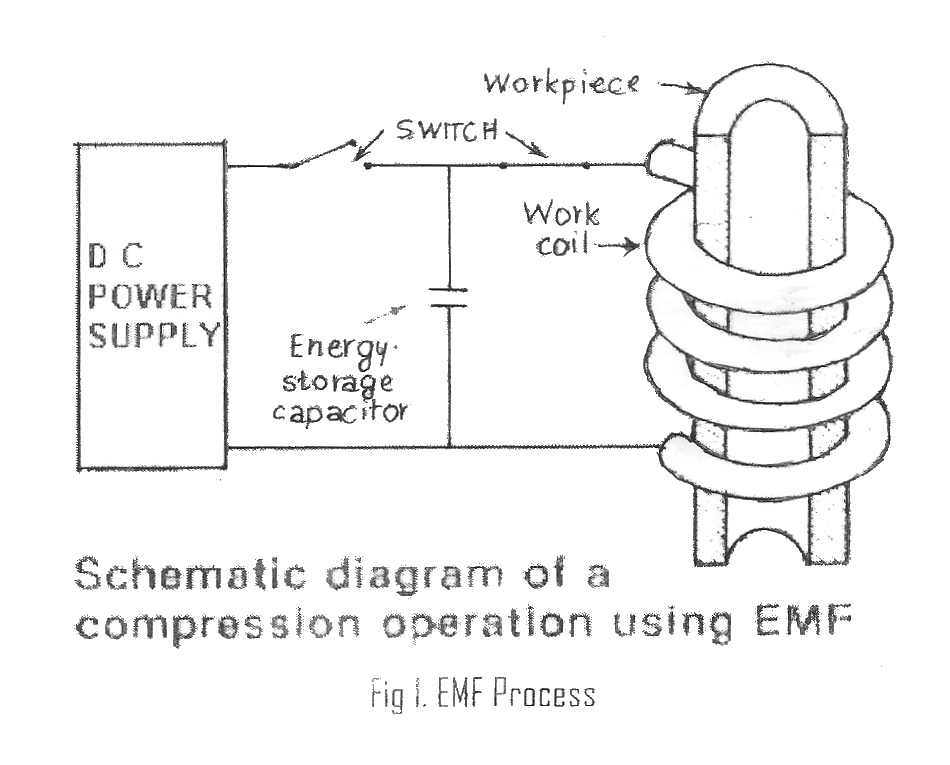
1. **INTRODUCTION**

Electronic magnetic Forming (EMF) is a process of using electromagnetic forces to form metal, without a tool or punch coming into contact with the part. It is also an ideal process for mechanically joining or assembling dissimilar metal components. An appropriate electromagnetic coil driven by an electric current in the form of a sharp pulse generates the required force for metal forming. A product formed by this process is free from toll marks and heat effects as there is neither tool coming in contact with the job nor any abnormal heat being produced during the process.

This process is ideally suited for forming techniques on aluminum leave wrinkles on the job and has other problems such as spring back and poor reproducibility. Aluminum is one of the potential lightweight materials for certain automobile and other components and parts. Hence EMF process has potential application in automobile and other industries especially for forming sheet metal components.

1. **PROCESS DESCRIPTION**

Electromagnetic forming relies on the force generated by a magnetic field to produce the desired shapes in electrically conductive metal work pieces. Essential components of an EMF system include a conductive coil, called the work coil, a charging and control system and energy storage capacitors. A typical setup is shown schematically fig 1.



The capacitors are charged from the line voltage supply, then the entire circuit is isolated from the power source. When the forming circuit switch is closed, charge stored in the capacitors flows as current through the work coil. The current creates a strong magnetic field (lenze’s law) between the coil and the work piece. This field in turn induces a current in the conductive work piece and sets up an opposing magnetic field. The integration between the two magnetic fields creates a magnetic pressure pulse strong enough to force the work piece into a new shape. The shape created depends on the type and location of the work coil. A tubular coil around the outside of a work piece will deform it inward. This is the most common application for EMF since it can be used to attach and assemble a wide variety of components. A tubular coil inside a work piece will bulge or flange it outward. A flat coil is used most frequently for electromagnetic riveting for removing dents in sheet products.

