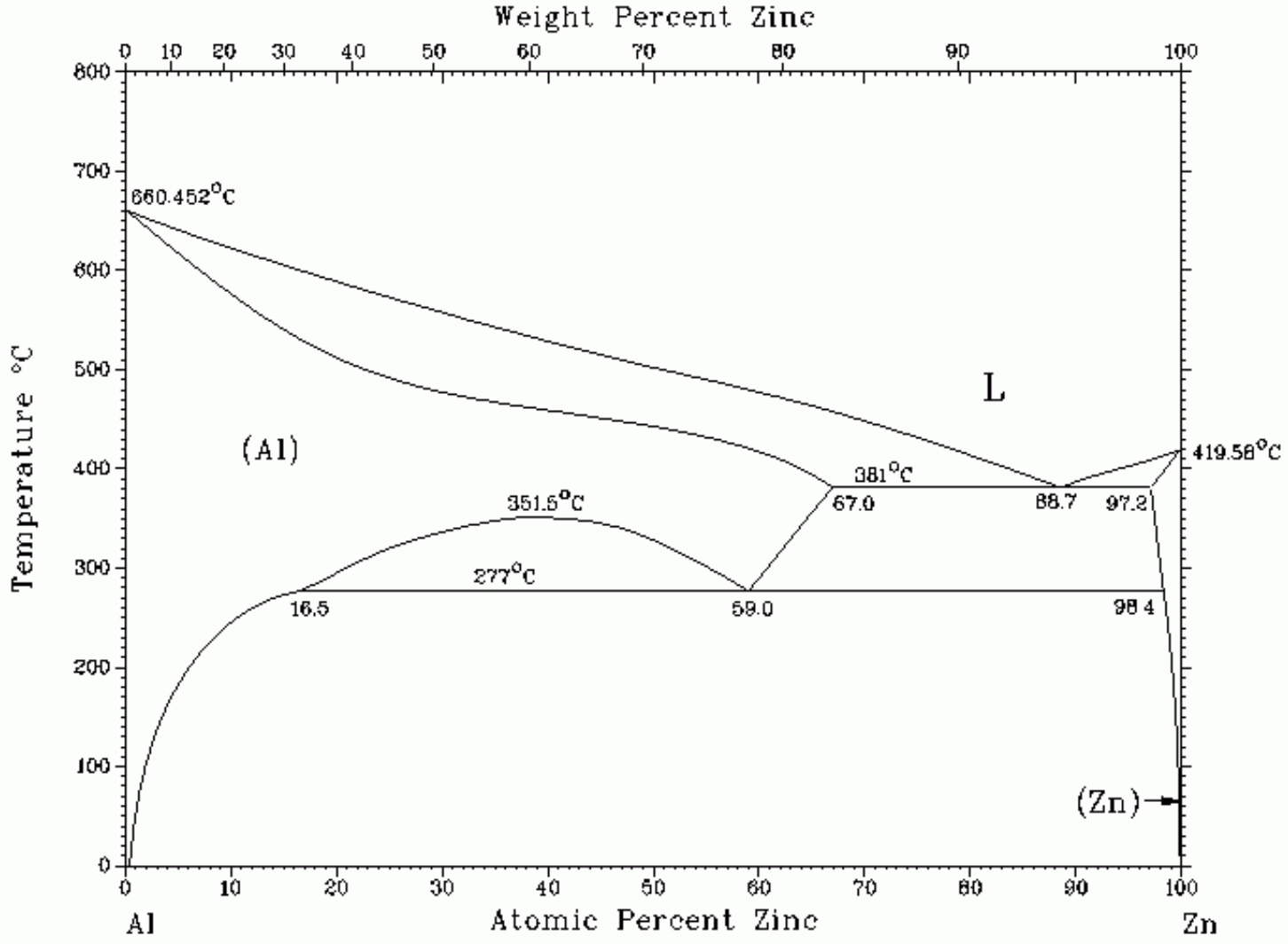
- Purity of zinc must be 99.0% - 99.98%.
- To improve surface tension, small amount of Pb can be added.
- Total amount of additions must not be higher than 1.65%.

3. Bath temperature

- If bath contains 0.3% Al, temperature must be between 445-465 °C.
- **Galfan* (Zn - Al 5%)** coating, bath temperature 420 °C.
- **Galvalume** (Zn - Al 55%)** coating, bath temperature 600 °C. (Take care of base material for structural changes.)

