Feb. 6, 1951 R. E. RICE 2,540,457

METHOD OF MAKING METAL ARTICLES AND PRODUCTS

Filed Dec. 5, 1945 2 Sheets-Sheet 1

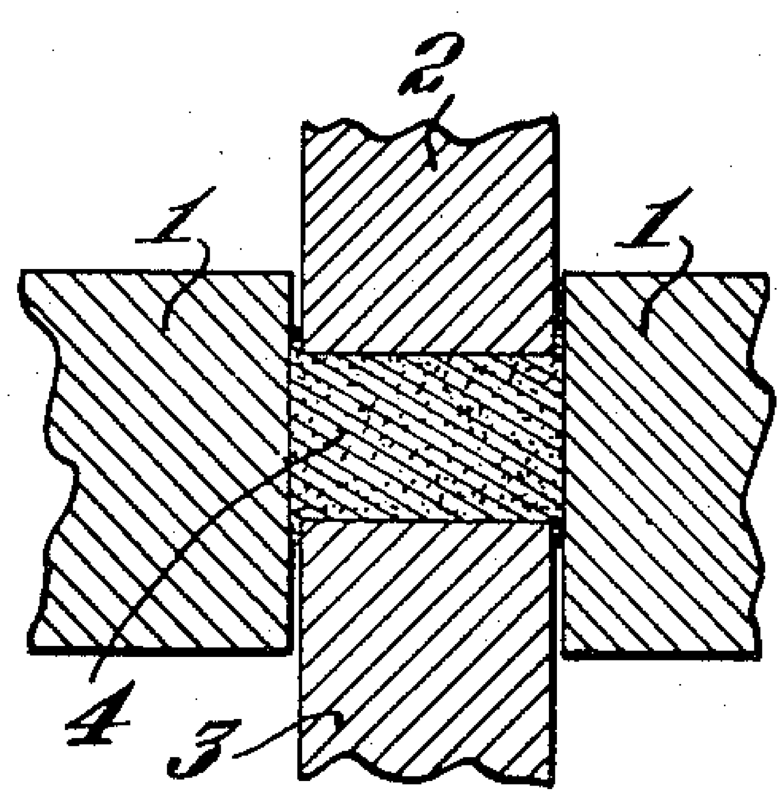

Fig. 1

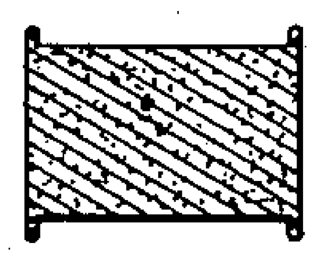
Fig. 2

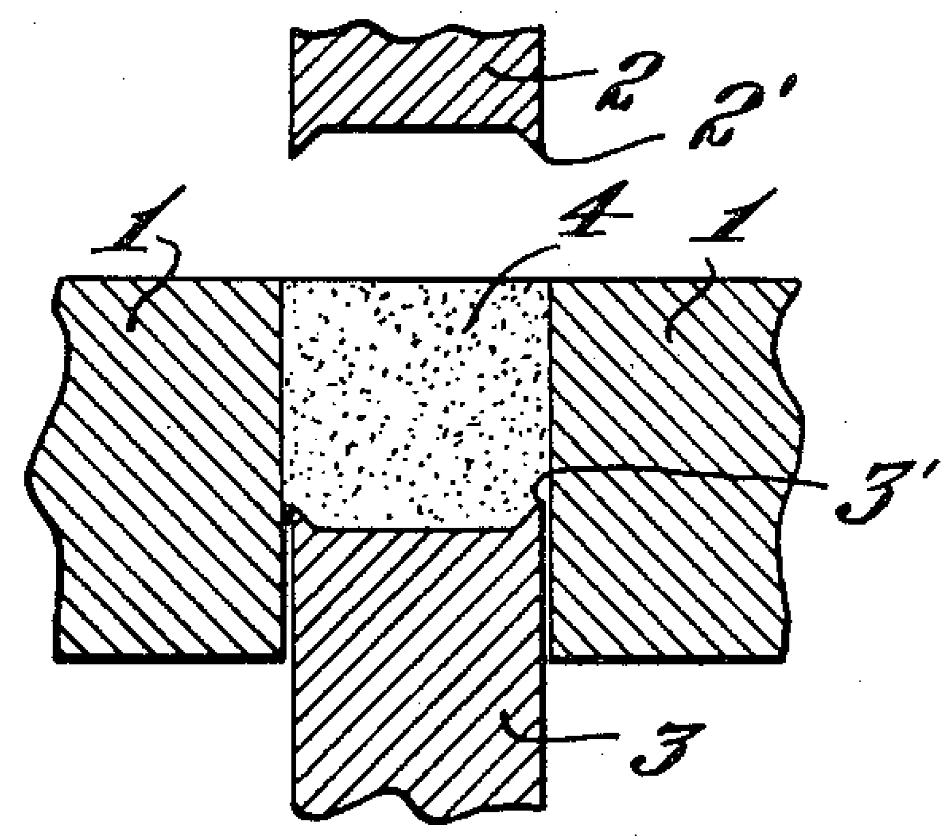

