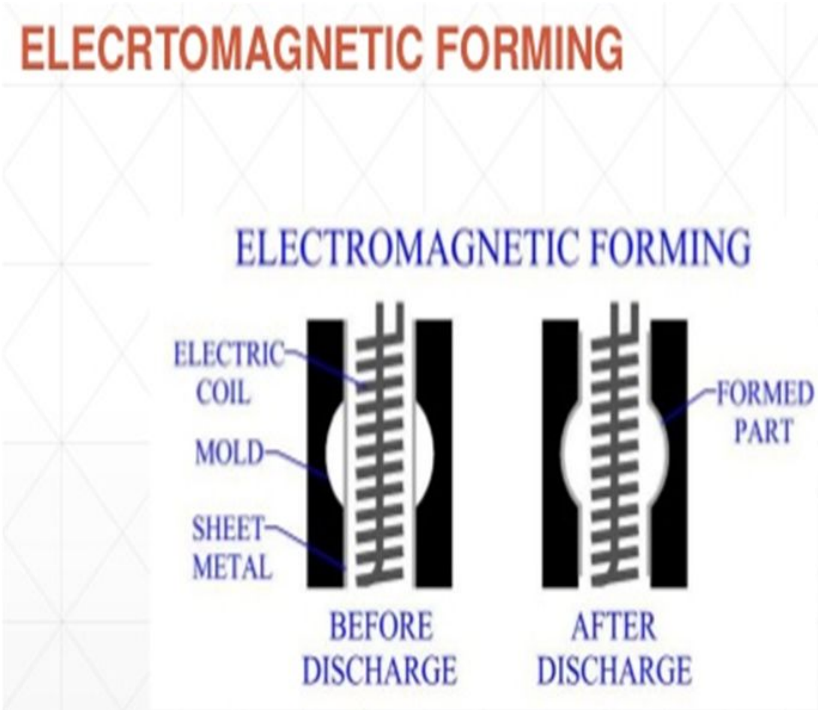


Uses electromagnetic surge to form sheet metal.
Electrical energy stored in capacitor is used to produce opposing magnetic fields by current carrying conductors around a tubular work.
Workpiece takes shape of external die cavity due to magnetic repelling force.
Suitable for small tube operations like collapsing, bending & crimping.
Electrical energy can be precisely controlled
Safer compared to explosive forming.

ELECTRO HYDRAULIC FORMING

- 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
- Better control of the pressure pulse as source of energy is electrical- which can be easily controlled.
- Safer in handling than the explosive materials.
- More suitable if the work size is small to medium.
- Thin plates can be formed with smaller amounts of energy

Process Principle :

- This process is based on the principle stated by lorentz force law that the electromagnetic field of an induced current always opposes the electromagnetic field of the inducing current.
- In this method a large capacitor bank is discharged producing a current charge through a coiled conductor.
- If the coil has been placed within a conductive cylinder, around a cylinder or adjacent to a flat sheet of metal, then the discharge induces a secondary current in the workpiece.
- This secondary current further causes it to be repelled from the coil and conformed to a die or mating work piece.
- The process is very rapid and is used primarily to expand or contract tubing or to permanently assemble component

Constructional Details and Working:

