UNCONVENTIONAL METHOD OF FORMING CIRCUMFERENTIAL RINGS ON SHEET METAL PARTS

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Abstract

The paper deals with the unconventional way of making thin-walled circumferential rings produced by classical technology. The essence of the phenomenon is induction. The accumulated energy drains through the coil to produce a repulsive force that causes a dull thrust. Further, the theoretical process conditions are described. Figures illustrate the entire forming process. The drawbar is designed as an all-metal (non-magnetic) with a divided die, from which the finished work is removed and elapsed after completion of the process. The electromagnetic pulse causes the necessary strain and forces to form peripheral rings on the drawing piece. After disconnecting the DC stream and rejecting the coil from the drawing piece, the divided die is scraped and the extraction is removed from the tool. The drawing pieces were almost plastically deformed, but the magnetic field built up had to be considerably larger than that of the experiments. It turns out that such a forming process is directly dependent on the size of the supplied current, the built-up magnetic field, and the drawing piece plate thickness. It is possible to expect a state where the drawing pieces can be formed even under the conditions of piece production just by applying the magnetic field to the process.

Keywords: Magnetic impulse, sheet metal forming, draw die, drawpiece, samples

1. INTRODUCTION

The following are the methods and possibilities of forming sheet metal workpieces by means of a magnetic field. For many years, the author has carried out experiments in laboratory conditions as described in the following text.

Based on performed and published scientific and research works of experts [1-11] and my works [12-14] there was found out, that electromagnetic shaping of sheet can be applied also for shaping of circumferential rings on drawn workpieces shaped by the standard way. The goal is to verify the possibility of electromagnetic field application for such an operation.

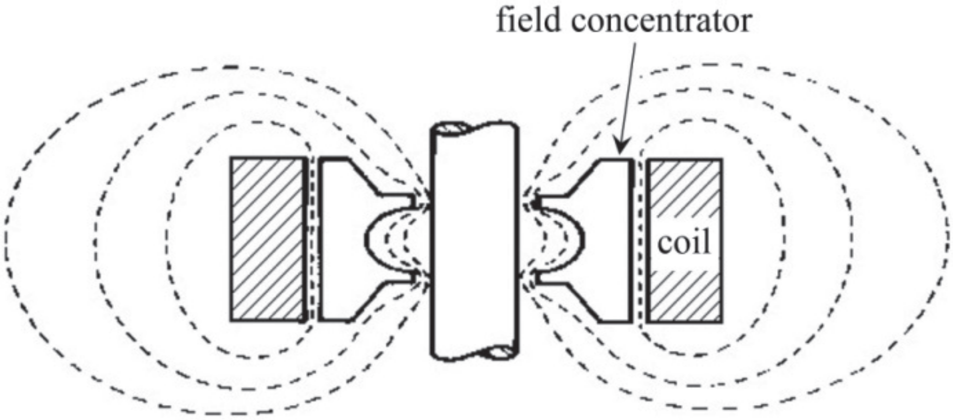

Figure 1 Principle of the magnetic forming

According to the mutual position of the coil and the workpiece, magnetic forming is divided into two types:

- expansion (the coil is inside the workpiece),
- and compression (the workpiece is inside the hollow coil).

Magnetic forming can be guided by so-called field concentrators (**Figure 1**).

Main advantages of this method are:

- low noise,
- simplicity (there are no moving parts),
- technological flexibility (by concentrator exchange),
- high uniform pressures,
- and low weight of the device.

2. APPLICATION OF ELECTROMAGNETISM

In the field of forming, a huge increase in new solutions to manufacturing problems has occurred over the last decades, applying knowledge predominantly from the field of physics [15-17]. This has increased productivity, quality, and the worker protection has reached a qualitatively higher level. A progressive approach is the solution presented in this paper. It concerns a possibility of forming a circumferential ring on metal sheet workpieces in a magnetic field [18].

The essence of electromagnetism is induction. Electromagnetic field must be generated around the components of the conductor to be shaped (formed). We have to make a coil through which the energy accumulated in a set of capacitors can be discharged. This generates repulsive force between the coil and the component - conductor, which causes deformation pulse. The resulting effect depends on the density of vector lines of the electromagnetic field flow.

3. EXPERIMENTAL WORK

3.1. Construction of an experimental tool

The experimental work was aimed at producing a drawn workpiece in a magnetic field, as shown in **Figure 2** left. We decided to produce two circumferential rings on a sheet metal vessel according to the sketch in **Figure 2** right.

Tool construction: the drawing tool is designed as an all-metal one with a split drawing die, placed in the workpiece manufacturing process in a socket, from which it is taken out after the process is completed, and the finished workpiece is ejected from it. **Figure 3** shows the experimental tool assembled and disassembled. **Figure 4** shows the experiment diagram.