Fig. 3

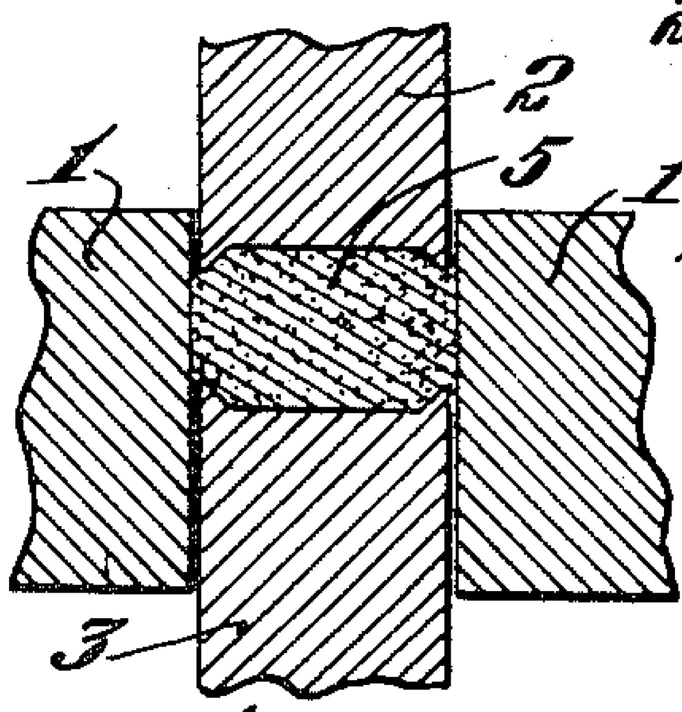

Fig. 4

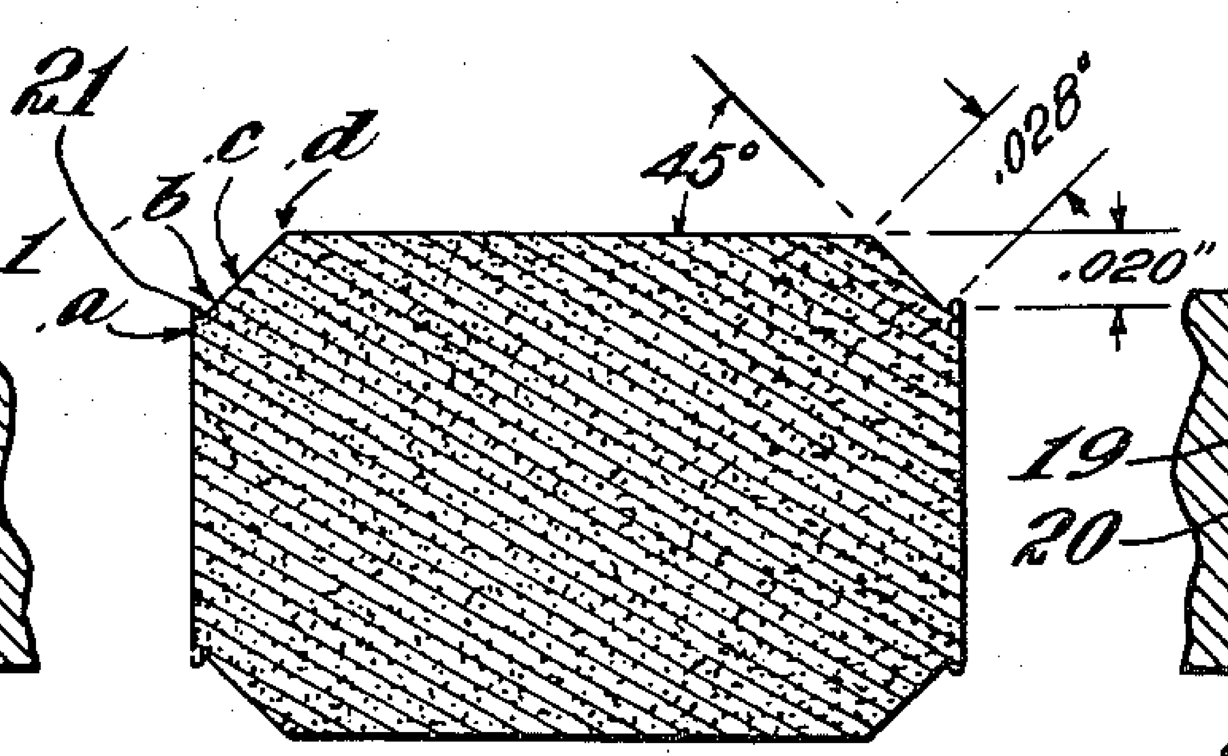

Fig. 5

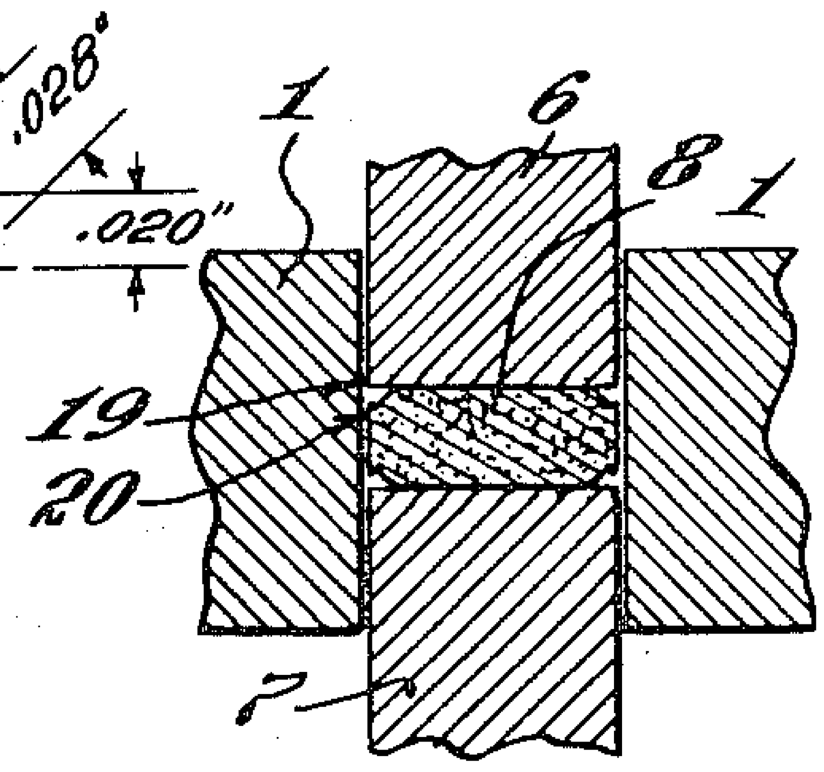

Fig. 6

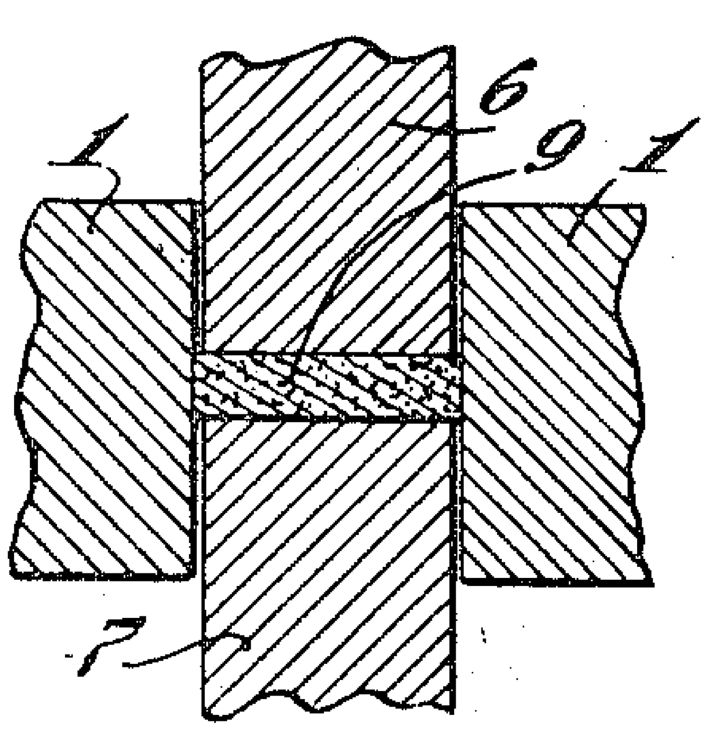

Fig. 7

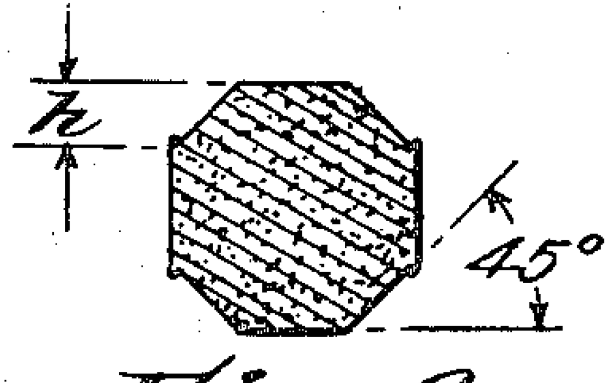

