May 3, 1966 J. M. HERRING, JR 3,248,917

HYDROSPARK FORMING APPARATUS

Filed May 15, 1963

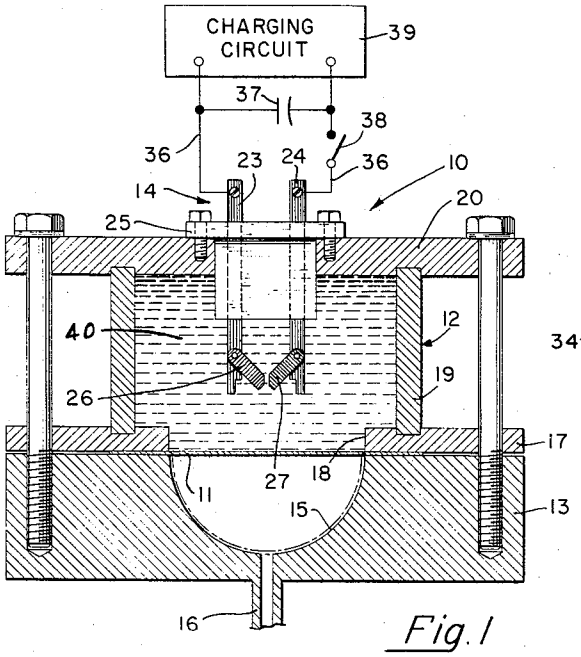

Fig. 1

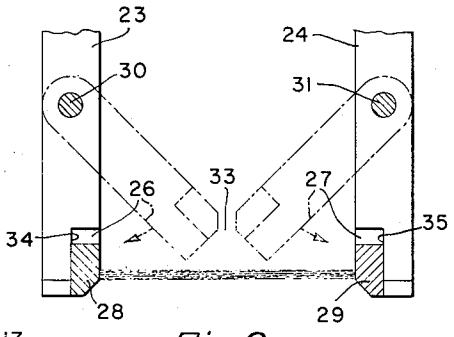

Fig. 2

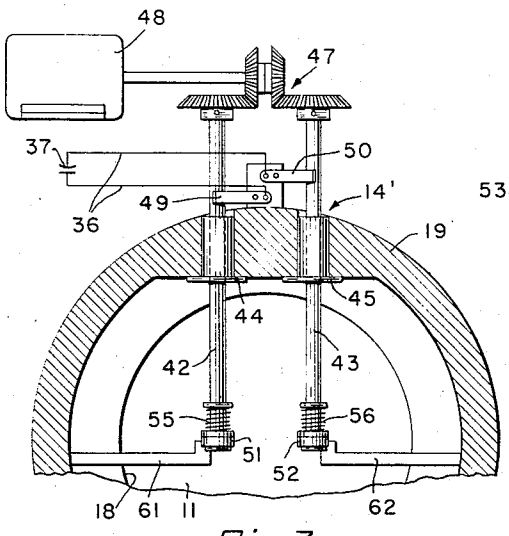

Fig. 3

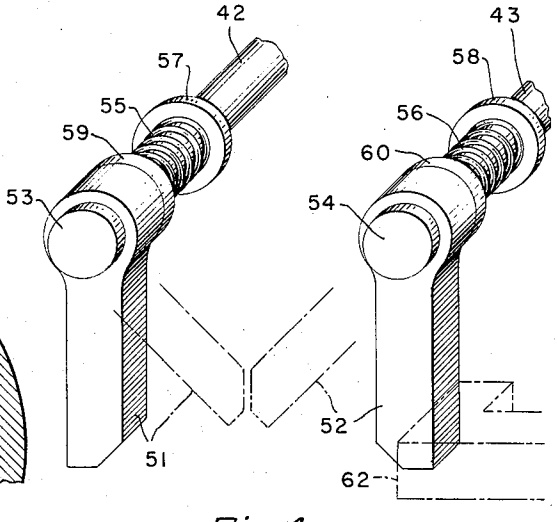

Fig. 4

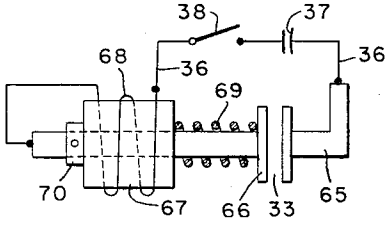

Fig. 5

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HYDROSPARK FORMING APPARATUS

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This invention relates to apparatus for forming metal by the hydrospark forming process and more particularly, to improved electrode arrangements for such apparatus.