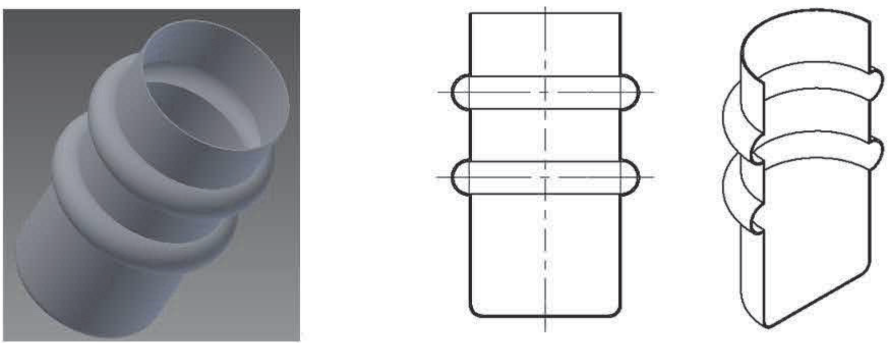

Figure 2 Drawn workpiece with two circumferential rings (left) and sketch of the drawn workpiece with two circumferential rings (right)

Figure 3 Assembled tool (left) and disassembled tool (right)

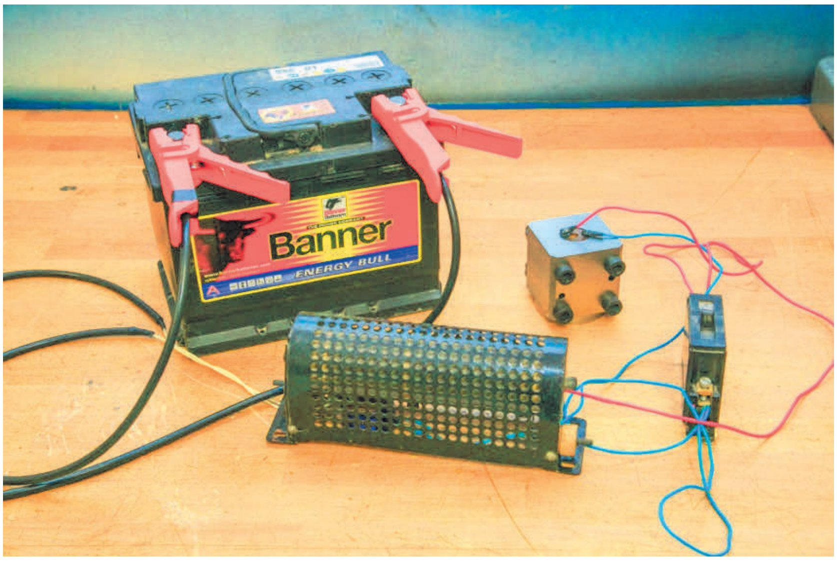

Figure 4 Experiment diagram of the device

3.2. Description of the process

Stage One: An appropriately sized blank is placed into the drawing tool in order to produce the vessel. The required dimensions are calculated using the formula:

$$D = \sqrt{d^2 + 4 \cdot d \cdot h} \quad (1)$$

where:

D - blank diameter (mm)

d - diameter of a drawnpiece (mm)

h - height of a drawnpiece (mm)

The vessel is drawn in a conventional manner. The drawn workpiece remains in the drawing tool.

Stage Two: The drawing tool is placed in an electromagnetic field that is generated by a coil, which is located in the drawn workpiece cavity. This will multiply the effect of the electromagnetic field. **Figure 5** shows the circuit diagram. The electromagnetic circuit is created when direct current is supplied. The electromagnetic field generates the necessary stress and forces that will form circumferential rings on the drawn workpiece. The electromagnetic pulse and its generation are described in [14].

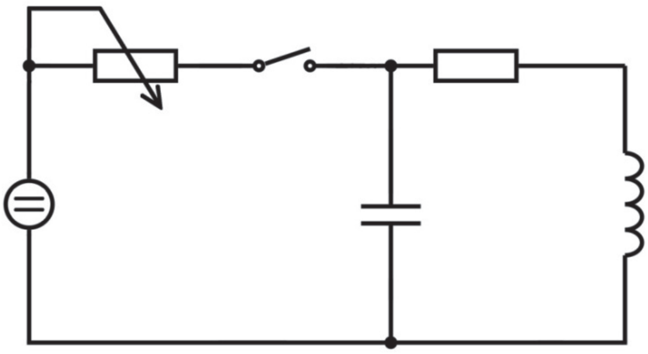

Figure 5 Experimental circuit to generate electromagnetic field

Stage Three: Direct current is disconnected, and the coil is removed from the drawn workpiece. The split drawing die is removed from the socket, dismantled, and the drawn workpiece is removed from the tool.