Fig. 8

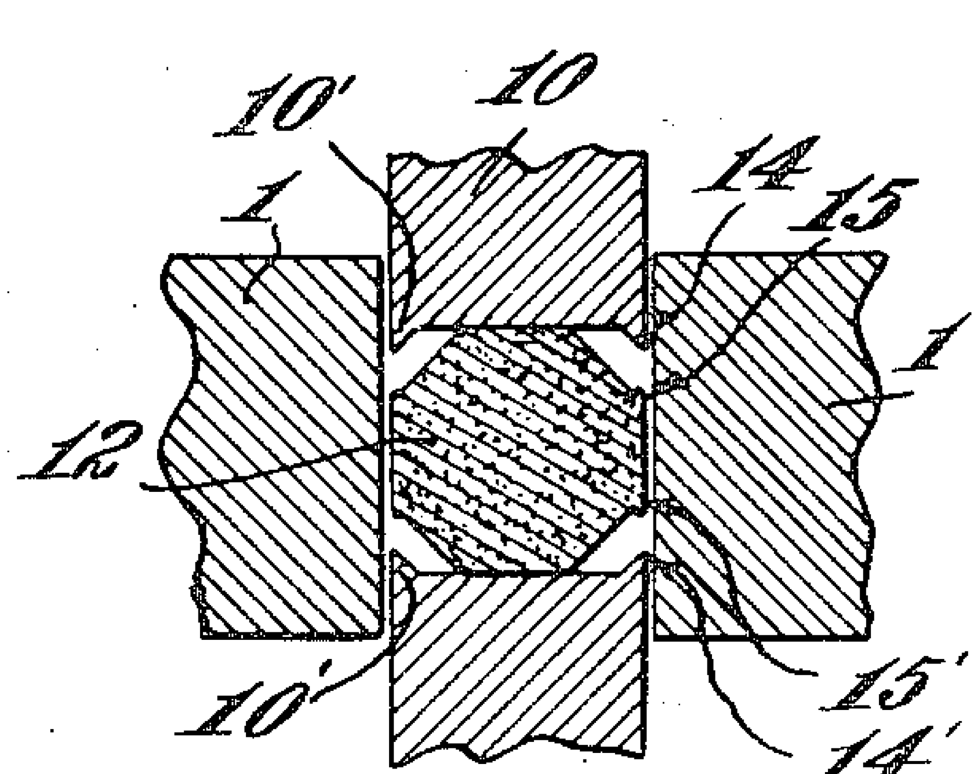

Fig. 9

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METHOD OF MAKING METAL ARTICLES AND PRODUCTS

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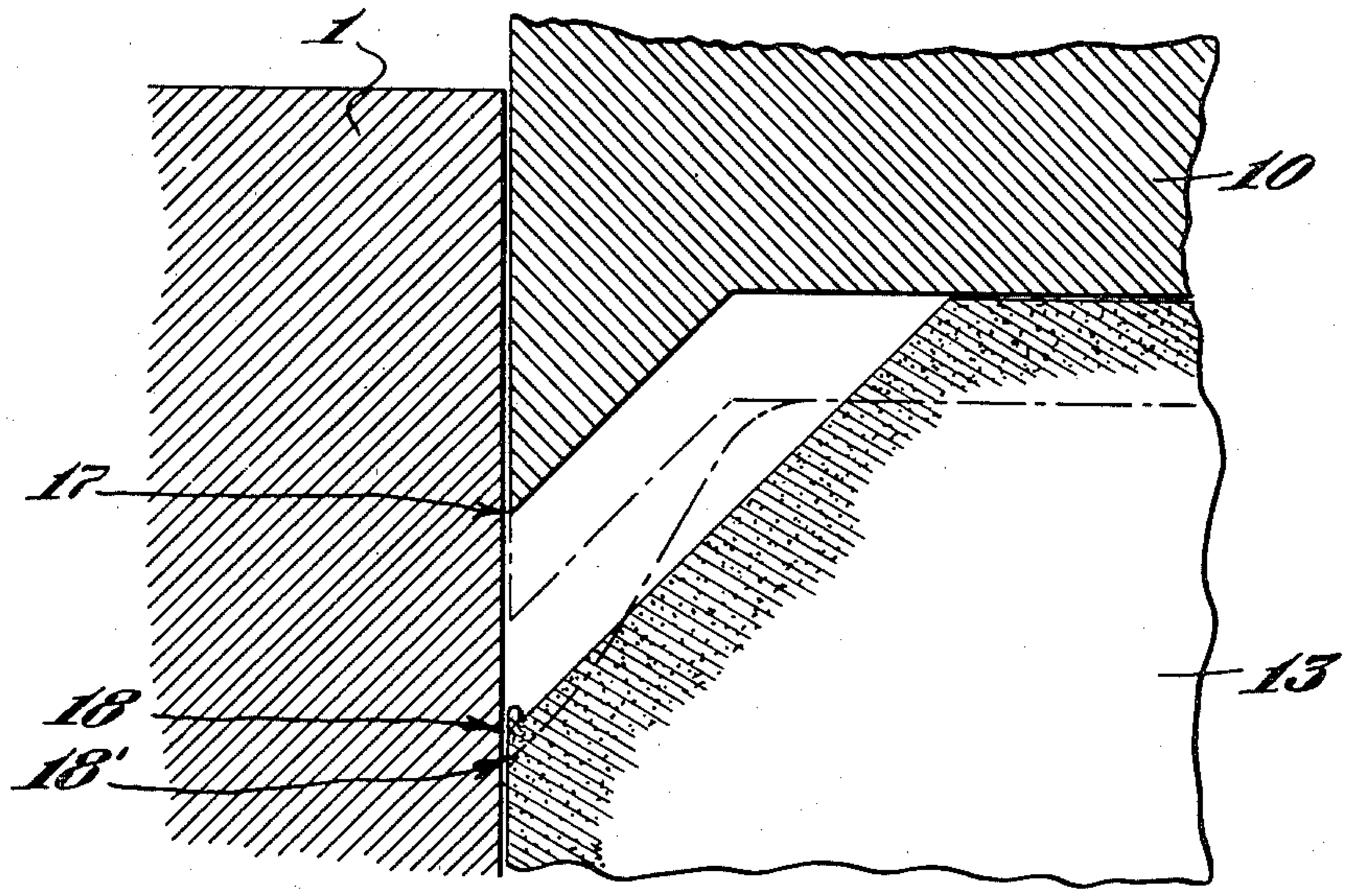

