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EXPLOSIVE FORMING IN LIQUID

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2 Sheets-Sheet 1

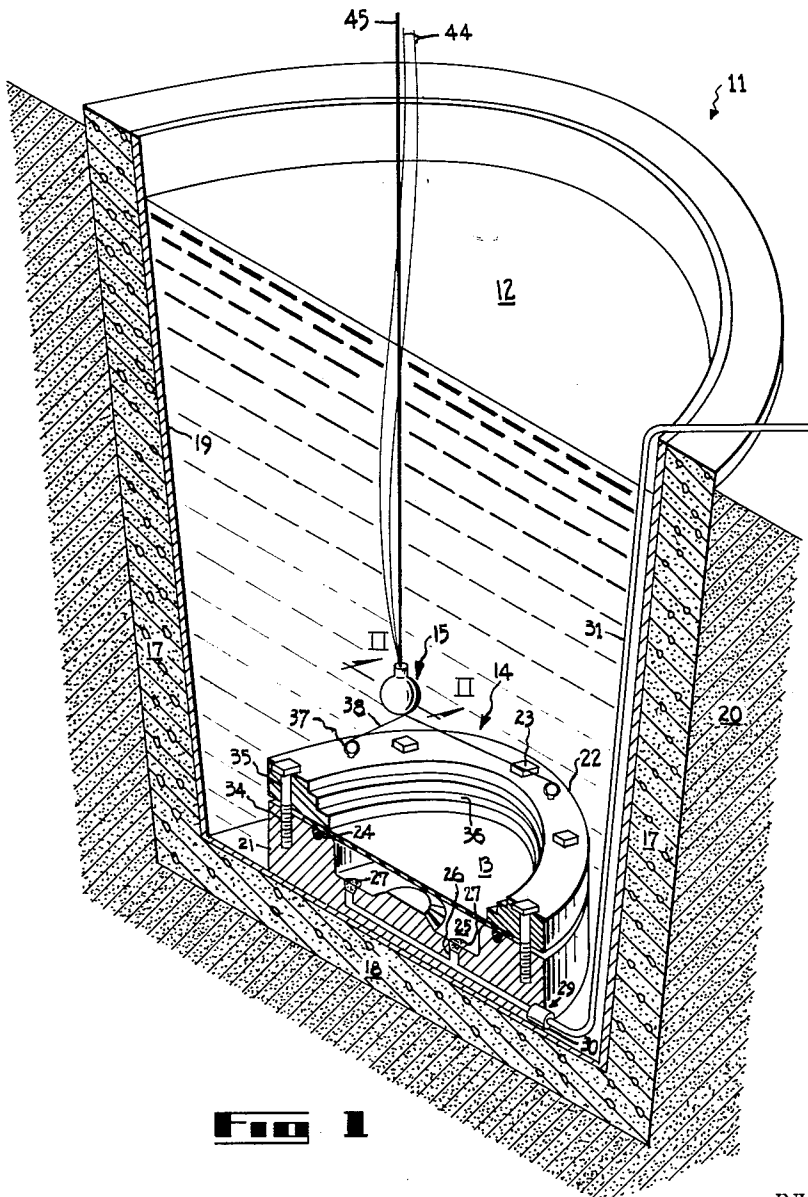


FIG 1

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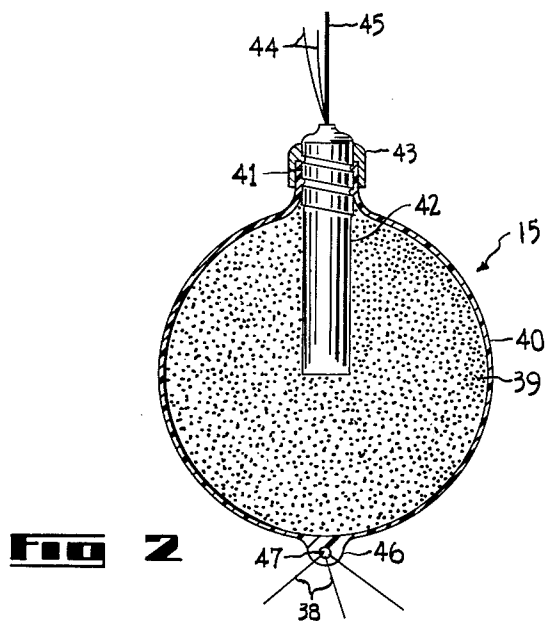
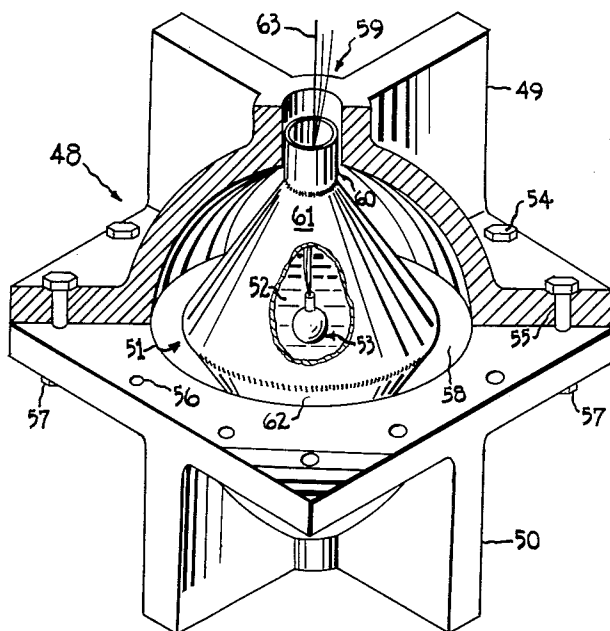
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2 Sheets-Sheet 2



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EXPLOSIVE FORMING IN LIQUID

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The present invention relates generally to an apparatus for the useful deformation of ductile materials and more particularly to an apparatus adapted for the useful shaping of ductile materials through the controlled utilization of the high energy releases derived from an explosive type reaction.

The current trend among manufacturers is toward the use of larger structural components, components having more complex configurations, and components involving heavy gauge materials. There have also been developed new and useful high strength, high temperature resistant metal alloys which are inherently very difficult to form by conventional means. It has, therefore, become necessary to devise new methods for the formation of such materials into desired shapes and configurations. The provision of a related apparatus is the objective of the present invention.

Heretofore methods of forming ductile materials have generally involved the use of large, complex machinery such as the well known hydraulic press, drop hammer, stretch former, etc. Several disadvantages are inherent in such methods. The machinery involved is expensive and a given piece of machinery is usually limited to a single type of operation. In many cases a single forming operation must be divided into a plurality of sequential steps involving several machines. In other cases, in which the formation of large parts or parts involving hard to form gauges or alloys is desired, the forming thereof by conventional means is prohibitively expensive and very difficult, if not altogether impossible.