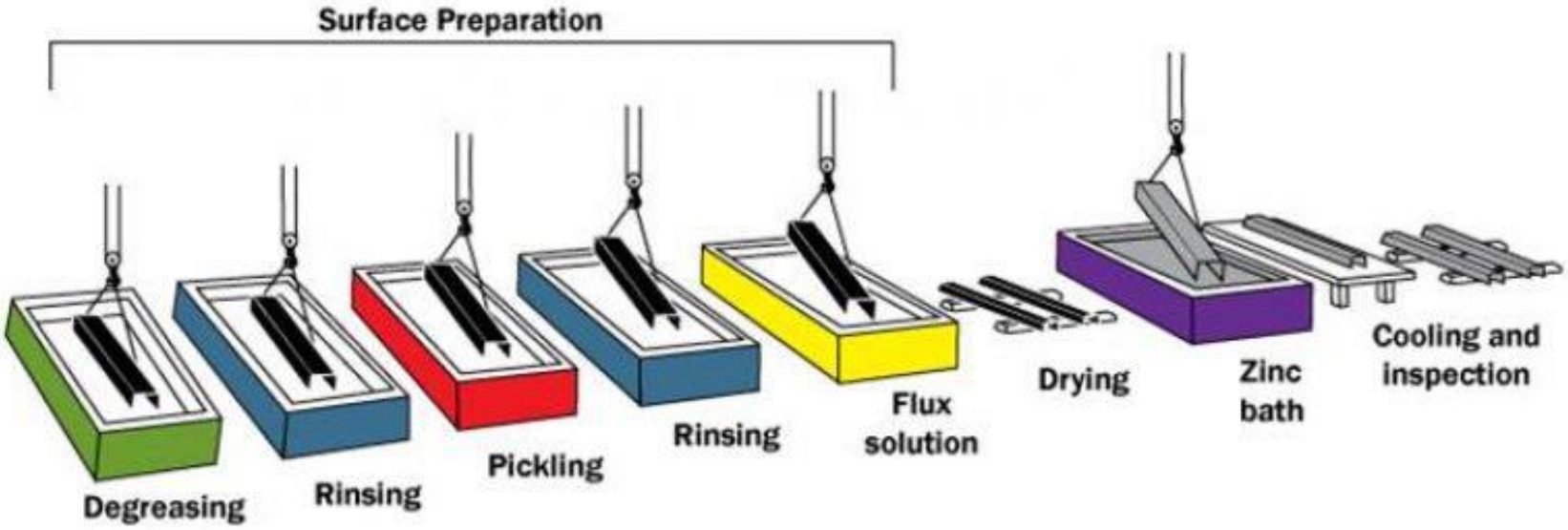
*Galfan: It is a kind of Zn-Al alloy includes 0.05 % Ce and La, 5% Al. It is an eutectic alloy . It has higher corrosion resistance also high plastic deformation capability. This coating is applied in case of post deformation process is required.

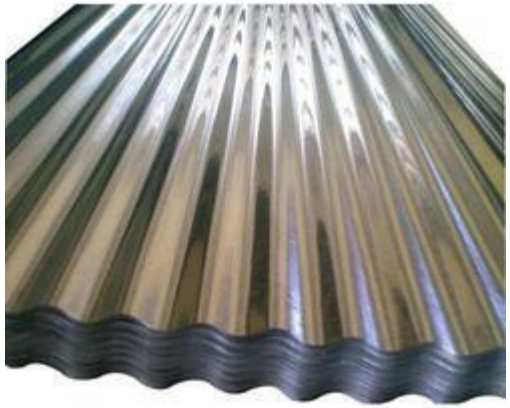
**Galvalume coated steel panels are especially used for roof sidings. It has smoother and brighter appearence than ordinay galvanizing.


Weight Percent Zinc
0 10 20 30 40 50 60 70 80 90 100
800
700
600
500
400
300
200
100
0
660.452°C
L
(Al)
381°C
67.0
88.7
97.2
419.58°C
351.5°C
277°C
16.5
59.0
98.4
(Zn)
Temperature °C
0 10 20 30 40 50 60 70 80 90 100
Al
Atomic Percent Zinc
Zn

4. Dipping time

- Excessive time causes thicker coatings.
- Complex shape parts need more time.
- Addition of 0.2 – 0.4 % Al to zinc bath provide thin, more ductile and more bright coatings.
- Reaction between Al and flux decreases quality of flux. So, dry galvanizing is necessary if bath contains Al.