Fig. 10

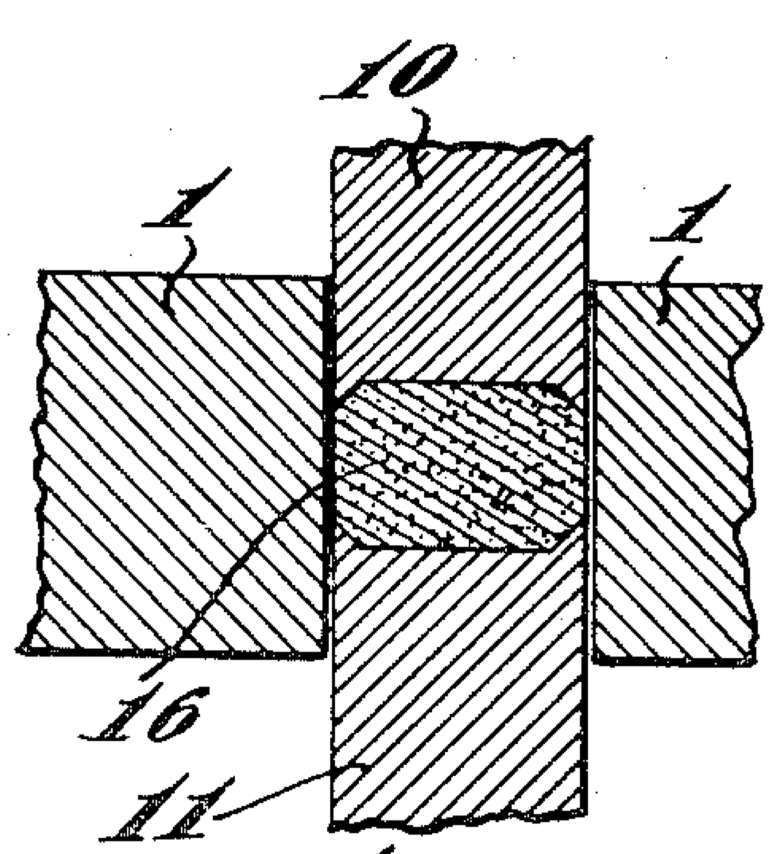

Fig. 11

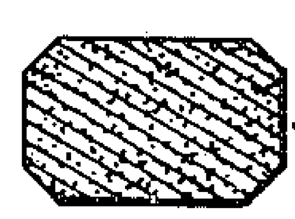

Fig. 12

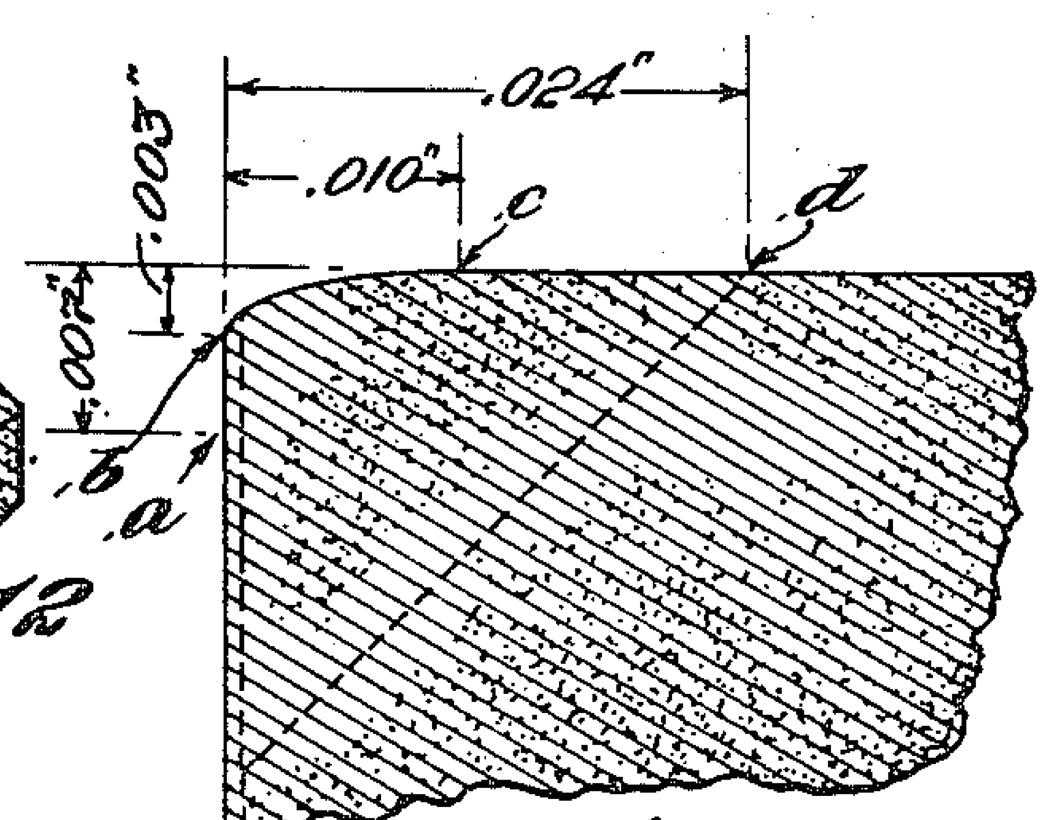

Fig. 13

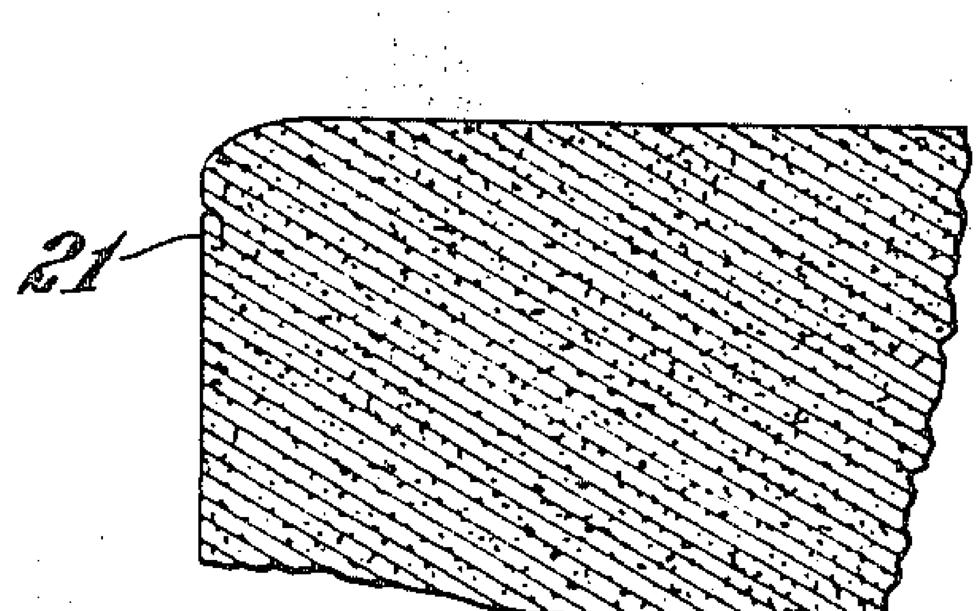

Fig. 14

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METHOD OF MAKING METAL ARTICLES AND PRODUCTS

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Application December 5, 1945, Serial No. 632,853

5 Claims. (Cl. 29—148)

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This invention deals with the making of metal articles by the methods of powder metallurgy. It provides a method by which such metal articles may be produced by two or more pressing operations, and one or more sintering operations, so that no burrs will result, thus eliminating costly deburring operations on the finished piece.

An object of the invention is to produce metal articles, which are made from metal powders by at least two pressing operations, which, at the completion of the last pressing operation are sufficiently free from burrs so that no deburring operations are necessary.

Another object is to produce metal articles having chamfered edges, by two or more pressing operations of which the first pressing operation is at a relatively low pressure, and the later pressings are at relatively higher pressures.

In conventional powder pressing practice, it is customary to use a die which contains a cavity shaped like the contour of the final piece. Working in this die cavity are usually two punches. These are illustrated in the drawings in which:

Fig. 1 is a cross-sectional view of a die of the type employed, in accordance with the prior art;

Fig. 2 is a view of the pressed product made therewith;