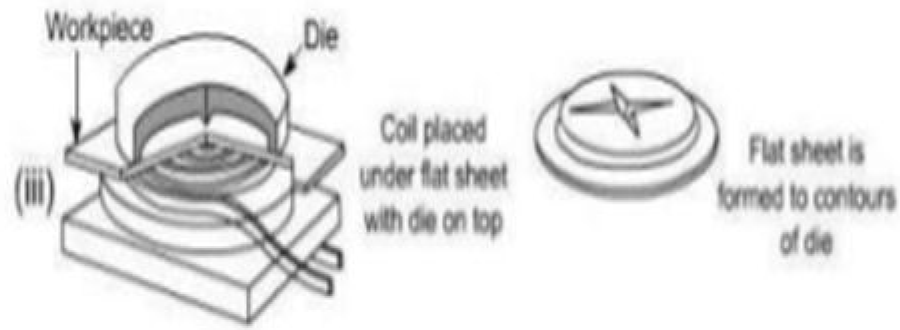
- The setup of EMF consists of the pulsed power generator, the inductor including a fieldshaper, if applicable, the workpiece and application-dependent further tool components such as form-defining dies etc.
- The process is started by charging and subsequently discharging the capacitor of the pulsed power generator.
- A sinusoidal current flows through the inductor. This current induces a corresponding magnetic field.
- If there is an electrically conductive workpiece in direct proximity to inductor, a second opposedly directed current is induced.
- The energy density stored in the magnetic field between workpiece and inductor acts as magnetic pressure which can reach several hundreds of megapascal and causes the acceleration and deformation of the workpiece.
- The direction of the movement is always targeted away from the inductor

Depending on the geometry and the alignment of tool and workpiece, three process variants can be distinguished. These are :

(i) electromagnetic compression of tubes and hollow profiles by means of an inductor enclosing the workpiece,

(ii) electromagnetic expansion of tubes and hollow profiles by means of an inductor positioned within the workpiece,

(iii) electromagnetic sheet forming, for which an inductor is positioned in close proximity of a flat semi-finished part or a preformed component.



Process Parameters:

- Workpiece thickness – A higher thickness means that the magnetic field diffuses slower through the workpiece wall.
- Electrical conductivity – The higher the electrical conductivity of the workpiece, the better the shielding of the magnetic field, the pressure difference in higher.
- Frequency – A higher frequency of the discharged current can balance a low conductivity or a small wall thickness.
- Size of the capacitor bank
- The strength of the current, which decides the strength of the magnetic field and the force applied.
- Gap between workpiece and tool coil – The smaller the air gap, higher is magnetic field and pressure.
- Winding of the tool coil – For each pulse generator and each forming task exists an optimum of number of turns.

Advantages :

- Suitable for small tubes
- Operations like collapsing, bending and crimping can be easily done.
- Electrical energy applied can be precisely controlled and hence the process is accurately controlled.
- The process is safer compared to explosive forming.
- Wide range of applications.

Disadvantages :

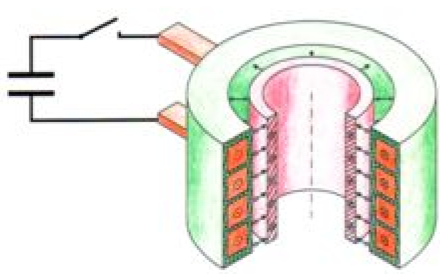
- Applicable only for electrically conducting materials.
- Not suitable for large work pieces.
- Rigid clamping of primary coil is critical.
- Shorter life of the coil due to large forces acting on it.

Advantages:
High production rates.
Lower Die costs.
Difficult to form metals can be easily formed.
Minimum (almost '0') spring back action.
Low production cost.
◦No need of power hammer/press.
Intricate shapes can be easily obtained.
Suitable for all ranges of production volumes
◦Small nos, Batches or Mass Production.

Disadvantages
Not suitable for highly brittle materials.
Careful handling of energy source required. (chemical explosive or electrical)
Highly skilled personnel required from design to execution.
Bigger dies required to withstand high energy rates & shocks or product may crack.

Electromagnetic forming

Electromagnetic forming (EM forming or magnetic forming) is a type of high velocity, cold forming process for electrically conductive metals, most commonly copper and aluminium. The workpiece is reshaped by high intensity pulsed magnetic fields that induce a current in the workpiece and a corresponding repulsive magnetic field, rapidly repelling portions of the workpiece. The workpiece 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 or electromagnetic pulse technology.
Explanation
A special coil is placed near the metallic workpiece, replacing the pusher in traditional forming. When the system releases its intense magnetic pulse , the coil generates a magnetic field which in turn accelerates the workpiece to hyper speed and onto the die. The magnetic pulse (MP) and the extreme deformation speed transforms the metal into a visco-plastic state – increasing formability without affecting the native strength of the material magnetic pulse forming illustration.
A rapidly changing magnetic field induces a circulating electric current within a nearby conductor through electromagnetic induction. The induced current creates a corresponding magnetic field around the conductor (see Pinch (plasma physics)). Because of Lenz's Law, the magnetic fields created within the conductor and work coil strongly repel each other.