The present invention comprises an apparatus wherein the energy in a high-release-rate source is liberated within a pressure transmitting medium, thereby generating pressures upon a workpiece, forcing it to conform to a desired shape as defined by a die of predetermined size and configuration.

The nature of an explosive energy release in a liquid medium is such that there are three distinct types of pressures generated, detonation shock, hydrostatic and reverberation. As the explosive charge is initiated, a detonation wave travels from the point of detonation to the surface of the charge. When the detonation wave reaches the surface, it continues into the surrounding medium as a shock wave. The impact energy produced by such a shock wave is generally very intense. In the second phase a gas bubble, formed by detonation of the explosive material, expands and forces the pressure transmitting medium to move in the direction of expansion, thereby generating hydrostatic pressure. The third phase occurs as a result of the over-expansion of the gas bubble. The momentum of the expanding surrounding medium forces the gas bubble to expand to a point where the gas pressure is greatly reduced. Such reduced pressure causes the gas bubble to contract to a point at which the gas pressure is greatly increased. This results in a further expansion of the gas bubble. Such "reverberation" may continue through several cycles and produce successively smaller pressures. In some forming operations it

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is desirable to alter the sequence in which the above events occur. This can be accomplished by varying the type of explosive, the number of charges or the placement of the charge or charges in relation to the workpiece.

