Welding Technology ME692

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Course details: L18

- ✓ Tuesday and Friday (2-3:15 PM): 3 hrs/ week
- ✓ Prerequisites for UG: TA 201 and TA202
- ✓ There are no prerequisites for PG students.

Evaluation/Grading

- ✓ Attendance (10%): less than 80%: 0 marks, ≥80%: 10 marks
- ✓ Quiz (20%): Two quizzes
- ✓ Mid-sem (28%)
- ✓ End-sem (42%)

Grading Policy: Relative and Granular Grading

Quiz	Weightage %	Date of Quizzes: L18, L19 and L20
Quiz 1	10	13th Feb evening (6:00 PM-7:30 PM)
Quiz 2	10	6th April evening (6:00 PM-7:30 PM)
Mid Sem	28%	
End Sem	42%	

First-class: 5th Jan, Last class: 19th Apr
Holiday: 26th Jan,8th Mar, 29th Mar

Mid-Sem Exam: Feb 19-24, 2024
Mid-Sem Recess: Mar 23-31, 2024

Course Policy

- ✓ Any form of academic misconduct (cheating, use of a mobile or carrying the mobile during exams or quizzes and talking with classmates during exams) will be rewarded with an **F grade**. Additional action may also be taken.
- ✓ Do not Use Mobiles: Switch off/Silent Mode
- ✓ Those who do not have 75% attendance at any point of time may be de-registered from the course.
- ✓ For the end-semester exam, a candidate may not be allowed to appear if their attendance falls below 80%.
- ✓ Without Mid Sem and End Sem: **Direct Fail (F grade)**

Textbooks:

1. **Principles of Welding (R. W. Messler)**
2. Principles of Welding Technology (L. M. Gourd)
3. Phase transformations in metals and alloys (D. A. Porter & K. E. Easterling)
4. Heat conduction (D. W. Hahn & M. N. Ozisik)
5. Fundamentals of solidification (W. Kurz & D. Fisher)
6. Welding Metallurgy (S. Kou)
7. Metallurgy of welding (J. F. Lancaster)
8. Manufacturing Science (A. Ghosh &A. K. Mallik)