Fig. 3 is a cross-sectional view of a die of the type employed, in accordance with the present invention;

Fig. 4 is a cross-sectional view of the die shown in Fig. 3, in closed position, with the pressing or shaped product therein, after the initial pressing;

Fig. 5 is an enlarged cross section of the molded product, as shown in Fig. 4;

Fig. 6 is a cross section of a die of the type employed, for the final pressing operation, with the intermediate pressing, or preliminarily shaped charge, therein, before compression;

Fig. 7 is a cross section of the die shown in Fig. 6, in position of the completed pressing operation;

Fig. 8 is a view of a preformed pressing having chamfered margins;

Fig. 9 is a cross section of a die for repressing with the preformed pressing of Fig. 8 therein, with punches suitable for final pressing to a chamfered shape, before such final pressing operation;

Fig. 10 is an enlarged cross section of the die, and pressing of Figs. 9 and 11 in partially closed position, with the consequently shaped product therein in the course of assuming its final form and dimensions;

Fig. 11 is a cross-sectional view of the die, as shown in Fig. 9, with the pressing therein, in finally closed position;

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Fig. 12 is a view of the shaped product of Figs. 9 and 11, by itself;

Fig. 13 is an enlarged cross section of the preliminarily chamfered pressing, after sintering and repressing by a flat-surface punch, as shown in Figs. 6 and 7; and

Fig. 14 is an enlarged detail cross section showing the position taken by the burr when the compact represented by Fig. 5 is repressed, in accordance with the invention.

