UNIT 5
High Energy Rate Forming (HERF) Processes

Introduction:

The forming processes are affected by the rates of strain used.

Effects of strain rates during forming:

1. The flow stress increases with strain rates
2. The temperature of work is increases due to adiabatic heating.
3. Improved lubrication if lubricating film is maintained.
4. Many difficult to form materials like Titanium and Tungsten alloys, can be deformed under high strain rates.

Principle / important features of HERF processes:

- The energy of deformation is delivered at a much higher rate than in conventional practice.
- Larger energy is applied for a very short interval of time.
- High particle velocities are produced in contrast with conventional forming process.
- The velocity of deformation is also very large and hence these are also called High Velocity Forming (HVF) processes.
- Many metals tend to deform more readily under extra fast application of force.
- Large parts can be easily formed by this technique.
- For many metals, the elongation to fracture increases with strain rate beyond the usual metal working range, until a critical strain rate is achieved, where the ductility drops sharply.
- The strain rate dependence of strength increases with increasing temperature.
- The yield stress and flow stress at lower plastic strains are more dependent on strain rate than the tensile strength.
- High rates of strain cause the yield point to appear in tests on low carbon steel that do not show a yield point under ordinary rates of strain.

Advantages of HERF Processes

i) Production rates are higher, as parts are made at a rapid rate.
ii) Die costs are relatively lower.
iii) Tolerances can be easily maintained.
iv) Versatility of the process – it is possible to form most metals including difficult to form metals.
v) No or minimum spring back effect on the material after the process.
vi) Production cost is low as power hammer (or press) is eliminated in the process. Hence it is economically justifiable.
vii) Complex shapes / profiles can be made much easily, as compared to conventional forming.
viii) The required final shape/ dimensions are obtained in one stroke (or step), thus eliminating intermediate forming steps and pre forming dies.
ix) Suitable for a range of production volume such as small numbers, batches or mass production.

Limitations:

i) Highly skilled personnel are required from design to execution.
ii) Transient stresses of high magnitude are applied on the work.
iii) Not suitable to highly brittle materials
iv) Source of energy (chemical explosive or electrical) must be handled carefully.
v) Governmental regulations/ procedures / safety norms must be followed.
vi) Dies need to be much bigger to withstand high energy rates and shocks and to prevent cracking.
vii) Controlling the application of energy is critical as it may crack the die or work.
viii) It is very essential to know the behavior or established performance of the work metal initially.

Applications:

i) In ship building – to form large plates / parts (up to 25 mm thick).
ii) Bending thick tubes/ pipes (up to 25 mm thick).
iii) Crimping of metal strips.
iv) Radar dishes

v) Elliptical domes used in space applications.

vi) Cladding of two large plates of dissimilar metals.

(I) Explosive Forming

Introduction:

A punch in conventional forming is replaced by an explosive charge.

Explosives used can be:

- High energy chemicals like TNT, RDX, and Dynamite.
- Gaseous mixtures
- Propellants.

Factors to be considered while selecting an HERF process:

- Size of work piece
- Geometry of deformation
- Behavior of work material under high strain rates
- Energy requirements/ source
- Cost of tooling / die
- Cycle time
- Overall capital investment
- Safety considerations.

Types of explosive forming:

1) Unconfined type or Stand off technique
2) Confined type or Contact technique

1) Unconfined type (or Standoff technique)

Principle:

The work is firmly supported on the die and the die cavity is evacuated. A definite quantity of explosive is placed suitably in water medium at a definite stand off distance from the work. On detonation of the explosive charge, a pressure pulse (or a shock wave) of very high intensity is produced.

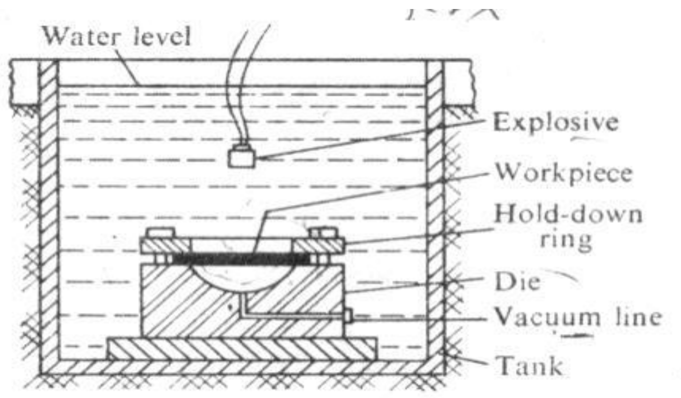

Fig. Unconfined Type Explosive Forming

A gas bubble is also produced which expands spherically and then collapses. When the pressure pulse impinges against the work (plate or sheet0, the metal is deformed into the die with a high velocity of around 120 m/s (430km/h).