1. **PRINCIPLE OF WORKING OF EMF MACHINE**

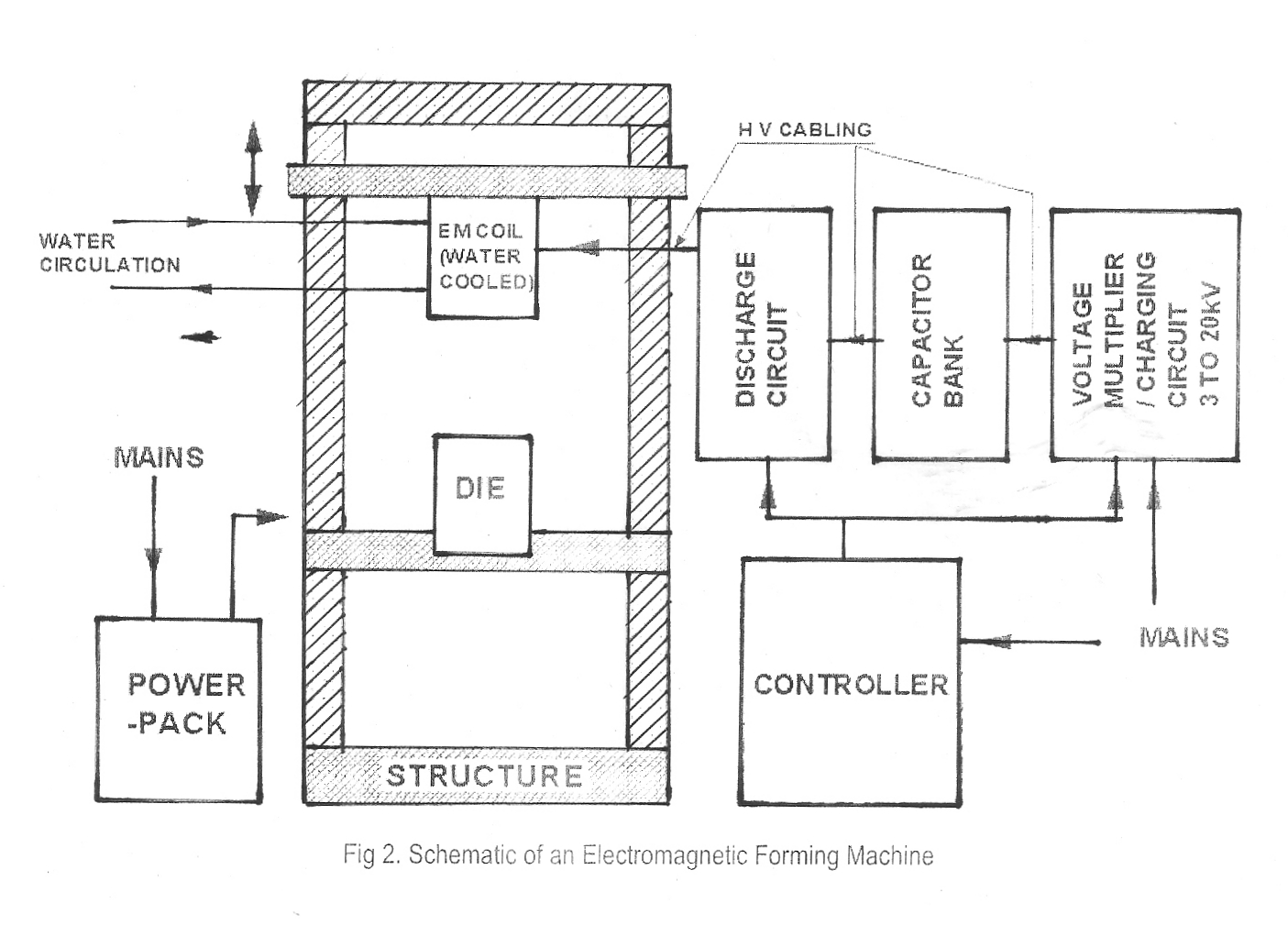


Fig. 2 shows the schematic of an Electromagnetic-forming machine. The machine consists of the main structure as shown in the figure. The function of the structure is to hold the die, the coil and to give the required flexibility to move the coil assembly for forming operation.