TAs

1. Radhika Sarawagi radhika20@iitk.ac.in
2. C. Narendra Kumar (narendrak20@iitk.ac.in)
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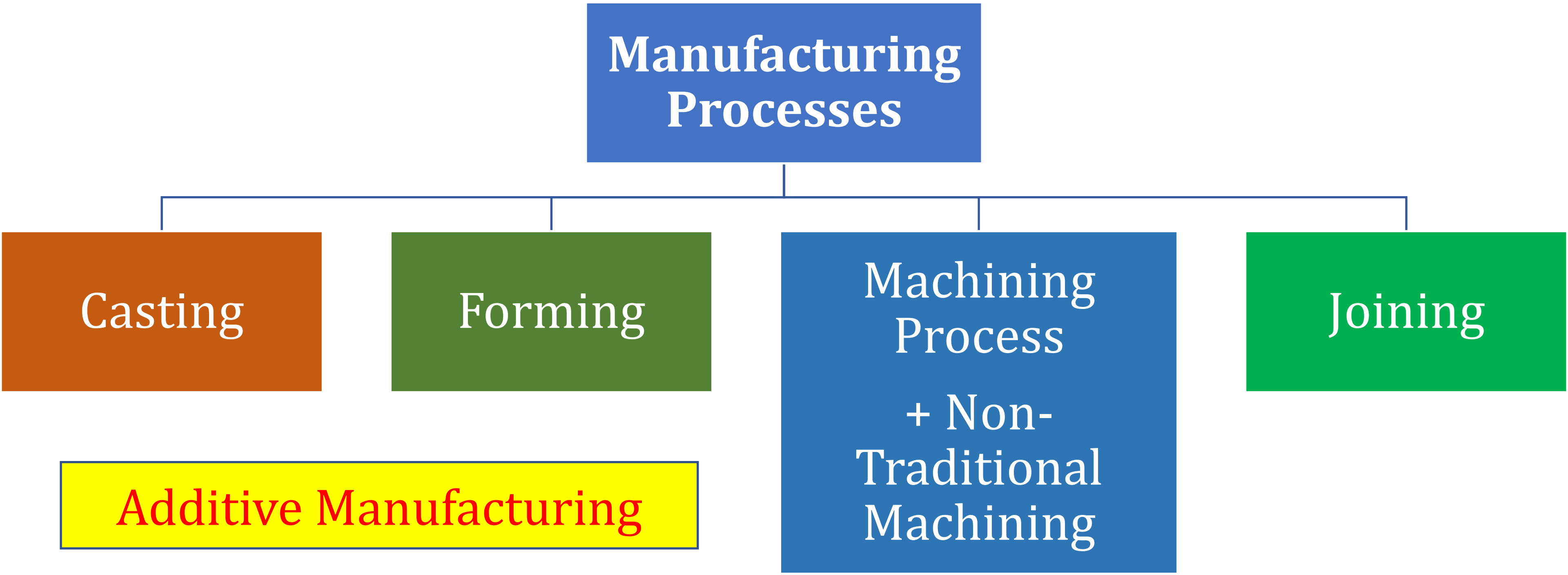
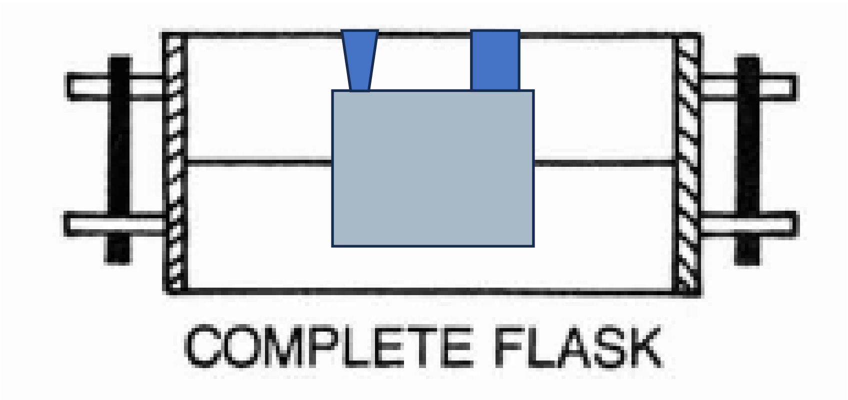
Introduction to welding

