Electro- hydraulic forming

7.1 Introduction:

The principle used in electro-hydraulic forming can be stated as the ability to generate high intensity shock waves by discharging stored electrical energy across electrodes submerged in a liquid medium.

Figure 7.1 shows diagrammatic illustration of an electro- hydraulic forming system for a tubular part. It uses two electrodes which are connected via a switch to a bank of capacitors. The electrode ends may be connected by a thin initiating wire which is vaporized during the discharge. As shown in figure 7.1 the workpiece is immersed in water together with electrodes which are connected via a switch to a blank of capacitors. The capacitors are charged from a power unit through a charging resistor to a predetermined voltage and energy level. When the switch connecting the capacitors to the electrodes is closed, the electrical energy is converted into a shock wave in the water which forms the workpiece into a die.

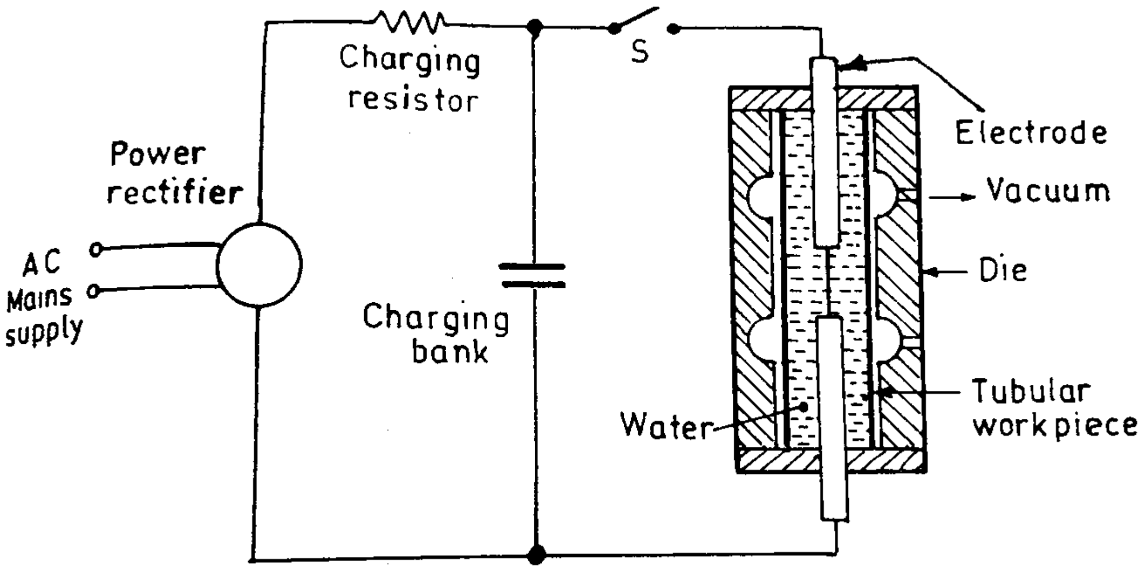


Figure 7.1 EHF System

the tubular shaped expanded component will be formed as shown in figure 7.2 and a product of this process is shown in figure 7.3

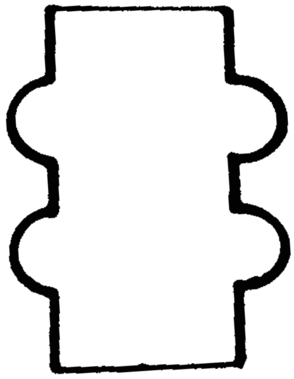


Figure 7.2 a tubular part formed by this process

Figure 7.3 a lightweight panel in automotive

In this process the energy stored in a charged capacitor is given by

$$E = \frac{1}{2}.C.V^2 \qquad 7.1$$

Where c= capacitance (farads), v= charge voltage, and E=energy in joules. The efficiency of converting stored electrical energy in the capacitors to plastic deformation of the workpiece varies considerably, *but is typically between 10 and 20 per cent*. therefore, to produce 300 Kg of useful work would require to total stored energy of between 13.5 -27 kj.

