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E. CHAPMAN

2,697,953

DIMPLING

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Fig. 1

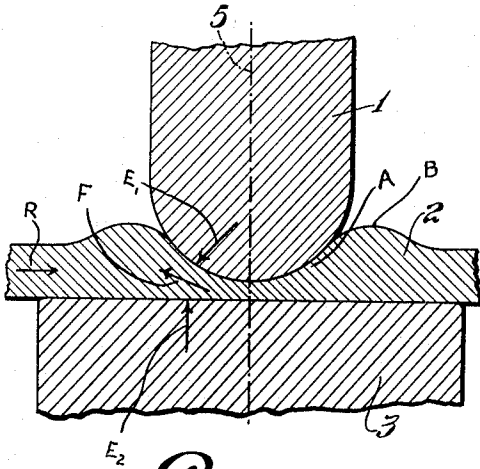


Fig. 2

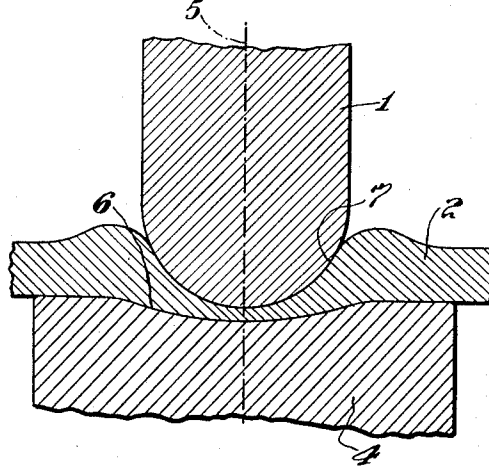


Fig. 3

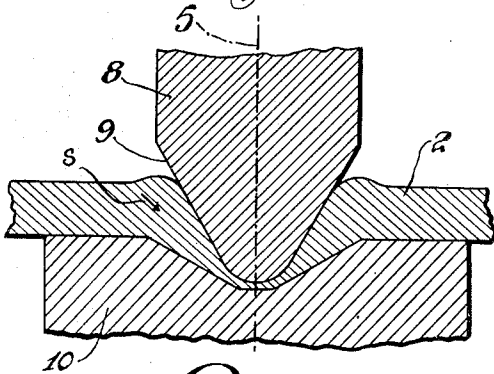


Fig. 4

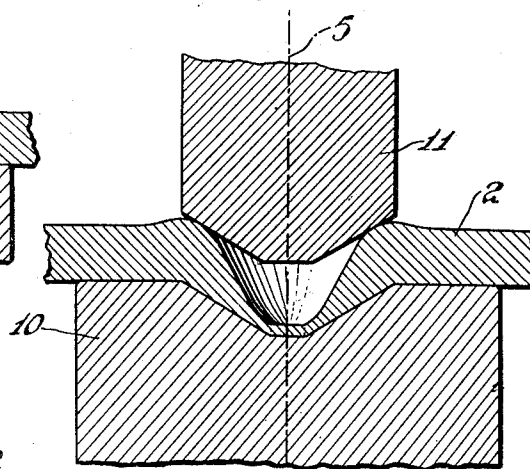
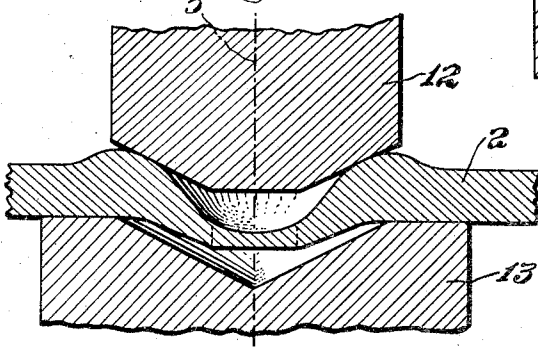


Fig. 5



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2,697,953

DIMPLING

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5 Claims. (Cl. 78—81)

The present invention relates to apparatus and method for dimpling sheet metal and more particularly to apparatus and method for dimpling sheet metal characterized by high strength and low elongation.

Heretofore existing apparatus and methods for forming crack-free dimples in high strength-low ductility sheet metal have not adequately provided for the criticality of sheer strength and desired configuration in dimples formed in the aforesaid metal.

