Group 4

High velocity impact welding techniques for dissimilar materials

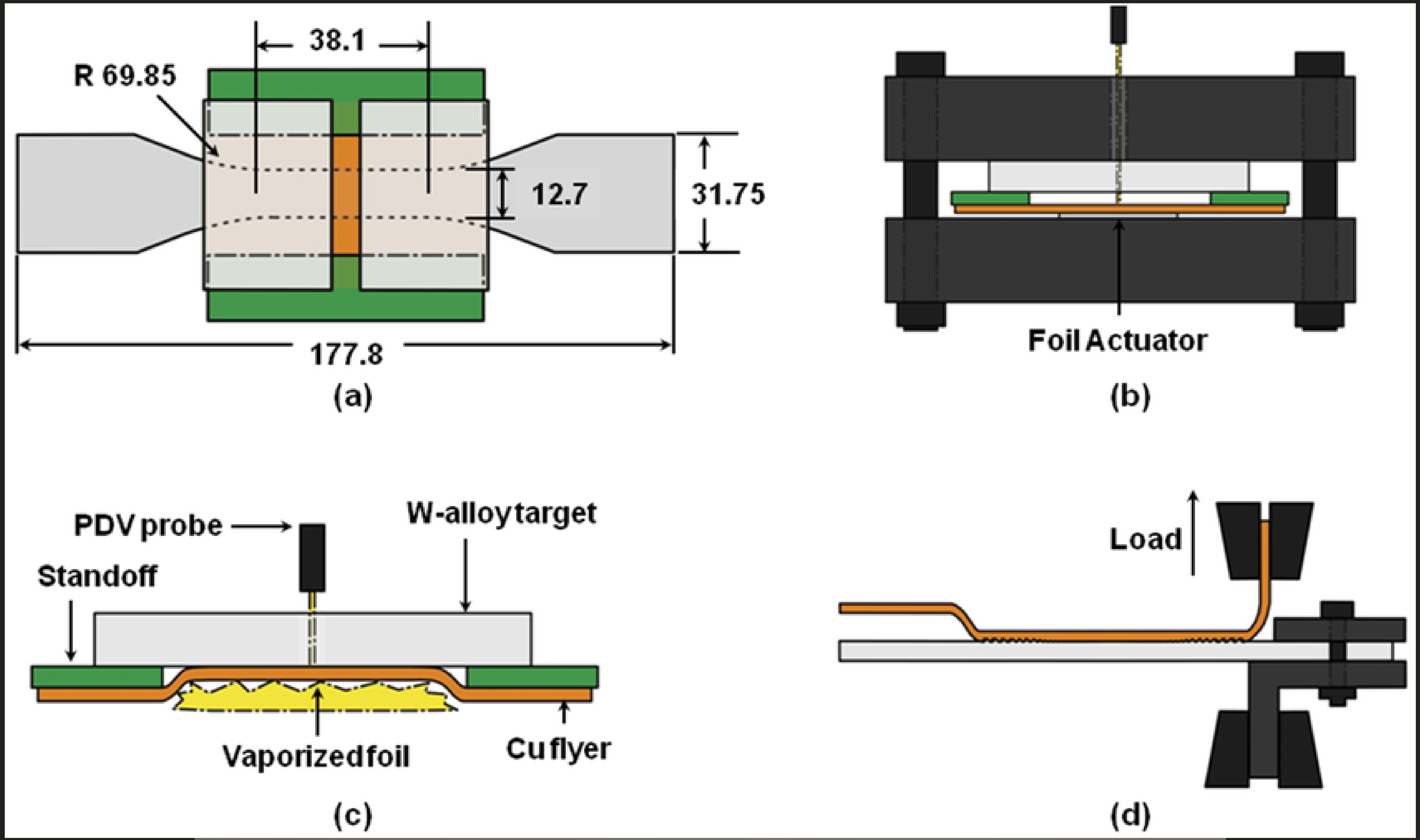
Presented By:
Ekanksh Kanojia (2022ME11326)
Sanidhya Mani Tripathi(2022ME11999)
Shefali Sharma (2022ME11324)
Shubham Kurre(2022ME11325)

TYPES OF TECHNIQUES

- Vaporizing Foil Actuator Welding
- Magnetic Pulse Welding(MPW)
- Laser Impact welding
- Gas Gun Welding(GGW)
- Explosive Welding(EXW)