Fig. 1 represents a section taken through an assembly of powder pressing tools. The assembly consists of a die, labeled 1 and inside the die cavity an upper punch 2, a lower punch 3, and a charge of powder 4 under compression between the two punches and the walls of the die cavity. In addition to the parts shown in Fig. 1 there may be one or more core rods to form holes in the piece, and frequently in making relatively complicated shapes, both the upper and lower punches may consist of two or more separately operating parts. In making such powder pressing tools, it is necessary to allow a certain amount of clearance space between all parts which move relative to each other. In Fig. 1 this is illustrated in greatly exaggerated scale by the space indicated between each punch and the inner wall of the die cavity. If core rods are used, a similar clearance must be allowed between them and the punches. This clearance space is necessary because under the heavy compressive loads used in powder pressing, the cross-sectional areas of the punches increase slightly more than does the cross-sectional area of the die cavity. Other reasons for clearance space, such as the impossibility of machining and grinding punches to "perfect fit" into the die cavity, are obvious. It should be further noted however, that the clearance space varies from point to point around the punches due to slight inaccuracies of machining, and that the clearance space increases during the useful lifetime of the tools due to wear.

In conventional powder pressing, during the compression of the powder, a certain amount of the powder is forced into the clearance spaces, as indicated in Fig. 1, thus forming burrs. When the piece is ejected from the die these burrs adhere to the pressing. Fig. 2 represents a section taken through such a pressing, and shows, in exaggerated size, the adhering burrs. Such burrs must usually be removed from the pressing before it can be put to its intended use, and on relatively complex shapes the operation of removing the burrs must often be done by hand, and may be relatively very costly. Occasionally such hand deburring operations cost as much as the sum total of all other operations which go into making the piece.

My invention provides a method by which powder pressings may be produced which are free from burrs, and thus require no costly deburring operations. My method is primarily adapted to those powder metallurgy methods which produce a product which has relatively high density and physical properties by means of two or more pressing operations. The method is applicable to the pressing of all metal powders which are adapted to such powder metallurgy methods. Briefly, the method consists of providing punches, other than those used in the final pressing operation, with projecting lips around their peripheries, and around all holes in the punches which receive core rods. These lips are so shaped that they produce a chamfer at all edges of the pressing where it is desired to eliminate burrs. In the final pressing operation, these chamfered edges may become substantially square, but are free from burrs.

This can be explained more clearly with reference to Figs. 3 to 7. It is to be understood that all the drawings are only diagrammatic, and that the actual shape of tools used in the practice of the invention may be whatever is required for the production of the specific piece being manufactured. Fig. 3 represents a section taken through a set of powder pressing tools, containing a charge of loose powder. **2** and **3** represent upper and lower punches each of which is provided around its edge with a lip of triangular cross section **2'** and **3'**. **1** represents the die, and **4** represents the loose powder ready to be compressed in the first of two pressing operations. Fig. 4 represents the same parts at the completion of the pressing operation, showing the powder compressed into a coherent compact, shown by **5**. Fig. 5 represents the compact after ejection from the die; the pressing has edges which have been chamfered, or beveled, by the lips of the punches **2** and **3**. Small burrs (**21**) are shown at the base of the chamfer caused by metal being forced into the clearance spaces between the punches and the die. After this first pressing operation, pieces are normally sintered to bond the particles together, to diffuse carbon and alloying agents when such are present, and to soften the metal by removing work hardening. The pieces may then be subjected to a second and final pressing operation, which imparts to them their final density, shape and dimensions. The tools for this operation are represented by Fig. 6, which is also a sectional view and represents the punches and sintered compact in the die in position for compression, but before the pressure has been applied. Numerals **6** and **7** represent the upper and lower punches, which differ from those used in the first pressing operation in that wherever it is desired to produce a square corner on the piece, the corresponding part of the punch has a square corner. That is, the faces of these punches correspond accurately to the shape and dimensions desired in the finished product. Fig. 7 shows the same elements as Fig. 6, except that the pressure has been applied, and the piece **8** has been compressed and shaped to its predetermined final density and dimensions **9**. During this compression the burrs, as described in detail later, become compressed into the sides of the piece and will not project beyond the top and bottom surfaces of the finished piece. For example, with electrolytic iron powder, I have found that it is possible to proportion the lips of the punches so that the above beneficial result can be obtained using a pressure in the first pressing operation which lies between 15 and 40 tons per square inch and a pressure in the 2nd pressing operation of between 45 and 100 tons per square inch with a sintering operation between the pressing operations.

Another embodiment of my invention may be illustrated with reference to Figs. 8 to 11. In certain cases it is necessary to produce powder-pressed parts which have chamfered or beveled edges on the finished piece. When such pieces must have high density and high physical properties, they are made usually by two, or occasionally by more than two, pressing operations with intervening heat treatments. The final pressing operation, with electrolytic iron powders, is usually at the relatively high pressure of about 75–100 tons per square inch, which is necessary in order to secure high density. With such high pressures, it is impossible to use punches of the design shown in Fig. 3 if the die is filled evenly and the full load for effecting this shape is applied to the lips of such punches. Under such conditions, after a small number of pressings have been made the punch breaks at its lip so that it is not economically practical to use such punches. My method overcomes this difficulty as described in the following.