Manufacturing Processes

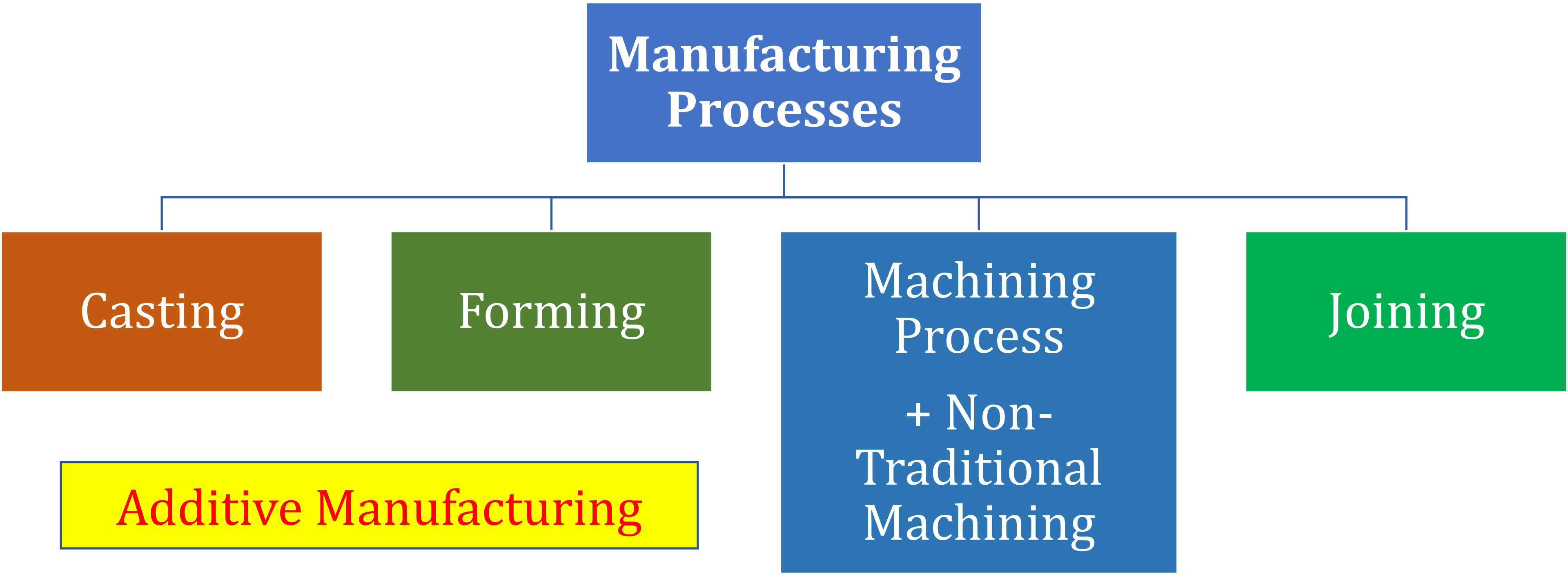


- ✓ Manufacturing: Turning raw materials into finished products.
- ✓ Casting is also one of the oldest known manufacturing processes.
  - ✓ Example: Green sand casting, Investment Casting, Permanent Mould Casting, Die Casting, Centrifugal Casting

