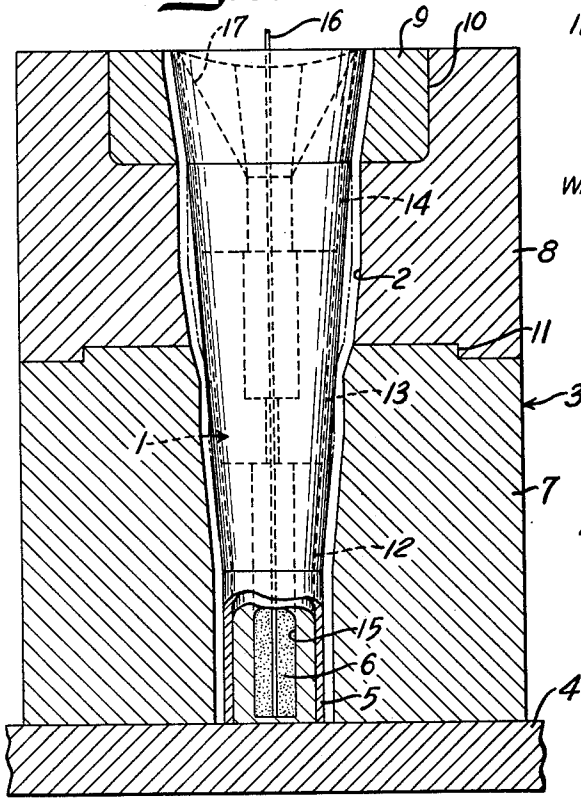
May 5, 1964 N. B. GRANBERG 3,131,661

EXPLOSIVE FORMING OF ARTICLES

Filed April 20, 1960

Fig. 1.



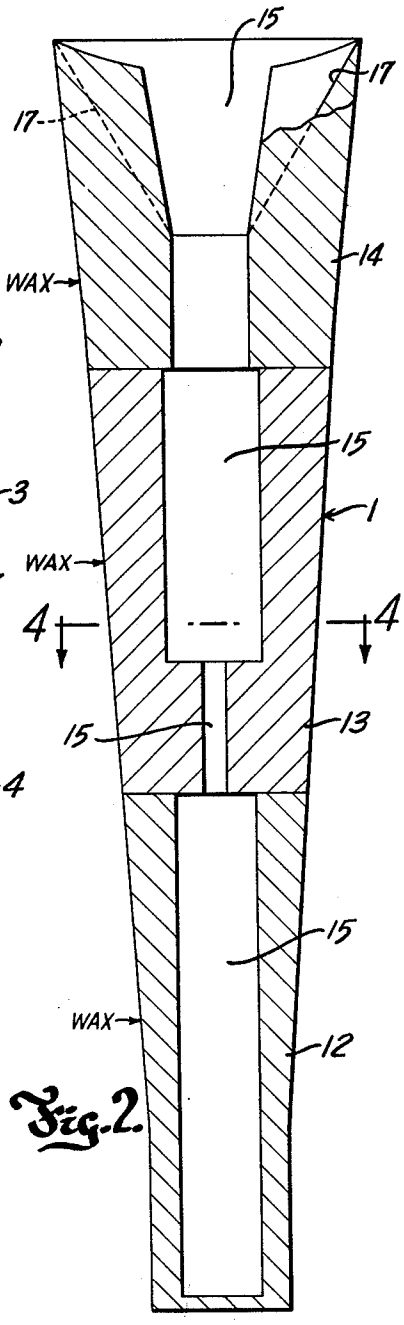


Fig. 2.

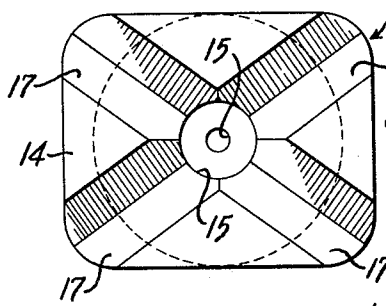


Fig. 3.

