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METHOD OF FORMING METAL PLATES WITH EXPLOSIVES

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Fig. 1.

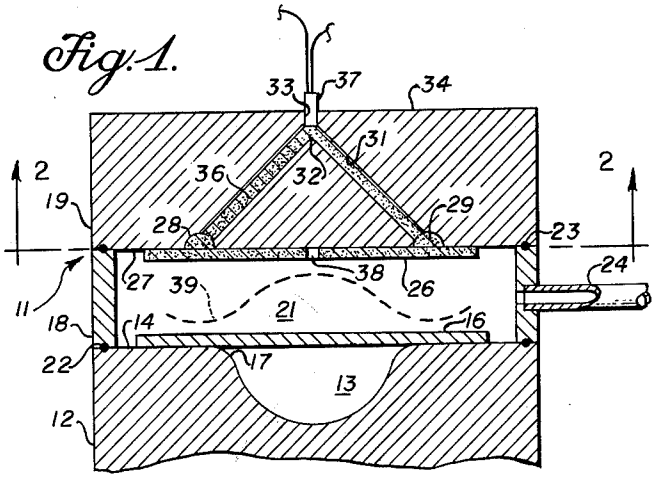


Fig. 2.

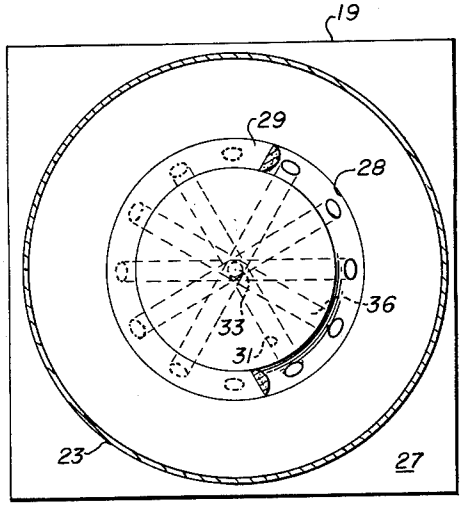
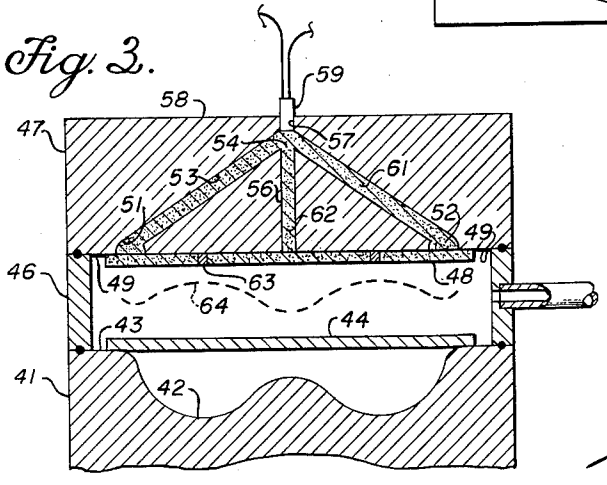


Fig. 3.



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METHOD OF FORMING METAL PLATES WITH EXPLOSIVES

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The present invention relates to a method for forming metal plates and more particularly to a method for forming metal plates by using shaped shock waves from an explosive charge.

The accurate forming of metal plates into contoured surfaces presents a difficult problem when the plates are made of hard metals, e.g., high carbon steels. Conventional dies and presses are wholly useless for this process because they are not able to exert the force needed to deform metals having low ductility and high yield stress characteristics. Conventional metal spinning processes are also incapable of shaping non-ductile metal plates. Until recently, the only satisfactory method for achieving contoured hard metal plates was to machine the desired shape out of a metal block. Machining hard metals, however, is in general a tedious and time consuming process and can produce irregularly contoured surfaces only with much difficulty, time and expense.

The use of explosives has been recently discovered as a method for shaping otherwise unworkable metal plates into various contoured forms. Conventional methods using explosives comprise placing a metal plate over the recess of a female die and thereafter exploding a charge located above the plate. The shock wave from the charge has a sufficient force to deform the metal plate into the die and cause it to take the shape thereof. This procedure is adequate so far as it shapes the plate to conform with the desired mold, but it is unsatisfactory for certain applications in that the resulting shaped plate generally has a non-uniform thickness.

In conventional exposive forming methods a simple spherical shock wave is used for the shaping operation and consequently the metal plate is not drawn equally from all its portions. As a result, the non-uniform elongation of the various plate portions is accordingly characterized by a non-uniform plate thickness. This non-uniform thickness is increasingly predominant for plates of relatively small area while with plates of larger area the non-uniformity becomes less significant.