Vaporizing Foil Actuator Welding

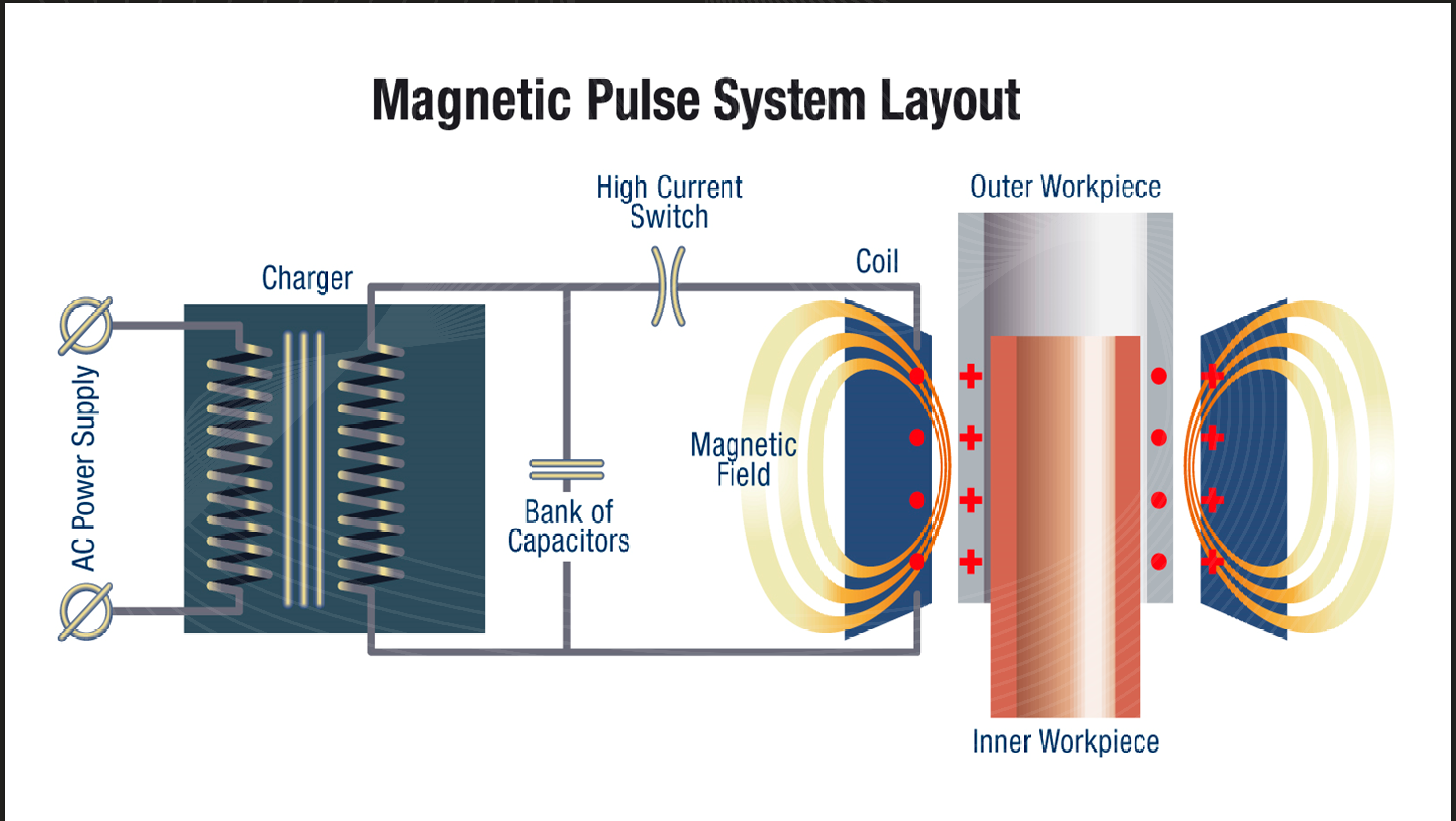
Vaporizing foil actuator welding is a form of impact welding, which can be carried out without the use of chemical explosives. Operating at smaller length scales, but with similar driving pressures as explosive welding, vaporizing foil actuator welding is capable of welding a wide variety of advanced and dissimilar metal combinations. With negligible heating developing during the process, thermal distortion does not occur, and the base-metal properties are retained in the weld. With vaporizing foil actuator welding, the flyer is propelled toward the target by the expanding plasma created when thin foils vaporize. Because aluminum foil vaporizes quickly, it offers a stronger mechanical impulse than copper foil. This welding technique has been successfully used to weld a variety of materials, including bulk metallic glass, steel, aluminum, titanium, copper, and magnesium.


38.1
R 69.85
12.7
31.75
177.8
(a)
Foil Actuator
(b)
PDV probe
W-alloy target
Standoff
Vaporized foil
Cu flyer
(c)
Load
(d)

MAGNETIC PULSE WELDING

Magnetic Pulse Welding (MPW): Magnetic pulse welding utilizes electromagneti forces to accelerate one metal component towards another at high velocities. A pulsed magnetic field induces a current in a conductive flyer plate, generating a repulsive force that propels it towards a stationary base plate. Upon impact, th kinetic energy is converted into heat, plastic deformation, and metallurgica bonding. MPW is commonly used for joining thin metal foils and sheets i automotive, electronics, and aerospace applications.

