March 12, 1968 H. SCHENK ETAL 3,372,566

DEVICE FOR FORMING METALLIC WORKPIECES
BY PULSED MAGNETIC FIELDS
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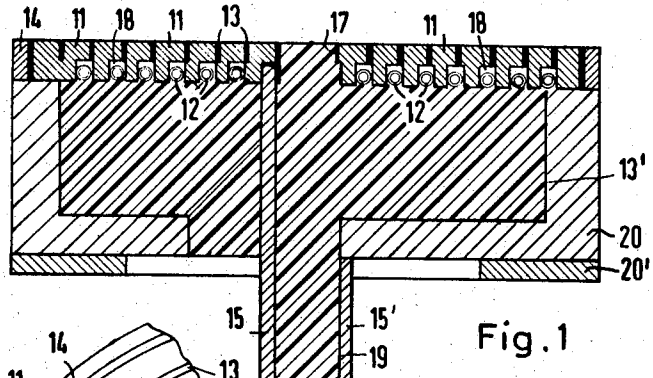


Fig. 1

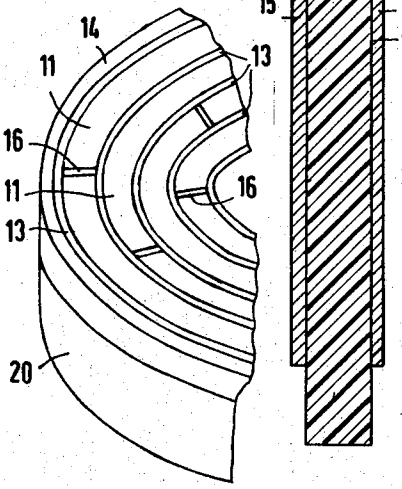


Fig. 1a

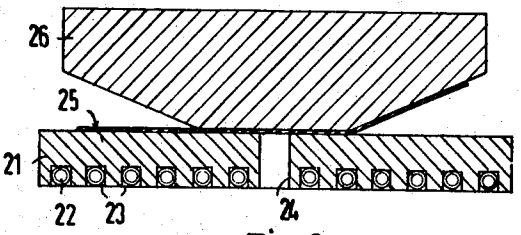


Fig. 2

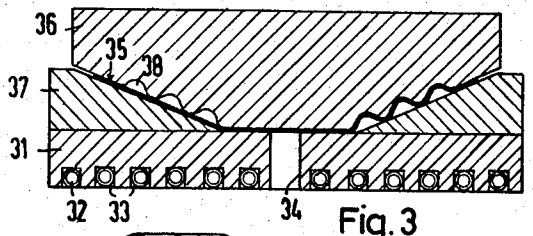


Fig. 3

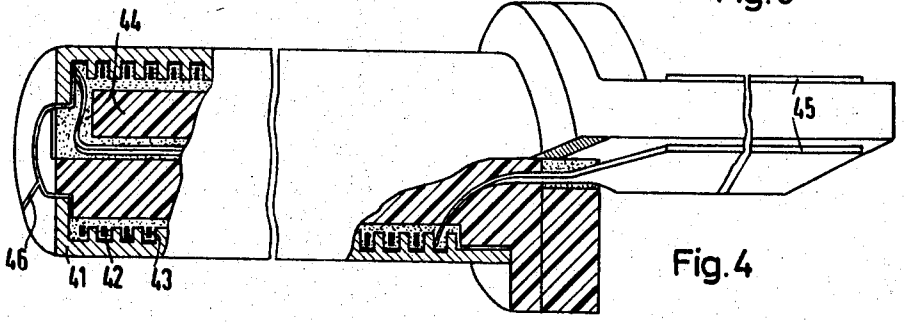


Fig. 4

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DEVICE FOR FORMING METALLIC WORKPIECES BY PULSED MAGNETIC FIELDS

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2 Claims. (Cl. 72—56)

ABSTRACT OF THE DISCLOSURE

Device for deep-drawing metallic workpieces by pulsed magnetic fields includes a plurality of coaxially disposed rings of relatively good electrically conductive materials, said rings being radially slotted and being electrically insulated from one another, a magnetic coil winding disposed beneath the rings and electrically insulated therefrom, the rings having an upper surface corresponding to the geometric shape of a workpiece to be deep-drawn.

