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ELECTRICAL DISCHARGE APPARATUS FOR FORMING

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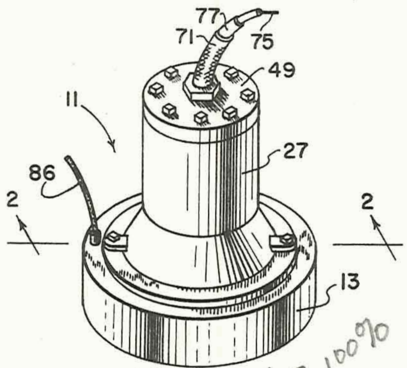

N70-34249 100%

FIG. 1

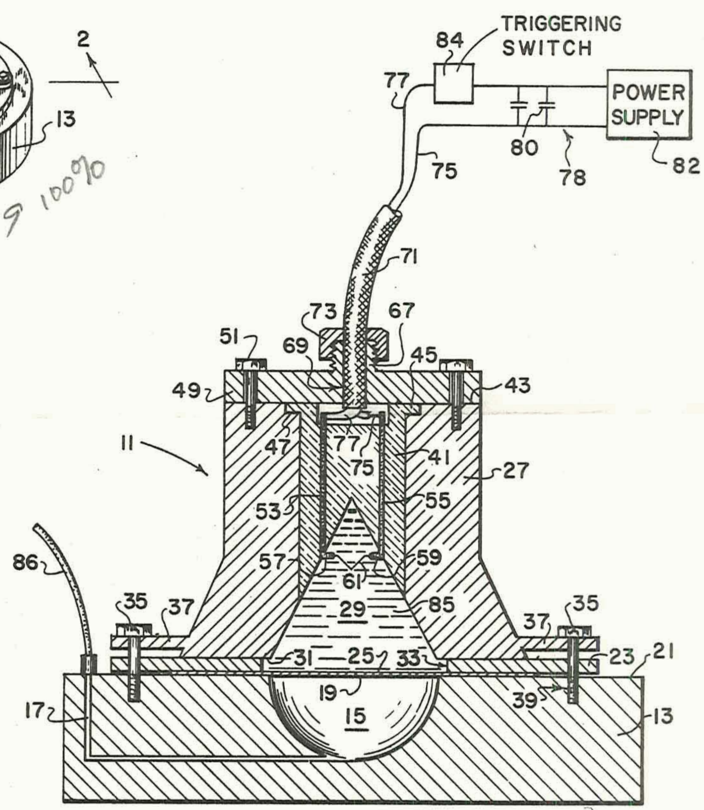

FIG. 2

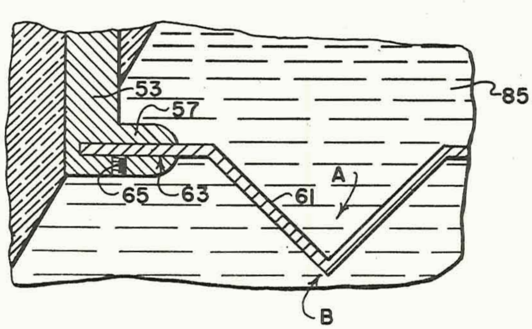

FIG. 3

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ELECTRICAL DISCHARGE APPARATUS FOR FORMING

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The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to high energy rate forming and more particularly to an electrical discharge apparatus for high energy rate forming.

Recent trends in manufacturing for formed metal parts in large sizes and formed metal parts having complex configurations have led to the development of high energy rate forming techniques which provide an instantaneous force for forming which would be impractical by conventional machinery such as the hydraulic forging press and drop hammer. These high energy rate forming techniques generally involve the use of chemical compounds which are exploded under water whereby shock waves are generated and transmitted by the water against a metal blank. Chemical explosives do not, however, provide for rapid and uniform repeatability and are often hazardous to handle and store.

The explosivelike energy release of a rapid discharge of electrostatically stored energy between two electrodes has also been satisfactorily utilized to a limited extent for high energy rate forming. The placing of a high electrical potential of several kilovolts between two electrodes located under water results in a current flow which first vaporizes the water in the vicinity of the electrodes and then causes the vapor to become highly dissociated and ionized. This ionized vapor is a highly conductive path and permits a tremendous electrical current discharge between the two electrodes with a corresponding intense pressure or shock wave that radiates radially from the conductive path and is transmitted by the water. However, a considerable amount of current is necessary before the ionized vapor is formed which means less useful work and somewhat unpredictable results from one electrical discharge to another. Also, the explosive path of the electrical discharge could not be shaped to obtain the versatility of chemical explosive charges which by having a cylinder, cord, or sheet shape could obtain an energy release pattern which would tend to apply a forming force exactly where needed.

Accordingly, it is an object of this invention to provide a highly efficient electrical discharge apparatus which rapidly and repeatedly obtains energy releases in a particular direction.

A further object is to provide an electrical discharge apparatus which will release and control sufficient energy to efficiently form materials.

Other and further objects, uses, and advantages of the present invention will become apparent as the description proceeds.