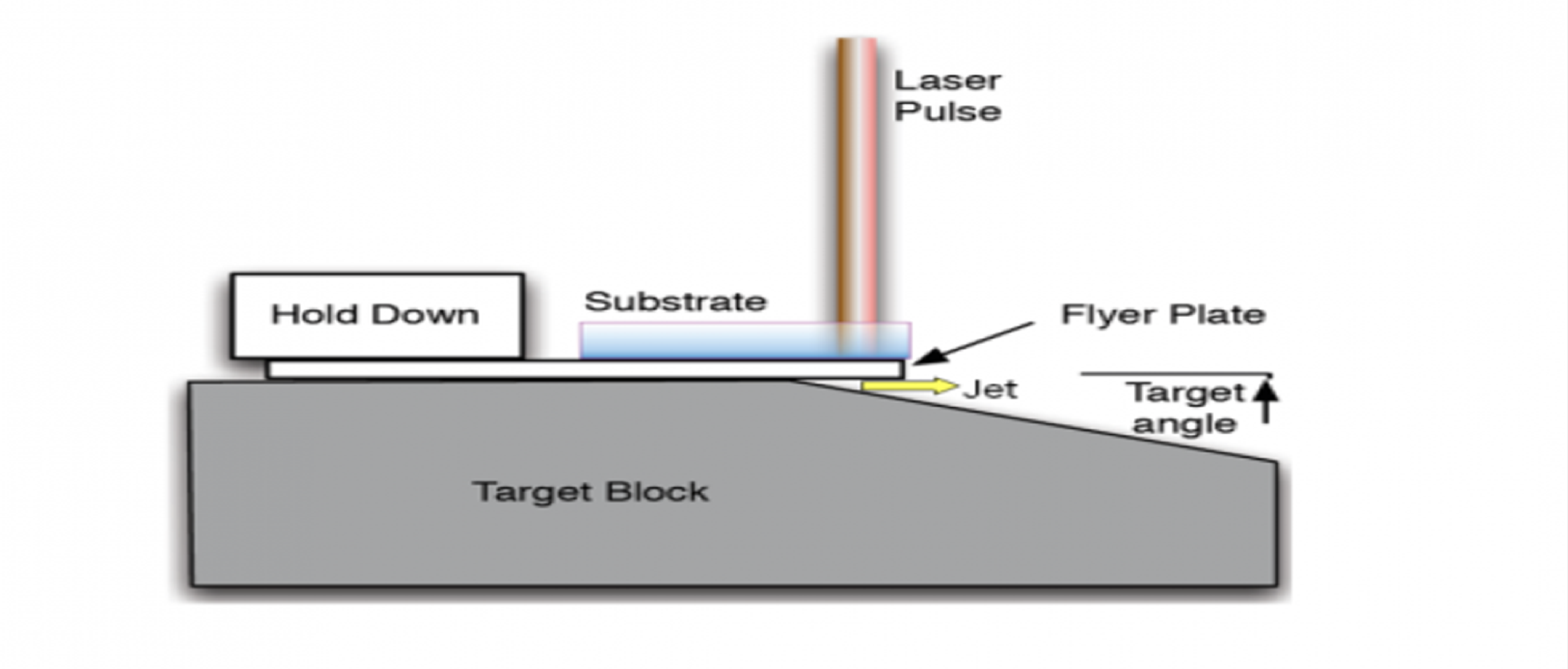
MAGNETIC PULSE WELDING



LASER IMPACT WELDING

- Laser impact welding is an advanced joining process that utilizes the energy of a laser beam to create a high-velocity impact between two metal surfaces, resulting in their fusion. This technique offers advantages such as high speed, minimal heat affected zone, and strong joints, making it suitable for various industrial applications

