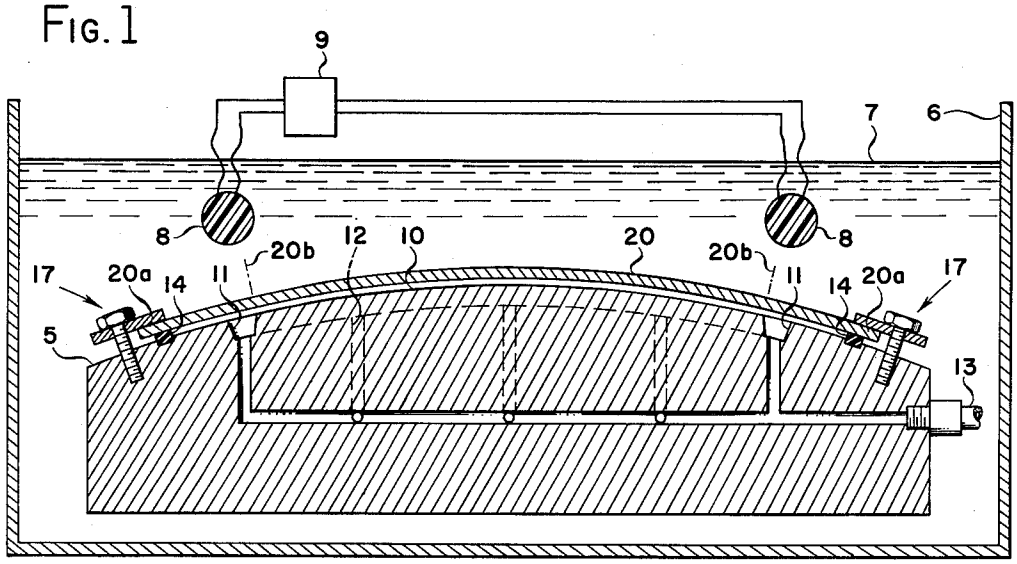
March 8, 1966 V. BENATAR ETAL 3,238,753

STRETCH FORMING APPARATUS AND METHOD

Filed Nov. 5, 1962

FIG. 1



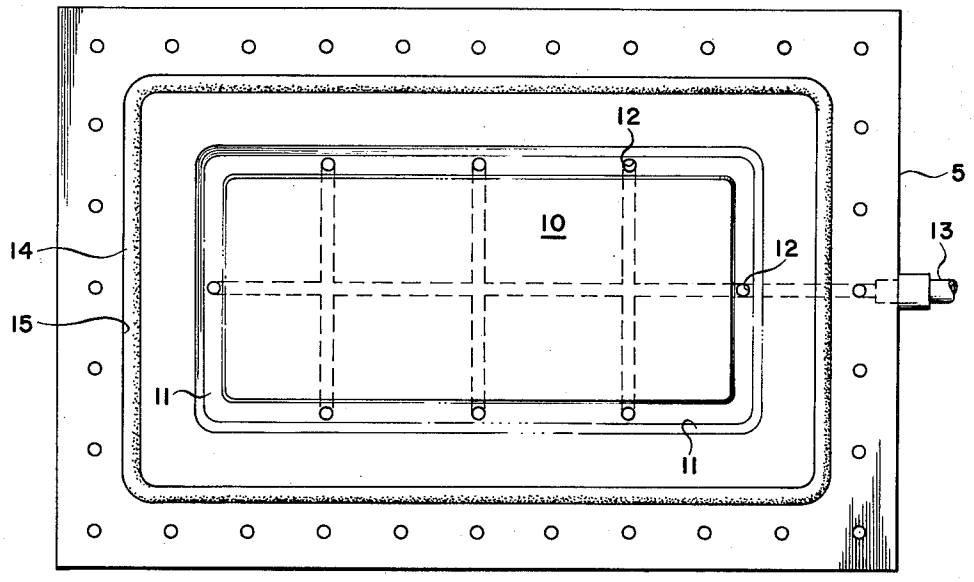


FIG. 2

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STRETCH FORMING APPARATUS AND METHOD

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5 Claims. (Cl. 72—56)

This invention relates to the forming of sheet and/or plate metals, and more particularly to a method and apparatus for the high energy stretch forming of metal parts from sheet and/or plate forms.

In recent years the aerospace industry has seriously sought to develop new economic methods and apparatus for the forming of parts from sheet and plate metals. Mechanical devices such as the hydropress and stretch form have been used in the past and are still being used for many forming operations. However, it has been found to be uneconomical to use such mechanical devices in the forming of high strength metals such as AISI type 302 stainless steel, for example, because of the inability of such devices to generate work forces sufficiently great to form the metal without resort to massive and costly new presses to do the job. Such mechanical devices have further limitations as to the physical size of the work pieces they can form and it is not economical to use them unless on a mass-production scale.