In this process:

1. The physical size and capital cost of the capacitors are mainly controlled by their energy storage capacity which is normally limited to about 100kj.
2. The capacitors are normally charged from either a 110 or 220-volt main supply via a rectifier and set up transformer.
3. The upper practical limit to the charge voltage is about 40 kv
4. The over- all cycle time of the process depends upon time taken to charge the capacitors between each shot.

5. Capacitors should be capable to withstand high voltage.
6. Variation of central deflection (y) of workpiece with electrical discharge energy is shown in figure 7.4

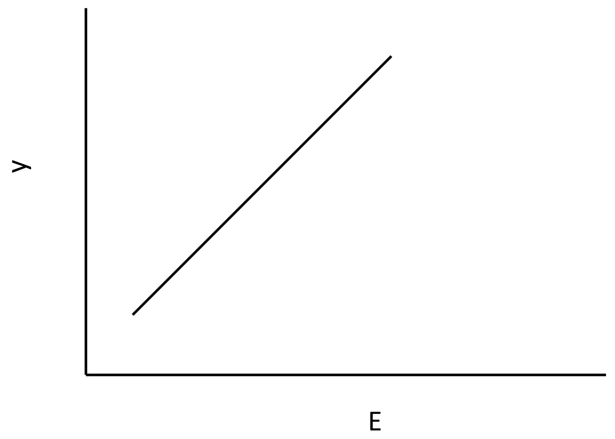


Figure 7.4 variation of deflection with energy

7.2 Applications

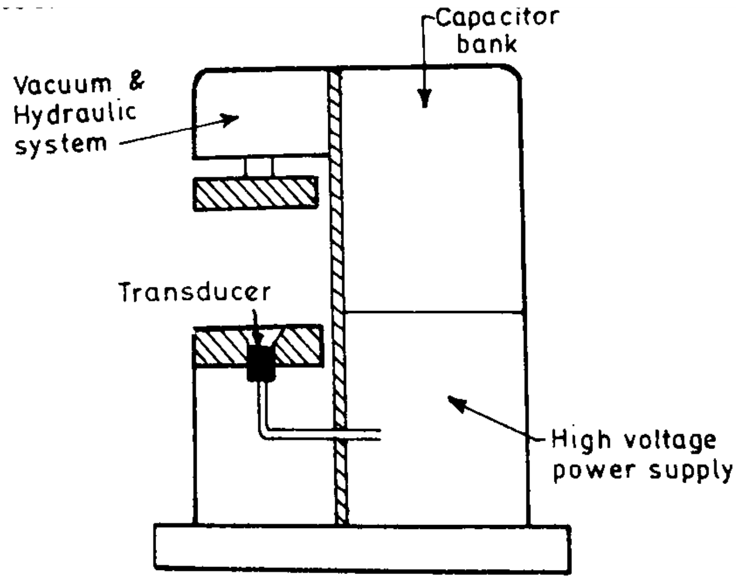
The speed at which material is formed in this process is of the same order as in explosive forming. ***This process commonly used for high volume production of small items***. It can be used for forming of tubular or dished shaped parts.

7.3 Energy Conversion Mechanism

In electro- hydraulic forming process, *the mechanism by which the discharged electrical energy is converted into useful work is the production of a steep fronted pressure wave. When the stored energy is discharged across the electrodes, the very high current causes the water and other material, such as an initiating wire, to be ionized very rapidly, and heated to an extremely high temperature. The water surrounding the ionized channel offers inertial resistance to the expanding gas which cannot expand at a rate proportional to the temperature rise. The pressure in the gas pocket therefore rises to a high value in a very short time. Pressure release is governed by the dynamic behavior of water and takes the form of a steep fronted wave. the workpiece is accelerated under the action of the shock wave, and is either allowed to free form, or else it is impressed into a die the kinetic energy acquired by the workpiece as a result of the passage of the shock wave is expended in plastic deformation*. the mode of deformation is similar to that of explosive forming, where cavitation and reloading effectives have an important influence on the process.