LASER IMPACT WELDING



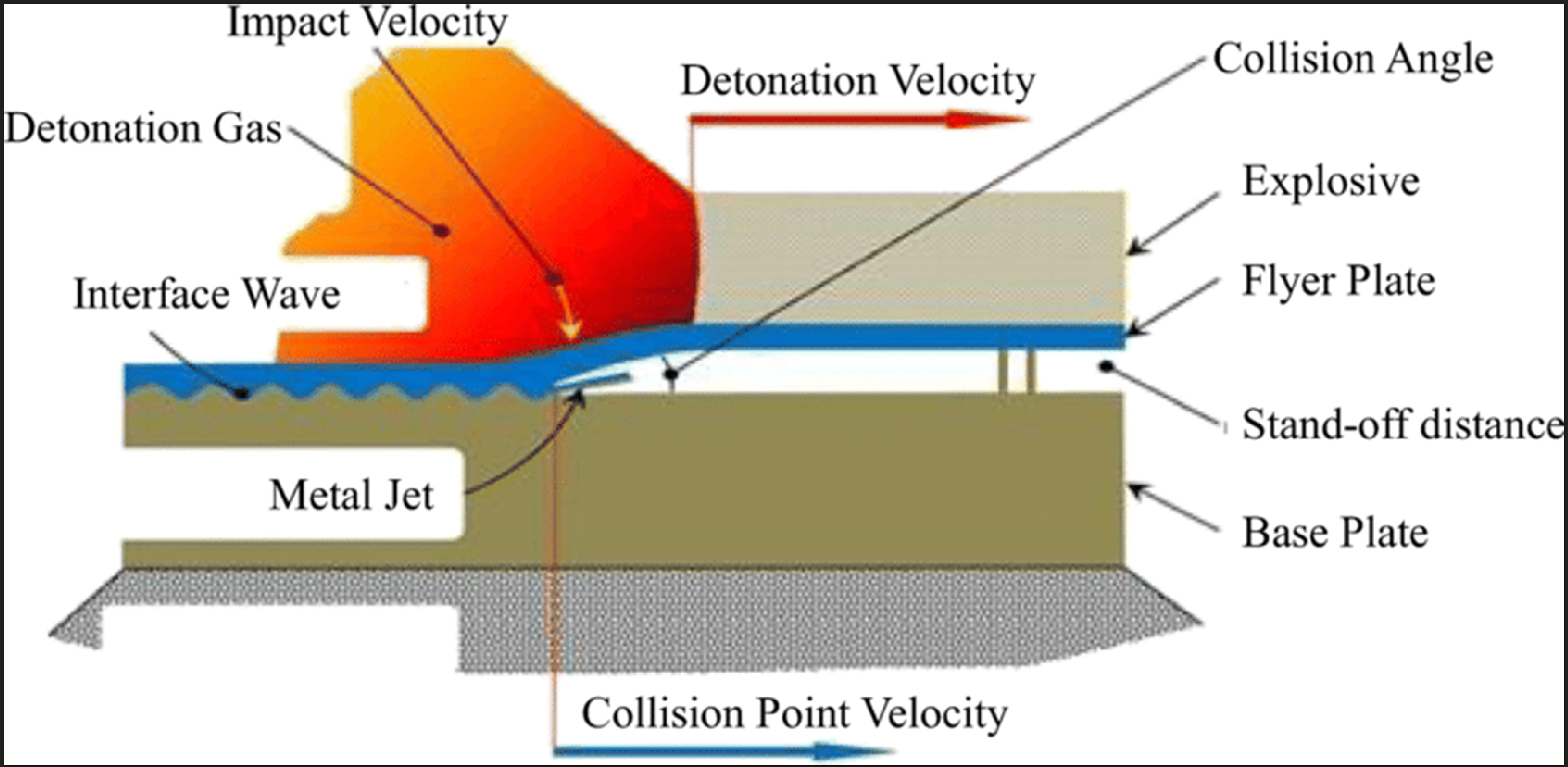
Gas Gun Welding

Since Explosive welding isnot easy to conduct within the laboratory, GGW is usually used to study the welding parameters and welding mechanism for EXW. In GGW, the flyer is accelerated by high speed and high-pressure gas to collide on the target. compressed helium was used since it is clean and easy to control. In GGW, the initial angle is preset either on the flyer or target. The impact velocity can be measured with a high-speed camera and electrical circuit.

EXPLOSIVE WELDING

Explosive Welding (EXW): In explosive welding, also known as explosive bonding, a controlled explosion propels one metal plate (the flyer plate) onto another metal plate (the base plate) with high velocity. The intense pressure and velocity generated by the explosion force the surfaces of the two plates to come into intimate contact, creating a metallurgical bond without melting. This process is widely used for joining dissimilar metals and for cladding applications in industries such as aerospace, shipbuilding, and chemical processing