Now a method has been discovered for shaping hard metal plates while retaining a uniform thickness over the entire formed area. Briefly, the invention is to effect an approximately equal drawing of all portions of the plate. By making the duration of pressure on each portion while being drawn approximately the same on all the portions, the plate is drawn uniformly throughout its total area. This equal distribution of pressure duration is accomplished by shaping the shock wave from the exploded charge to register with the die such that the shock impact is delayed on the portions which must be drawn to a relatively greater depth.

Apparatus for performing this method comprises a female die having a machined recess therein. The hard metal plate to be formed is placed flat over this recess. A flat sheet of explosive charge is centered above the plate and the volume enclosed between the plate and the recess is evacuated. The charge is detonated at preselected portions thereof. The explosition of the charge creates a shock wave which travels towards the metal plate and wherein the shock wave is shaped to make initial contact with the plate at portions thereof positioned over the shallowest recess surfaces. Subsequent impacts against the plate occur at portions thereof positioned over successively deeper surfaces of the recess. The plate is thus drawn in a uniform manner and the resulting shaped plate is consequently of a uniform thickness.

Accordingly, it is a primary object of this invention to provide a method for forming a metal plate.

It is another object of the invention to provide a method for forming a hard metal plate into a contoured shape characterized by a uniform plate thickness over the entire shaped area.

Still another object is to provide an apparatus for accurtely shaping a hard metal plate with explosive charges.

A further object is to provide an apparatus for forming an explosive shock wave of predetermined shape.

A still further object is to provide a method of forming a uniformly thick contoured metal plate by a preselected shaped explosive shock wave.

Other objects and advantages of the invention will become apparent upon consideration of the following description taken in conjunction with the accompanying drawing of which:

FIGURE 1 is a cross-sectional elevation of one apparatus used in a preferred embodiment of the invention for making hemispherical shaped plates;

FIGURE 2 is a view of section 2—2 in FIGURE 1 showing the arrangement of detonating charges; and

FIGURE 3 shows an apparatus and resulting shock wave used to form a metal plate into a convoluted configuration.

There is shown in FIGURE 1 an apparatus 11 which is used in forming a hard metal plate into a hemispherical shell. A block die 12 has a hemispherical recess 13 formed in a surface 14 thereof. Die 12 is made of an epoxy plastic material reinforced with fiberglass. Although the use of a hard tool steel die is possible, the epoxy material is preferable because of its expendability and relative low cost. Repetitive use of the die tends to roughen and deteriorate the surface of the recess thus making periodic replacement necessary. The problem of deterioration is somewhat reduced by lubricating the recess surface, but the number of drawing operations on the die is somewhat limited.

A metal plate 16 which is to be formed into a hemispherical configuration is placed on surface 14 over the recess 13. A rounded edge 17 is formed at the juncture of recess 13 and surface 14 to prevent the plate from being sheared during the forming operation. Resting on surface 14 and concentric with recess 13 is a short tubular cylinder 18. The upper open end of cylinder 18 supports a block 19 and also forms vertical walls enclosing a chamber 21. A vacuum seal 22 is formed between the lower end of cylinder 18 and die 12. Another vacuum seal 23 is situated between the upper end of cylinder 18 and block 19. Chamber 21 and recess 13 are evacuated by a vacuum line 24 which connects through cylinder 18.

A disk of explosive charge 26 is suspended above plate 16 on the under surface 27 of block 19 and disk 26 is centered over the hemispherical recess 13. Referring now also to FIGURE 2, a circular groove 28 is recessed into surface 27 of block 19, groove 28 having a diameter slightly larger than that of die hemisphere 13. The groove 28 is filled with an explosive material 29 so that the material 29 contacts a peripheral region of charge disk 26. A plurality of cylindrical bores 31 communicate from evenly spaced points along groove 28 to common junction 32 situated in the upper portion of block 19, common junction 32 being coincident with an axis passing through the center of explosive disk 26. A bore 33 extends per-

pendicularly downwards from a top surface 34 of block 19 and connects to junction 32. The bores 31 are equal in length and are all filled with an explosive material 36. Bore 33 contains therein an explosive detonator 37. A small hole 38 is made in the center of charge disk 26 to prevent jetting when the implosion of disk 26 reaches the center thereof. Dashed line 39 designates the resulting shock wave front created upon detonation of explosive charge 26.

In operation, the detonator 37 is fired which in turn simultaneously ignites the explosive charges 36 at junction 32. Charges 36 all burn explosively at the same rate thus explosive ring 29 is simultaneously detonated at all juncture points with charges 36. Explosive ring 29 detonates the charge disk 26 around a circle near its periphery and causes the disk to start burning radially inward and outward therefrom. The shock wave 39 caused by the detonation of charge disk 26 has a leading peripheral portion traveling towards the edge of recess 13. Because the center of disk 26 is ignited at a later time than the periphery, the center portion of the shock wave is delayed behind the initial peripheral portion. The resulting shock wave is thus shaped as shown by dashed line 39.