Manufacturing Processes

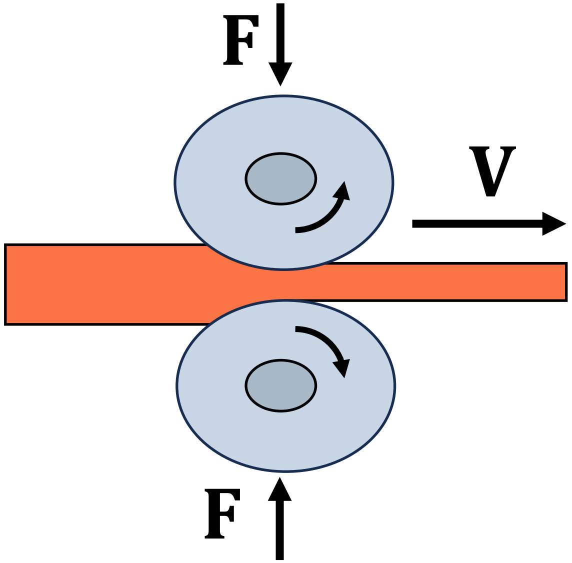


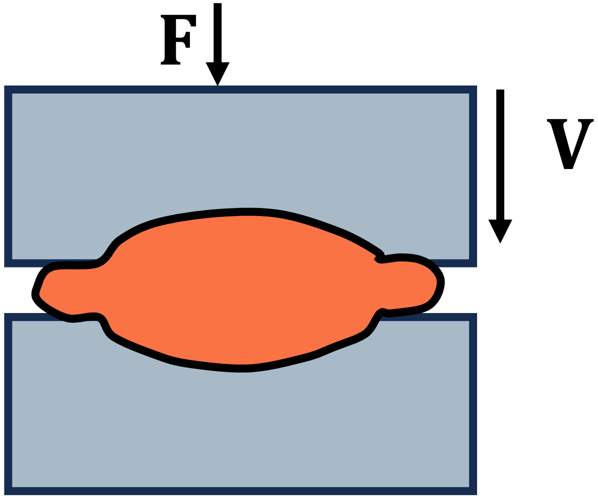
Manufacturing Processes

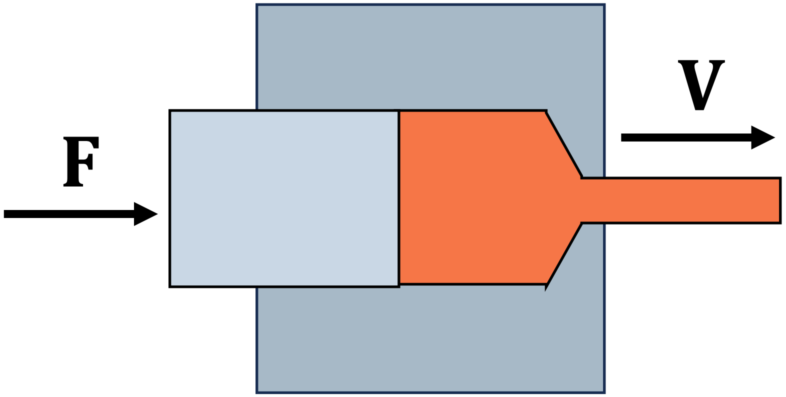


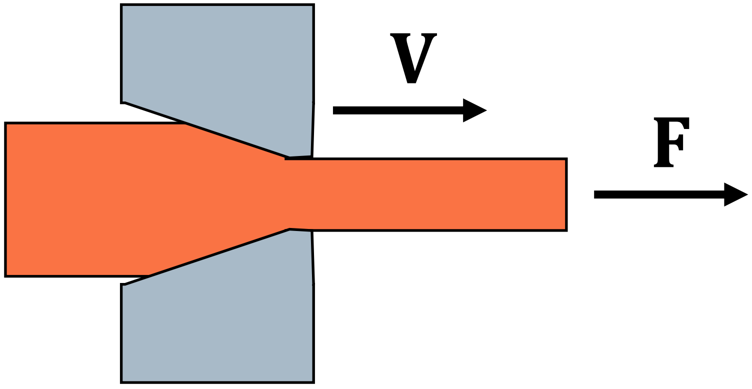
- ✓ Forming: Using plastic deformation to obtain the desired shape.
  - ✓ Examples: Open/Close Die forging, Drop/ Press Forging, Rolling, Extrusion, Deep drawing, Sheet metal forming, etc.