When the switch is closed, electrical energy stored in the capacitor bank (left) is discharged through the forming coil (orange) producing a rapidly changing magnetic field which induces a current to flow in the metallic workpiece (pink). The current flowing the workpiece produces a corresponding opposite magnetic field which rapidly repels the workpiece from the forming coil, reshaping the workpiece - in this case, compressing the diameter of the cylindrical tube. The reciprocal forces acting against the forming coil are resisted by the 'supportive coil casing (green).
In practice the metal workpiece to be fabricated is placed in proximity to a heavily constructed

coil of wire (called the work coil). A huge pulse of current is forced through the work coil by rapidly discharging a high voltage capacitor bank using an ignitron or a spark gap as a switch. This creates a rapidly oscillating, ultrastrong electromagnetic field around the work coil.
The high work coil current (typically tens or hundreds of thousands of amperes) creates ultrastrong magnetic forces that easily overcome the yield strength of the metal work piece, causing permanent deformation. The metal forming process occurs extremely quickly (typically tens of microseconds) and, because of the large forces, portions of the workpiece undergo high acceleration reaching velocities of up to 300 m/s.

Applications

The forming process is most often used to shrink or expand cylindrical tubing, but it can also form sheet metal by repelling the work piece onto a shaped die at a high velocity. High-quality joints can be formed, either by electromagnetic pulse crimping with a mechanical interlock or by electromagnetic pulse welding with a true metallurgical weld. Since the forming operation involves high acceleration and deceleration, mass of the work piece plays a critical role during the forming process. The process works best with good electrical conductors such as copper or aluminum, but it can be adapted to work with poorer conductors such as steel.

Comparison with Mechanical Forming

Electromagnetic forming has a number of advantages and disadvantages compared to conventional mechanical forming techniques.
Some of the advantages are;

- Improved formability (the amount of stretch available without tearing)
- Wrinkling can be greatly suppressed
- Forming can be combined with joining and assembling with dissimilar components including glass, plastic, composites and other metals.
- Close tolerances are possible as springback can be significantly reduced.
- Single sided dies are sufficient which can reduce tooling costs
- Lubricants are reduced or are unnecessary, so forming can be used in clean room conditions
- Mechanical contact with the workpiece is not required, this avoids surface contamination and tooling marks. As a result, a surface finish can be applied to the workpiece before forming.

The principle disadvantages are;

- Non conductive materials cannot be formed directly, but can be formed using a conductive drive plate
- The high voltages and currents involved require careful safety considerations

Electro Magnetic Forming

The process is also called magnetic pulse forming and is mainly used for swaging type operations, such as fastening fittings on the ends of tubes and crimping terminal ends of cables.

Other applications are blanking, forming, embossing, and drawing. The work coils needed for different applications vary although the same power source may be used.

To illustrate the principle of electromagnetic forming, consider a tubular work piece. This work piece is placed in or near a coil, Fig 9.3. A high charging voltage is supplied for a short time to a bank of capacitors connected in parallel. (The amount of electrical energy stored in the bank can be increased either by adding capacitors to the bank or by increasing the voltage). When the charging is complete, which takes very little time, a high voltage switch triggers the stored electrical energy through the coil. A high – intensity magnetic field is established which induces eddy currents into the conductive work piece, resulting in the establishment of another magnetic field. The forces produced by the two magnetic fields oppose each other with the consequence that there is a repelling force between the coil and the tubular work piece that causes permanent deformation of the work piece.