Main components of the machine are:

* The structure
* The Die
* Hydraulic power-pack and hydraulic circuit
* Machine Control Circuit
* Electromagnetic coil with accessories
* Capacitor
* Voltage multiplier circuit for capacitor charging
* Capacitor charging circuit
* Capacitor Discharging circuit

1. **TECHNICAL CONSIDERATION**

In deciding whether EMF is the appropriate technique for a particular application following should be considered:

* Work piece characteristics
* Work coils
* Die forms
* Energy storage and control
  1. **WORKPIECE CHARACTERISTICS**

For EMF to work well the work piece must be electrically conductive, continuous, and fairly thin. EMF works best with materials such as copper, aluminum, low-carbon and 400 series steel, gold, silver and brass that have relatively high electrical conductivity. Lower conductivity materials, such as 300 series stainless steels, titanium and nickel based alloys, can be formed by using a “driver”-a piece of copper or aluminum that is placed between the coil and the work piece. The magnetic field exerts pressure on the driver that in turn, forces the work piece into the desired shape. After forming, the driver is sometimes removed and discarded.

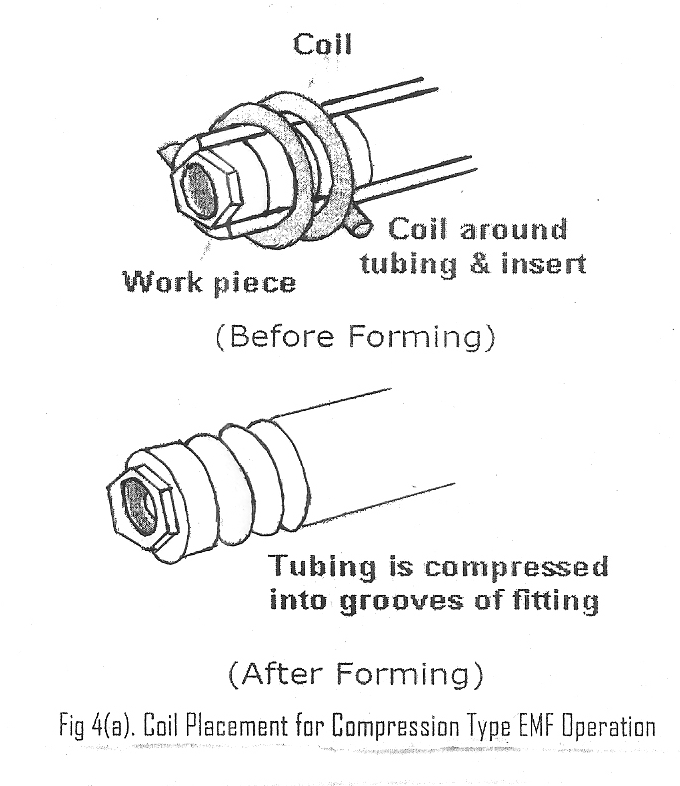
Work piece geometry must allow uninterrupted current flow. If, for example, a tube is to be shaped, its wall must be continuous; long slots would inhibit current flow and prevent proper forming.

Material thickness is another important characteristic. EMF works best with materials thinner than about **6mm**. There is a trade-off among conductivity, yield strength and thickness. Since aluminum is more conductive and requires less energy to form than, say, stainless steel, the same strength electromagnetic pulse will form a thicker piece of aluminum.