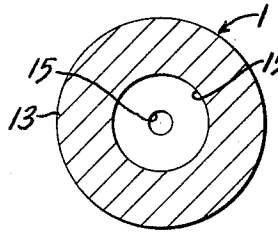


Fig. 4.

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EXPLOSIVE FORMING OF ARTICLES

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This invention is directed to a method of explosive forming of articles and to a pre-formed member for distributing an explosive charge adjacent a blank to be formed. The pre-formed member also serves as an effective media for transmitting the shock waves from the explosive charge to the blank, causing the blank to be expanded to the contour of a forming die.

Explosive forming is a relatively new method of metal forming. It utilizes a controlled energy explosion to shape metal articles to contours determined by a stationary external die disposed in close proximity to a metal blank. The metal blank is disposed between the explosive charge and the stationary die and the impact waves generated by an ignited explosive charge force the metal blank outwardly against the wall of the stationary die.

Explosive forming is particularly adapted to the forming of contoured tubular metal articles, such as wheel spindles, since the impact waves are generated in all directions equally, and the expanded articles will take the shape of the surrounding stationary die to a surprising degree of precision. Since the blank takes the contour of the die so accurately in the explosive forming process only, a minimum of external machining is required as compared to more conventional cold forming processes. Not only is it difficult to fabricate the contoured tubular article by means of a conventional cold forming process, but the speed of the explosive forming operation cannot be duplicated by conventional devices.

Prior methods of explosive forming have employed pre-shaped solid explosive charges to distribute the intensity of the impact forming wave inside the tubular blank. Such a pre-shaped charge is designed to place more explosive charge in the portion of the blank requiring more forming such as the movement of the metal, the thinning of the metal and the like.

In the usual method, the pre-shaped charge, the blank and the die are immersed in water. The charge is disposed centrally in the tubular blank, and the surrounding water provides the media for transferring the impact wave to the blank, forcing it out against the contoured stationary die.

The use of water for an impact wave transmitting media presents several problems. The explosive charges must be predesigned and formed in advance for a specific forming job. The pre-shaped charges must be available in a sufficient quantity to permit an efficient production rate.

To keep the pre-shaped explosive charges for mass production stored creates a serious safe storage problem particularly in densely populated areas. Special governmental regulations and the like presently govern the storage of such explosives in urban areas, thereby greatly limiting the geographical locations where the process can be practically and economically employed in production.

The present invention provides a solution to the above problems by the use of a solid pre-formed member of

wax or a similar material. The pre-formed member includes a cavity contoured to receive and distribute an explosive charge or a mixture of explosive components which can be selected to be explosive only in the combined or mixed state. The pre-formed member is mounted with the metal blank in the die, and automatically positions and shapes the explosive charge in correct relationship to the blank to establish the desired forming of the blank.

The pre-formed member of wax or the like also provides an excellent medium for transmitting the explosive energy to the metal blank, thereby causing it to expand into intimate contact with the surrounding stationary die.

Since component materials for the explosive charge can be selected which are not dangerous until mixed together, the component materials may be safely stored separately until just prior to the forming operation, even in urban areas. This feature greatly increases the possible number of geographic locations where this explosive forming method can be economically and practically employed, since the problem of safe storage of explosives is eliminated.

The drawing illustrates the best mode of carrying out the invention as presently contemplated and set forth below.

In the drawing:

FIG. 1 is a side elevational view, partly in section, of a die assembly and molded form for explosive forming in accordance with the present invention;

FIG. 2 is a longitudinal section through the molded form of FIG. 1;

FIG. 3 is a top view of FIG. 2; and

FIG. 4 is a section taken on line 4—4 of FIG. 1.