The shaped shock wave 39 makes initial impact against plate 16 near the edge 17 of recess 13. Hence, the drawing or elongation of plate 16 is also initially begun near the edge 17. Subsequent impact against the plate takes place progressively into the center portion thereof. The plate is thus drawn first at the edges and then, in sequence, at portions closer to the center. As a result, the impacting forces on the centermost portions are accordingly delayed and an equal drawing of all portions is effected. The evacuation of recess 13 serves to reduce pressure resistance on the underside of the plate thus contributing to the prevention of non-uniformities in the finished plate.

Recess 13 is most readily evacuated by evacuating chamber 21 which then draws from the recess thereby creating a vacuum in both the chamber and the recess. However, to increase the coupling between the explosive shock wave and the plate the recess can be sealed off from chamber 21 and the chamber then filled with air to atmospheric pressure. Even greater shock wave coupling is effected by filling the chamber with a liquid after the evacuated recess is sealed off from the chamber. When using a shock coupling liquid conventional sealing means are employed between the plate and top surface of the die to preserve the vacuum in the recess.

It should be understood that the present invention is an applicable method and apparatus for shaping metal plates into various contoured configurations other than the above-described hemispherical form. For instance, FIGURE 3 illustrates an apparatus for forming a convoluted plate. There is shown therein a die 41 having a contoured recess 42 in the top surface 43 thereof. Recessed surface 42 is a surface of revolution about a central axis perpendicular to surface 43, and a metal plate 44 is placed on surface 43 over recess 42. A cylinder 46 separates die 41 from a block 47. A disk of explosive charge 48 is suspended above plate 44 on the underside surface 49 of block 47. A circular groove 51 is recessed into surface 49 of block 47 and a ring of explosive charge material 52 is filled into groove 51 to contact charge disk 48. A plurality of cylindrical bores 53 connect to groove 51 and incline inwardly therefrom to a common junction 54. A vertical bore 56 connects junction 54 to the center of disk 48. Another vertical bore 57 extends downward from the top surface 58 of block 47 and a detonator 59 contained therein connects into junction 54. The bores 53 are all filled with an explosive charge material 61 to contact both charge material 52 and detonator 59. Another explosive charge material 62 fills vertical bore 56 to connect junction 54 to the center portion of charge disk 48. A circular ring 63 of non-explosive material separates charge disk 48 into an inner and outer portion. Ring 63 serves to prevent jetting at the juncture where the explosion initiated at the center of disk 48 meets the explosion originating at the periphery of disk 48.

In operation the detonator 59 is fired which in turn ignites the charge materials 52 and 62 at junction 54. Charge material 62 is selected from a proper explosive mixture and burns at a slower rate than material 52 in order that the periphery of charge disk 48 be ignited slightly before the center portion thereof. It should be noted that various compositions of solid explosives are commercially available having varied rates of burning. Hence it is apparent that by properly selecting the bore positions and charge materials a shock wave of virtually any shape can be created. The subsequent explosion of charge disk 48 results in a shaped shock wave front designated by dashed line 64. As defined by the principle of the invention, this shock wave impacts against successive selected portions of plate 44 such that the shallower portions are drawn prior to the deeper portions as discussed in hemispherical drawing, supra.

The procedure and results of an actual experiment are now cited as a specific example of both the method and apparatus of the present invention. The apparatus used is illustrated in FIGURES 1 and 2 and comprised a cubic die one foot on an edge made of fiberglass reinforced epoxy resin. The hemispherical recess therein had a radius of one inch, with the edge thereof rounded in a radius of one-eighth of an inch. A one-eighth inch thick plate four inches square made of type 302 stainless steel was placed over the hemispherical recess. The explosive charge disk was a solid high explosive composition consisting of 60% RDX and 40% TNT bonded together by wax. Such explosive is commonly designated as composition B and was one-eighth of an inch thick and four inches in diameter. The charge material in the cylindrical bores was a high explosive consisting of 92% RDX and 8% isobutylene polymer commonly known as composition C–4. The vacuum chamber and recess were reduced in pressure to five inches of mercury. The initiator was ignited and the explosive charge was detonated. Following the detonation of the explosive disk, the steel plate was removed from the recess of the die and observed to have taken the exact shape of the hemispherical recess. The thickness of the formed hemispherical sheil was observed to have been uniform over its entire area to within an accuracy of five one-thousandths of an inch.

