March 23, 1965 D. M. FOX 3,174,318

METHOD OF FORMING ARTICLES FROM DUCTILE MATERIALS

Original Filed Jan. 23, 1958 2 Sheets-Sheet 1

Fig. 1.

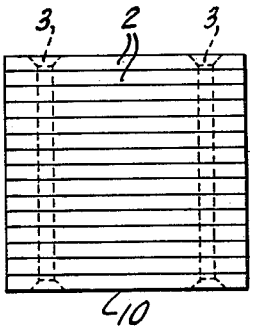


Fig. 2.

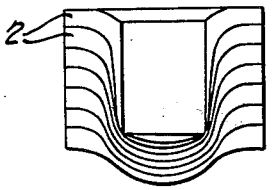


Fig. 3.

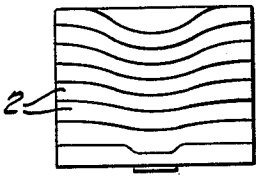
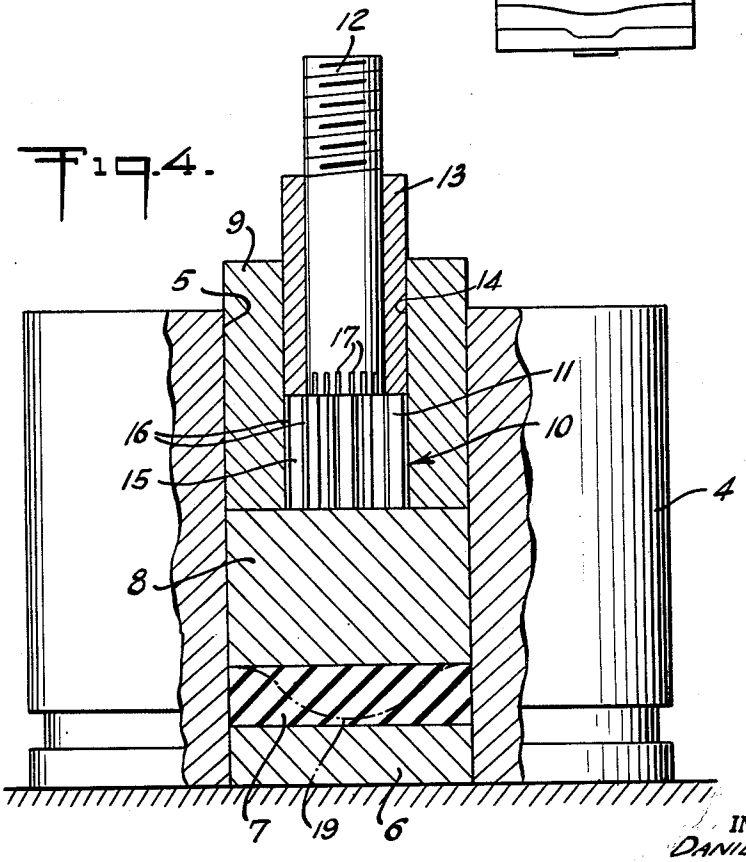


Fig. 4.



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Original Filed Jan. 23, 1958 2 Sheets-Sheet 2

Fig. 5.

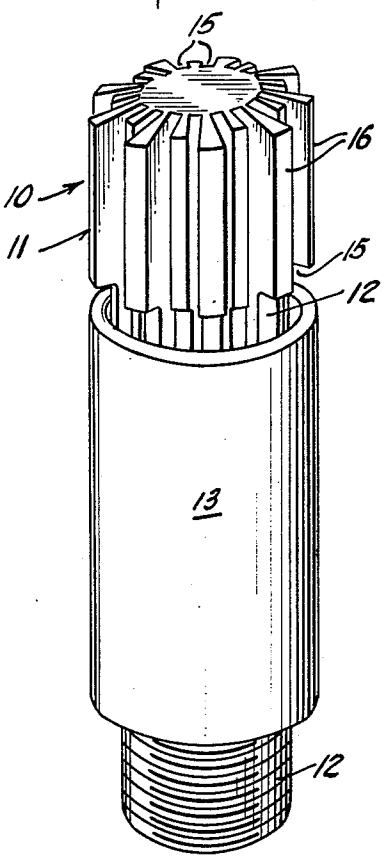


Fig. 6.