Fig. 8 represents a pressed compact in an intermediate stage of compression. It might have been made with tools similar to those shown in Fig. 3. The pressing of Fig. 8 has a lower density than it will have upon its completion, and the height of the chamfer, *h*, will be reduced during subsequent densification. After a suitable heat treatment, the piece may be densified and brought to the desired chamfer, in shape and dimensions, by a final pressing. The tools for this operation together with the pressing are indicated by Fig. 9. Here, the pressing **12** is shown in the die **1**, and in contact with an upper punch **10** and a lower punch **11** at the instant when the punches have come into contact with the pressing, but before compressing has begun. As indicated by the drawing, the lips **10'** and **10'** of the two punches are smaller in dimension than the chamfers on the piece, so that no part of the punch lips contacts the pressing. At this instant, the points **14** and **14'** of the punches may be separated from the points **15** and **15'** respectively of the pressing by a distance, so chosen that at the completion of the compression stroke, points **14** and **14'** just barely contact points **15** and **15'** respectively, thereby putting minimum stress on the lips of the punches. Fig. 10 shows, in greatly enlarged scale, the relative positions of the upper punch **10** and the pressing **13** (corresponding to pressing **12** in Fig. 9) at the beginning of compression, and also after the punch **10** has traveled about ½ of its compression stroke (indicated by broken lines). Clearance spaces are indicated between punch and die, and between pressing and die. However, if the dimensions of the system are so chosen that the distance between points **17** and **18** is equal to the distance traveled by the punch **10** during its compression stroke plus the distance which point **18** moves down during compression, no metal will be forced into the clearance space, and no burr will be produced. The case just described wherein the distance between points 17 and 18 is made equal to the distance the punch travels during its compression stroke plus the distance point 18 moves down during compression is a preferred instance, for the purpose of illustration, but the invention is not limited to this special case.

As previously stated with reference to Fig. 5 it is found that when a compact is formed from metal powder with chamfered edges adjacent to the clearance spaces, as described above, a burr may form near the edge of the chamfer but it will be small, both absolutely and in relation to the height of the chamfer.

Such preliminary pressing with a chamfer formed by lips upon and projecting from the forming faces of the punch, which advances into a charge of metallic powder particles, originally of substantially uniform depth, will have slightly greater density beneath the chamfered margins than in the center of the compact. But this does not impose a serious stress or strain upon the lips of the punch because the pressure employed is low, relative to the ultimate pressure contemplated for a final shaping and high density.

In the final pressing operation upon a previously pressed compact, containing chamfered edges, the compact is first contacted by the punches on the non-chamfered portions of its surfaces. However during compression, some densification takes place even at the surfaces not contacted by the punches. This is illustrated in Fig. 10 where it is shown that the point 18 moves down into position 18′ during compression before being contacted by the punch. During compression the metal of the compact flows outward, as shown, until it is substantially completely in contact with the inner surface of the punch lip. However, I prefer to so choose the dimensions of the punch lips used in the first and final pressing operations, that in the final pressing operation densification is completed before metal has flowed into the clearance spaces between the punches and dies to form burrs.

The angle of the chamfer may be varied in the practice of my invention, but at 45° for example, the lips of the punches are sufficiently strong and durable.

As described above with reference to Fig. 5 small burrs may be produced during the first pressing operation but as previously stated during the second pressing operation they will become embedded in the wall of the piece and thereafter will not project out from the surface of the piece.

Example I

Suppose it is desired to produce cylindrically shaped iron parts which are .505 inch in diameter, .536 inch thick and contain a centrally located round hole which is .100 inch in diameter. The finished pieces are required to be free from projecting burrs. The parts are to have a minimum density of 7.60 grams per c. c. In order to accomplish this without exceeding practical pressures it is necessary to use two pressing operations with an intervening sintering operation. Both pressing operations are done in a die such as shown in Figs. 3 and 4 having a cylindrical cavity .505 inch in diameter. Suitable annealed electrolytic iron powder is mixed, as in a ball mill, with 1% of stearic acid. This powder is pressed cold under a pressure of 27 tons per square inch in the die between two punches, as previously described with reference to Figs. 3, 4 and 5, except that the punches will be provided with centrally located holes to receive, with proper clearance, a .101″ diameter core rod. The clearance spaces between punches and die, and between core rods and punches, are .001″ to .002″.

Both punches are provided with projecting lips, as indicated in Figs. 3 and 4, around the outside edges, and similar lips are provided around the center holes of each punch. The height of these lips, indicated by h, Fig. 3, is .020″. This results in a pressing, as shown in Fig. 5, having chamfered edges, around the outside and also similarly chamfered edges around the central hole whose dimension h is .020″ in each case. This pressing operation produces a coherent piece which has a density of approximately 6.8. The piece is sintered in an atmosphere of dry hydrogen or cracked ammonia (75% H_2 and 25% N_2) at 2000° F. for a period of one hour, and subsequently cooled in the sintering atmosphere, so that the sintered piece is bright and free from oxide. The piece is then repressed cold as previously described with reference to Figs. 6 and 7, except that these punches also have centrally located holes to receive, with proper clearance, a core rod which is .100″ in diameter. These punches, both upper and lower, have square corners around the outside and also round the central holes; i. e., they have no lips. Before entering the die, the piece may be lubricated with stearic acid, or other suitable lubricant. Pressure of 90 tons per square inch is applied to the piece by means of the two punches, which produces the required density of 7.60 or better. During this repressing operation the chamfer surface forming the outside edges and the edges around the hole of the pressing are made to conform to the surfaces of the opposing punches and become substantially square and are freed from projecting burrs.

In the case just described, the motions of the upper and lower punches during the compression cycle are equal with respect to time and distance, the upper punch moving downward .028″ and the lower punch moving upward an equal amount, during which motion the required density of 7.6 is produced. During this compression no metal is extruded into any of the clearance spaces, and the final piece is free from burrs. Referring to Fig. 10, it has been previously stated that the point 18 of the pressing moves downward during compression and that at or before the end of the compression stroke the point 17 of the punch contacts the point 18 of the pressing. The above remarks also apply to the case illustrated by Fig. 6 where in the compression operation the punch moves downward until points 19 and 20 contact. It is to be noted in the example described above that although the distance between points 19 and 20 at the beginning of the compression stroke is only .020″ the punch actually moves downward .028″ in order to bring points 19 and 20 into contact with each other. This is due in part to the compression (downwardly) of the charge of the pressing as a whole.

As previously stated with reference to Fig. 5, burrs may be produced during the first pressing operation at the clearance spaces between the die wall and the projecting lips of the punches. When such a compact is coined between flat punches, as above described, a certain portion of the surface of the chamfer is coined into contact with the punch and part of the balance is coined into contact with the surface of the die, and thus embedding and subsequently integrating such burrs, 21, as illustrated in the following example (see Fig. 14).