Based on scientific literature research, and following my findings from previous experiments, I approached the design and manufacture of a device for electromagnetic forming [15]. The material used in the experiments included: 0.4 mm, made of STN 42 5715 steel. The chemical composition of the material is as follows: C_{max} = 0.18%, P_{max} = 0.050%, S_{max} = 0.050%. **Figure 5** shows the circuit diagram used in the experiment. As the power source we used a 12V/60Ah car battery Banno Energy Bull K20. We used this power source because of great transforming pulses requiring the so-called hard DC power source - and the car battery reliably accomplished that. We installed a coil on the wires. The number of coil threads (N) was determined according to equation (2):

$$N = \frac{B \cdot l}{\mu_0 \cdot \mu_r \cdot I} \tag{2}$$

where:

- N - number of coil treads (-)
- B - magnetic flux density (T)
- l - target spool (mm)
- μ_0 - permeability of vacuum (H/m)
- μ_r - relative permeability (μ/ μ_0)
- I - current (A)

3.3. Magnetic intensity of the single-layer coil axis

The magnetic intensity on the circular cross-section coil axis, onto which an N-thread coil is wound in one layer, is determined by applying the magnetic intensity relation on the axis of the circular thread that, using the markings shown in **Figure 6**, will take the form:

$$dH = \frac{I}{2} \cdot \frac{R^2}{2 \cdot \sqrt{\left(R^2 + x^2\right)^3}} \tag{3}$$

where

- H - intensity of magnetic field (A/m)

and meaning of other symbols is evident from **Figure 6**

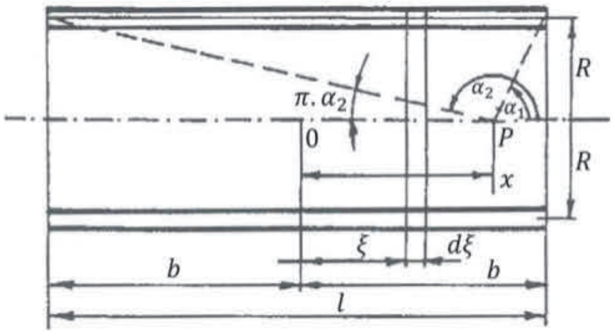

Figure 6 To calculate the electromagnetic field on the axis of a single-layer coil

If a coil (solenoid) is densely wound, it can be considered as the sum of stacked round threads. The elemental length solenoid section d*x* is equivalent to the current passing through the "thread" $N{\cdot}I\, d\xi / l$ and the magnetic induction caused by this "thread" is:

$$dH = \frac{I}{2}\cdot\frac{R^2}{\sqrt{\left[R^2+(x-\xi)^2\right]^3}}\cdot\frac{N}{2\cdot b}\cdot d\xi \qquad (4)$$

The magnetic intensity caused by the entire coil is done by the following integration:

$$H = \frac{N\cdot I\cdot R^2}{4\cdot b}\cdot\int_{-b}^{b}\frac{d\xi}{\sqrt{\left[R^2+(\xi-x)^2\right]^3}} = \left[\frac{N\cdot I\cdot R^2}{4\cdot b}\cdot\frac{(\xi-x)}{R^2\cdot\sqrt{(\xi-x)^2+R^2}}\right]_{-b}^{b} = $$
$$= \frac{N\cdot I}{4\cdot b}\cdot\left[\frac{b-x}{\sqrt{(b-x)^2+R^2}}-\frac{b+x}{\sqrt{(b+x)^2+R^2}}\right] \qquad (5)$$

The magnetic intensity in the middle of the coil, i.e. for $x = 0$ will be:

$$H(0) = \frac{N\cdot I}{2\cdot\sqrt{b^2+R^2}} = \frac{N\cdot I}{l}\cdot\frac{1}{\sqrt{1+\left(\frac{2\cdot R}{l}\right)^2}} \qquad (6)$$

and on the edges of the coil, i.e. for for $x = \pm b = \pm l / 2$:

$$H\left(\pm\frac{l}{2}\right) = \frac{N\cdot I}{2\cdot\sqrt{(2\cdot b)^2+R^2}} = \frac{N\cdot I}{2\cdot l}\cdot\frac{1}{\sqrt{1+\left(\frac{R}{l}\right)^2}} \qquad (7)$$

It turns out that before a long coil where $2R \ll 1$ is:

$$H(0) = \frac{N\cdot I}{l} \text{ and } H\left(\frac{l}{2}\right) = \frac{N\cdot I}{2\cdot l} = 0.5\cdot H(0) \qquad (8)$$

Thus, the magnetic intensity at the end is half of that in the middle of the coil.

This calculation is completely explained in [12].

4. CONCLUSION

The problematic element appeared to be the coil, since it must be greater by at least 40%. It is similar to explosive forming. A larger diameter = a larger coil (dimensionally), and a thicker wire. Reality: The dent was only by a few tenths of mm. This was the result of the coil being weak.

Experiments and their results have been described in the previous text. It turns out that such a forming process is directly dependent on the size of the supplied current, the generated magnetic field and the drawn workpiece sheet metal thickness. It is possible to expect a state where drawn workpieces can be formed even under the conditions of piece production just by applying magnetic field to the process.

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