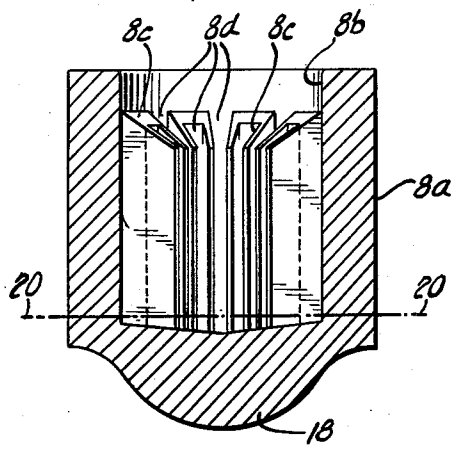
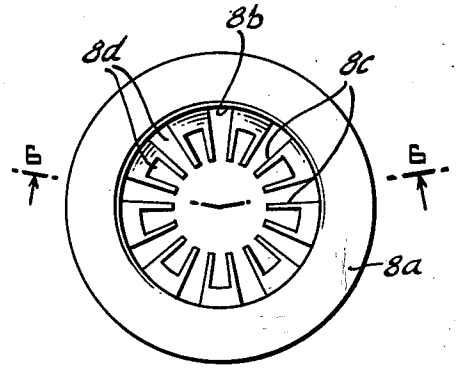


Fig. 7.



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3,174,318
METHOD OF FORMING ARTICLES FROM DUCTILE MATERIALS

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Original application Jan. 23, 1958, Ser. No. 710,828. Divided and this application June 22, 1962, Ser. No. 210,283

3 Claims. (Cl. 72—55)

This application is a division of Serial No. 710,828 filed Jan. 23, 1958, which in turn is a continuation-in-part of patent application Serial No. 535,539, filed September 20, 1955, for Hobbing Apparatus by Daniel M. Fox, both of which applications, Serial #710,828 and Serial #535,539 are now abandoned.

This invention relates to the formation of articles from ductile materials, and is of particular application to the formation of articles of ductile metal at about room temperatures such as the production of magnetron anode blocks from copper or other ductile metal slugs by penetrating a confined slug of the ductile metal with a forging or forming tool.

An object of this invention is to provide an improved method for forming slugs of ductile materials into objects of a desired configuration and size that are all uniform and accurate, with which the formation may be accomplished easily and rapidly at approximately room temperatures, that is; without the application of outside heat to the slug during the formation of the objects, with which objecs with relatively deep holes or cavities may be formed, with which the density of the material will be automatically increased during the formation of the objects and with which the number of rejects will be greatly reduced.

A further object is to provide an improved method for forming slugs of a ductile metal, such as copper, into objects with cavities or holes with selected designs in the walls of such cavities or holes that will all be uniform and accurate in such designs, which employs a minimum of simple and rapidly performed operations and relatively simple and inexpensive apparatus, which increases the density of the formed metal, and which enables formations of such articles at about room temperatures, that is, without the application of outside heat to increase the ductility of the metal.

Another object is to provide an improved method for forming magnetron anode blocks from copper or other ductile metal slugs, with increased density of the copper or other metal and consequently improved dissipation of heat during use of the block, which enables production of such a block with a minimum of machine operations and without the application of outside heat, with which the resonant anode cavities will all be uniform and accurate in dimensions, with which the number of rejects will be approximately nil, with which the anode blocks may be formed with relatively simple and inexpensive apparatus and forming operations, and which may effectively utilize forging or forming operations.

Other objects and advantages will be apparent from the following description of an embodiment of the invention, and the novel features will be particularly pointed out hereinafter in connection with the appended claims.