Example II

Electrolytic iron powder was pressed at 27 tons per square inch in a die having a cylindrical cavity .505" in diameter between punches, as shown in Figs. 3 and 4, having lips .020" in height as above described. After sintering for one hour at 2000° F. in hydrogen the pieces were coined at 90 tons per square inch to a thickness .355" and a density of approximately 7.7 between flat punches as shown in Figs. 6 and 7. Fig. 13 represents a part of a greatly enlarged section (drawn to scale) through the finished piece showing part of the top surface and part of the side. The portion between point *a* and point *d* represents that portion of the surface which, before coining, was the chamfer surface produced by the lip of the punch used in the first pressing operation. As shown in the figure .024" appears from the top surface and .007" from the side. Of these portions of the original chamfer surface which was .028", .004" (*a* to *b* Fig. 13) expands outwardly and into contact with the internal surface of the die while .014" (*c* to *d* Fig. 14) expands upwardly into contact with the surface of the upper punch. The ratio of these distances (viz. *a* to *b* and *c* to *d*) is as .004" is to .014", which corresponds to the generally applicable ratio of these values of about 1 to 3. The balance of the chamfered surface (*b* to *c* Fig. 13) is curved and therefore does not come into contact with the clearance space between the die and punch and hence cannot flow into the clearance spaces to form a burr. Therefore, as shown, the portions *c* to *d* and *a* to *b* are completely in contact with the punch, and with the die wall, respectively. The portion *b* to *c* was not compressed into contact with either the die or the punch and therefore a slight radius was produced at the corner. The slight burr which was present at point *a* prior to coining was compressed into the side of the piece. Fig. 14 shows in exaggerated scale the form taken by the burr (21). The fold which is therein indicated becomes substantially "sealed" during the final sintering operation which may be one hour at 2000° F. in dry hydrogen or cracked ammonia.

The distances which the points 20 and 18 of Figs. 6 and 10 respectively move downward in the die during the compression of the piece depend on several factors including (1) the distance from the surface of the piece to its neutral axis, (2) the smoothness of the surface of the die cavity, (3) the direction of the scratches remaining on the surface of the die cavity from the final lapping or polishing operation, (4) the amount and kind of lubricant used on the pressing, and (5) the amount of clearance allowed between the piece and the die and the degree of densification taking place.

Surface-boundary as used in the claims appended is intended to mean the area or line in which two surfaces of the article terminate one of which has been formed by contact with a punch and the other of which has been formed by contact with a die as illustrated in the drawings.

The magnitude of the radius remaining at the corner after coining depends on the height of the chamfer, the thickness of the piece, the degree of compression, and other factors.

I claim:

1. The art of making powder metal articles with surfaces terminating in a surface-boundary of predetermined final shape free of burrs by double pressing comprising molding a charge of metal powder to initial dimensions said charge having surfaces which intersect to form an edge, compressing the charge to intermediate dimensions by first-pressing the charge in one direction while constraining it at right angles to said one direction and concomitantly reshaping said edge to form a surface-boundary of blunter shape than said predetermined final shape, sintering the first-pressed charge to relieve work-hardening and then second-pressing the charge to final dimensions while reshaping said blunter surface-boundary to a surface-boundary of lesser bluntness, said surface-boundary reaching its final shape and said charge reaching its final dimensions concomitantly.

2. The art of making powder metal articles with surfaces terminating in a surface-boundary defined by a line of predetermined final shape free of burrs by double pressing comprising molding a charge of metal powder to initial dimensions said charge having surfaces which intersect to form an edge, compressing the charge to intermediate dimensions by first-pressing the charge in one direction while constraining it at right angles to said one direction and concomitantly reshaping said edge to form a surface-boundary of blunter shape than said predetermined final shape, sintering the first-pressed charge to relieve work-hardening and then second-pressing the charge to final dimensions while reshaping the said blunter surface-boundary to a surface-boundary of lesser bluntness, said surface-boundary reaching its final shape and said charge reaching its final dimensions concomitantly.

3. The art of making powder metal articles with surfaces terminating in a surface-boundary defined by an area of predetermined final shape free of burrs by double pressing comprising molding a charge of metal powder to initial dimensions said charge having surfaces which intersect to form an edge, compressing the charge to intermediate dimensions by first-pressing the charge in one direction while constraining it at right angles to said one direction and concomitantly reshaping said edge to form a surface-boundary of blunter shape than said predetermined final shape, sintering the first-pressed charge to relieve the work-hardening and then second-pressing the charge to final dimensions while reshaping said blunter surface-boundary to a surface-boundary of lesser bluntness, said surface-boundary reaching its final shape and said charge reaching its final dimensions concomitantly.

4. The art of making powder metal articles with surfaces terminating in a surface-boundary of predetermined final shape free of burrs by double pressing comprising molding a charge of metal powder to initial dimensions said charge having surfaces which intersect to form an edge, compressing the charge to intermediate dimensions by first-pressing the charge in one direction while constraining it at right angles to said one direction and concomitantly eliminating said edge by forming a surface-boundary of greater area and of blunter shape than that of said predetermined final shape, sintering the first-pressed charge to relieve work-hardening and then sec-

ond-pressing the charge to final dimensions while diminishing the area of the surface-boundary to one of lesser bluntness, said surface-boundary reaching its final shape and said charge reaching its final dimensions concomitantly.

5. The art of making powder metal articles with surfaces of predetermined final shape and area terminating in surface-boundaries of predetermined final shape free of burrs by double pressing comprising molding a charge of metal powder to initial dimensions said charge having one surface of substantially its desired final shape and area and another surface of area larger than its desired final area said surfaces intersecting to form edges, compressing the charge in one direction while constraining it at right angles to said one direction to decrease the area of said other surface and concomitantly reshaping said edges to form surface-boundaries of blunter shape than said predetermined final shape, sintering the first-pressed charge to relieve work-hardening and then second-pressing the charge to reduce said other surface to its final shape and area while reshaping said blunter surface-boundaries to those of lesser bluntness, said surface-boundaries and said other surface reaching their final shape and said charge reaching its final dimensions concomitantly.

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