Surface Preparation
Degreasing
Rinsing
Pickling
Rinsing
Flux solution
Drying
Zinc bath
Cooling and inspection



Galvalume

Post galvanizing treatments

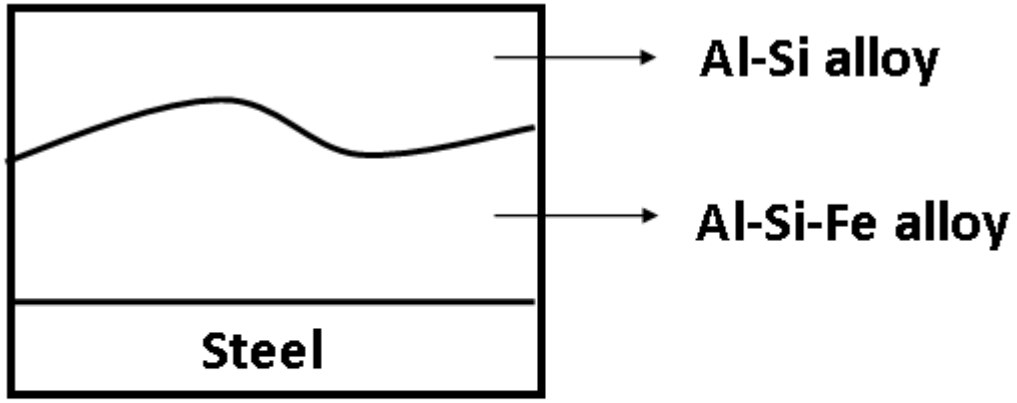
- **Galvannealing:** Annealing of galvanized coating at ~500 °C. It develops diffusion between Fe-Zn phases.
- The resulting coating has a matte appearance, and is hard and brittle.
- Due to iron present in the surface alloy phase galvanneal develops a reddish patina in moist environments - it is generally used painted.
- It brings weldability, paintability, higher hardness and higher resistance to heat. In comparison to a zinc (galvanized) coating galvannealed has better spot weldability, and is paintable.
- Phosphate, chromate coatings and painting can be carried out.

Hot dip aluminium coating

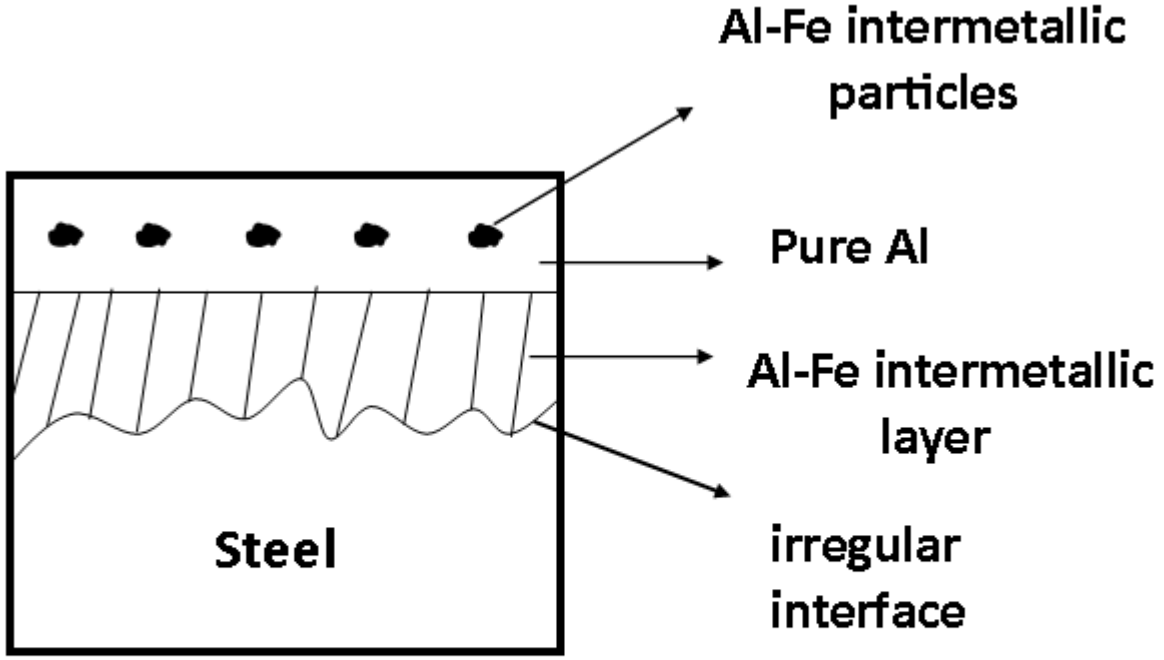
Process temp ~700 °C. Base metal structure can be changed. Thera are two types coating compositions.