It is, therefore, an object of the present invention to provide an apparatus adapted for forming materials, as desired, by utilizing the forces generated by the high explosive release of energy in a liquid or resilient solid medium.

Another object of the invention is the provision of an apparatus for forming metal alloys which are virtually unresponsive to conventional forming practices.

Yet another object resides in the provision of an apparatus for the shape formation of objects of large dimensions.

A further object is to provide an apparatus with which to form materials which will eliminate the necessity for complex forming machinery and an external power source.

A still further object of the invention is the provision of an apparatus for forming materials which is accurate in formation, and simple and economical in construction and operation.

These and other objects and advantages will be apparent to those skilled in the art from the following description of the appended drawings wherein:

Figure 1 is a perspective cross-sectional view of a typical apparatus employed in carrying out the present invention,

Figure 2 is a cross-sectional view, taken along line II—II of Figure 1, of a typical explosive charge used in the invention, and

Figure 3 illustrates an apparatus adapted for the formation of a spherical shaped object.

Referring now to the drawings, in Figure 1 there is shown a typical apparatus employed in the practice of the present invention. This apparatus comprises a mortar 11, a pressure transmitting medium 12, a workpiece 13, a workholding device 14 and an explosive charge or squib 15.

Mortar 11, which is disposed within the ground 20, consists of a reinforced concrete vessel having downwardly directed walls 17 and a horizontal floor 18. Covering the inner surfaces of the vessel is a steel liner 19 which serves to protect the vessel from the detrimental effects of an explosive energy release.

Within mortar 11 and resting on the floor 18 there is positioned a workholding device 14 containing workpiece 13. These are assembled prior to their location within mortar 11. Workholding device 14 comprises a female die 21, an inertia member 22, a plurality of high-strength bolts 23 and a seal ring 24 of rubber or other suitable sealant material.

The female die 21, although similar to conventional forming dies, has several unique features. Because the forming operation is of such short duration (generally no more than a few thousandths of a second), it is necessary to evacuate the air trapped in the die cavity 25 between workpiece 13 and die 21 in order to prevent the formation of air pockets therein which, when compressed, become superheated and may cause undesirable deformation of the workpiece 13. Such evacuation is effected through a plurality of orifices 26 which are fitted with plugs 27 of a suitable porous material. This material, in addition to permitting the passage of air therethrough, also serves to prevent deflection of the workpiece 13 into the orifices 26. These orifices 26 extend downwardly and communicate with passage 28 which exits from die 21 at aperture 29. This aperture 29 is equipped with a fitting 30 which is adapted to receive vacuum line 31. This vacuum line 31 is con-

nected to a vacuum pump (not shown) by means of which evacuation of air in die cavity 25 is effected.

Die 21, since it is submerged in the liquid or pressure transmitting medium 12, must also be provided with means for sealing die cavity 25 from the pressure transmitting medium 12. This is accomplished by fabricating the die with an annular groove 32, which is semi-circular in cross-section, on the uppermost face thereof and within which is disposed seal ring 33. Die 21 is further fabricated with a plurality of threaded holes 34, located at a uniform distance from the center of the die, for the acceptance of bolts 23.

Over the uppermost face of die 21 and upon seal ring 33 there is placed a workpiece 13, which has been lubricated with a film coat of lubricant. This workpiece 13 is of such diameter that its outermost edge extends beyond seal ring 33 and inside the area defined by threaded holes 34, thereby providing a sealing surface and allowing for the insertions of bolts 23.

Upon the upper surface of workpiece 13 is positioned inertia member 22, as shown. This inertia member 22 consists in a steel ring having a plurality of apertures 35, which align with the threaded holes 34 of die 21. Bolts 23 are inserted into apertures 35 and holes 34 and, when tightened, secure workpiece 13 in the desired position. Inertia member 22 is further fabricated with several rows of serrations or steps 36 on its inner surface to prevent undesirable deformation and overformation in a manner to be hereinafter explained.