Manufacturing Processes



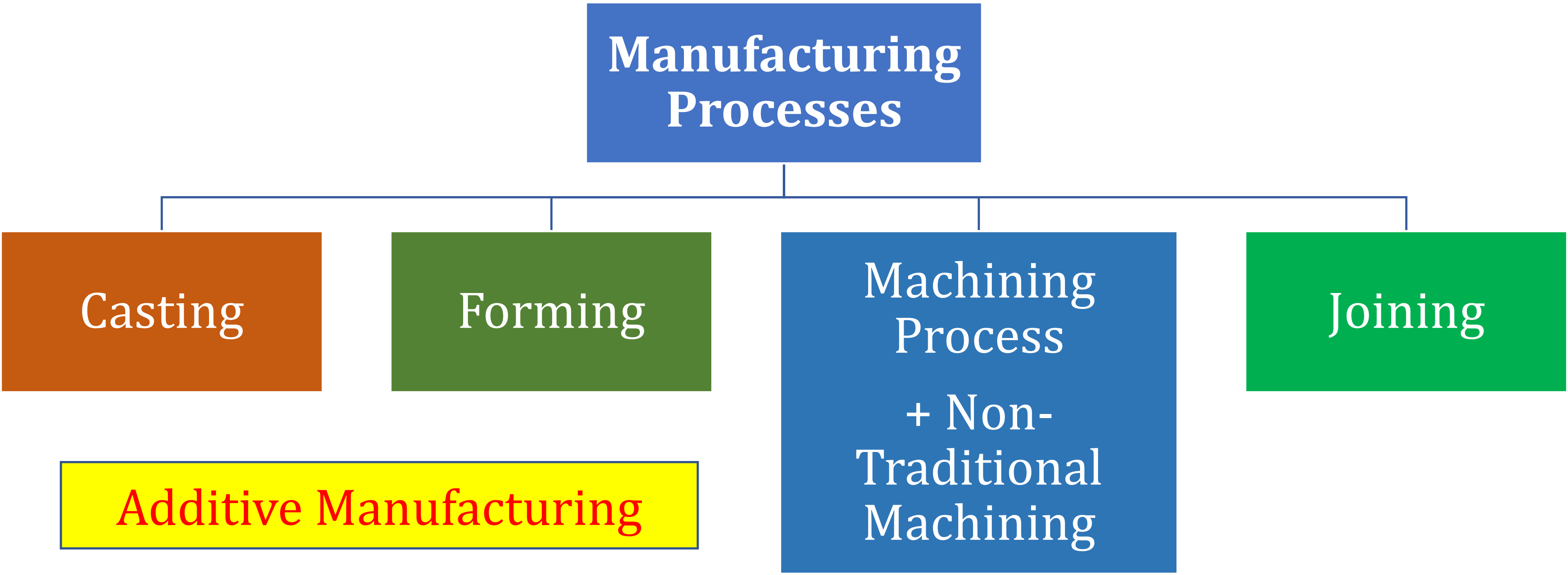






Manufacturing Processes

Manufacturing Processes



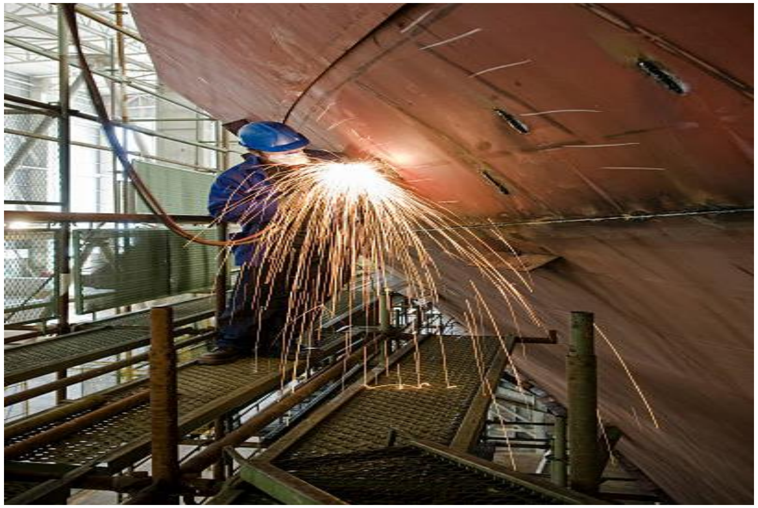
- ✓ Machining Process: It is a secondary manufacturing process where the removal of materials forms the product. It delivers very good dimensional accuracy and a good surface finish.
- ✓ Example: Turning, Drilling, Milling, Grinding, etc.
- ✓ Advanced processes such as EDM, ECM, AJM, etc., are non-traditional machining.

Manufacturing Processes

Joining

Joining is important when a product is impossible to manufacture as a single piece or different material properties are required for different parts.

Example: Welding in Ships, size is very large, so it can not be manufactured in one part.



https://fsmdirect.com/mission-dust-control/

https://www.diversinstitute.edu/programs/underwater-welding/

Joining Classification

There are 3 main classifications of joining:

- ✓ Mechanical
  - ➢ Nails
  - ➢ Rivets
  - ➢ Bolts

- ✓ Chemical
  - ➢ Adhesives
  - ➢ Glues

- ✓ Physical (either phase change/diffusion)
  - ➢ Welding, soldering, brazing etc.

Introduction: Welding

- ✓Welding is a fabrication process where two interfaces are physically and chemically coalesced using heat, pressure, or both.
- ✓Welding does not apply just to metals.
- ✓Thermoplastic polymers, crystalline oxide or non-oxide ceramics, intermetallic compounds, and glasses can all be welded.
- ✓ Maybe these processes can be named "thermal bonding for thermoplastics or fusion bonding or fusing for glasses," **but it is part of welding!**

Overview of Welding

- ✓ Welding: Multiple parts can be used to make a single entity by **material continuity**
- ✓ Continuity implies the absence of any physical disruption on an atomic scale, that is, no gaps.
- ✓ Unlike mechanical attachment or fastening, where a physical gap always remains, no matter how tight the joint is.
- ✓ The tendency for atoms to bond is the fundamental basis for welding.

Overview of Welding

- ✓ All that is required to produce a weld is to bring atoms together to their equilibrium spacing in large numbers to produce aggregates and to bring separate aggregates together to do the same for atoms comprising their surfaces at mating interfaces.
- ✓ The result of bonding is the creation of continuity between aggregates or crystals and the formation of an ideal weld.

Ideal weld: achieving continuity

- ✓ When two or more atoms are separated by infinite distance:

  There is no force of attraction or repulsion between them.

- ✓ As they are brought together from this infinite separation: A force of electrostatic or Coulombic attraction arises between the positively charged nuclei and negatively charged electron shells or clouds.