In the accompanying drawing:

FIG. 1 is an elevation of a laminated anode slug used to illustrate the flow displacement of ductile metal in a forging or forming operation;

FIGS. 2 and 3 are schematic diagrams illustrating the flow displacement in different portions of the laminated slug after a forging or forming operation;

FIG. 4 is a sectional elevation of apparatus used to form objects such as magnetron anode blocks from copper slugs;

FIG. 5 is a perspective of the forging or forming tool used in FIG. 4, disposed apart from the remainder of the apparatus;

FIG. 6 is a longitudinal sectional elevation of a magnetron anode block made by the apparatus of FIG. 4; the section being taken approximately along the line 6—6 of FIG. 7; and

FIG. 7 is a plan of the anode block of FIG. 6.

The invention has been illustrated and will be described as it is used in the production of magnetron anode blocks for which the invention is particularly useful, as a good example to illustrate the principle of the invention, but it may also be used, within the broadest concept of the invention, to make other articles of other shapes and of other ductile materials for other purposes. The invention utilizes the plastic flow displacement of ductile materials, which may be obtained at approximately room temperatures, that is, without the application of large amounts of outside or external heat in order to increase the normal ductility or flow ability of the material. Such plastic flow displacement of the normally rigid material tends to increase the density of the material displaced, in contrast to the porosity that is usually imparted to a ductile material when that material is bent or stretched, which increase in density is useful in many cases, such as in magnetron anode bodies, where greater density of the material increases the desired dissipation of heat that is created in the operation of a magnetron.

In the illustrated embodiment of the invention, the principle of the flow displacement in copper that occurs when a slug of that metal is penetrated by a simple forging or forming tool is shown as a study in FIGS. 1, 2 and 3. A slug 1 is shown in FIG. 1 as formed of a stack of copper plates 2, disposed in face to face contact and connected together into a unit by rivets 3. When such a slug is penetrated by a tool such as a forging or forming tool, while the slug is confined peripherally and at one end, the uppermost group of plates 1 will receive the greatest flow of the metal, the flow or displacement decreasing with the depth of penetration, as shown in FIG. 2 where an upper group of the plates has been removed. There is less displacement in the plates of the lower group shown in FIG. 3.

In FIGS. 4 to 7 this principle of flow displacement is applied to the formation of magnetron anode blocks with resonant anode cavities communicating with a central cathode space around which the cavities are arranged. A steel or other strong rigid ring 4 is provided with a central cylindrical passage 5 from end to end. One end of this passage is closed by a hard plate or anvil 6 which fits and closes that end of the passage, and while shown as made separate in order to facilitate machining of the passage 5, it could, if desired, be made integral with the ring 4. Disposed within and preferably cross-sectionally fitting the passage 5 and abutting the inner face of plate 6 is a plate or disc 7 of a solid elastomeric material of substantial thickness, and relatively incompressible but readily deformable at room temperatures without great pressures thereon. It occupies, however, only a minor fraction of the length of the passage 5, but its thickness, as shown in FIG. 4, is not sharply critical but adequate to provide for its large deformation under pressure to accommodate bulging of the metal being forged, as indicated by the line 19. An example of such a material is very resilient rubber, either natural rubber or any of the synthetic substitutes or functional equivalents of natural resilient rubber. It preferably is substantially free of holes or air or gas cells.

A slug 8 of a solid material that is ductile at room temperatures, such as copper, is placed in the passage 5 against the exposed face of the deformable body 7, and it preferably fits approximately the passage 5 in a cross sectional direction, but it leaves a substantial and major part of the passage 5 unfilled. A sleeve 9 of hard, rigid material such as steel, is placed in the outer end of the passage 5 which it fits and slides along so that its inner end abuts against the upper, exposed face of the slug 8. A forging or forming or penetrating tool 10, such as is shown separately in FIG. 5, has a penetrating head 11 on a root or shank 12 of lesser diameter than the outside diameter of the head. A sleeve 13 surrounds, fits and slides on, the root or shank and has an outside diameter that fits and slides in the passage 14 of sleeve 9, but with the outer end of the root 12 extending outwardly beyond the outer end of sleeve 13 and there threaded for attachment to operating means, not shown, by which the tool is advanced and retracted.