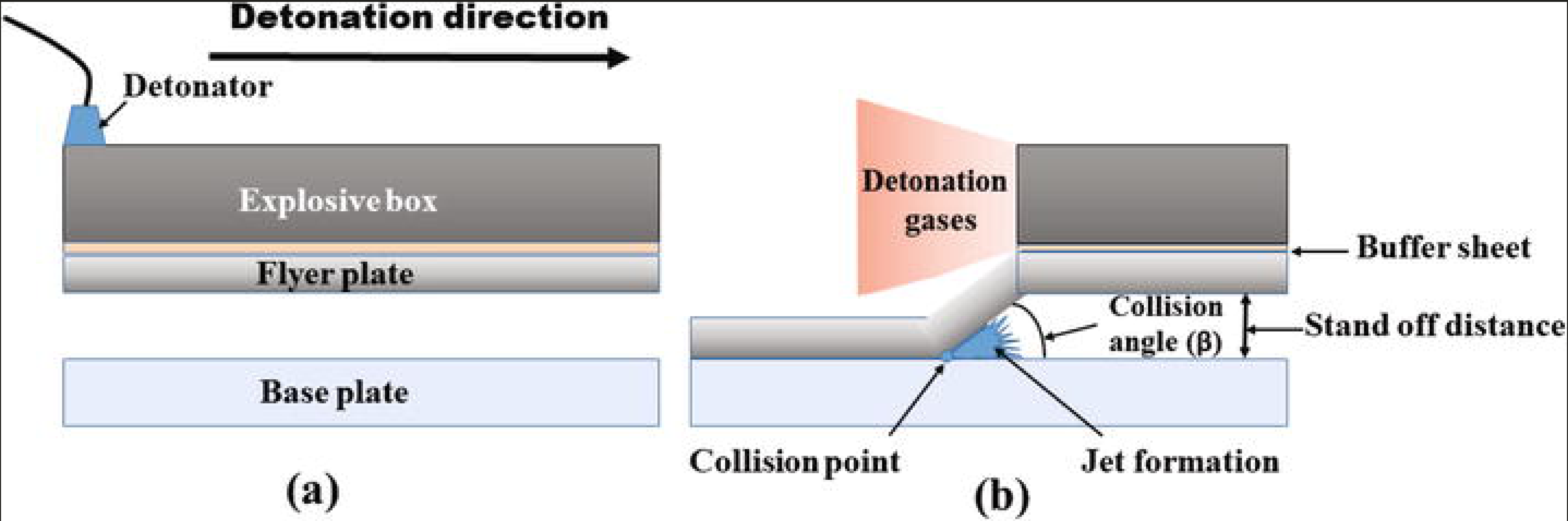
EXPLOSIVE WELDING



Explosive Welding

Working principle of explosive welding

In explosive welding, the explosive serves as an energy source to propel one metal plate towards another. Initially, two plates are set up: the stationary base plate and the movable flyer plate, separated by a calculated distance called the stand-off distance. A buffer sheet is placed over the plates to protect the flyer plate from explosion damage. The main explosive detonator initiates the process from above the explosive. After detonation, the collision point between the plates is observed, where bonding occurs. Jetting, an essential criterion for bond formation, happens during an oblique collision at the collision point, cleaning the mating surfaces of oxide layers and contaminants. This enables intimate contact at the atomic level when subjected to high-impact pressure waves generated by the explosion. Explosive welding involves two basic steps: jetting cleans oxide layers, and high-impact pressure forces the mating surfaces into intimate contact, resulting in a strong metallurgical bond.


Detonation direction
Detonator
Explosive box
Flyer plate
Base plate
(a)
Detonation gases
Buffer sheet
Collision angle (β)
Stand off distance
Collision point
Jet formation
(b)

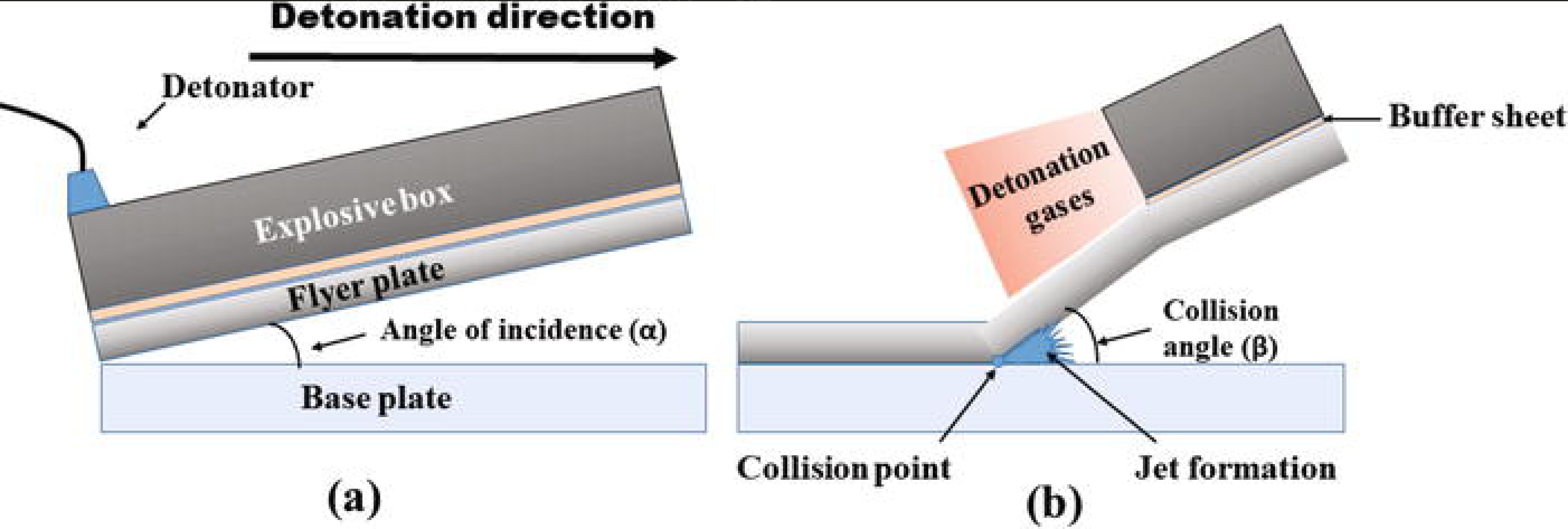
Plastic deformation in explosive welding process

In the explosive welding process, several critical phenomena occur due to the detonation effect of the explosive, including the release of a large gas product, high-impact collision between mating surfaces, generation of heat, plastic deformation in the metal plates, pressure generation, jetting, and bonding, all within microseconds. Plastic deformation at the weld interface, induced by high impact pressure, is crucial for achieving a strong bond. It occurs when the pressure at the collision front exceeds the yield strength of the materials, bringing the mating surfaces into intimate contact where atomic reactions occur. Plastic deformation can be analyzed using visioplastic methods without altering the original material properties. A distinctive form of plastic deformation observed in explosive welding is wave formation. This process leads to grain refinement and differences in grain size adjacent to the weld interface due to severe plastic deformation. Microhardness examination studies have shown high hardness values at the weld interface, attributed to intense plastic deformation. The level of plastic deformation decreases gradually with increasing distance from the weld interface.

Types of experimental set-up

There are two different kinds of explosive welding setups: inclined and parallel. The parallel setup, in which the two plates are positioned parallel to one another, is seen in Figure 1. This type of arrangement is utilized to combine thick, big plates. In Figure 2, an inclined setup with flyer plates inclined at a specific angle (α) is depicted. Usually, this type of arrangement is used to join thin, tiny plates. angle in the inclined mode. Since it was not capable of handling large sheet metal, the parallel setup was developed later.