The vacuum is necessary in the die to prevent adiabatic heating of the work which may lead to oxidation or melting.

Role of water:

i) Acts as energy transfer medium
ii) Ensures uniform transmission of energy
iii) Muffles the sound of explosion
iv) Cushioning/ smooth application of energy on the work without direct contact.

Process Variables

i) Type and amount of explosive: wide range of explosive sis available.
ii) Stand off distance – SOD- (Distance between work piece and explosive): Optimum SOD must be maintained.
iii) The medium used to transmit energy: water is most widely used.
iv) Work size:

v) Work material properties
vi) Vacuum in the die

Advantages;

i) Shock wave is efficiently transmitted through water and energy is transmitted effectively on the work
ii) Less noise
iii) Less probability of damage to work.
iv) Large and thick parts can be easily formed
v) Economical, when compared to a hydraulic press

Limitations:

i) Optimum SOD is essential for proper forming operation.
ii) Vacuum is essential and hence it adds to the cost.
iii) Dies must be larger and thicker to withstand shocks.
iv) Not suitable for small and thin works.
v) Explosives must be carefully handled according to the regulations of the government.

Applications:

- Ship building,
- Radar dish,
- Elliptical domes in space applications

2) Confined System (or Contact Technique)

Principle:

The pressure pulse or shock wave produced is in direct contact with the work piece (usually tubular) and hence the energy is directly applied on the work without any water medium.

The tube collapses into the die cavity and is formed. It is used for bulging and flaring operations.

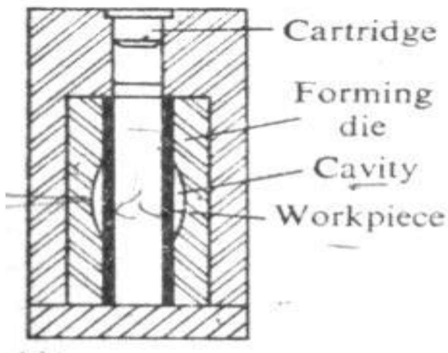

Fig. Confined (Contact) type Explosive Forming

Advantages:

i) Entire shock wave front is utilized as there is no loss in water.
ii) More efficient as compared to unconfined type.
iii)

Disadvantages:

i) More hazard of die failure
ii) Vacuum is required in the die
iii) Air present in the work piece (tube) is compressed leading to heating.
iv) Not suitable for large and thick plates.

Applications;

Bulging and flaring of tubes.

(II) Electro hydraulic Forming

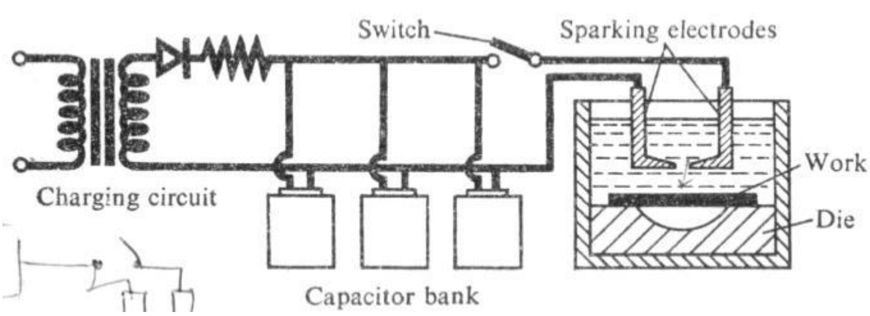

Fig. Electro Hydraulic Forming

Principle

A sudden electrical discharge in the form of sparks is produced between electrodes and this discharge produces a shock wave in the water medium. This shock wave deforms the work plate and collapses it into the die.

The characteristics of this process are similar to those of explosive forming. The major difference, however, is that a chemical explosive is replaced by a capacitor bank, which stores the electrical energy.

The capacitor is charged through a charging circuit. When the switch is closed, a spark is produced between electrodes and a shock wave or pressure pulse is created. The energy released is much lesser than that released in explosive forming.