Our invention relates to the direct-forming of metallic workpieces with the aid of pulsed magnetic fields. According to this method, often called "Magneform" method, capacitors are discharged through a work coil within extremely short intervals in time, for example micro-seconds, to produce high-intensity magnetic fields which subject the workpiece to forming pressure. This method and suitable devices for performing it are known, for example, from U.S. Patent 2,976,907.

The work coils employed for magnetic-pulse forming of metals are of the compression type, expansion type or flat (pancake) type. Compression coils are cylindrical and surround the workpiece for subjecting it to inwardly directed compressive forces due to the high-intensity field pulses. Expansion coils are designed to be located inside a tubular workpiece for subjecting it to radially outward magnetic forces so as to widen the workpiece, usually at singular localities. Flat-type or pancake coils have a flat surface which, during operation, is located adjacent to a workpiece, such as a sheet-metal member, and are usually employed for deep-drawing purposes. Compression coils have been equipped with field shapers designed as annular pole structure between the cylindrical work coil and the workpiece for receiving the current-produced forces of the working coil and concentrating the magnetic pressure forces upon particular localities of the interiorly located workpiece. Metal forming with expansion coils and deep-drawing (pancake) coils, however, has been effected without field shapers and without concentrating the field forces in any similar manner, because the desired localization of the forming effect at the workpiece can and has been obtained with the aid of dies which, with such work coils, are readily applicable since the workpiece remains freely accessible for dies or abutments from the outside.

It is an object of our invention to provide a device for forming metallic workpieces by pulsed magnetic field with deep-draw (pancake) coils and expansion coils, that afford performing workpiece widening and deep-drawing processes by a multiple of the amount of energy heretofore permissible or applicable with such devices under otherwise the same or comparable conditions.

According to the invention, we provide one or more field concentrator structures between the workpiece and the deep-drawing or expansion coil. According to another feature of the invention, it is preferable to provide the field concentrator structure with grooves, similar to the slots of electrical machines, in which the turns of the working coil are accommodated. According to another feature, the geometric shape of the field concentrator

structure at its side directly adjacent to the workpiece is largely adapted to the pre-shaped profile or contour of the workpiece being subjected to the forming process.

The invention will be further described with reference to the drawing showing schematically various embodiments of magnetic forming devices according to the invention by way of example.

FIG. 1 shows in section a flat pancake coil with a field concentrator.

FIG. 1*a* is a partial perspective view onto the work coil according to FIG. 1.

FIG. 2 illustrates diagrammatically and in section a flat coil with a field concentrator according to the invention in conjunction with a representation of a workpiece forming process.

FIG. 3 shows schematically and in section a device similar to the one according to FIG. 2, except that a second field concentrator according to the invention is added.

FIG. 4 shows in perspective and partly in section an expansion coil with a field concentrator according to the invention.

The device illustrated in FIGS. 1 and 1*a* is suitable particularly for deep drawing. It comprises a field concentrator structure composed of individual slitted and mutually insulated ring portions **11** mounted within each other and forming downwardly open slots which supplement each other to a single spiral. Located in the spiral slot is the coil winding **12**. The individual rings are insulated by means of interposed members **13** of insulating material, and the entire group of rings is rigidly held together by an outer ring **14** of steel. The ends of the coil **12** are electrically connected to terminal straps **15** and **15'**. The subdividing slits in the rings of the field concentrator are denoted by **16**. The central opening **17** of the field concentrator and the interior of the device are filled with insulating material **13'**. The terminal strap **15'** is electrically connected with the outer end of the coil **12** through a conducting plate **20'** and through the housing structure **20** of metal.

The rings **11** of the field concentrator consist of a metal alloy having high electrical conductance and high mechanical hardness, for example copper-beryllium. The grooves **18** for receiving the spiral winding **12** are machined into the concentrator rings and the winding turns are insulated relative to the concentrator rings **11**. The insulating material **13** and **13'** may consist of an epoxide resin, for example. The terminal straps **15** and **15'** are insulated from each other by an insulating plate **19** and serve to supply the coil with the above-mentioned current surges from a battery of capacitors (not illustrated). The plate **19** may be integral with the insulation **13'** as shown.