To eliminate the disadvantages and limitations of such prior art mechanical devices, extensive work has been done in developing explosive forming techniques for forming metal work pieces. Toward that end, methods and apparatus have been developed for the explosive forming of metal work pieces which have met with considerable success. One limitation of such explosive forming devices, however, is that they are not well-suited for the forming of shallow contoured parts to close tolerance; and the forming of shallow contoured parts by such devices has resulted in a substantial number of rejected parts. In experimenting and working with explosive forming of shallow contoured parts, it was determined that the inability to form parts to close tolerance was caused by "spring back" of the part after instantaneously taking the configuration of the die and that "spring back" was caused by a failure of prior art die structures to provide a space or area to permit the elongation of the work pieces in their plastic range so that they would set into the contour of the die, the shallow contoured die in effect backing the work piece so as to prevent such elongation of the work piece. It was further found that the use of presently known high velocity explosive forming techniques in combination with evacuation of the space between the work piece and the die, although effective in reducing spring back did not eliminate it from consideration in the forming of shallow contoured parts to close tolerance. Accordingly, this invention is directed at improving upon explosive forming techniques and the extension of their use to the forming of parts of shallow contour to close tolerance. Toward this end there is provided method and apparatus for explosive stretch forming and setting a work piece into the configuration of a shallow contoured die with closer tolerance than heretofore obtainable, this objective being achieved by the provision of die structure which permits the elongation of the work piece throughout its area in its plastic range so that it will be formed or set to the configuration of the die.

Accordingly, it is an object of this invention to provide an apparatus and method for forming metal work pieces into shallow contoured parts without large and heavy forming device installations.

Another object of this invention is to provide a method and apparatus for the explosive stretch forming of large integral shallow contoured parts to close tolerance.

It is a further object of this invention to provide an apparatus and method for forming metal work pieces into shallow contoured parts with close tolerances without concern to spring back.

A still further object of this invention is to provide an apparatus and method for the high energy stretch forming of a work piece to the configuration of a shallow contoured die.

Other objects and advantages will become apparent from the following description taken in connection with the accompanying drawings in which:

FIGURE 1 is a sectional side view of one embodiment of the high energy stretch forming apparatus of this invention immersed in an energy transfer medium; and

FIGURE 2 is a top plan view of the explosive forming die of FIGURE 1.

Generally stated, the invention is practiced by forming a metal work piece through utilization of the dynamic forces of pressure waves generated by the detonation of an energy source or explosive medium such as high explosives, chemical reaction, etc., and directing the pressure waves through an energy transfer medium against the work piece in such a manner as to form it to the configuration of a shallow, simple or compound, contoured male form die. In accordance with this invention, the shallow contoured die is constructed so as to permit the stretching or elongation of the metal being formed throughout its area in the plastic range so that it will set to the configuration of the die. Toward this end, a shallow contoured male form die is provided with a peripheral stretch groove and the work piece is elongated or stretched into the stretch groove such that the work piece is elongated sufficient that its plastic range is achieved and the work piece is drawn and stretched into the configuration of the die. Either low or high velocity forming techniques may be employed; however, high velocity forming is preferred because of the advantages attendant its use.

Referring now to the drawings, there is shown in FIGURE 1 a shallow contour male form die **5** which has been depicted as being of simple contour, mounted in a container **6**, and covered with the energy transfer medium **7**, preferably water. The male form die **5** has an upper forming surface **10** of shallow contour in which is formed a preferably continuous peripheral stretch groove **11**. The stretch groove **11** is connected by a plurality of openings **12** which are connected by line **13** to a vacuum system, not shown. Disposed in concentric surrounding relation to the groove **11** there is provided an annular seal **14** fitted into a groove **15** to hold it in place, and disposed outside the seal **14** are a plurality of clamping assemblies **17** which clamp the work piece **20** into sealing engagement with the seal **14** and prevent movement of the work piece outer edge during the forming operation. Also, at least one or more energy sources, explosive medium or charges **8** are disposed in the energy transfer medium **7** above the work piece **20** in the vicinity of stretch groove **11** such that the pressure waves formed by their detonation will be equally distributed over the area of the work piece covering the stretch groove **11**.

In operation, a metal work piece or part **20** is placed on the upper forming surface **10** of the male form die **5** and is clamped in place with its peripheral edge **20***a* firmly fixedly clamped into sealing engagement with the seal **14** by the clamp assemblies **17**. The die assembly **5** is then placed in the container **6** within the energy transfer medium **7**; explosive medium or charges **8** are placed above the work piece **20** in the vicinity of the stretch

groove; and the air entrapped in the passage **12**, the groove **11** and between the work piece **20** and the surface **10** is evacuated by the vacuum system such that the entrapped air will not cushion the explosive force and prevent forming of the work piece into the shallow contour of the forming surface **10**. After the air has been evacuated from between the work piece **20** and the die **5**, the explosive medium **8** are detonated and upon detonation generate pressure waves which are transmitted through the energy transfer medium **7** at least over the area of the work piece **20** covering the stretch groove **11** such that the work piece **20** covering the stretch groove **11** is stretched and elongated in its plastic range into the stretch groove **11** and in so doing draws, stretches or elongates the remaining portion of the work piece **20** in its plastic range into the shallow contour of the top surface **10** of the die so that the work piece **20** will retain the configuration of the top forming surface **10**.