In accordance with this invention an electrical discharge apparatus is constructed having a blast head with a cone-shaped chamber and a die block in cooperative relationship thereto which has a forming cavity aligned with the chamber. A metal blank which is adapted to be formed separates the chamber from the forming cavity.

Within the chamber and adjacent the apex thereof are two spaced electrodes having a metal wire bridged therebetween which has a V-shaped portion converging away from the apex of the blast chamber. Also, within the blast chamber is a pressure transmitting liquid.

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The two electrodes are electrically connected to a condenser bank through a suitable triggering switch. When the condenser bank is discharged through the electrodes and wire, the wire explodes and generates a shock wave which is transmitted by the liquid toward the blank. The electrical circuit and wire parameters are selected whereby a current pause or "dunkelpause" does not occur.

This will be more readily understood by the following detailed description when taken together with the accompanying drawings, in which:

FIGURE 1 is a perspective view of an apparatus for electrical discharge forming.

FIGURE 2 is an elevation cross-sectional view taken along line 2—2 of FIGURE 1, showing some parts in full, and including an electrical schematic wiring diagram.

FIGURE 3 is a partial elevation cross-sectional view showing the electrode and wire relationship for the apparatus of FIGURE 1.

Referring now to the drawings, there is shown in FIGURES 1 and 2 an apparatus **11** for electrical discharge forming having a die block **13** with a forming cavity **15** and a bore **17** communicating with the cavity **15**. A metal blank **19** rests upon the upper surface **21** of the die block **13** and covers the forming cavity **15**. The blank **19** has a hold-down ring **23** upon its upper surface **25** to frictionally hold it in position. A blast head **27** with an inner cone-shaped chamber **29** converging from an opening in its base surface **31** is situated upon the upper annular surface of the hold-down ring **23**. The forming cavity **15** of the die block **13**, the aperture **33** of the hold-down ring **23**, and the conical chamber **29** of the blast head **27** are in an aligned relationship. As shown best in FIGURE 2, cap screws **35** extend through lugs **37** integral with the blast head **27** and on through the hold-down ring **23** near its outer periphery, and into threaded bores **39** within the die block **13**.

The blast head **27** has a dielectric material portion **41** which forms the region adjacent the apex of the chamber **29** and extends to the upper surface **43** of the blast head **27**. The dielectric material portion **41** has a peripheral flange **45** resting upon an annular shoulder **47** of the blast head **27** to prevent it from slipping down into the chamber **29**. A pressure plate **49** is secured by a series of cap screws **51** to the upper surface **43** of the head **27** to prevent the dielectric material portion **41** from being blown out by an electrical discharge within the chamber **29** as described hereinafter.

Extending through the dielectric material portion **41** are two spaced electrodes **53** and **55** having inner bent portions **57** and **59**, respectively, directed in an opposed manner into the chamber **29** adjacent its apex. A metal wire **61** having a centrally located V-shaped portion is fixed by its opposite ends to the opposed bent portions **57** and **59** of the electrodes **53** and **55**, respectively. This is accomplished as shown in FIGURE 3 by placing each end of the wire **61** into a bore **63** provided within each of the bent portions **57** and **59** and securing it by a set screw **65**. The wire **61** is positioned whereby its V-shaped portion converges in the diverging direction of the chamber **29** and points toward the metal blank **19**.

The pressure plate **49** has a centrally located boss **67** upon its upper surface and an opening **69** which extends through the boss **67** and plate **49**. A coaxial transmission line **71** extends through the opening **69** and is held therein by a collet chuck **73** which fits tightly about the line **71** and is in threaded contact with the boss **67**.

The coaxial transmission line **71** is electrically connected to the electrodes **53** and **55** by attaching its core conductor **75** to electrode **55** and its shield conductor **77** to the other electrode **53**. The electrical conductors **75** and **77** are also attached to a high energy electrical storage bank **78**, which is illustrated in FIGURE 2 as a series of parallel related capacitors **80** having a power supply **82** to charge them to their high electrical potential. A suitable triggering switch **84** is provided in the electrical conductor **77** for discharging at the proper moment the capacitors **80** through the electrodes **53** and **55** and wire **61** whereby the wire **61** will be vaporized with explosive violence.

The chamber **29** is filled with liquid **85**, water for example, for transmitting the shock wave generated by the exploding wire **61** against the metal blank **19** so that it will be formed against the die cavity **15**.

The metal blank **19**, although tightly held between the die block **13** and the hold-down ring **23**, is able to slip slightly when being forced into the forming cavity **15**. This slight slippage prevents the blank **10** from rupturing when undergoing the forming operation.

As the exploding wire **61** within the chamber **29** will form the blank **19** against the cavity **15** faster than the air therein has time to leave through the bore **17**, it is necessary to exhaust the air within the cavity **15** before the wire **61** explodes by attaching a vacuum line **86** to the bore **17**. Otherwise, the air, after being compressed by the blank **19**, would deform the blank.