Types of experimental set-up



Terminology used in explosive welding

Base plate: It is placed at the open ground or at the anvil. It is kept stationary and is the one on which the cladding is performed. Both the base plate and the flyer plate are cleaned thoroughly and polished gently before welding.

Flyer plate: It is placed above the base plate. During collision, this plate hits onto the base plate. Flyer plate and base plate are selected on the basis of mass per unit area, whoever is less is placed as flyer plate. As compared to base plate it has the lowest density as well as tensile strength.

Buffer sheet: This sheet is placed over the flyer plate. It is made up of rubber or PVC. The main role of this sheet is to protect the flyer plate from damage which can occur during collision due to explosion effects.

Stand-off distance: It is the one which maintains the distance between the flyer plate and the base plate. Stand-off distance helps the flyer plate to accelerate and acquire the required impact velocity to generate jetting. Apart from this, it also provides the exit path to the jet and the air formed between the flyer and base plate during the collision. In general stand-off distance is kept half or equal to the thickness of flyer plate.

Explosive box: It is placed over the metal plates to be welded. This acts as a source of energy which provides the required forces to weld the materials. Explosive can be used as powder, slurry or sheet form which is spread over the buffer sheet uniformly.

Detonator: This is placed at the top of the explosive box. The main function of the detonator is to help in initiating the main explosive. The detonator is detonated with the help of dynamo placed at some distance from the trial site.

Important points in explosive welding

- For deformation to have occurred at the weld contact, the pressure generated at the collision point needs to be sufficiently high to surpass the dynamic elastic limits of the mated materials.

- In order to guarantee that the flyer plate can accelerate to the necessary impact velocity for good bonding, stand-off distance needs to be calculated correctly. High stand-off distance usage will cause edge instability and may degrade the quality of the bond.

- The flyer plate should accelerate to the desired velocity with enough energy from the explosive used. It is advisable to steer clear of explosives with high detonation velocities as they may cause spalling and harm to the joining materials. As a result, the detonation velocity needs to be less than 1200% of the materials' sonic velocity when welding.

- The collision and flyer plate velocities (Vp and Vc) in both participant materials should be slower than the speed of sound. In order to prevent the incident wave at the point of collision from being interfered with by the reflected stress waves

Advantages of explosive welding

- Very large work pieces can be welded.
- (Al + Steel) materials can be welded.
- Can bond many dissimilar, normally unweldable metals.
- Material melting temperatures and coefficients of thermal expansion differences do not affect the final product.
- Process is compact, portable, and easy to maintain.
- Welding can be achieved quickly over large areas.
- No need for surface penetration.
- Backer plate has no size limits.

Advantages of explosive welding

• Welding can be achieved quickly over large areas.
• No need for surface penetration.
• Backer plate has no size limits.
• Inexpensive.
• The strength of the weld joint is equal to or greater than the strength of the weaker of two metals joined.
• No heat-affected zone (HAZ).

Disadvantages of Explosion Welding

- Metals must have high enough impact resistance and ductility.
- The geometries welded must be cylindrical, conical.
- The cladding plate can't be too large simple-flat,
- Noise & blast can require worker protection, vacuum chambers buried in sand/water.

Applications

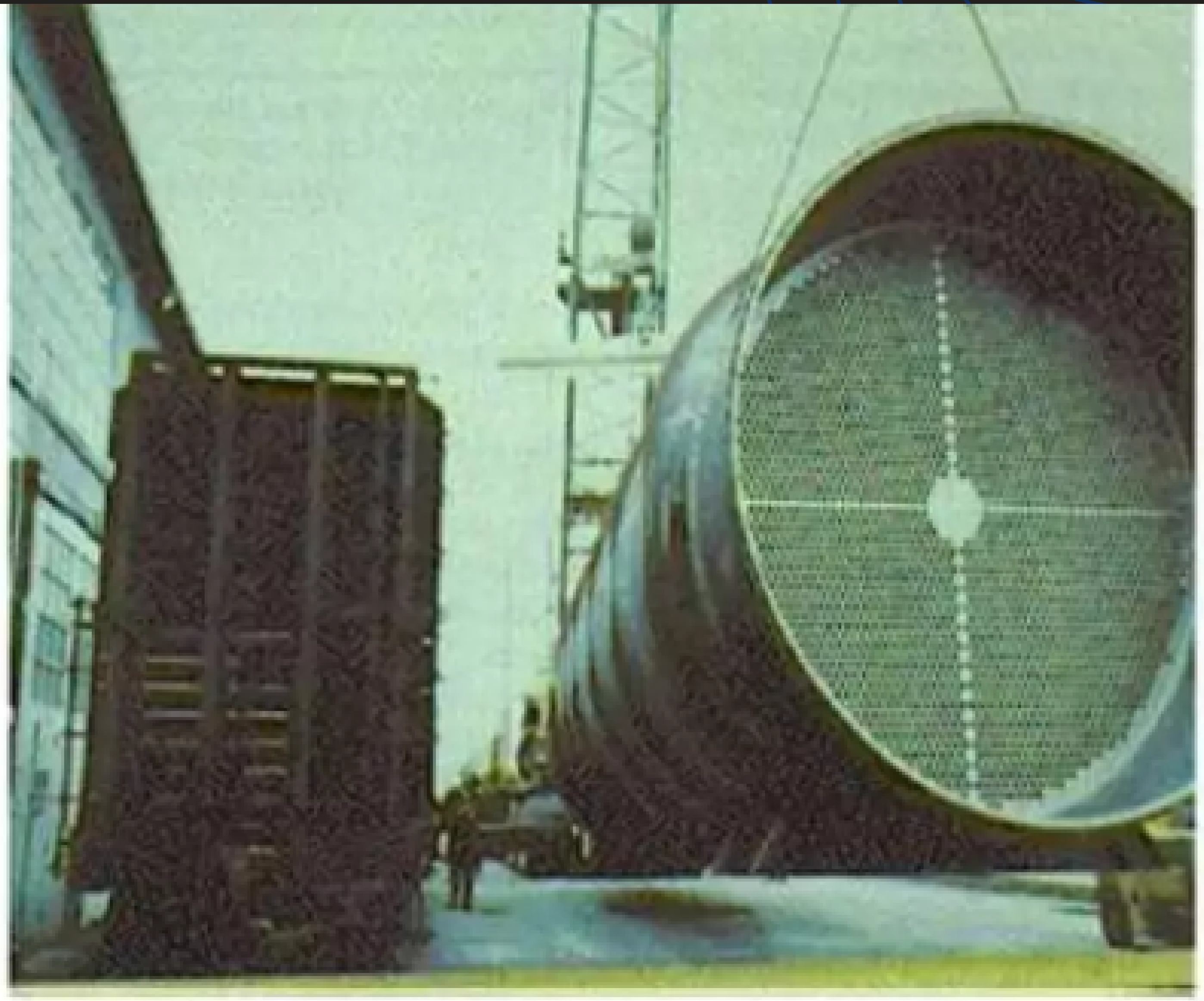
- Cladding of base metals with thinner alloys e.g. cladding of Ti with mild steel.
- Seam and lap welds.
- Reinforcing aerospace materials with dissimilar metal ribs.
- Heat exchangers.