As is well known, hydrospark forming involves generating a transient high pressure pulse or shock wave of short duration in a fluid in contact with a metal blank, by creating a high intensity arc through a spark discharge or explosion of wire in the fluid. The electrical energy is first stored in a high voltage capacitor bank which, upon discharging, creates the spark or explodes the wire. For a given available voltage, the exploding wire technique produced a longer arc than does the spark discharge technique but the exploding wire technique is disadvantageous because the wire must be replaced or renewed after each discharge, whereas the spark discharge technique, using fixed electrodes, does not require a similar operation. The longer arc is more desirable because it creates a more favorable impedance match for transfer of electrical energy into the shock wave which forms the metal blank.

Accordingly, one of the objects of the invention is to provide a hydrospark forming device that combines the advantages of the prior art hydrospark forming apparatus of both the spark discharge and exploding wire types.

Another object of the invention is to provide a spark discharge type hydrospark forming device having means for increasing the arc length to provide a more efficient transfer of energy.

Still another object of the invention is to provide hydrospark forming apparatus which eliminates the need for an external switch which initiates the discharge.

Other objects and advantages of the invention would be apparent from the following description taken in connection with the accompanying drawings wherein:

FIG. 1 is a vertical view, partly in section and partly schematic, of hydrospark forming apparatus embodying the invention;

FIG. 2 is an enlarged view, with portions removed, of a detail shown in FIG. 1;

FIG. 3 is a horizontal view, partly in section, looking downwardly in hydrospark forming apparatus embodying a modification;

FIG. 4 is an enlarged perspective view of a detail shown in FIG. 3; and

FIG. 5 is a schematic view of still another embodiment of the invention.

Referring now to the drawing and first to FIGS. 1 and 2, there is illustrated a hydrospark forming apparatus **10** for forming a circular metal blank **11** into a spherical shape, the apparatus comprising a tank **12**, a die **13**, and an electrode assembly **14**. Die **13** comprises a concave spherical die cavity **15** which, immediately prior to forming, underlies blank **11** and defines a space therebetween which is adapted to be connected to a vacuum pump, by a conduit **16**, to reduce the pressure within the chamber or space.

Tank **12** lies above die **13** and blank **11** and includes a lower plate **17** having an aperture **18** aligned with and above cavity **15** whereby blank **11** is held in a position-to-be-formed by the adjacent perimetric portions of the die and plate surrounding cavity **15** and aperture **18**. Tank **12** further includes a tubular cylinder **19** that extends upwardly from plate **17**, and an upper plate **20** covering cylinder **19**.

Electrode assembly **14** is mounted in the center of plate **20** and comprises a pair of vertical, conductive rods **23** and **24** which extend through a support member **25** of insulation material bolted to plate **20**. These rods support, at their lower ends, a pair of movable electrodes **26** and **27** respectively. The upper ends of electrodes **26** and **27** are bifurcated and straddle rods **23** and **24** whereas the lower ends are bridged by bridges **28** and **29** between which a spark jumps in a manner more fully described hereafter. The electrodes are mounted on parallel pivot pins **30** and **31** which extend through rods **23** and **24** and are designed to frictionally hold the electrodes in a position (shown in FIG. 1 and by the dotted lines in FIG. 2) defining a spark gap **33** between the bridges and yet allow swinging movement from this position until the bridges hit stops **34** and **35** on the lower ends of the rods.