A directional shock wave is generated by the exploding wire **61** because it is bent into a V-shape. This is believed to be due to the magnetic flux which normally surrounds an electrical current path and which tends to bring itself into a state of equilibrium. When the current path is bent, as would result in using the V-shaped wire **61**, the magnetic flux in the acute angle region of the bent path, region A in FIGURE 3, would have a high density due to its concentration in a region of smaller dimensions, and, correspondingly, the magnetic flux in the obtuse angle region, region B in FIGURE 3, would have a low density due to its spreading out in a region of greater dimensions. Accordingly, a situation occurs in the region of the bent current path which results in a preferential motion of particles of matter away from the high density magnetic flux toward the low density magnetic flux in an effort to bring about a state of equilibrium. It is this preferential motion which is believed to result in the shaped shock wave generated by an electrical discharge through a V-shaped path being directed in the converging direction of that path.

The shock wave generated by exploding the wire **61** has substantially the same V-shape as the wire so that when the shock wave moves outwardly from the vaporized wire **61** its apex strikes against the middle region of the metal blank **19**. This is advantageous because the forming of the middle portion of the metal blank **19** first will result in a more uniform wall thickness to the finished blank **19** and more efficient forming. Otherwise, if the apex of the shock wave front first came against the metal blank **19** adjacent its outer periphery and formed that portion against the cavity **15** and then started forming the middle portion, the blank **19** would have been prevented from slipping properly. Improper slipping of the metal blank **19** may cause a rupture, non-uniform wall thickness, and decrease in efficiency of the forming operation.

In addition, the cone-shaped configuration of the chamber **29** further shapes the explosive pressure or shock wave generated by the exploding of the wire **61**. The conical shape of the chamber **29** represents the minimum volume condition for deforming a metal blank **29**, and with the explosion occurring adjacent the apex of the chamber **29**, the shock wave is driven toward the diverging direction of the chamber **29** without appreciable loss of energy. If, for example, the wire **61** exploded in an unconfined medium, only that portion of the resulting spherical energy distribution which would be useful would be encompassed within the conical volume defined by the metal blank **19** and the wire **61**. The rest of the energy distribution outside of this conical volume would have been lost from performing useful work.

For efficient operation, the parameters of the metal wire **61** and its eleecterical circuit should be selected by known criteria whereby a current pause or "dunkelpause" will not occur and whereby the capacitors **80** are completely discharged approximately instantaneously with the exploding of the wire **61**. It is also preferred if the included angle of the V-shaped portion of the wire **61** has an angle between 50 and 70 degrees and the included cone angle of the chamber **29** has an angle of approximately 55 degrees.

It is apparent that an electrical discharge system utilizing a bent bridge wire has been disclosed which is instrumental in concentrating the explosive force of an electrical discharge and this system has been incorporated into an apparatus which takes full advantage of the directional sense of the electrical discharge by bringing the explosive force generated thereby against a metal blank with high efficiency.

Obviously, many modifications and variations of the present invention are possible in the light of the above teachings. It is, therefore, to be understood that within the scope of the appended claims the invention may be practiced other than as specifically described.

What is claimed is:

1. In combination with a die having a forming cavity adapted to be covered by a restrained blank:

(a) means for directing a shock wave having a substantially V-shaped front toward the center of said forming cavity whereby the point of said shock wave will strike the middle portion of said blank to form said blank from its center outwardly;

(b) said means including:

  (1) a blast head having an inner cone-shaped chamber converging from an opening in the peripheral surface thereof;

  (2) said blast head joining said die with said opening being aligned with said cavity;

  (3) two spaced electrodes supported by said blast head and extending into said chamber adjacent the apex thereof;

  (4) a wire having a V-shaped portion substantially aligned with the center of said cavity and fixed to and extending between said electrodes, and

  (5) said V-shaped portion converging away from said apex of said chamber.

2. In an apparatus for forming metal blanks:

(a) a blast head having a base surface adapted to rest upon the surface of a die block having a forming cavity;

(b) said blast head having an inner cone-shaped chamber converging from an opening in said base surface, said opening adapted to be aligned with the forming cavity of said die block;

(c) two spaced electrodes supported by said blast head and extending into said chamber adjacent the apex thereof;

(d) a wire having a V-shaped portion;

(e) said wire being fixed to and extending between said electrodes and having its V-shaped portion converging in the diverging direction of said chamber and pointing toward the center of the opening in said blast head;

(f) said wire being adapted to vaporize with explosive violence upon the placing of a high electrical potential between said electrodes so as to cause a shock wave having a V-shaped front diverging toward the opening in said blast head and pointing toward the center of the opening in said blast head whereby a metal blank adapted to be placed over the forming cavity of the die block will be formed from its center outwardly;

(g) said cone-shaped chamber of said blast head being adapted to drive the shock wave toward the opening of said blast head without appreciable loss of energy; and

(h) means including a switch for supplying a high electrical potential to said electrodes so as to cause said wire to explode at a desired instant;

(i) said means and said wire having parameters selected whereby a current pause or "dunkelpause" does not occur.

References Cited by the Examiner

FOREIGN PATENTS

119,435 3/58 Russia.

OTHER REFERENCES

"Shape Fasten Engrave Test Materials With Explosives," Materials in Design Engineering, February 1959, pages 82–87.

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