Ideal weld: achieving continuity

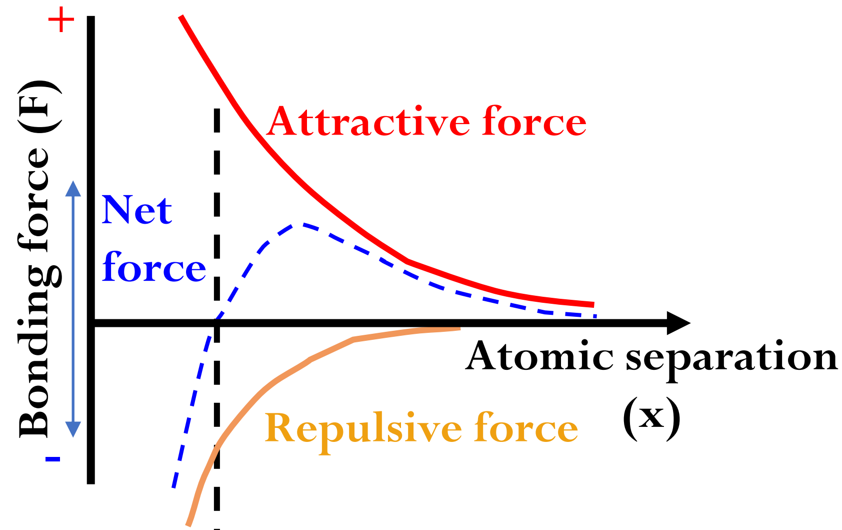
- ✓ As the separation distance decreases to the order of a few atom diameters, the outermost electron shells of the approaching atoms begin to feel one another's presence, and a repulsion force between the negatively charged electron shells increases more rapidly than the attractive force.

Ideal weld: achieving continuity

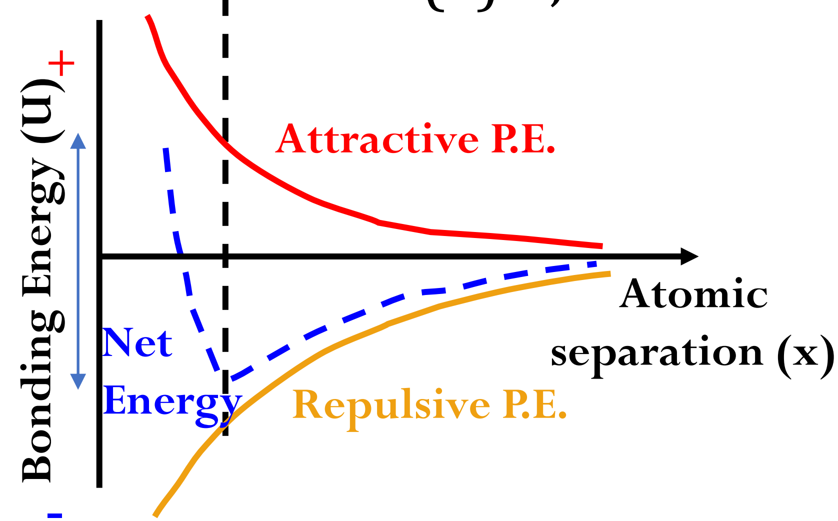
- ✓ The attractive and repulsive forces combine to create a net force, which at some separation distance becomes zero: the equilibrium interatomic distance

$$F = -\frac{dU}{dx}$$

- ✓ At this equilibrium spacing, the net potential energy is minimal, the aggregate of atoms is stable, and the atoms are bound to be bonded.



AF α $1/(x)^n$, n~2-6
RF α $(x)^m$, m~12



Ideal weld: achieving continuity

Ideal weld: achieving continuity

- ✓ Welding process Goal: bring atoms together to their equilibrium spacing.
- ✓ There are three distinctive mechanisms for obtaining metallic continuity
  - ✓ Solid-phase plastic deformation, without or with recrystallization,
  - ✓ Diffusion
  - ✓ Melting/solidification.

