Electromagnetic Forming (magnetic pulse forming)

Introduction

Electromagnetic forming (EM forming or magneforming) is a type of high velocity, cold forming process for electrically conductive metals, most commonly copper and aluminum. The work piece is reshaped by high intensity pulsed magnetic fields that induce a current in the work piece and a corresponding repulsive magnetic field, rapidly repelling portions of the work piece. The work piece can be reshaped without any contact from a tool, although in some instances the piece may be pressed against a die or former. The technique is sometimes called high velocity forming.

Electromagnetic forming is the only high velocity forming technique to gain significant acceptance in commercial metal working. The electromagnetic forming technique has been in use commercially for the last 30 years. Mostly, it has been used for joining and assembly of concentric parts. The minimal springback inherent in all high velocity forming processes provides high-quality joints.

6.1 Process description:

in this process the sheet metal is deformed by the mechanical force of an electromagnetic field induced in the workpart by an energized coil. The coil, energized by a capacitor, produces a magnetic field. This generates eddy currents in the work that produce their own magnetic field. The induced field opposes the primary field, producing a mechanical force that deforms the part into the surrounding cavity. It is typically used to form tubular parts

6.2 formation methods:

Electromagnetic formation can usually be applied to three forming methods: ***compression, expansion, and counter forming***. As shown in figure (6-1 a), a tubular workpiece is compressed by an external coil, usually against a grooved contoured insert, plug, tube or fitting inside the workpiece. A tubular workpiece is expanded by an internal coil as shown in figure (6-1 b), usually against a collar or other component surrounding the workpiece. flat stock is almost always contour-formed against a die as seen in figure (6-1 c).

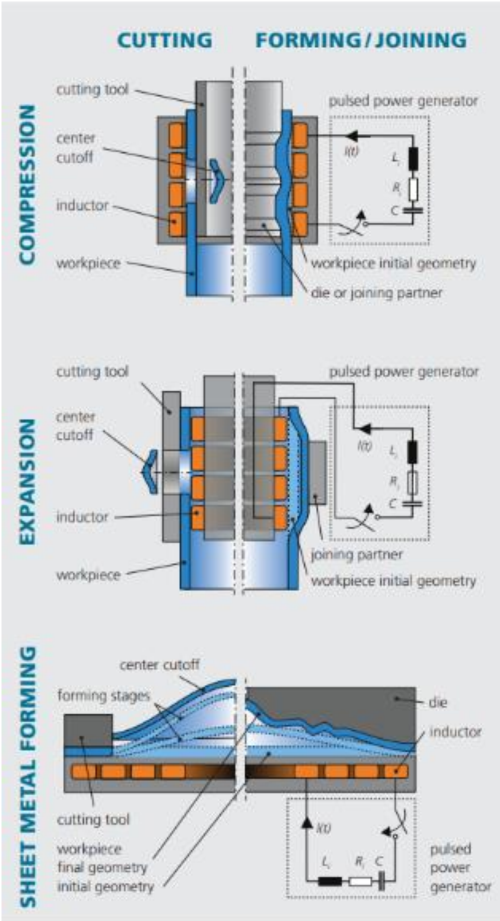

Figure (6-1)

This process is primarily applied in the forming of good conducting materials such as: copper, aluminum, silver and low carbon steel. It can also be used to form a poor conductor like stainless steel. The efficiency of the magnetic pulse forming depends upon the resistivity of metal being formed. For good results the resistivity of the material should be less than 15 micro-ohm-centimeters.

<u>6.3 Advantages and limitations:</u>

1. It gives a high rate of production
2. Non-contact: unlike other mechanical processes in which a tool contacts a workpiece, in EMF the magnetic field that applies the pressure requires no lubrication, leaves no tool marks and therefore requires no cleanup after forming.
3. No Springback: the springback often associated with mechanical processes is virtually eliminated, because there is no mechanical contact.

4. The EMF process allows increased ductility for certain aluminum alloys because of the lack of mechanical stress and friction normally encountered with mechanical processes.
5. Tooling: the tooling for process is relatively inexpensive. the machine and the work coils can be viewed as general –purpose tooling.

General limitations

The speed of joining or formation also represents one of the limitations of the process. Because forming take place in such a short period, the material does not lend itself to deep drawing of materials. **The process is also limited to those materials that are electrically conductive** .materials with an electrical resistivity of 0.15 micro –ohm- meter or less are ideal candidates for the process. Included in this group are such materials as copper, aluminum, brass, and mild steels.

Pressure limit:

The maximum pressure that can be applied by standard compression coils is approximately 340 Mpa, thus the process is restricted to relatively thin –wall tube or sheet products.