Applications

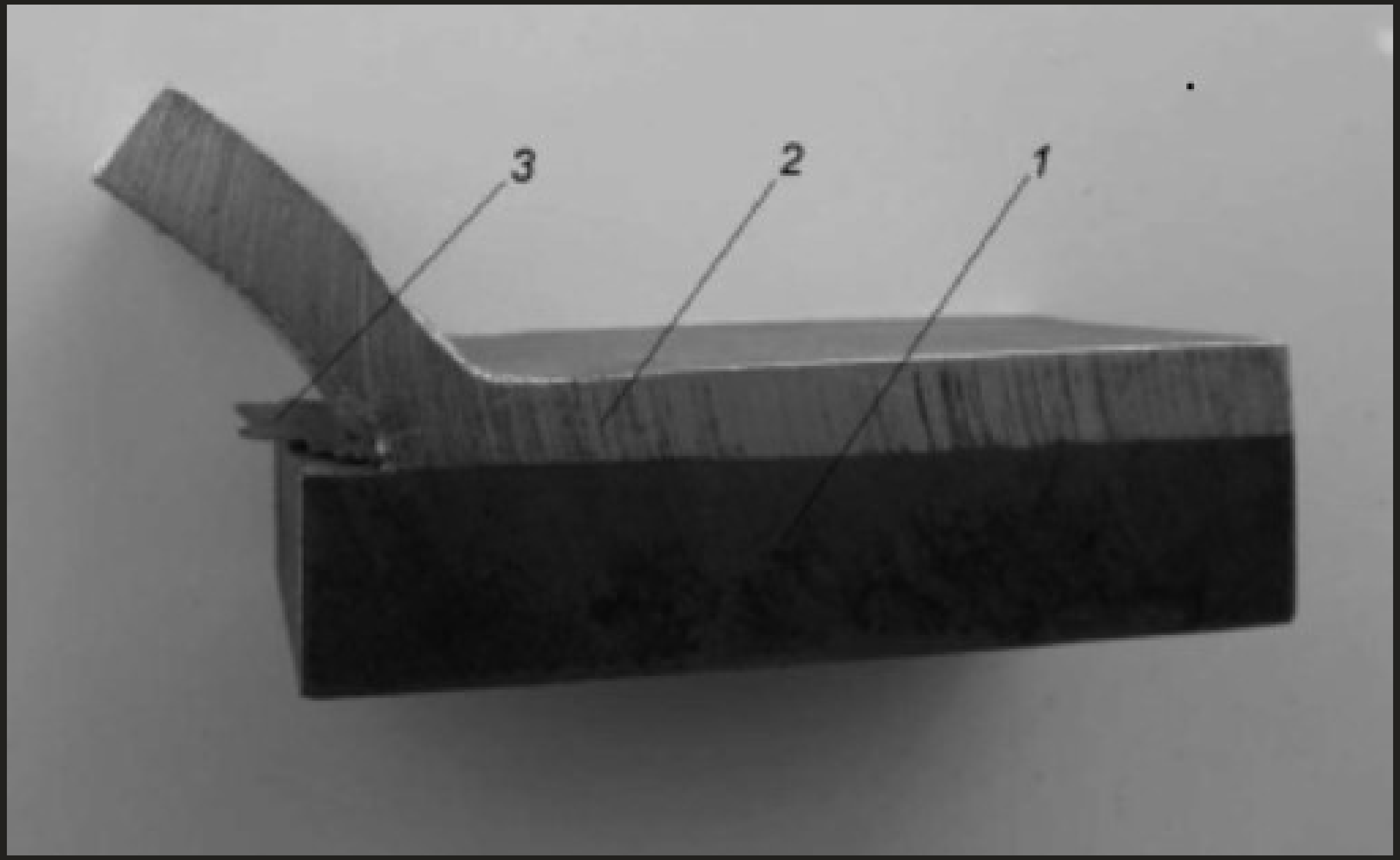
- Tubular transition joints.
- Used as a repair tool for repairing leaking tube-to-tube sheet joints.
- Spot welding.
- Flat plates.
- Joining of pipes in socket joints.