Advantages and Disadvantages of Welding

Advantages	Disadvantages
The welded joint has high strength, sometimes more than the parent metal	Impossible to disassemble joints without destroying detail part
Wide variety of process embodiments	Heat of welding degrades base properties
They can be done in any shape and any direction.	Members may become distorted due to uneven heating and cooling during welding.
Manual or automated operation	Requires considerable operator skill
Leak-tight joints with continuous Welds	Can be expensive (e.g., thick sections)
Process cost is usually reasonable, Welding can be performed any place, no need for enough clearance.	Capital equipment can be expensive (e.g., electron-beam guns and vacuum chambers)

Classification of welding

Use of Heat and pressure

- ✓One extreme: no pressure but sufficient heat to cause melting
- ✓Another extreme: a sufficiently large pressure to cause gross plastic deformation without the addition of heat

Fusion Welding

- ✓Electric Arc Welding Processes
- ✓Chemical Fusion Welding Processes
- ✓High-Intensity Radiant Energy or High-Density Beam Welding Processes

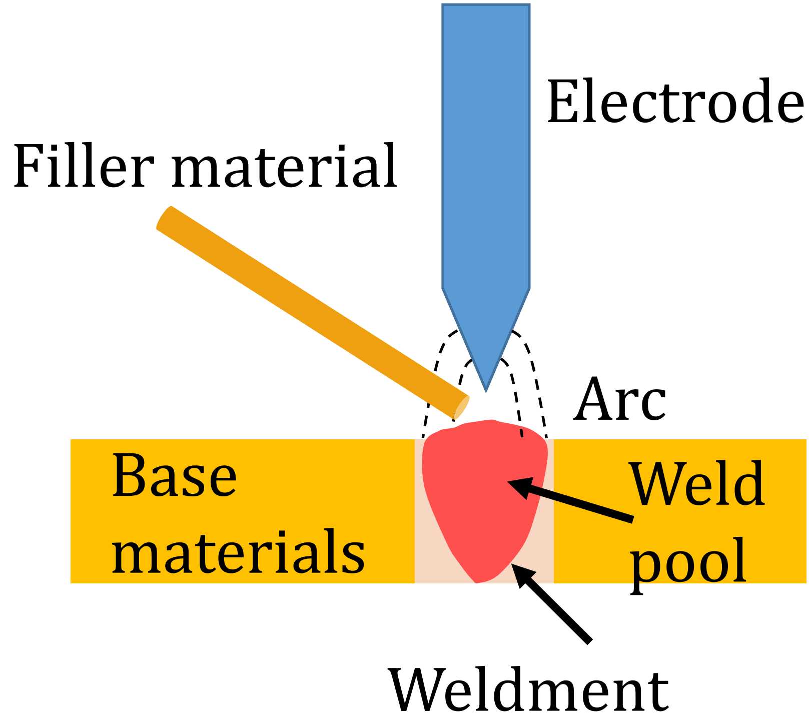
- ✓Resistance Welding

Non-Fusion Welding

- ✓Pressure Welding Processes
- ✓Friction Welding Processes
- ✓Diffusion Joining Processes

Terminology in Fusion Welding

- ✓ The parts that are joined are known as the parent/base material.
- ✓ The completed welded joint may be referred to as a weldment.
- ✓ The material added to help form the join is called filler or consumable.
- ✓ The filler material can be the same type as the base material, even if not the same composition as the base material(s).
- ✓ Sometimes, the filler material may not be required.



Terminology in Fusion Welding

Energy for Arc Welding

For an electric arc, the available input power at the source:

Q (Watt)=IU

U: the arc (or electron beam) voltage

I: the arc (or electron beam) current.

- ✓ Energy density: Transferred power per unit area (effective contact between a heat source and the workpiece)
- ✓
- ✓ The units of energy density: Watts per square meter.

Energy for Arc Welding

Heat input in welding:

The net energy input is computed as the ratio of the total input power of the heat source (in watts) to its travel speed.

$$H_{input} = \text{Heat input} = \mathbf{P/V = IU/V}$$

H_{input} = Energy input (in watt-seconds per mm or joules per mm)