Efforts have been made to provide tools and methods by which high-strength dimples can be formed, but such efforts have not been successful due to the fact that the deformation of the metal in the forming of the dimples induced a weakness resulting from cracking, thinning, and the creation of high tension areas in the deformed portions of the metal. Furthermore, the deformation of the metal in the forming of the dimples has not heretofore been sufficiently controlled to provide a desired dimple configuration especially with regard to the peripheral crest of said dimples wherein it is highly desirable that the contour of the dimple crest be sharply defined and in the plane of the metal sheet.

In forming the dimple, e. g. cold forming, a bore is preferably first formed through a metal sheet and subsequently an area around said bore is dimple punched. In the punching operation, the area around said bore is bent within safe limits, e. g. limits which do not create an excessive tension in the bent area which is potentially inductive to the formation of cracks therein. Having dimple punched the sheet metal in such manner which constitutes a first stage, neither the crest contour nor the angulation of the dimple is desirable and a further deformation or second stage is necessary. It is with such further deformation that undesirable stresses and strains manifest themselves and it is particularly with such further deformation that various means and methods have been proposed in the formation of dimples.

Among the several proposals for dimpling low ductility sheet metal are means and methods for coining the deformed areas and means and methods for heat treating said deformed areas. The former proposed means and methods are directed to relieving the tension in the bent area by producing a counteracting compression, but which compression is not adequate in that the tension created in the vicinity of the peripheral crest of the dimple is merely decreased but not sufficiently counteracted to prevent at least some cracking, e. g. internal sheer cracks in the zone of deformation away from the plane of the sheet metal. The cracking potential of inadequate compression increases as the ductility of the work material decreases and proper compression becomes particularly important in the brittle materials at high strength and low elongation, e. g. in materials such as hardened aluminum or magnesium alloys. Among such alloys are:

Aluminum alloy:	Per cent
Cu	1.6
Mg	2.5
Zn	5.6
Cr	0.3
Al	Remainder
Magnesium alloy:	Per cent
Al	3.0
Mn	0.3
Zn	1.0
Mg	Remainder

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The latter proposed means and methods involve the use of heated tools which are particularly applicable to especially hard metals. However, heating these metals introduces a compromise between ease in formation of the dimple and the strength of the dimple. The heating of such metals necessitates a critical annealing temperature which must be sufficient to prevent the formation of cracks and still not great enough to disadvantageously weaken the metal. For example, heating these metals too hot will result in a loss of strength, since the metals are previously heat treated or hard-rolled for maximum strengths and excessive temperatures will anneal and soften the metal so that the best physical properties are no longer present, and some of the alloying elements may be precipitated to create regions which would be subject to intergranular corrosion.

The above mentioned compromise may be advantageous in certain instances with, however, sacrifices in portability of the equipment and the ability to use small tools in restricted places. The hazard of working with hot tools, the use of expensive and complicated control equipment and the time element, are objectionable where rapid and economical dimpling is preferred.

It is an object of the present invention to provide a method and means therefore which provide a superior dimple of great strength and desirable configuration. It is another object of the present invention to provide a method and means for the economical and rapid formation of dimples. It is another object of the present invention to provide a superior dimple by the use of simple solid tools. It is a further object of the present invention to provide a method and means for forming dimples in hard metals without the necessity of using heated tools. It is a still further object of the present invention to provide a method and means for forming dimples and whereby the deformation of a sheet metal in the forming of said dimples is controlled to substantially inhibit the creation of high tension areas in said metal. Other objects and advantages of the present invention will become apparent from the description hereinafter following and the drawings forming part hereof, in which:

Figs. 1 through 3 are schematic illustrations of a punch and die in a first stage operation according to the present invention, and

Figs. 4 and 5 are schematic illustrations of a punch and die in a second operation according to the present invention.

In bending metal, especially metal of high strength and low ductility, around a corner to a sharp radius, cracking and the attendant loss of strength can be prevented if a compressive neutralizing force can be introduced against a tension region or area created by the operation.

In the forming of a dimple in a sheet of metal, crackless deformation can be achieved if the formation of a tension area is inhibited by the use of a punch and die shaped so that the metal undergoing deformation is directed back against the region which would otherwise be in tension. Under such conditions, large deformations can be produced cold, without cracks, in materials that are low in ductility.