It is important to take particular note at this point that for the work piece **20** to retain the shallow contour of the die forming surface **10**, it must be elongated or stretched such that it undergoes plastic deformation throughout its area extent circumscribed by the stretch groove **11**, which may properly be called the network piece or part, without exceeding the ultimate strength of the metal work piece and that the die structure comprising stretch groove **11** provides a sufficient area whereby this elongation or stretching of the net part may occur.

After forming and setting the work piece **20** into the shallow contour of the top surface **10** of the die, the die **5** is removed from the energy transfer medium **7** or the energy transfer medium **7** is removed from surrounding relation to the die **5**, as would be preferable if a large die were used, and the work piece **20** is removed from the die. Thereupon the work piece **20** may be cut along the line **20***b* leaving the final shallow contoured net part.

It will be seen from the above that the apparatus and method of this invention provides for the high energy forming of materials into shallow contoured parts of close tolerance without concern for spring back, and that such is made possible by the provision of the stretch groove around the periphery of the male form die so that the work piece can be stretched or elongated in tension sufficient that it is stretched throughout in its plastic range.

By way of emphasizing the importance and value of the explosive stretch forming method and apparatus of this invention, it should be pointed out that such method and apparatus makes possible for the first time the forming of large aircraft fuselage skin sections and large tank dome gore segments of space craft of integral construction and shallow contour within close tolerances without resort to mechanical forming devices. This construction has the important advantages of eliminating or minimizing welding and heat treating which results in degradation of the structural properties of the parts in the weld area and eliminates or minimizes costly chemical milling of such parts to reduce their thickness, except in the weld zone, to minimize the weight penalty attendant to welding.

While a particular embodiment of the invention has been illustrated and described, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from the invention, and it is intended to cover in the appended claims all such modifications and equivalents as fall within the true spirit and scope of this invention.

What is claimed is:

1. A method of stretch forming a piece of sheet metal into a shallow contoured work piece over a male die of shallow contoured configuration having a peripheral stretch groove, said stretch formed work piece having trim stock around the periphery thereof with a groove formed from the die stretch goove located in the trim stock portion of the sheet metal outside of the periphery of the final desired area of the stretch formed work piece comprising the steps of: securing the edge of the sheet metal piece to the die in covering relation to the stretch groove; placing explosive medium above the sheet metal such that pressure waves generated by its detonation will impinge upon and be distributed over the area of the sheet metal covering the stretch groove; and detonating the explosive medium to stretch the sheet metal into the stretch groove whereby the portion of the sheet metal located within the area bounded by the die stretch groove to constitute the work piece is stretched in its plastic range and drawn and set into the configuration of the die.

2. A method of stretch forming a piece of sheet metal into a shallow contoured work piece having trim stock around the periphery thereof comprising the steps of: providing shallow contoured male die structure having a peripheral stretch groove external to the area of the final configured work piece and within the area of the work piece trim stock; evacuating the space between the sheet metal and the die; placing explosive medium above the sheet metal in the vicinity of the die; and detonating the explosive medium to generate pressure waves thereby to stretch the sheet metal into the groove whereby the portion of the sheet metal located within the area bounded by the die stretch groove to constitute the work piece is stretched in its plastic range and is drawn and set into the shallow contour of the die.

3. A method of stretch forming a piece of sheet metal into a shallow contoured work piece having trim stock around the periphery thereof comprising the steps of: providing shallow contoured male die structure having a peripheral stretch groove external to the area of the final configured work piece and within the area of the work piece trim stock; evacuating the space between the sheet metal and the die; placing the die in an energy transfer medium; placing explosive medium above the sheet metal in the vicinity of the die; and detonating the explosive medium to generate pressure waves thereby to stretch the sheet metal into the goove whereby the remaining portion of the sheet metal circumscribed by the stretch groove is stretched in its plastic range and is drawn and set into the shallow contour of the die.

4. For use in the explosive stretch forming of metal sheet to work pieces of shallow contour, a male form die assembly comprising: a male form die having a shallow contoured upper forming surface, the area of said upper forming surface greater than the area of the formed work piece; a stretch groove formed in said upper forming surface external to the area of the forming surface used to form the work piece and about at least a portion of the work piece forming area of said forming surface; and clamping apparatus disposed outside said stretch groove for fixedly clamping a piece of sheet metal to said forming surface in covering relation to said stretch groove.

5. For use in the explosive stretch forming of metal sheet to work pieces of shallow contour, a male form die assembly comprising: a male form die having a shallow contoured upper forming surface, the area of said upper forming surface greater than the area of the formed work piece; a stretch groove formed in said upper forming surface external to the area of the forming surface used to form the work piece and about the periphery of the work piece forming area of said forming surface; a vacuum system connected to said stretch groove; a seal mounted in surrounding relation to said stretch groove; and clamping apparatus disposed outside said stretch groove for fixedly clamping a piece of sheet metal to said forming surface in sealing relation with respect to said seal and in covering relation to said stretch groove.

References Cited by the Examiner

UNITED STATES PATENTS

3,065,720 11/1962 Rardin ..... 113—44

FOREIGN PATENTS

115,846 2/1946 Sweden.

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