The electrodes are electrically connected via leads **36** in series with a high voltage capacitor bank **37** and a normally open single pole switch **38**, and the capacitor bank in turn is connected in series with a conventional charging circuit **39** designed to charge the capacitor bank so that it can be discharged upon closing the switch **38**, and produce a spark across the electrodes.

Tank **12** and blank **11** contain a body of fluid **40**, such as water, that contacts the upper surface of the blank. The electrodes are directly above the exposed upper surface of blank **11** and are arranged, as described above, so that the spark extends parallel to the plate.

Prior to forming the blank, the apparatus is assembled as shown in FIG. 1 wherein electrodes **26** and **27** are positioned to define spark gap **33**. The length of the spark gap is sufficiently small to allow the fluid therein to break down and become ionized under the applied voltage whereby a spark can jump between the electrodes.

After capacitor bank **37** has been charged, switch **38** is closed thereby allowing the potential across the capacitor to be applied to the electrodes creating a spark and discharging the capacitor bank. When the current flows between the electrodes through the spark, pressure forces created by the initiating spark pivot the electrodes so that the bridges **28** and **29** move away from each other. The duration of the spark or arc is relatively short and in the order of many microseconds but it is long enough so that the pivoting of the electrodes increases the length of the arc and thereby raises its impedance and delivers more energy to the load than would be the case if the spark gap were fixed or constant.

Referring now to FIGS. 3 and 4, the embodiment there illustrated is similar to that shown in FIGS. 1 and 2 except for the electrode arrangement. In this embodiment, an electrode assembly **14'** is provided which comprises a pair of parallel, rotatable, conductive rods **42** and **43** that extend through cylinder **19** and are mounted in insulating bushings **44** and **45** therein. The outer ends of rods **42** and **43** are connected to a gear train **47** which, in turn, is connected to a motor **48**. The gear train is arranged so that operation of motor **48** causes rods **42** and **43** to rotate in opposite directions. A pair of brushes **49** and **50** are connected by leads **36** directly across the capacitor bank **37** without the need of a switch and the brushes in turn deliver energy through rods **42** and **43** to electrodes **51** and **52** mounted on the inner ends of the rods.

As best seen in FIG. 4, the upper ends of electrodes **51** and **52** are biased against enlarged heads **53** and **54** of rods **42** and **43** by a pair of compression springs **55** and **56** whose ends bear against a pair of collars **57** and **58** affixed to rods **42** and **43** and a pair of washers **59** and **60** which bear against the electrodes. The stiffness of springs **55** and **56** is relatively light so that the frictional engagement between washers **59** and **60** and electrodes **51** and **52** allows the electrodes to be rotated from the position

shown in full lines in FIG. 4, towards the position shown in phantom lines FIG. 4. In the full line position, the electrodes are spaced far enough apart so that when capacitor bank 37 is charged no spark will jump between the electrodes. Upon operation of motor 48, the electrodes are rotated in opposite direction causing the lower ends to move towards each other and, when they have moved to define a spark gap across which a spark can jump, the capacitor bank discharges and the electrodes rotate in opposite directions to increase the length of the arc.

A pair of stops 61 and 62 extend inwardly from the side walls to cylinder 19 and limit the rotation of the electrodes away from each other. Stops 61 and 62 are equidistant from the electrodes so that each time the motor is operated, the electrodes will meet approximately at their center line.

In this embodiment, the electrodes form the switch for discharging the capacitor. To prevent current leakage during the charging period, the fluid is a dielectric, such as a suitable oil.

Referring now to FIG. 5, there is illustrated schematically an electrode arrangement comprising a fixed electrode 65 and a movable electrode mounted for movement along its axis in a bushing surrounded by a solenoid which is electrically connected in series with electrode 66. The electrode 66 is of a ferromagnetic material. A return spring 69 biases the electrode to a spark gap defining position and a collar 70, on the electrode, limits movement of electrode 66 towards electrode 65.