7.4 Electro-Hydraulic Forming Machine

An electro-hydraulic machine is shown in figure 7.5. a high energy storage capacitor bank is connected to a transducer, which releases the stored energy into a water –filled cavity. the workpiece is placed over the water cavity, and hydraulically clamped on the table via a female die fitted to the upper platen of the machine. The capacitor bank is located at the rear of the machine. immediately above the high voltage power supply and the switching system



7.5 process variables

The various variables which affect the efficiency of the electro-hydraulic forming system are as follows:

A. Electrode gap width: the gap between electrodes depends mainly upon charge voltage. *B* = gap width = 12 mm at 10 kv and = 50mm at 50kv, optimum gap width affects:
   - Deformation of workpiece
   - Process efficiency

   gap width also depends on conductivity of water. Figure 7.6 shows the variation of deformation of workpiece with gap width.

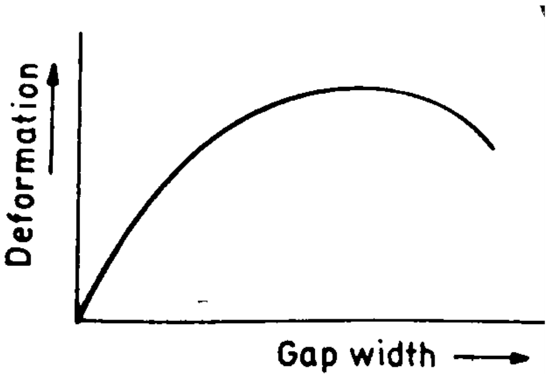


Figure 7.6 variation of deformation of workpiece with gap width

The optimum gap with distilled water is only about half that when tap water is used. *at zero gap there will be no explosive discharge while at very large gaps the initiating wire connecting the electrodes will not vaporize completely thus causing the efficiency to fall.*

B. Stand-off distance: it is the distance from the spark gap to the workpiece figure 7.7 shows the variation of central deformation with stand- off distance.

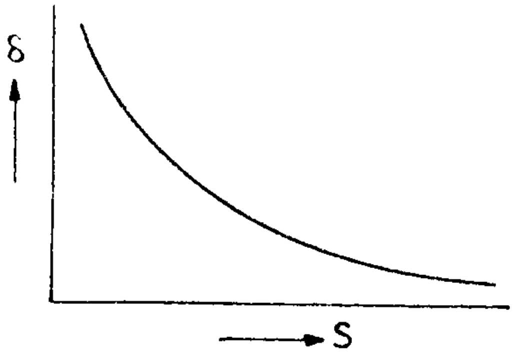


Figure 7.7 variation of central deformation with stand- off distance.

S= stand-off distance, δ= central displacement of workpiece. small stand-off distances are used to produce conically shaped free formed components because of the concentration of energy at the Centre of the blank.

The forming of large diameter tubes involves large stand-off distances and therefore peak pressures and amount of deformation are proportionally reduced.

C. Charge energy: the deformation of the workpiece depends directly on the energy discharge. The relationship is as follows:

$$\delta \propto E^k$$

δ= central deformation of the workpiece, E= discharge energy, and K =empirical constant = 0.36 to 0.56. the value of this constant depends mainly upon the time during which discharge takes place.

A low inductance system with a correspondingly fast discharge time is a far more efficient generator of shock waves than a system having a high inductance and a slow discharge time. Figure 7.8 shows variation of central deformation with electrical discharge energy.

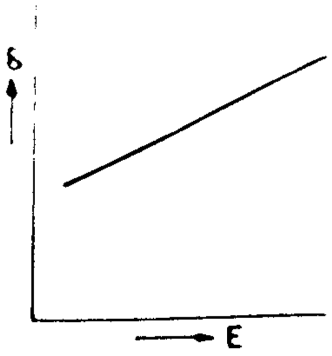


Figure 7.8 variation of central deformation with electrical discharge energy

D. Hydrostatic head: *it is the vertical distance between the spark gap and surface of water.* Since the majority of electro-hydraulic forming operations take place in completely closed containers, hydrostatic head has no relevance, but in installations where there is a free water surface, it has a considerable influence on the mount of deformation produced as shown in figure 7.9. in order to obtain the maximum amount of deformation the hydrostatic head should be at least equal to the stand-off distance.