Upon the upper surface of inertia member 22 are positioned several eyelets 37 to which are attached, by means of tethering wires 38 of appropriate length, the explosive charge or squib 15, an enlarged cross-sectional view of which is shown in Figure 2. This squib comprises an explosive substance 39 such as dynamite, trinitrotoluene, etc. incased within a spherical, frangible, plastic container 40. This container 40 is provided with a tapped aperture 41 into which there is threadably received an externally threaded detonation cap 42. The lower end of cap 42 is positioned at the approximate center of the spherical container, in order to give the desired uniform energy distribution upon the workpiece. After detonation cap 42 has been properly inserted, a sealing compound 43 is applied about opening 41 to effect a watertight seal thereof. From the upper end of detonation cap 42 a pair of electrical conduit wires 44 extend upwardly to a detonation generator (not shown) which, when operated, generates an electrical spark, which in turn ignites detonation cap 42 and thereby detonating the explosive substance 39.

Also attached to the upper end of detonation cap 42 there is another tethering wire 45 which, when pulled taut, definitely affixes, together with tethering wires 38, the distance between the workpiece 13 and squib 15. Diametrically opposite to the opening 41 is a small protuberance 46, having an aperture 47 to which are attached the upper ends of tethering wires 38.

The forming operation is accomplished in the following manner: After the workpiece 13 (Figure 1) has been properly located in workholding device 14 and bolts 23 have been tightened to secure the workpiece in the desired position, the pre-assembled squib 15 is located in the proper relation to the workpiece by adjusting locating wires 38 to the proper length. Vacuum line 31 is then connected to die 21 at fitting 30. Workholding device 14, workpiece 13 and squib 15 are then lowered by suitable means (not shown) into mortar 11 to the position illustrated. Guide wire 45 is next pulled taut, thereby, in conjunction with locating wires 38, definitely affixing the proper distance between squib 15 and workpiece 13, as previously explained. Mortar 11 is then filled to the appropriate depth with the pressure transmitting medium 12, which preferably and in most operations will be water. The vacuum pump is then operated to evacuate the air entrapped in space 25 on assembly.

Upon achievement of a satisfactory vacuum, the detonation generator is actuated, thereby detonating squib 15. When squib 15 is detonated, a shock wave emanates therefrom followed by an expanding gas bubble. As the shock wave contacts workpiece 13, there is an extremely rapid, downward acceleration of that portion of said workpiece 13 above die cavity 25. As this occurs, there is a simultaneous tendency for that portion of workpiece 13 which is confined between die 21 and inertia member 22 to be pulled inwardly in order to compensate for the above mentioned downward acceleration of workpiece 13. The inertia member 22, when properly secured by bolts 23, serves to restrict such inward motion and thereby prevent "overformation" of the workpiece 13. The serrations or steps 36 on the inner surface of inertia member 22 serve to prevent shock wave deflection which might result in an undesirable workpiece deformation, and to provide more effective horizontal area upon which the shock wave will impinge in order to increase the effectiveness of the frictional restricting pressure of inertia member 22 to resist the inward pull of the workpiece.

After the forming operation is accomplished, the workholding device 14 is lifted from mortar 11 and disassembled to remove the formed part. After removal the part is trimmed to size, if necessary, and is then ready for use.