* 1. **WORK COIL**

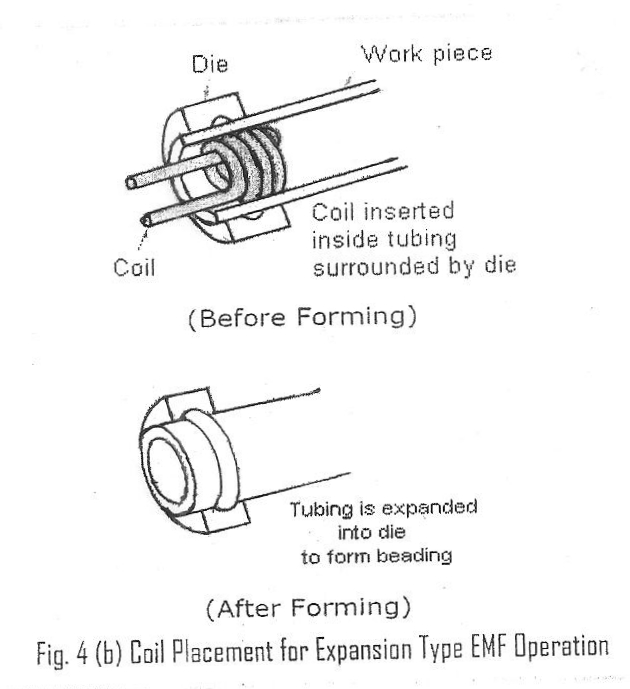
EMF operations fall into three main categories compression, expansion, and sheet contouring. The operation performed is determined by the coil design and its placement. The three types of coils are shown in Figure 4 (a,b,c).

* + 1. **COMPRESSION COIL**



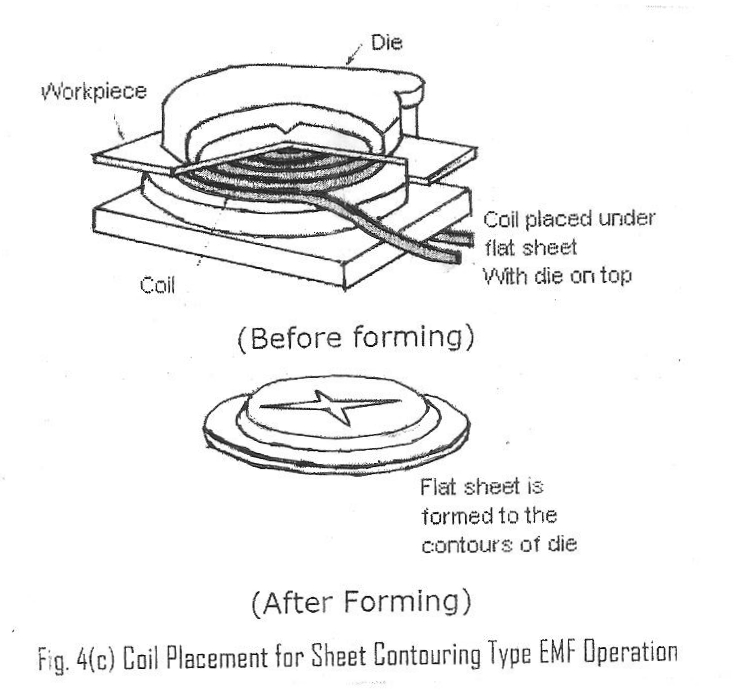
Compression coil enclose a tubular work piece and deform it radially inward (figure 4a). They are generally used for attaching tubing to fittings and for clamping components to produce tight seals as in attaching tubing to fittings and for clamping components to produce tight seals as in attaching rubber boots to automobile ball joints. Another application is shaped tubular work pieces to fit tapered components. Compression forming is done on work piece ranging from-about 3mm to 600mm in diameter.

* + 1. **EXPANSION COILS**



Expansion coils are placed inside tubular work piece and deform it radially outward (Figure 4b). they are commonly used to bulge, flange or shape work pieces ranging from about 50 to 1800mm in diameter and up to 1200mm. long. Expansion coils are also used to make contoured ducting intersection parts, and to punch holes in tubing. A coil can also be attached to a rigid or flexible rod for insertion into tubular work pieces where only part of the length is to be formed.