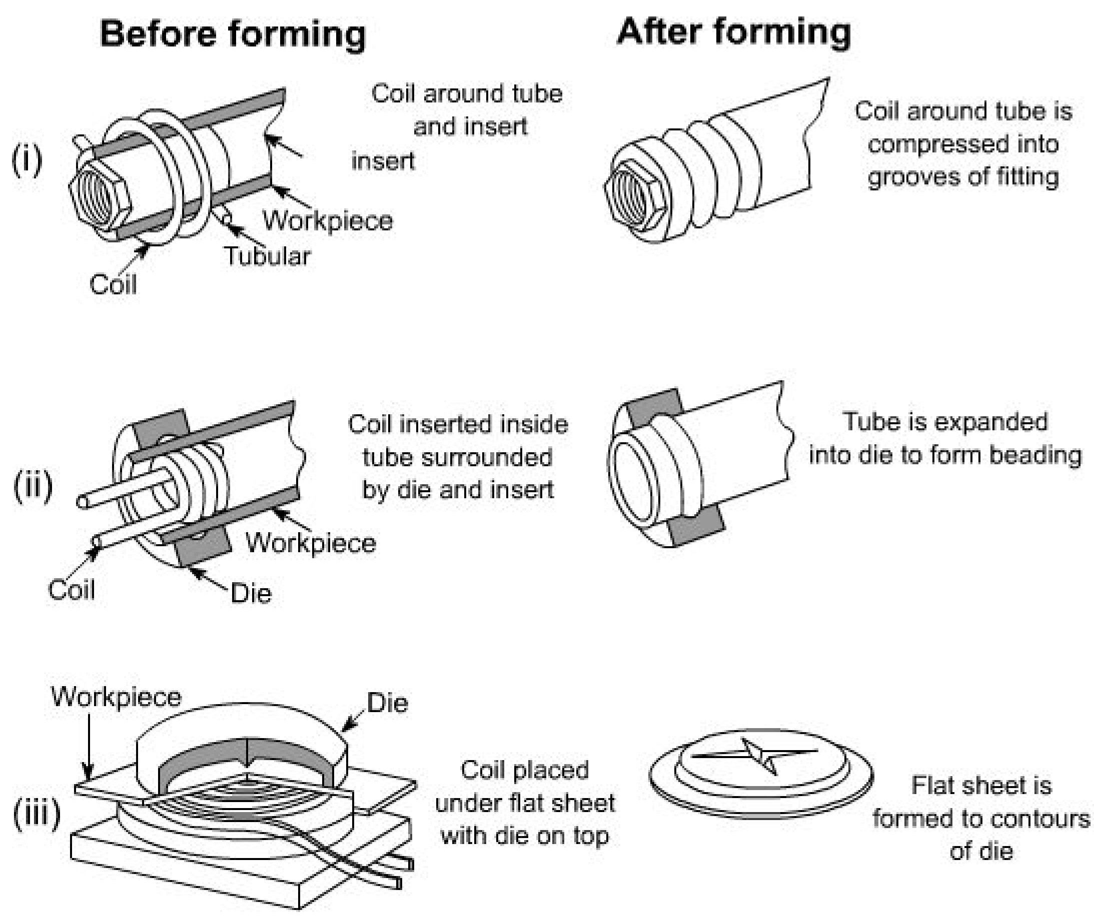


Fig 9.3 Various applications of magnetic forming process. (i) Swaging, (ii) Expanding, and (iii) Embossing or blanking.

Either permanent or expandable coils may be used. Since the repelling force acts on the coil as well the work, the coil itself and the insulation on it must be capable of withstanding the force, or else they will be destroyed. The expandable coils are less costly and are also preferred when high energy level is needed.

Magnetic forming can be accomplished in any of the following three ways, depending upon

the requirements.
•	Coil surrounding work piece. When a tube – like part x is to fit over another part y (shown as insert in Fig 9.3(i)), coil is designed to surround x so that when energized, would force the material of x tightly around y to obtain necessary fit.
•	Coil inside work piece. Consider fixing of a collar on a tube – like part, as shown in Fig 9.3(ii). The magnetic coil is placed inside the tube – like part, so that when energized would expand the material of the part into the collar.
•	Coil on flat surface. Flat coil having spiral shaped winding can also be designed to be placed either above or below a flat work piece, see Fig 9.3(iii).These coils are used in conjunction with a die to form, emboss, blank, or dimple the work piece.