- Type 1: Al-Si (5-11 %) alloy is used.
- Type 2: Commercial purity Al is used.

- Type 1 gives thinner coating and bath temperature is lower.


Al-Si alloy
Al-Si-Fe alloy
Steel

TYPE 1

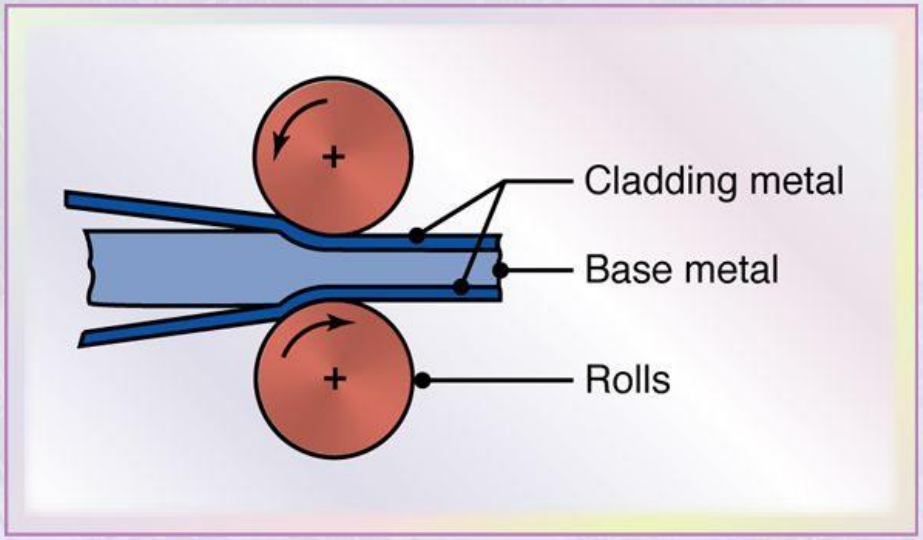

Al-Fe intermetallic particles
Pure Al
Al-Fe intermetallic layer
irregular interface
Steel

TYPE 2

Cladding (Roll bonding)

- Cladding refers to the metallurgical process of coating a metal onto another metal under high temperature and pressure so as to protect the inner metal from corrosion.
- The base metal is sandwiched or cladded between two sheets of coating metal. This sandwich is then passed through two heavy rollers maintained at high temperature and pressure.
- Cladding may be done using, aluminium, stainless steel, anodized aluminium or copper. Of the lot aluminium cladding is traditionally preferred due to its features like flexibility, lightweight and recyclable nature.