In directing the metal undergoing a dimpling deformation to counteract the tension producing potential according to the present invention, the compressive forces introduced by the punch and die are multiaxial and promote a plastic flow of metal in the direction of the dimple crest to provide a region, including said dimple crest, which is in a state of high residual compression. The residually compressed region is very amenable to further crackless deformation since the punch and die of the invention are so shaped that a substantially large amount of plastic flow, which created said residually compressed region, is available for further deformation under compression without the attendant disadvantages of deformation characteristic of metal under tension.

Figs. 1 through 3 schematically illustrate a first stage operation in the deformation of a metal sheet in the formation of a dimple according to the present invention. In order to clarify the invention, Fig. 1 is introduced as a somewhat exaggerated illustration directed primarily to-

ward the theoretical consideration of multiaxial forces involved in the first dimpling stage. For example, when punch 1 is forced into a sheet of metal 2 which is supported by a flat anvil 3, a volumetric displacement occurs, due to a plastic flow of metal under compression, such that a volume of compressed sheet metal A is displaced outwardly of punch 1 and becomes localized at B outwardly of and around the depression formed by the punch 1. This displacement occurs entirely under compression and the compressed displaced metal B is characteristically tension-free and as such cannot tear. The forces acting on and within the sheet 2 and which result in this particular displacement of metal A to its new locale B are the normal opposing forces E_1 and E_2 which produce a resultant force F in the direction of least resistance and in which direction the plastic flow of compressed metal is directed. It is apparent from the illustrations that part of the displaced metal B is in the form of a raised annulus around the depression formed by the punch and which is created by the outward radial plastic flow of metal under the influence of the resistance R disposed radially inward and afforded by the stiffness of the sheet 2 surrounding the region of flow. Therefore, a raised annulus is formed outwardly of the depression by the displaced metal.

The punch and die of the present invention are so shaped that the plastic flow of metal as above described is not choked by any throat constriction, but, on the contrary, the radial extrusion throat area is increased in a direction away from the punch and the metal flows into a more and more open channel, e. g. a channel being radially symmetrical about a common punch-die axis and having right cross sections characterized as annuli with the radial width of said annuli increasing in a direction away from the end of said punch. Furthermore, the plastically displaced metal including said annulus is in a state of locked-up residual compression stresses and, therefore, capable of far more deformation plastically than if the residual stress system was zero or under tension.

Fig. 2 departs from the structure of Fig. 1 only in that the theory above outlined is applicable and practical when the flat anvil 3 is replaced with a die 4. However, the relationship between the punch and die is of utmost importance. The relationship is critical in that the dimpling punch 1 and the dimpling die 4 are unmated during the first stage operation, i. e. the punch 1 comprises an end portion having walls unmated with the die of female configuration, e. g. a die comprising a coned countersink or an arcuate depression, so that from a common axis 5 the walls 6 of the die are of greater divergence than the walls 7 of the punch which may be radially convex or otherwise rounded, said difference of divergence from said axis providing the radial extrusion throat above set forth and directing the plastic flow of metal as heretofore described.

Fig. 3 illustrates a modification in the first stage dimple forming operation whereby the punch 8 is provided with tapered sides 9, said sides being applicable and cooperative with a die 10 wherein the arcuate or coned depression is of substantial depth or of depth in conformity with the desired angularity of the completed dimple. The tapered sides 9 of the punch 8, similarly to the walls of the punch described with regard to Fig. 2, are of lesser divergence from a common punch-die axis than the walls of the die and maintain the aforesaid relationship between punch and die to direct a plastic flow of metal under compression having a tendency to form a raised annulus or with the consequent formation of an annulus as hereinbefore set forth, whereby the displaced metal including said annulus is in a state of locked-up residual compression stresses and capable of further plastic deformation substantially free of tension stresses. In this modification, since the depression or countersink of the die is of substantial depth, a new force S will appear in a direction opposing the desired compressive force F. The new force S represents a movement of metal necessary to contact the walls of the depression, said movement being normally a tension producing movement, but, due to the fact that the tapered sides 9 act primarily upon the displaced metal, i. e. the annular compressed metal, in order to contact the walls of the depression with sheet metal, tension is inhibited since only compressed metal is plastically moved to fill the depression. A prime consideration in the contacting of the walls of the die depression with sheet metal is that the punch and die are so shaped to actually provide an excess of compressed metal in the form of said annulus

as above described so that the forcing of the metal into the die by the tapered sides 9 does not consume all compressed metal and the potentially tension producing force S is, therefore, less than the compressive force F with locked-up residual compression being still present in the deformed metal.