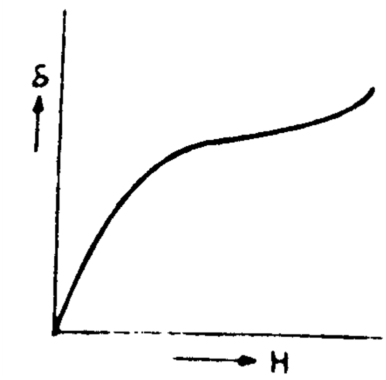


Figure 7.9 the relation between hydrostatic head and deformation

As shown H= hydrostatic head, δ = central deflection

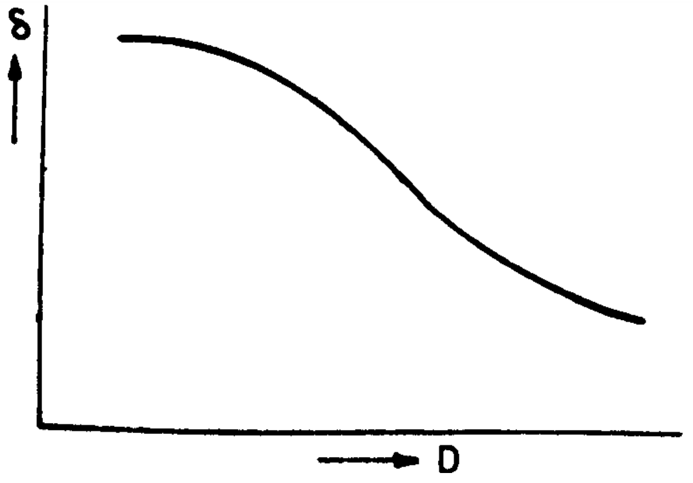
E. Initiating wire between electrodes: this wire between electrodes is purely used for spark ignition purpose. the wire should be made of good conducting material such as

i) Copper

ii) Aluminum

iii) Iron

The diameter of the wire should be as small as possible. The diameter of wire usually varies between 0.125 to 1.25 mm. figure 7.10 shown the vacation of central deflection (δ) with wire diameter (D).



F. Electrodes: the electrodes are commonly made of the following materials:

i) Mild steel

ii) Stainless steel

iii) Copper

iv) Brass

G. Speed of deformation: the range of forming speeds is similar to those obtained during explosive forming. the typical values of speed of deformation for free forming for different sheet materials are as follows:

v= speed of deformation = 30 m/s to 60 m/s for copper and aluminum and = 100m/s for stainless steel.

H. Die material: die is commonly made of the following materials:

1. Epoxy resin
2. Steel

7.6 Advantages and Limitations

The various advantages of electro-hydraulic forming process are as follows:

1. It is versatile process and can be used for the forming tubular or dished shaped parts very successfully.
2. The requirement of only a female die results in substantial reductions of tooling costs. This, combined with the possibility of using low cost die materials, makes short run and prototype production economically more attractive.
3. Large amounts of energy can be directed to isolated areas of the workpiece.

The limitations are

1. This process is suitable only for making relatively smaller components because of maximum energy that can be generated by this process.
2. Materials with critical impact velocities less than 30m/s not suitable for this method

7.7 Comparison Between Electro-Hydraulic Forming and Explosive Forming

I. The deformation speed is same in both operations.

II. Both processes can be successfully used for making tubular and dished shaped parts

III. Electro- hydraulic forming process is used for the production of smaller components in large number whereas explosive forming is used to produce larger components to be produced in smaller number.

IV. Explosive forming requires very small amount of explosive charge to produce very amount of energy. but in case of electro-hydraulic system the size of equipment become quite large and high cost to produce large amount of energy.

V. The capital cost of electro-hydraulic forming unit is more than same capacity explosive forming unit.