In electromagnetic forming, the initial gap between the work piece and the die surface, called the fly distance , must be sufficient to permit the material to deform plastically. From energy considerations, the ideal pressure pulse should be of just enough magnitude that accelerates the part material to some maximum velocity and then let the part come to zero velocity by the time it covers the full fly distance. All forming coils fail, expendable coils fail sooner than durable coils, and because extremely high voltages and currents are involved, it is essential that proper safety precautions are observed by the production and maintenance personnel.

Applications

Electromagnetic forming process is capable of a wide variety of forming and assembly operations. It has found extensive applications in the fabrication of hollow, non – circular, or asymmetrical shapes from tubular stock. The compression applications involve swaging to produce compression, tensile, and torque joints or sealed pressure joints, and swaging to apply compression bands or shrink rings for fastening components together. Flat coils have been used on flat sheets to produce stretch (internal) and shrink (external) flanges on ring and disc – shaped work pieces.

Electromagnetic forming has also been used to perform shearing, piercing, and rivettting.

Magnetic Pulse Forming

The magnetic pulse forming process which uses opposing magnetic fields to force a sheet of metal onto a mandrel or other form. First, an extremely large current discharge is directed through a coil which creates a magnetic field. Capacitor banks are used to store charge for larger discharges. In the nearby sheet of metal, an opposing magnetic field is induced which causes the metal sheet to be pushed into a form of some shape. The method generates pressures up to 50 Kpsi creating velocities up to 900 fps. The process production rate can climb to 3 parts a second.

Applications -

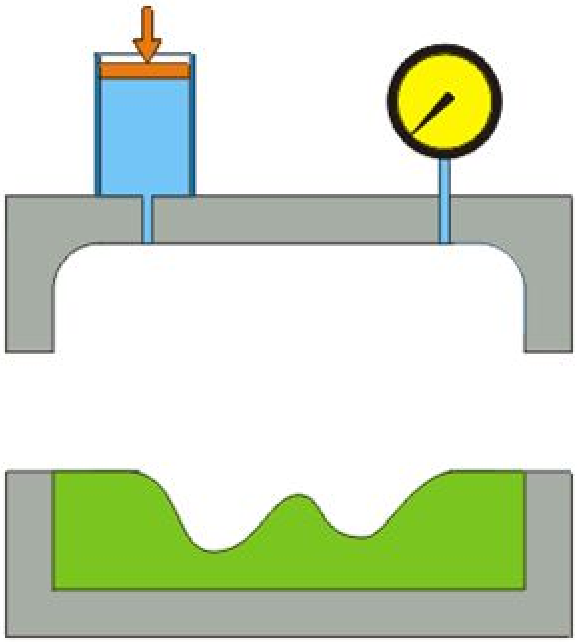
1. fittings for ends of tubes
2. embossing
3. forming

Three methods of magnetic pulse forming -

1. **Swaging** - An external coil forces a metal tube down onto a base shape (tubular coil).
2. **Expanding** - an inner tube is expanded outwards to take the shape of an outer collar (tubular coil).
3. **Embossing and Blanking** - A part is forced into a mold or over another part (a flat coil) - This could be used to apply thin metal sheets to plastic parts.

Hydroforming

Hydroforming is a cost-effective way of shaping ductile metals such as aluminum, brass, low alloy steel, and stainless steel into lightweight, structurally stiff and strong pieces. One of the largest applications of hydroforming is the automotive industry, which makes use of the complex shapes possible by hydroforming to produce stronger, lighter, and more rigid unibody structures for vehicles. This technique is particularly popular with the high-end sports car industry and is also frequently employed in the shaping of aluminium tubes for bicycle frames.