Figs. 4 and 5 illustrate the critical second dimple forming stage of the invention. Having completed the first stage operation with the punch and die described, at least a second punch is necessary, or a second punch and a second die, to complete the final configuration of the metal in the form of a dimple. The second punch 11, according to Fig. 4, is cooperative with a die 10 as shown in Fig. 3. The punch 11 is essentially such that an end thereof is provided with dimple forming walls of greater divergence from a common punch die axis than the dimple forming walls of the punch employed in the first stage operation, e. g. the walls of the second punch, as a preferred embodiment, mate with the walls of the second operation die. Since the second punch mates the die, it is apparent that the punch dimple-forming walls act upon the compressively displaced metal of the first stage operation to plastically form the final configuration of the dimple. Where a second punch 12 and a second die 13 are employed for the second dimple-forming operation, the requirements of the second punch are as above described and the second die is employed in such instances where the first stage die was not of sufficient depth to provide the final dimple configuration. For example, a second die is necessary if the first stage operation employed a die according to Fig. 2 whereas it would be unnecessary if a die according to Fig. 3 was utilized. It is, therefore, obvious that two punches are essential and that the use of a second die is matter of choice depending upon the metal being dimple-punched or such other requirements wherein one form of die may be preferred over the other.

The punches and dies herein set forth are schematically illustrated and it is within the scope of the invention to provide the sheet metal worked upon with bores formed therethrough so that the area around the bores are dimple punched as is the common practice. It is also within the scope of the invention to provide said punches and dies to cooperate with a pilot or guide to maintain alignment where a lamination of bored metal sheets are dimple-punched. However, the pilot or guide means is absolutely unessential in the deformation of the metal and does not contribute in the deformation to attain a multiaxial compression as described.

Since the punches and dies above set forth act on metal in compression, there is no bending of the sheet metal at the periphery or dimple crest in the second operation and the result is that the dimple crest itself is formed under compression to provide a sharp and clearly defined periphery in the plane of the dimpled sheet metal.

The advantages of a sharp and clearly defined dimple periphery is well-known in the art in that said dimple may contain the head of, for example, a rivet, with the rivet head exactly fitting said dimple and leaving no departure from the plane of the sheet metal to provide a spacing between the rivet head and the sheet metal.

It is, therefore, apparent that the present invention in general deals with a method and apparatus therefore whereby a first hit dimpling operation utilizes simple solid tools which compressively displace a metal into a selected position from which a subsequent second hit operation can continue to act on the metal left in compression to provide a final dimple configuration free of cracks and therefore of high shear strength together with a desired dimple crest heretofore unattainable.

What I claim is:

1. The method of dimpling sheet metal comprising forming a bore through said sheet metal, compressively displacing metal around said bore upwardly and outwardly thereof and thereafter compressively forming the compressed metal in the form of a frusto-conical dimple while simultaneously compressing said outwardly displaced metal into the plane of said sheet metal.

2. The method of dimpling sheet metal comprising forming a bore therethrough, indenting the area around said bore against the countersunk walls of a die and in the form of a dimple and simultaneously displacing the walls of said dimple upwardly and outwardly thereof, and then compressing said outwardly displaced metal into the plane of said sheet metal.

3. The method of dimpling sheet metal comprising

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forming a bore therethrough, indenting an area of metal around said bore against the countersunk walls of a die thereby forming a dimple and simultaneously displacing the walls of said dimple upwardly and outwardly thereof forming a crest around said dimple, and then compressing said crest into the plane of said sheet metal and said dimple walls into frusto-conical dimple form.

4. The method of dimpling sheet metal according to claim 3, comprising compressing said crest into the plane of said sheet metal and simultaneously compressing said dimple walls into a frusto-conical dimple form.

5. The method of dimpling laminated sheet metal comprising forming a bore therethrough, indenting an area

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of metal around said bore against countersunk walls of a die thereby forming a dimple and simultaneously displacing the walls of said dimple upwardly and outwardly thereof forming a crest around said dimple, and subsequently compressing said displaced metal including said crest into a finished frusto-conical form, whereby said crest is compressed into the plane of said sheet metal.

References Cited in the file of this patent

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