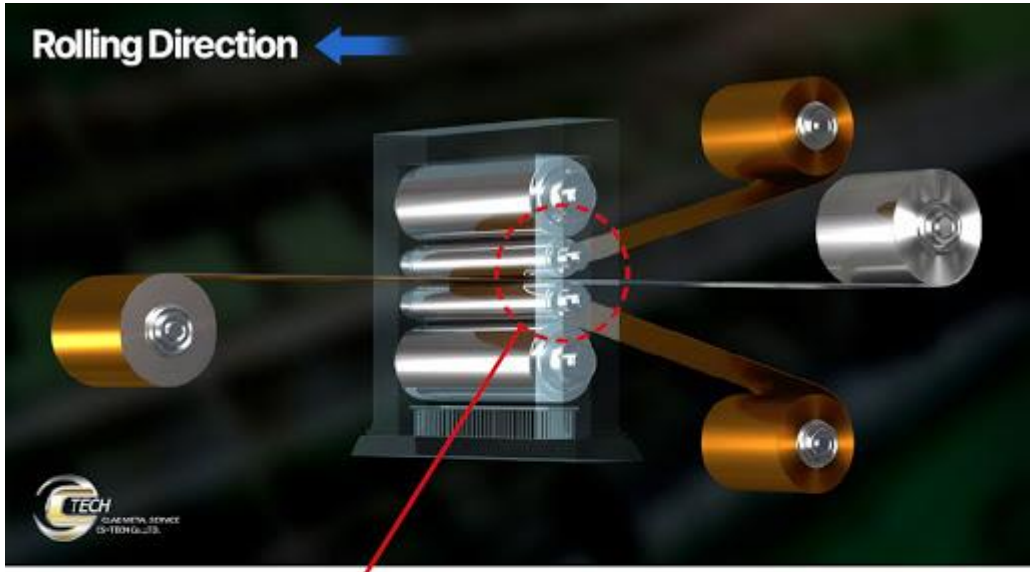
Roll Bonding

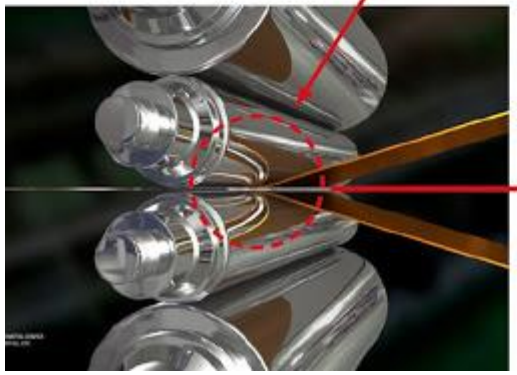


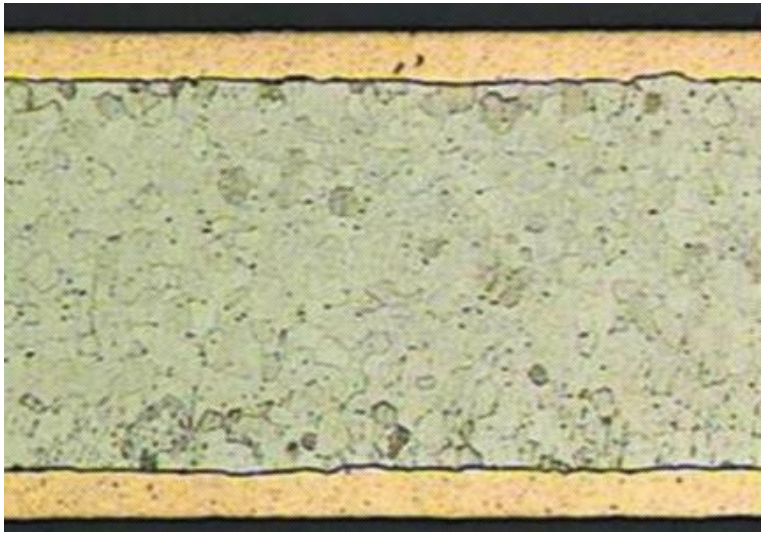
Schematic illustration of the roll bonding or cladding process.

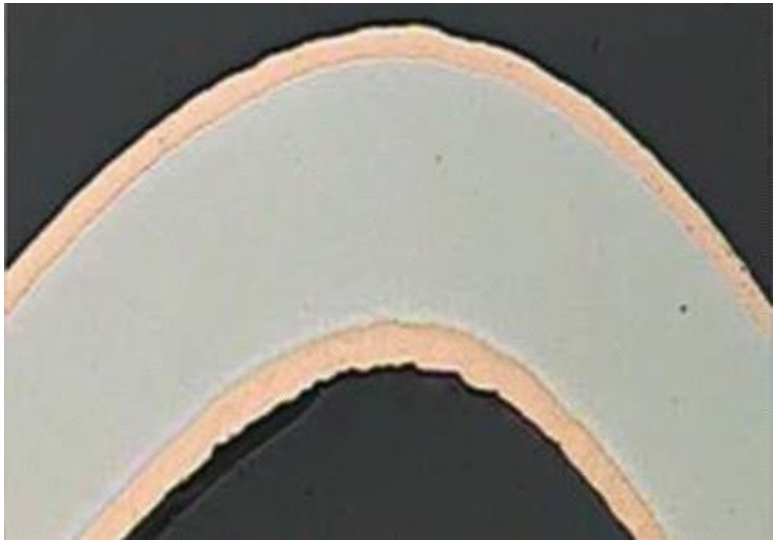
Applications

- Al clad sheets used in aircraft industry in which a plate of duralumin is sandwiched between two layers of 99.5 %pure Al.
- Cu clad steel wire is obtained by forcing steel rod into closely fitted Cu tube is used for electrical conductors processing combining strength of steel with the high conductivity of Cu.
- Several metals like Au, Ni, PdAg alloy or Sn can be cladded on Cu or stainless steel plates for electronic connector production.
- To develop surface properties like corrosion resistant in steel sheets.
- The cladding metal provides electrolytic protection to the base metal.


Rolling Direction







Video links

- https://www.youtube.com/watch?v=UE7zY9JoVIc
- https://www.youtube.com/watch?v=kwCyq06aatA
- https://www.youtube.com/watch?v=ZXvLLIjBMvo
- https://www.youtube.com/watch?v=ClPS68_XYs0
- https://www.youtube.com/watch?v=ZpHuTbl9ZCk
- https://www.youtube.com/watch?v=FtPWjkATDfc
- https://www.youtube.com/watch?v=y31OSPuLYl4