Hydroforming is a specialized type of die forming that uses a high pressure hydraulic fluid to press room temperature working material into a die. To hydroform aluminum into a vehicle's frame rail, a hollow tube of aluminum is placed inside a negative mold that has the shape of the desired result. High pressure hydraulic pumps then inject fluid at very high pressure inside the aluminum tube which causes it to expand until it matches the mold. The hydroformed aluminum is then removed from the mold. Hydroforming allows complex shapes with concavities to be formed, which would be difficult or impossible with standard solid die stamping. Hydroformed parts can often be made with a higher stiffness-to-weight ratio and at a lower per unit cost than traditional stamped or stamped and welded parts. Virtually all metals capable of cold forming can be hydroformed, including aluminum, brass, carbon and stainless steel, copper, and high strength alloys.[1]

Main process variants

Sheet hydroforming

This process is based on the 1950s patent for hydramolding by Fred Leuthesser, Jr. and John Fox of the Schaible Company of Cincinnati, Ohio in the United States.[2] It was originally used in producing kitchen spouts. This was done because in addition to the strengthening of the metal, hydromolding also produced less "grainy" parts, allowing for easier metal finishing.[3] In sheet hydroforming (SHF) there are bladder forming (where there is a bladder that contains the liquid; no liquid contacts the sheet) and hydroforming where the fluid contacts the sheet (no bladder). Bladder forming is sometimes called flexforming.[4] Flexforming is mostly used for low volume productions, as in the aerospace field.[5] Forming with the fluid in direct contact with the part can be done either with a male solid punch (this version is sometimes called hydro-mechanical deep drawing[6]) or with a female solid die. In hydro-mechanical deep drawing, a work piece is placed on a draw ring (blank holder) over a male punch then a hydraulic chamber surrounds the work piece and a relatively low initial pressure seats the work piece against the punch. The punch then is raised into the hydraulic chamber and pressure is increased to as high as 15000 psi which forms the part around the punch. Then the pressure is released and punch retracted, hydraulic chamber lifted, and the process is complete.

Alternative names, other variants and similar processes

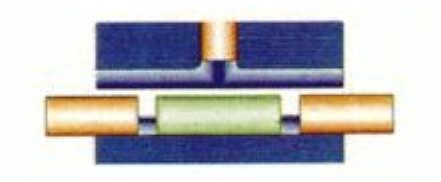
- Hydromec (Hydromechanical deep drawing)

- Aquadraw
- Bulge forming
- Explosive forming
    - For large parts, explosive hydroforming can generate the forming pressure by simply exploding a charge above the part (complete with evacuated mold) which is immersed in a pool of water. The tooling can be much cheaper than what would be required for any press-type process. The hydroforming-into-a-mold process also works using only a shock wave in air as the pressuring medium. Particularly when the explosives are close to the workpiece, inertia effects make the result more complicated than forming by hydrostatic pressure alone.
- Rubber pad forming

Tube hydroforming

In tube hydroforming (THF) there are two major practices: high pressure and low pressure. With the high pressure process the tube is fully enclosed in a die prior to pressurization of the tube. In low pressure the tube is slightly pressurized to a fixed volume during the closing of the die (this used to be called the Variform process). Historically, the process was patented in the '50s,[7] but it was industrially spread in the '70s for the production of large T-shaped joints for the oil & gas industry.Today it is mostly used in the automotive sector, where many industrial applications can be found.[8][9] It is also a method of choice for several tubular members of bicycles.

In tube hydroforming pressure is applied to the inside of a tube that is held by dies with the desired cross sections and forms. When the dies are closed, the tube ends are sealed by axial punches and the tube is filled with hydraulic fluid. The internal pressure can go up to a few thousand bars and it causes the tube to calibrate against the dies. The fluid is injected into the tube through one of the two axial punches. Axial punches are movable and their action is required to provide axial compression and to feed material towards the center of the bulging tube. Transverse counterpunches may also be incorporated in the forming die in order to form protrusions with small diameter/length ratio. Transverse counterpunches may also be used to punch holes in the work piece at the end of the forming process.