* + 1. **SHEET CONTOURING COILS**

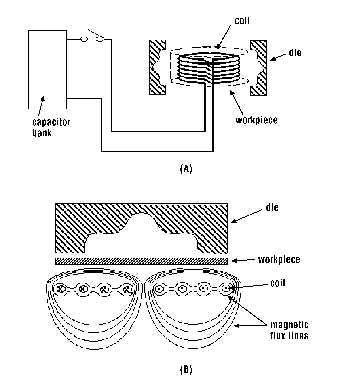


Sheet metal contouring coils are flat, and are placed above or below a flat work piece (Figure 4c). These coils are typically used with a die to form coin, dimple or blank a work piece as in, for example, faceted lighting reflectors. Recently, flat coils have found a couple of novel uses as a magnetic hammer for correcting deformations on very large surfaces, such as aircraft wings, and for electromagnetic riveting. Two facing EM coils drive rams that head both ends of rivet at the same time. Magnetic hammering and riveting are now the main uses for flat coils.

Coil design and placement determine product quality in EMF. No matter which type of coil is used, the gap between it and the work piece should be as small as possible to maximize the pressure pulse for a given energy input. For a shop making a range of products, this could mean a range of relatively expensive work coils. Usually, though, large compression coils are adopted to make smaller products by using a field shaper, an electrically conductive insert placed between the coil and the work piece. A final consideration is coil wear. Compression coils are designed for 1,000,000 shots and expansion coils for 100,000. Generally, the greater the force applied to the work piece, greater the opposing force on the coil and the shorter the coil life.

* 1. **DIE FORMS**

The forming die imposes the desired shape on the work piece. Frequently it is a component of the final part. For example, in Figure 5, the yoke to which the drive shaft is attached serves as the die.



If a die is to be reused, it should be designed for the work piece material and the number of parts to be produced. For easily formed materials requiring relatively low impact, dies can be made of aluminum, brass or impact resistant plastics. For harder materials, especially in larger sizes, steel dies are usual.

For this light track drive shaft, the driver band and the driven shaft tube are simultaneously crimped by EMF and driven into the splines of the yoke to create a permanent mechanical joint.

If a split die is needed to permit part removal, it should fit well at the split line to avoid mismatch defects on the product. To avoid arcing and possible burn marks, split dies should, if possible, be made of a non-conducting material such as impact-resistant plastic.

* 1. **ENERGY STORAGE AND CONTROL**

EMF units are classified by the total amount of energy they can store. Commercially available units have capacitor banks rated at 8, 12 and 16 kilo Joules (kJ). Units can be combined to increase system capacity. The correct size unit for a particular application depends on how much energy is required to form each part, the rate at which magnetic pulses are applied (production rate), and how fast the coil and other electronic components can dissipate heat.

To maintain close tolerance and consistent product shape, the electromagnetic pulses must be carefully controlled. Pulse must be carefully controlled. Pulse magnitude depends on the amount of energy released from the capacitor bank. The voltage charging the capacitors is carefully measured and is turned off as soon as a present level is reached. The timing of the electromagnetic pulses is also carefully controlled to ensure maximum production rates. Rates of 200-600 parts/hour with manual loading, and up to 12,000 parts/hour with automatic loading, are possible.

EMF equipment operates at high voltage and current, so appropriate caution is needed to avoid accidents. Points at different potentials, such the coil and the work piece, must be adequately insulated to prevent shorting and the insulation checked frequently for signs of wear. All coils fail eventually, usually as a result of insulation breakdown. Since failure may be accompanied by flying debris, a safety shield is used between personnel and the work coil.

1. **ECONOMICAL CONSIDERATIONS**

In deciding whether an EMF installation is economically feasible, both startup and operating cost have to be considered.

STARTUP COST

Start up costs include capital equipment and training expenses. Equipment cost is determined mostly by energy storage capacity. An 8kJ unit, the smallest available, cost around $35,000. A 16kJ unit, the size most frequently used, cost $60,000-65,000. EMF does not require particularly skilled operators hence training costs are not high.

OPERATING COST

These include new coils ($4000-8000) or field shapers ($1000-5000) for different products, dies or drivers if these are necessary, and electric power. EMF equipment places no special demands on the power supply.

Energy consumption is 1kWs per kJ capacity. Therefore, assuming 1kwh cost Rs. 6-00, the cost per form (second) in a 16kj system is (16x6)/3600 or Rs 0.026.