In order to illustrate the latitude of the present invention, Figure 3 shows an apparatus, generally referred to by the numeral 48, utilized to fabricate a spherical shaped container or reservoir. Such apparatus comprises an upper die-half 49, a lower die-half 50, a welded workpiece 51 filled with a liquid pressure transmitting medium 52 (water), and an explosive charge or squib 53 suspended in medium 52. Both die-half 49 and die-half 50 are fabricated with hemispherical concavities such that they may be positioned together and secured in place by means of bolts 54, extending through holes 55 of die-half 49 and holes 56 of die-half 50, and nuts 57. A spherical cavity 58 is thus formed therebetween. The upper die-half 49 has an opening 59 to provide means of introducing pressure medium 52 and squib 53 into the workpiece 51. This workpiece 51 comprises a cylindrical neck 60, an upper, frustoconical portion 61 and a lower, inverted, frustoconical portion 62 all of which are welded together prior to location within die-halves 49 and 50. Squib 53, which is essentially the same as squib 15 (Figure 2) described above, is suspended in the pressure transmitting medium 52 by means of a tethering wire 63.

The workpiece 51 is then positioned within die-halves 49 and 50 and the die-halves 49 and 50 secured together by means of bolts 54 and nuts 57. Workpiece 51 is then filled with water 52, and squib 53 is suspended therein by means of tethering wire 63. The squib 53 is then detonated by an electrical impulse from a detonation generator (not shown). The pressures generated by the explosion of the squib 53 force the workpiece to expand in all directions until it conforms precisely with spherical cavity 58. All air which would otherwise be entrapped within the cavity is allowed to escape through aperture 59 in die-half 49.

As thus described the present invention is characterized as a novel, economical, simple, and advanced method of forming metals and other materials through the proper utilization of forces derived from the detonation of a high release rate energy source in a suitable pressure transmitting medium, these forces being directed against a workpiece which is thus caused to assume the exact shape of a die of the desired configuration.

Many variations are possible within the scope of the present invention. The energy source may be of a solid consistency, a liquid or a gas, and may require a detonator or be self detonating. The pressure transmitting fluid medium may be a liquid, a resilient solid or a granular or powdered solid. The die, which determines the shape or configuration of the formed object, may be fabricated

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of steel, lead, aluminum or virtually any common metal or metal alloy. In some cases where only a small number of similar forming operations are desired, or where the fabricating of the die is especially difficult or expensive, the die may be made of wood, plastic, or even of ice. The workpiece may be of any material having a reasonable degree of malleability.

Although the present method may be used independently, it may also be used to supplement present methods of forming. In some instances it may be found to be more practical to partially form an object by conventional means, and later complete the desired formation by the present method.

While only the preferred embodiments of the present invention have been herein disclosed, it is understood that the invention is not limited thereto, as many variations will be apparent to those skilled in the art; and the invention is to be given its broadest interpretation within the scope of the following claims:

What I claim is:

1. Apparatus for forming a workpiece of ductile material into a desired configuration comprising a container, a pressure transmitting medium in said container, a die of desired configuration within said medium, means for placing said workpiece over said die in leakproof relation to prevent access of said medium therebetween, said means comprising an inertia ring frictionally gripping the edges of said workpiece, said ring having stepped upper surfaces receiving pressure from said medium to additionally grip said edges in greater frictional relationship, an explosive charge positioned within said medium for creating pressures through said medium to deform said workpiece into said die and to apply pressure to said inertia ring surfaces, said explosive charge applying shock wave impingement pressures to said ring upper surfaces to increase the frictional pressure effectiveness

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of said inertia member for resisting inward pull of said workpiece.

2. Apparatus for forming a workpiece of ductile material into a desired configuration comprising a container, a quantity of transmitting medium within said container, means for producing a shock wave in said medium, a die of desired configuration in said medium, said die having sealing means and gripping means for holding said workpiece across the face of said die and preventing leakage of said medium therebetween, means for evacuating air from between the configuration surfaces of said die and said workpiece comprising at least one orifice in said configuration surface, a pump, a passageway extending from said orifice to said pump, and a plug of porous material in said orifice to permit passage of air therethrough while restricting further deformation of said workpiece, said gripping means comprising an inertia ring releasably compressing the edges of said workpiece against said die, said ring having a plurality of stepped upper surfaces to prevent undesirable shock wave deflection and effect multiple refractions of shock waves in said medium to provide a multiple of impingement forces against said ring with each shock produced.

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