P = IU=Total input power of the heat source (in watts),

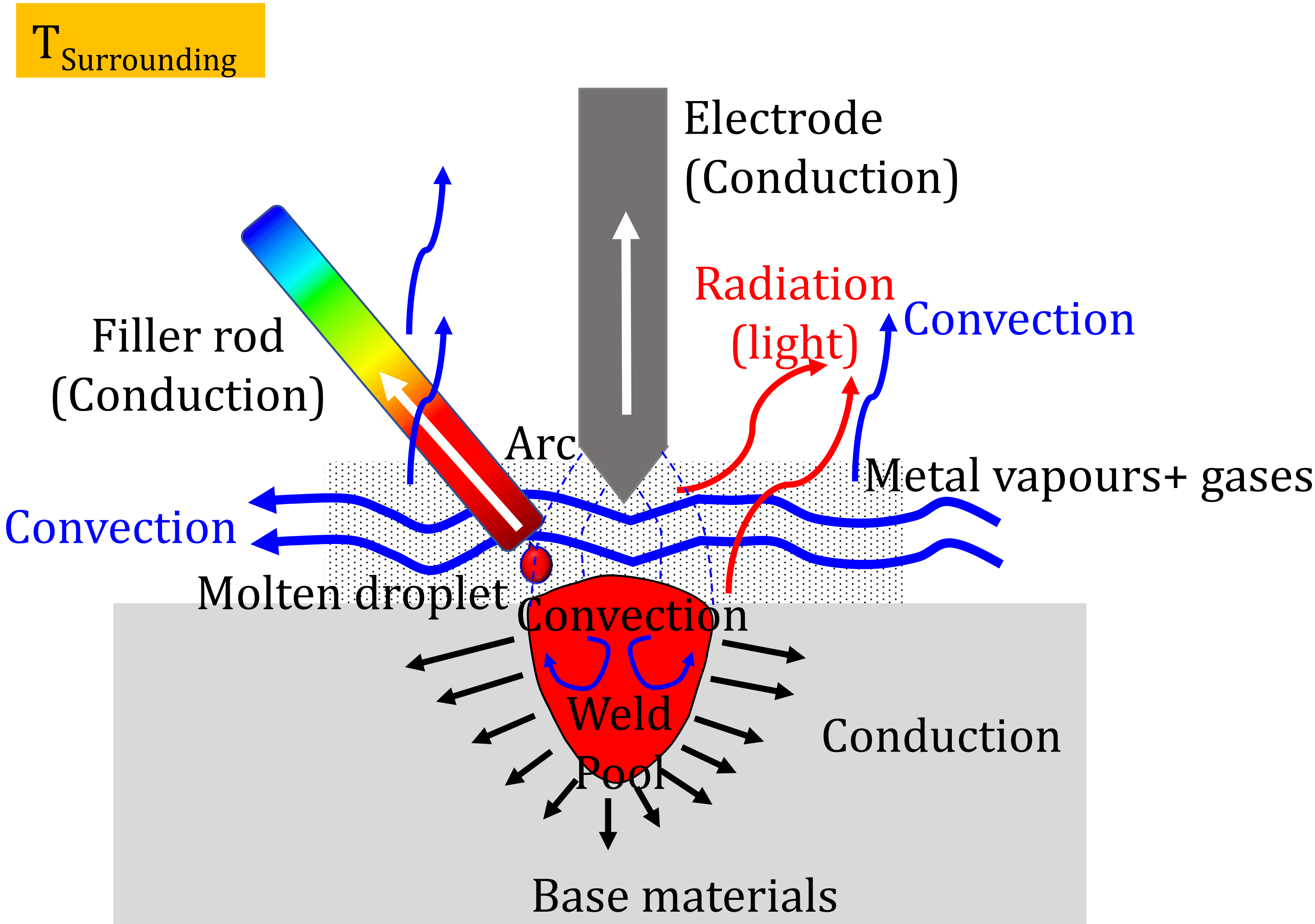
V= Travel or welding speed or velocity (in mm per second).

The higher the heat input to a workpiece, the greater the effect of the heat, both good and bad.

Energy for Arc Welding

Heat input in welding:

Energy loss during fusion welding



Mode of Heat Transfer

Conduction mode of heat transfer

Conduction in solids: **lattice vibrations of the molecules** and **the movement of free electrons**.

In gases and liquids: **collisions and diffusion** of the molecules during their random motion.

Fourier's law of heat conduction

Rate of heat conduction:

$$Q_{cond} = -kA\frac{dT}{dx}$$

Heat is conducted from high to low temperature.

Heat is conducted in the positive x-direction.