Referring particularly to FIG. 1, the illustrated embodiment of the invention generally includes a molded form 1 disposed within a contour forming cavity 2 in a die 3. The cavity 2 extends completely through die 3 and is closed at the lower end by a supporting table 4 or the like upon which die 3 rests. The molded form 1 is spaced from the wall of cavity 2 and a tubular blank 5 is disposed between the wall and the form 1. An explosive charge 6 is centrally disposed within an opening or recess in form 1 and upon ignition establishes shock or impact waves forcing blank 5 to the contour of the adjacent wall of cavity 2.

In the illustrated embodiment of the invention, blank 5 is, prior to forming, generally a tubular frusto-conical member of metal or the like. The present invention is particularly adapted to forming of low carbon steel members because of an apparent cold working of the steel. After forming, blank 5 is contoured with a non-uniformly expanded diameter in accordance with the configuration of cavity 2 in die 3.

The die 3 comprises three stacked die sections 7, 8 and 9 to permit ready and simple forming of the cavity 2 in accordance with the shape of the article to be formed. The illustrated sections 7, 8 and 9 are held together by press fitting the upper section 9 and the lower section 7 upon corresponding telescoping portions on section 8, as at 10 and 11.

As shown in FIGURE 1, the lowermost section 7 of die 3 includes a generally increasing diameter terminating in an upper relatively constant diameter portion. The second section 8 increases somewhat more rapidly and

the final or uppermost section 9 again provides a relatively constant increasing diameter.

The illustrated final shape of the tubular blank 5 is adapted to a three section die comprising sections 7, 8 and 9. In some instances, a split die is essential to facilitate removal of the formed article.

In the illustrated embodiment of the invention, the molded form 1 similarly comprises three stacked sections 12, 13 and 14 corresponding in axial dimension to die sections 7, 8 and 9 defining a frusto-conical form generally corresponding to the inner configuration of the unformed blank 5. Each section 12–14 is provided with a central passage defining an opening 15 for receiving the charge 6 and a charge detonating line or cord 16. The opening 15 has an integral closed lower end in section 12 to retain the charge 6. The diameter of the opening 15 in each form section 12–14 is selected generally in accordance with the desired thinning of the metal in blank 5, the radial movement of the blank 5 from the initial unformed state to the final state engaging the wall of cavity 2, as shown in dotted lines in FIG. 1. Thus, in section 12, opening 15 is of a constant diameter because the movement of metal is constant. In section 13, a somewhat larger diameter opening 15 is provided in the upper portion and a relatively minute diameter opening maintains communication with the portion of opening 15 in section 12. The minute diameter opening in section 13 is adjacent an area wherein the unformed blank and the contoured blank are essentially the same. The minute opening permits extension of the detonating cord 16 downwardly through the opening for igniting of charge 6 within section 12 of form 1. The uppermost section 14 includes a constant diameter opening adjacent section 13 and a flared upper opening including V-shaped grooves 17 in each corner of section 14. The grooves 17 are employed to increase the charge 6 within section 14.

A greater amount of charge 6 is needed in proportion to the amount of explosive expansion required at a given point on a tubular blank 5, which is indicated by dotted lines in FIG. 1. The varying diameter of opening 15 is generally in accordance with the amount of expansion of blank 5 in changing from the original conical configuration to the final contoured configuration.

Molded form 1 is formed of suitable material providing a shock-transmitting media from charge 6 to blank 5. The form 1 may be formed of styro-foam, plastic resins, epoxies, ceramics, cotton, synthetic and natural rubbers, fiber glass, ice, packed snow, or any other material capable of being pre-formed and providing the necessary transmission of the explosive energy to the blank 5. The most suitable substance appears to be paraffin wax which readily melts at temperatures above the ambient temperature in which the operation is performed and which solidifies easily at lower temperatures. Form 1 can then be easily preformed by a simple molding process. The wax is relatively non-compressible and consequently is also very effective in transmitting the explosive energy to the blank.