1. **ADVANTAGES**

Compared with other competing technologies EMF is:

* Easy to use. The process is easy to implement and requires no special operator skill.
* Non-contact. There is generally no need for lubricants, and usually no surface marring, so cleaning and post finishing are rarely necessary.
* Fast. Energy release to the work coil takes only microseconds and capacitors recharge in a few seconds.
* Repeatable. All process variables can be precisely controlled.
* Amenable to automation. High production rates are possible.
* Clean room compatible. Parts made in an ultra clean or sterile environment can be sealed in a plastic bag and formed through the bag.
* Cost effective. The whole process is performed in one step rather than the two or three typical of competing techniques.
* Joins metals to other metals or nonmetals. Since only one component needs to be conductive, metals also can be jointed to rubber, glass, ceramics, plastics and fiberglass.
* Save dies. In assembling, the “die” is often an integral part of the product. Other parts may required only half of a matched-die set—the electromagnetic force forms the other half.
* Causes minimal tool wear. Only the coils need to be replaced occasionally.
* Forms most parts cold. Product handling is simplified.

1. **LIMITATIONS**

* Work piece must be electrically conductive, and, preferably, have a low electrical resistivity (high conductivity).
* Process works best with thinner materials.
* Minimum internal diameter of the tube should be about 50mm for expansion applications.
* Work coils are relatively expensive.
* High-resistance work pieces usually require drivers, which can be used only one and may have to be removed.
* Number of equipment suppliers is limited.

1. **APPLICATIONS**

EMF is widely used in Automotive, aerospace, appliance, ordnance, electrical and nuclear industries for:

* Fastening clamping rings over rubber sleeves on shock absorbers
* Attaching reinforcing bands on oil filters
* Assembling aluminum gas tank, filler tubes and plastic gas cap holders.
* Clamping steel covers on aluminum automobile fuel pumps
* Attaching aluminum drive shafts to yokes.
* Assembling coaxial-cable termination joints.
* Assembling lighter-fluid nozzles and wicks
* Attaching flanges to tubing
* Forming contoured tubing parts for ductile intersections.
* Correcting surface deformations on aircraft skins.
* Riveting aircraft wing spars.
* Welding end closures on nuclear reactor fuel rod.

Some of the Manufacturing problems successfully solved with EMF include:

* On Blower wheels, the louvers that move the air must be tightly fastened to three discs mounted on a shaft. Possible fastening method includes fastening each lover simultaneously by electromagnetic forming. EMF was chosen because it was least expensive, fastest and produced the most satisfactory product.
* Nuclear fuel elements and closures were made by tungsten-inert-gas welding. Such welds were difficult to make, difficult to inspect and unreliable. By changing to EM pulse welding, the manufacturer obtained more consistent, metallurgically-bonded joints at a lower cost. The time to manufacture and inspect each fuel element was reduced from 40 to 8 hours.

1. **COMPETING TECHNOLOGIES**

In compression applications, the main competing technologies are conventional swaging, rotary roll forming and multiple-jaw shrinking. Multiple-piece steel mandrels and steel roller bearing tools are traditionally used in expansion applications. Standard joining methods include welding, brazing, bolting and pinning. Most of these methods include welding, brazing, bolting and pinning. Most of these methods require two or three separate steps, and all involve direct mechanical contact between the tool and the work piece, resulting in surface flaws that may have to be removed in a later finishing process. EMF is a one-step, non-contact process, so surface finishing is not a problem: Furthermore, the magnetic field passes through non conducting materials so parts can be formed after anodizing or application of other surface finishes, or after they have been sealed in plastic bags in a clean room. Although research is underway to improve the process, EMF does not yet easily handle thick-walled, high strength materials. For these applications, contact methods are more cost effective.

1. **CONCLUSION**

* Excellent technique for forming thin metals.
* Good for mechanically joining metals or non-metals.
* Its quicker, easier, and easy to implement.
* Easily automated and product formed is free from any defects.
* Likely rapid growth of EMF machines.

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