When switch 38 is closed, after the capacitor bank 37 has been charged, a spark jumps between the electrodes and the resultant pressure forces electrode 66 away from electrode 65, against the bias of spring 69, to lengthen the arc. Since the current also flows through the solenoid 68, electromagnetic forces attract electrode 66 and this action supplements the movements caused by the pressure of the spark. After discharge, spring 69 returns electrode 66 to the spark defining position in readiness for the next firing.

Although the invention has been illustrated for forming a circular blank into a spherical shape, it will be apparent that it is applicable to forming other blanks, such as tubular, cup-shaped, etc. which can be hydrospark formed.

It will be apparent to those skilled in the art that many changes can be made in the details and arrangement of parts without departing from the scope of the invention as defined in the appended claims.

What is claimed is:

1. In hydrospark forming apparatus for forming a metal blank by means of a shock wave generated in a fluid in contact with the blank, the combination of: a pair of electrodes adapted to be submerged in the fluid, means mounting said pair of electrodes for relative movement one with respect to the other, from a first position defining an initial spark gap setting to a second position defining a further spacial relationship of said electrodes, and capacitor means connected to said pair of electrodes and operative to generate a shock wave between the electrodes when in said first position which travels through said fluid to cause the electrodes to be pushed apart to assume said second position and to thereby increase the length of the spark therebetween.

2. Apparatus in accordance with claim 1 and including electromagnetic means operatively associated with at least one electrode of said pair of electrodes for moving the same in response to the flow of current upon discharge of said capacitor means.

3. In hydrospark forming apparatus for forming a metal blank in contact with a fluid by a shockwave created by a spark discharge in the fluid, the combination of: a pair of spaced electrodes adapted to be submerged in the fluid, means mounting said pair of electrodes for relative movement one with respect to the other, from a first position defining an initial spark gap setting to a second position defining a further spacial relationship of said electrodes, drive means operatively connected to said mounting means to rotate said electrodes of said pair toward each other, and capacitor means connected to said pair of electrodes and operative to generate a shock wave between the electrodes when rotated to said first position which travels through said fluid to cause the electrodes to be pushed apart to assume said second position to thereby increase the length of the spark gap therebetween.

4. In apparatus for forming a metal blank by the discharge within a body of fluid in contact with the metal blank of a current pulse creating a shock wave for forming the metal blank, the combination comprising: a pair of electrodes adapted to be submerged in the body of fluid, a pair of spaced apart electrical conductive support means one for each electrode, pivot means mounting each electrode to its respective support means, spring means associated with said pivot means, drive means operatively connected to said support means for rotating the latter so that said pair of electrodes assume an initial spark gap setting, capacitor means electrically connected to said support means and operative to generate a shock wave between the electrodes which travels through said fluid to cause the electrodes to be pushed apart against the reaction of said spring means to assume a second position thereby increasing the length of the spark therebetween, and stop means for limiting the pivotal movement of said electrodes away from each other.

5. In hydrospark forming apparatus for forming a metal blank by means of a shock wave generated in a fluid in contact with the blank, the combination of: means defining a container for said fluid, capacitor means, means for charging said capacitor means, a pair of electrodes mounted within the container, one of said electrodes being fixed against movement, solenoid means mounting the other of said electrodes for relative movement with respect to the fixed one of said electrodes from a first position defining an initial spark gap setting to a second position defining a farther spaced apart relationship, means operatively connecting said capacitor means to said solenoid means for energizing same and to said one and the other of said electrodes, and means for discharging said capacitor means whereby a shock wave is generated between said electrodes when in said first position which travels through said fluid to cause the other of said electrodes to be pushed apart relative to said one electrode to thereby increase the length of the spark therebetween and to be aided in such movement by said solenoid means.

6. Apparatus in accordance with claim 5 and including means disposed between said solenoid means and the other of said electrodes for automatically resetting said other electrode in said first position after discharge of said capacitor means.

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