A plurality of forms 1 can then be pre-formed and stored for subsequent use. The charge 6 is separately stored for insertion into opening 15 at the time blank 5 is to be formed. Consequently, an inventory of preformed explosive charges is not necessary for mass production processes.

Explosive charge 6 is any suitable explosive medium, either liquid or solid, adapted to establish shock waves suitable for forming of blank 5. Explosive materials, such as a mixture of ammonium nitrate and seven percent by weight of number two fuel oil, are highly satisfactory for the present invention because of the low cost and effective forces established.

If the operation is to be performed in an urban area, the preferred components for the explosive charge 6 are materials which are inactive when stored separately, but which can be detonated when mixed. Relatively large quantities of these materials may then be stored safely in populated areas and mixed only as needed in carefully controlled operation to essentially eliminate the problem of dangerous, spontaneous explosions. Fuel oil and ammonium nitrate, previously noted as a suitable explosive mixture, are inactive prior to mixing and are therefore well suited for use in the present invention.

In the illustrated embodiment of the invention, charge 6 is electrically ignited by energizing of cord 16. The detonator cord 16 is coaxially disposed in the opening 15 and embedded or immersed within the charge 6. Cord 16 is connected to a suitable source of electrical power and detonator cap, not shown, to permit selective energization of the charge 6.

In a forming operation, the tubular blank 5 is placed in the opening in die 3. The lower section of die 3 rests on table 4. The form 1 is placed inside the tubular blank 5. The detonating cord 6 is then centrally disposed in opening 15 of the form 1 and the opening is filled with the explosive charge 6. Power is supplied to cord 16 and ignites the explosive charge 6 which burns rapidly in accordance with a normal explosion process, forming high pressure impact waves of a velocity faster than the speed of sound.

The pressure impact waves expand against the molded form 1, which transmits the instantaneous force of the impact waves to the tubular blank 5, forcing it out against the contoured die 3. The tubular blank 5 is thereby formed to the contour of the cavity 2 with highly accurate external dimensions. By pre-forming of a plurality of forms 1, tubular blank 5 can be successively contoured in a mass production operation.

A distinct advantage of this invention is therefore that the pre-molded form 1 provides an automatic charge shaping means and an excellent explosive shock wave transmittal media in the actual forming operation. The explosive charge 6 can be any suitable medium including an inexpensive mixture of fuel oil and a nitrate. In most instances, recovery of the paraffin wax is relatively simple, and it may be melted and then remolded into new forms for reuse.

Although explosive forming by the method of the present invention is particularly adapted to forming tubular metal articles, the invention is also applicable to contouring other members such as metal sheets or the like into disced or other configurations.

The present invention thus provides a method of charge shaping in explosive forming which is particularly adapted to mass production of contoured blanks in a safe and inexpensive operation.

Various modes of carrying out the invention are contemplated as being within the scope of the following claims particularly pointing out and distinctly claiming the subject matter which is regarded as the invention.

I claim:

1. In the method of explosive forming an article having an irregular contour by igniting an explosive charge within an irregularly shaped confining cavity to force a blank into engagement with the wall of the cavity, providing an impact wave transmitting member with an inner charge receiving chamber of non-uniform cross section arranged to irregularly shape the charge and distribute the intensity of the impact forming wave within the cavity, mounting the wave transmitting member within the cavity with the blank between the member and the cavity, filling the irregularly shaped charge chamber with a mixture of substances which are only explosive when combined to provide an irregularly shaped charge having its greatest density adjacent those portions of the blank where the greatest forming force is required, and igniting the charge disposed within the chamber.

2. An article for use in explosive forming wherein a blank is forced into engagement with a spaced wall of a female die by ignition of a charge to contour the blank, comprising a self-supporting form including an impact wave transmitting medium, said form having an irregu-

larly contoured charge shaping cavity therein, the diameter of said cavity being directly proportional to the distance of the wall of said female die from the outer surface of the blank at any given transverse plane to most effectively distribute the impact forming wave intensity within the form incident ignition of the charge.

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