Process sequence in tube hydroforming of a t-shape with counterpunch

Designing the process might be a very challenging task, since analytical modeling is possible only for very simple cases.[10] Often FEM simulations must be performed in order to find a feasible process solution and to define the correct loading curves: pressure vs. time and axial feed vs. time.[11]

Typical tools

Tools and punches can be interchanged for different part requirements. One advantage of hydroforming is the savings on tools. For sheet metal only a draw ring and punch (metalworking) or male die is required. Depending on the part being formed, the punch can be made from epoxy, rather than metal. The bladder of the hydroform itself acts as the female die eliminating the need to fabricate it. This allows for changes in material thickness to be made with usually no necessary changes to the tool. However, dies must be highly polished and in tube hydroforming a two-piece die is required to allow opening and closing.

Geometry produced

Another advantage of hydroforming is that complex shapes can be made in one step. In sheet hydroforming (SHF) with the bladder acting as the male die almost limitless geometries can be produced. However, the process is limited by the very high closing force required in order to seal the dies, especially for large panels and thick hard materials. Small concave corner radii are difficult to be completely calibrated, i.e. filled, because too large a pressure would be required. in fact, the die closing force can be very high, both in tube and sheet hydroforming and may easily overcome the maximum tonnage of the forming press. In order to keep the die closing force under prescribed limits, the maximum internal fluid pressure must be limited. This reduces the calibration abilities of the process, i.e. it reduces the possibility of forming parts with small concave radii. Limits of the SHF process are due to risks of excessive thinning, fracture, wrinkling and are strictly related to the material formability and to a proper selection of process parameters (e.g. hydraulic pressure vs. time curve). Tube hydroforming (THF) can produce many geometric options as well, reducing the need for tube welding operations. Similar limitations and risks can be listed as in SHF; however, the maximum closing force is seldom a limiting factor in THF.[12]

Tolerances and surface finish

Hydroforming is capable of producing parts within tight tolerances including aircraft tolerances where a common tolerance for sheet metal parts is within 0.76 mm (1/30th of an inch). Then metal hydroforming also allows for a smoother finish as draw marks produced by the traditional method of pressing a male and female die together are eliminated.

Examples

Notable examples include:

SHF

- Satellite antennas up to 6 meters in diameter, such as those used in the Allen Telescope Array.[13]
- Lighting fixture housing and reflector

THF

- The brass tube of Yamaha saxophones.[14]
- The process has become popular for the manufacture of aluminium bicycle frames. The earliest commercially manufactured one being that of the Giant Manufacturing Revive bicycle[15] first marketed in 2003.
- Many motor vehicles have major components manufactured using this technology, for example:
    - The technique is widely used in the manufacture of engine cradles.[16] The first mass-produced one was for the Ford Contour and Mystique in 1994.[17] Others from a long list

include the Pontiac Aztek,[18] the Honda Accord[19] and the perimeter frame around the Harley Davidson V-Rod motorcycle's engine.[20]

- As well as engine cradles, the main automotive applications for hydroforming are suspension, radiator supports and instrument-panel support beams. The 1994 Buick Regal and Oldsmobile Cutlass had hydro-formed instrument panel beams. [16] The first mass-produced automotive component was in 1990 with the instrument panel support beam for the Chrysler minivan.[17]
- Various vehicle bodies and body components, the earliest mass-produced one being the 1997 Chevrolet Corvette.[21] A selection from many examples are the current versions of the three major United States pickup trucks—the Ford F-150, Chevrolet Silverado, and Ram—which all have hydroformed frame rails,[21] 2006 Pontiac Solstice[22] and the steel frame inside the John Deere HPX Gator Utility Vehicle.[23]

Basic structure proposed by HOD sir

Basic Introduction

Types if any

Working principle

Equipment

Process Description

Process Variations

Process Parameters

Performance Characteristics

Advantages

Disadvantages

Applications