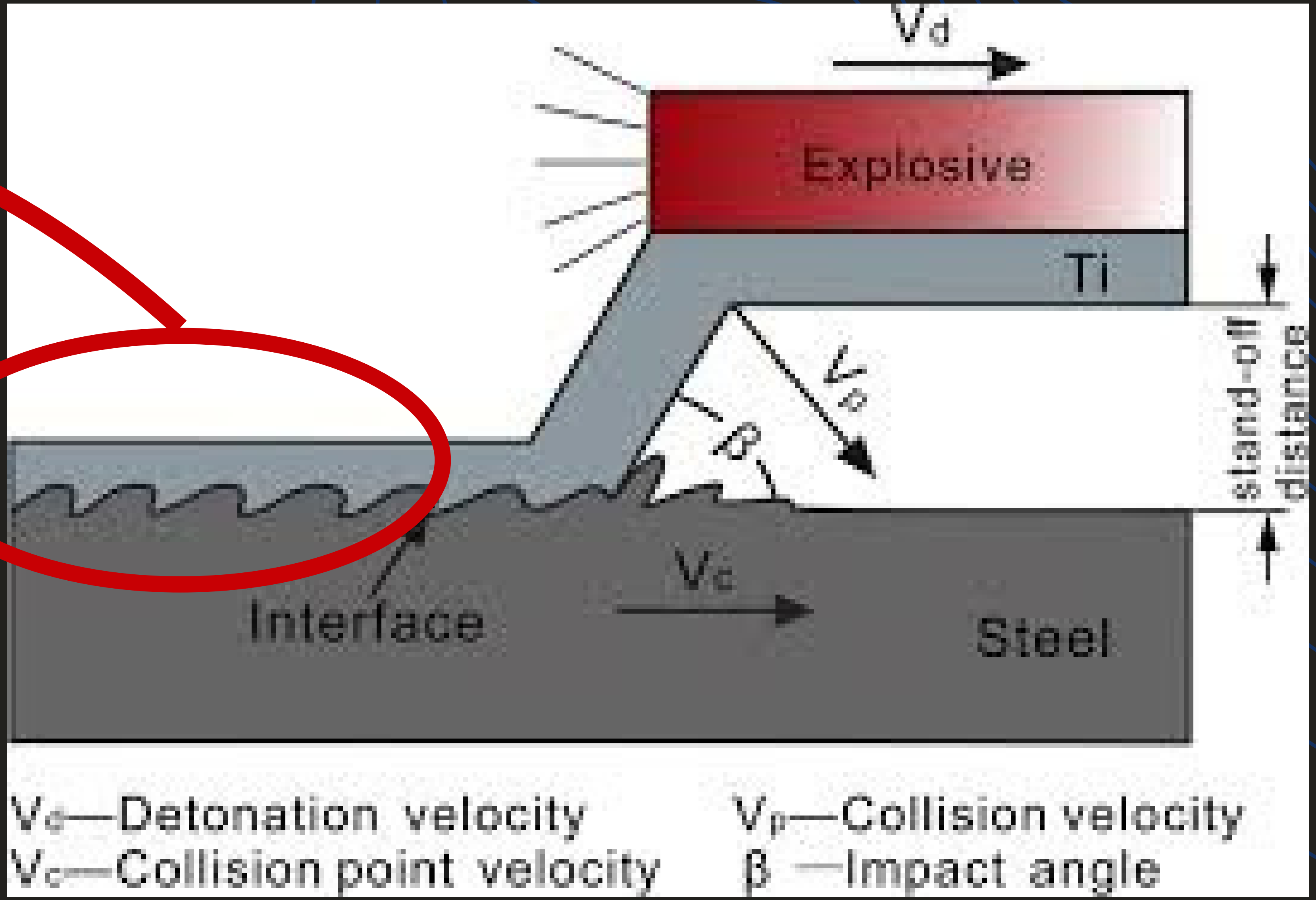
Some Examples

Explosion welded 12 inch diameter 3003 aluminum to A106 grade B steel tubular transition joint.



Finished vessel fabricated from explosion clad plate.


3
2
1


V_d
Explosive
Ti
V_p
β
stand-off distance
Interface
V_c
Steel
V_d—Detonation velocity
V_p—Collision velocity
V_c—Collision point velocity
β —Impact angle

Thank You!