FIG. 2 shows schematically how a pancake coil with a field concentrator according to the invention is employed for forming a metallic workpiece. Denoted by **21** is the field concentrator and by **22** its spiral winding in the slots **23** of the concentrator. The center bore **24** of the field concentrator corresponds to the opening **17** in FIG. 1. The metallic workpiece **25** to be formed consists of sheet metal. Placed against the workpiece is a die consisting, for example, of steel or brass. Shown in the left portion of FIG. 2 is the condition of the workpiece **25** prior to the forming process. Shown at the right is the shape of the same workpiece after performance of the process. The sheet-metal workpiece is thus drawn to the shape of a pan.

FIG. 3 shows schematically a subsequent magnetic forming process to which a workpiece, pre-shaped in accordance with FIG. 2, may be subjected. Employed is a pancake coil with an additional field concentrator. The coil is equipped with a concentrator **31** corresponding to

those denoted by **11** and **21** in FIGS. 1 and 2. The spiral-shaped winding **32** of the coil is located in slots **33** of a field concentrator **31** whose central opening is denoted by **34**. The metallic workpiece **35** is constituted by the pre-formed workpiece resulting from the process described above with reference to FIG. 2. Placed adjacent to the workpiece is a frusto conical die **36** consisting for example of steel or brass. An additional field concentrator **37** is placed between the concentrator **31** and the die **36**. The die **36** has recesses **38**.

In analogy to FIG. 2, the left-hand portion of FIG. 3 shows the condition of the workpiece **35** prior to the forming process, whereas the right-hand portion of the same illustration shows the workpiece upon the performance of the process. The additional field concentrator **37** may consist of copper-beryllium, for example.

The expansion coil with field concentrator shown in FIG. 4 comprises a cylindrical field concentrator structure **31** with internal grooves **42** in which the helical turns **33** of the work coil are located. Denoted by **44** are insulating materials and by **45** the terminal straps for supplying current surges to the work coil. In this case, too, the concentrator is made of a metal alloy having a high electrical conductivity and high mechanical hardness, copper-beryllium alloy being suitable for this purpose. The illustrated slit **46** in the field concentrator may have a width of about 1 mm. The winding **43** in the grooves **42** is insulated relative to the field concentrator. The insulating materials **44** consist of epoxide resin, for example.

The illustrated expansion coil **33** shown in FIG. 4 may consist of 7 to 30 turns of copper wire having a cross section of 3 x 3 to 3 x 5 $mm.^2$. The inductivity of the coil in approximately 1 μH. For performing the process, the coil is supplied with discharge current from a capacitor having a capacitance of 200 μR. and applying to the coil a voltage of 8 kv. for a short interval of time.

A tubular workpiece placed about the cylindrical surface of the illustrated expansion-coil device is thus subjected to the effect of a force resulting from the magnetic field of the coil and the eddy currents induced in the workpiece, and these forces have the effect of widening the tubular workpiece.

It will be understood that the above-mentioned numerical data are given by way of example only, and that they may be modified in accordance with any particular requirements or desiderata.

The advantages of devices according to the invention reside particularly in the fact that by virtue of the use of field concentrators, the flat-type and expansion coils become capable of absorbing a higher amount of forming energy because the field concentrator renders them more stable than self-supporting coils of this type. Furthermore, the spacing between workpiece and working coil in devices according to the invention is reduced to a few tenths of one millimeter, because it is only necessary to provide insulation for step-down transformed voltage. This affords imposing an increased mechanical pressure upon the workpieces.

By virtue of the additional field concentrator placed upon a deep-drawing or pancake coil as exemplified in FIG. 3, the invention permits the application of forming operations subsequent to pre-forming of a workpiece. As a result, two or more forming processes become applicable so that high degrees of deformation and complicated profiles can be imparted to the workpieces.

We claim:

1. Device for deep-drawing metallic workpieces by pulsed magnetic fields comprising a plurality of coaxially disposed rings of relatively good electrically conductive material, said rings being radially slotted and being electrically insulated from one another, a magnetic coil winding disposed beneath said rings and electrically insulated therefrom, said rings having an upper surface corresponding to the geometric shape of a workpiece to be deep-drawn.

2. Device according to claim **1**, wherein said individual rings are formed with grooves in the underside thereof for accommodating said coil winding therein.

References Cited

UNITED STATES PATENTS

3,108,325	10/1963	Harvey et al.	72—56
3,126,937	3/1964	Brower et al.	72—56
3,253,443	5/1966	Malmberg	72—56
3,279,228	10/1966	Brower	72—56

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