It is of special note that the operation of the present invention depends upon the deformation of a flat metal plate by a shaped explosive shock wave, wherein the shock wave is best described as being a proportionately inverted image of the die recess configuration into which the plate is to be pressed. The shock wave need not be a mirror image of the die recess but it should be curved approximately in proportion to the die configuration and inverted thereto.

It is to be observed that many possible shaped plate configurations can be formed by the present invention. The invention is readily applicable for creating shaped plates in the form of parabolas, cones, hyperbolas, etc., and an unlimited number of variations thereof. The detailed description given herein is by way of description and illustration only and is not to be taken by way of limitation, the spirit and scope of this invention being limited only by the terms of the appended claims.

What is claimed is:

1. In a method for shaping a flat metal plate into a contoured surface using explosive shock waves, the steps comprising placing said metal plate over a contoured recess of a female die, shaping an explosive shock wave in a configuration essentially inverted to the configuration of said contoured recess, disposing said shock waves to travel towards said recess in a mirror relation thereto, and impacting said shock waves against said metal plate.

2. In a method for shaping a flat metal plate into a contoured surface using explosive shock waves, the steps

comprising placing said plate over a contoured recess of a female die, evacuating the volume defined by said recess and said plate, shaping an explosive shock wave in a configuration essentially inverted to the configuration of said contoured recess, disposing said shock wave to travel towards said recess in mirror relation thereto, and impacting said shock waves against said metal plate.

3. In a method for forming a flat metal plate into a contoured surface using explosive shock waves, the steps comprising placing said plate over a contoured recess of a female die, evacuating the volume defined by said recess and said plate, shaping an explosive shock wave in a configuration essentially inverted to the configuration of said contoured recess, disposing said shock wave to travel towards said recess in mirror relation thereto, impacting said shock waves against said metal plate, forcing said plate against said recess, and removing the shaped plate from said recess.

4. In a method for forming a flat metal plate into a contoured surface using explosive shock waves, the steps comprising placing said plate over a contoured recess of a female die, evacuating the volume defined by said recess and said plate, shaping an explosive shock wave in a configuration essentially inverted to the configuration of said contoured recess, disposing said shock wave to travel through a liquid coupling fluid towards said recess in a mirror relation thereto, impacting said shock waves against said metal plate, forcing said plate against said recess, and removing the shaped plate from said recess.

5. In a method for shaping a flat metal plate into a contoured surface using explosive shock waves, the steps comprising placing said plate over a contoured recessed surface of a female die having relatively shallower and deeper portions, impacting against said plate a shock wave shaped to apply initial forces on portions of said plate disposed over the relatively shallowest portions of said recess and to apply successive forces on portions of said plate disposed over successively deeper portions of said recess, forcing said plate into the form of said recessed surface by said shock wave, and removing the formed plate from said recess.

6. In a method for shaping a flat metal plate into a contoured surface using explosive shock waves, the steps comprising placing said plate over a contoured recessed surface of a female die having relatively shallower and deeper portions, evacuating the volume defined by said plate and said recess, disposing a shock coupling fluid adjacent to the exposed side of said plate, impacting an initial explosive shock force against said plate on portions thereof disposed over the relatively shallowest portions of said recess, impacting successive subsequent shock forces against portions of said plate disposed over successively deeper portions of said recess, forcing said plate into the form of said recessed surface by said shock forces, and removing the formed plate from said recess.

7. In a method for shaping a flat metal plate into a contoured surface using explosive shock waves, the steps comprising placing said plate over a contoured recessed surface of a female die having relatively shallower and deeper portions, evacuating the volume defined by said plate and said recess, disposing a sheet of explosive charge above said plate parallel thereto and spaced apart therefrom, disposing a shock coupling fluid between said plate and said explosive sheet, detonating said sheet at portions thereof in opposition to the relatively shallowest portions of said recessed surface, shaping an explosive shock wave by said detonation in a configuration essentially inverted to the configuration of said contoured recess, conducting said shock wave through said coupling fluid towards said recess in a mirror relation thereto, impacting the leading portions of said shock wave against said plate at portions thereof disposed over the relatively shallowest portions of said recess, impacting successive subsequent forces from said shock wave against portions of said plate disposed over successively deeper portions of said recess, forcing said plate into the form of said recess by said shock wave, and removing the formed plate from said recess.

8. In a method utilizing explosive shock waves for shaping a flat metal plate into a hemispherical surface, the steps comprising placing said plate over a hemispherical recessed surface in a female die, shaping an explosive shock wave into an essentially hemispherical configuration, evacuating the volume defined by said recess and said plate, disposing said shock wave to travel towards said recess in a mirror relation thereto, impacting said shock wave against said metal plate, forcing said plate against said recessed surface, and removing the formed plate from said recess.

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