Process Characteristics:

i) Stand off distance: It must be optimum.
ii) Capacitor used: The energy of the pressure pulse depends on the size of capacitor.
iii) Transfer medium: Usually water is used.
iv) Vacuum: the die cavity must be evacuated to prevent adiabatic heating of the work due to a sudden compression of air.
v) Material properties with regard to the application of high rates of strain.

Advantages:

i) Better control of the pressure pulse as source of energy is electrical- which can be easily controlled.
ii) Safer in handling than the explosive materials.
iii) More suitable if the work size is small to medium.
iv) Thin plates can be formed with smaller amounts of energy.
v) The process does not depend on the electrical properties of the work material.

Limitations:

i) Suitable only for smaller works
ii) Need for vacuum makes the equipment more complicated.
iii) Proper SOD is necessary for effective process.

Applications:

They include smaller radar dish, cone and other shapes in thinner and small works.

(III) Electromagnetic forming

The electrical energy stored in a capacitor bank is used to produce opposing magnetic fields around a tubular work piece, surrounded by current carrying coils. The coil is firmly held and hence the work piece collapses into the die cavity due to magnetic repelling force, thus assuming die shape.

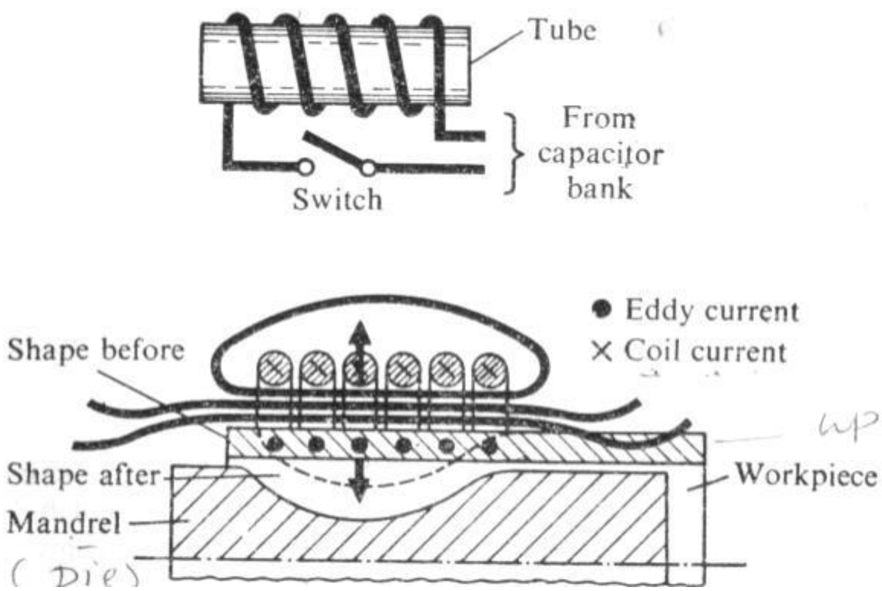

Fig. Electro Magnetic Forming

Process details/ Steps:

i) The electrical energy is stored in the capacitor bank

ii) The tubular work piece is mounted on a mandrel having the die cavity to produce shape on the tube.

iii) A primary coil is placed around the tube and mandrel assembly.

iv) When the switch is closed, the energy is discharged through the coil

v) The coil produces a varying magnetic field around it.

vi) In the tube a secondary current is induced, which creates its own magnetic field in the opposite direction.

vii) The directions of these two magnetic fields oppose one another and hence the rigidly held coil repels the work into the die cavity.

viii) The work tube collapses into the die, assuming its shape.

Process parameters:

i) Work piece size

ii) Electrical conductivity of the work material.

iii) Size of the capacitor bank

iv) The strength of the current, which decides the strength of the magnetic field and the force applied.

v) Insulation on the coil.

vi) Rigidity of the coil.

Advantages:

i) Suitable for small tubes

ii) Operations like collapsing, bending and crimping can be easily done.

iii) Electrical energy applied can be precisely controlled and hence the process is accurately controlled.

iv) The process is safer compared to explosive forming.

v) Wide range of applications.

Limitations:

i) Applicable only for electrically conducting materials.

ii) Not suitable for large work pieces.

iii) Rigid clamping of primary coil is critical.

iv) Shorter life of the coil due to large forces acting on it.

Applications:

i) Crimping of coils, tubes, wires

ii) Bending of tubes into complex shapes

iii) Bulging of thin tubes.