6.4 Applications:

In forming

in case of forming, sheet metal components are used. here a wide spectrum of drawing depths is possible, starting from values of less than on millimeters in the case of coining tasks up to some tens of millimeters. limitation for sheet metal forming and expansion processes are usually caused by material failure (more precisely) **necking or cracking** of the part. in case of compression the formation of **wrinkles** is usually the limiting effect. *the reason for this is that due to the high velocities only very limited materials flow is possible from the adjacent areas into the forming zone*. accordingly, the material flow comes from the thickness of the workpiece so that an increase of the surface - as it occurs in case of expansion and sheet forming process- is compensated by thickness reduction and vice versa.

the technology of EMF is suitable for forming small- to medium-sized components. for larger ones, such as body panels for the automotive industry, the technology can be applied advantageously in combination with conventional forming procedures, e.g. deep drawing in order to shape local details such as door handle or license plate cavities.

in order to meet the demand for the economic production multiple similar part geometries can be produced with one and the same set of tools by using the mentioned process integration. for realizing different details, exchangeable tool segments can be inserted into the die.

due to the contact -free force application, the applied inductor is associated less to the part geometry, compared to conventional forming tools. provided that part geometries and especially the dimensions of the cavity that is to be formed are similar, the coil need not be exchanged.

Joining

by means of EMF, similar as well as dissimilar material combinations can be connected to each other.

the interest in electromagnetic welding of sheets is steadily increasing. independent of the geometry of the semi-finished parts, an important precondition for the joining by EMF is, that the joining partner that is to be deformed, should be of preferably high electrical conductivity. in case of joining of profiles, this is frequently the outer component.

Cutting

in contrast to conventional cutting processes, in electromagnetic cutting the workpiece is not sheared between two mechanical tools. in fact, one half of conventional cutting tool is replaced by the inductor. during the process, parts of the workpiece are accelerated, so that initially a deformation takes place and finally -as a consequence of the interaction with the remaining half of the cutting tool- the desired separation of metal results.

Explosive forming process

6.5 Introduction:

Explosive forming has evolved as one of the most dramatic of the new metalworking techniques. In this process the punch is replaced by an explosive charge. The process derived its name from the fact that the energy liberated due to the detonation of an explosive is used to form the desired shape. the charge is very small but it is capable of exerting tremendous forces on the workpiece.

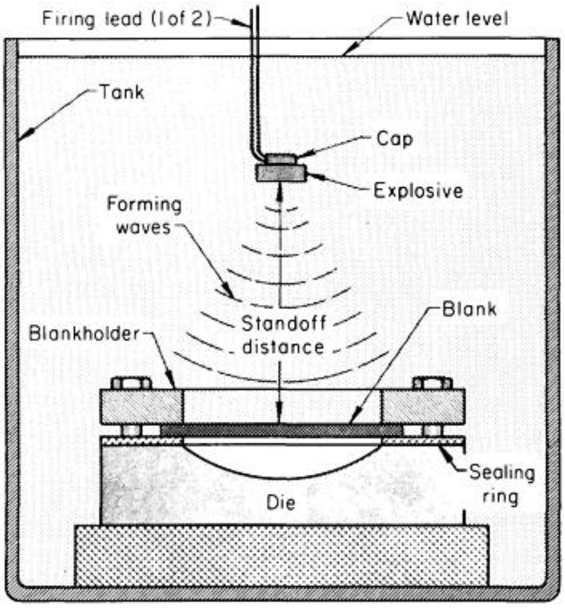

Figure (6.2) show the explosive forming process

6.6 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.

6.7 Process Variables

1. Type and amount of explosive: wide range of explosive sis available.
2. Standoff distance – SOD- (Distance between work piece and explosive): Optimum SOD must be maintained.
3. The medium used to transmit energy: water is most widely used.
4. Work size:
5. Work material properties vi) Vacuum in the die

6.8 Procedure steps:

1. The workpiece is clamped over a die, and the air in the die cavity is evacuated.
2. Then the workpiece with the die is lowered into a tank filled with water which acts as a transfer medium.
3. An explosive charge is then located at a certain height and detonated.
4. The rapid conversion of the explosive into gas generates a shock wave.
5. The pressure of this wave is sufficiently high to form the metal.

6.9 The peak pressure

The peak pressure generated in water is given by the expression

$$p = K.\frac{\sqrt[3]{W}}{R}$$

Where p=peak pressure in pounds per square inch (psi),K=a constant that depends on the explosive (e.g. 21600 for TNT), W= weight of the explosive in pound (Ib),R= a distance of the explosive from the workpiece (stand off) in feet (ft), a= a constant , generally taken as 1.15. an important factor in determining peak pressure is the compressibility of the transmitting medium (e.g. ,water, air ….etc) and its acoustic impedance [i.e. the product of mass density (ρ) and the sound velocity (υ) in the medium. the lower the compressibility and the higher the density of the medium , the higher peak pressure .the pressure transmitting medium should have a high density and low compressibility. Water is commonly used medium. The distance between the water level and the explosive should not be too low , otherwise the energy is dissipated to the environment.

Depending on the number of parts to be formed dies may be made of aluminum, steel, zinc alloy, wood, plastic and composite materials. Safety is an important factor in this process. Explosive forming is suitable for small quantity production; this process is employed in aerospace and aircraft industries.

6.10 Explosives:

Explosives are substances that undergo rapid chemical reaction during which heat and large quantities of gaseous products are evolved.

Explosives can be: Solid like (TNT), Liquid (nitroglycerine), Gaseous (oxygen and acetylene mixtures).

Explosives are divided into two classes:

- Low explosives in which the ammunition burns rather than exploding, hence pressure build up not large
- High explosive which has a high rate of reaction with large pressure build up

6.11 Advantages of explosion forming

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

6.12 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.

6.13 Applications

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