The head 11 of the tool has the cross-sectional configuration and size of the cavity to be formed in the slug, and in the case of the anode block for a magnetron the head 11 may have longitudinally extending grooves 15 formed in its periphery to create vanes 16 that are radial to the central longitudinal axis of the head. These grooves and vanes usually extend from end to end of the head, and the root or shank 12 of reduced diameter enables one to mill or otherwise machine or form the grooves endwise of the head and run into the shank or root 12 somewhat, when necessary, as shown at 17 in FIG. 4, in order that the milling cutter or tool can move far enough to create grooves that extend fully through the head from end to end thereof.

With the parts assembled as shown in FIG. 4, and with a slug 8 of ductile copper or other ductile metal in passage 5 between the tool and the rubber or deformable plate 7, where heavy pressure is applied, as by any press, against the outer end of the tool root or shank, the advance or free end face of the tool, which is flat in the example illustrated, will penetrate the copper slug 8. By flow displacement of the copper or metal in the slug, the copper will be displaced by the advancing tool, some of the displaced metal being displaced lengthwise along and against the peripheral face of the tool as a path of lesser resistance, which elongates the slug endwise, and at the same time the confined body 7 of incompressible but deformable material acts as a cushion for the slug and will be deformed and flow somewhat up the sides of the passage 5, so that a convex bulbous projection 18 (FIG. 6) will be formed on the inner end of the modified slug, this convex bulbous shape being also shown by the dot and dash line 19 in FIG. 4. The material of plate 7 moves up the sides of passage 5 somewhat as shown, because the material of the slug is also being flow-displaced in the area around the tool head by the pressure of the advancing head. The sleeve 9 is free to move outwardly in passage 5 somewhat to accommodate the lengthening of slug 8 during penetration of the latter by the advancing tool head. The sleeve 9 guides the tool head during its advance, and the sleeve 13 in which the root or shank 12 of the tool is guided, by its sliding fit in the sleeve 9 furnishes a further guide for the advancing tool. Thus as the head 11 of tool 10 advances out of sleeve 9 into the slug, the tool will still be firmly and accurately guided by the root or shank 12 and sleeves 13 and 9.

After penetration of the slug by the tool to the desired depth, the tool is retracted from the bull-ring 4, and the slug may be stripped or dislodged from the tool by then applying endwise pressure against the outer end of sleeve 9 to prevent the slug from following the tool being retracted. The re-formed slug 8*a* is shown separately in FIG. 6, and it will be noted that it is now longer axially than the solid slug 8 which was placed in the passage 5. After the re-formed slug 8*a* is removed from the bull ring

and penetrating tool, its lower end may be machined off such as along the dot and dash line 20 in FIG. 6, and also along the top end face to provide the magnetron anode block with its central cavity opening through both ends which have been machined flat entirely across them. One may also, when desired, machine away a small amount of the ends of the ribs of the re-formed slugs in one end of the cavity in further preparation of the block for use in a magnetron.

It will be observed that by this forging or forming operation all of the re-formed slugs 8*a* will have uniformly accurate cross-sectional dimensions and configurations that are exact counterparts of the vanes or variations on the periphery or end face of the tool. In the example where the head 11 has spaced vanes, the re-formed slug 8*a* in its cavity 8*b* will have vanes 8*c* separated by grooves 8*d* which are the opposites or counterparts of the vanes and grooves of the head 11 in that grooves 8*d* were formed by the vanes 16 of the tool head. In other words, all of such re-formed slugs will be uniformly identical in their cavities. The plastic flow displacement of the material of the slug 8 is under heavy compressive pressure, and this decreases the porosity of the slug material and hence increases its density. When metal is merely bent into different shapes in a forming die, the tensioning of the outer part of the bent portion in the bending increases the porosity of that part of the metal, whereas by the compression and flow displacement of all of the metal of the slug in accordance with this invention, all of the metal in the slug will have its density increased. This is important in a magnetron anode body where high temperatures are created in use and effective dissipation of the created heat through the anode block is desirable.

Internal cavities are always difficult and expensive to create and finish accurately and uniformly, and by this invention this is easily done. The external surfaces of an object are more easily machined or finished, and their accuracy and uniformity usually are less important. With this manner of forming the objects or articles of the desired shape, no additional or outside heat to increase the ductility of the material is necessary, although some added heat to increase the ductility could be applied in a special case if it is not high enough to damage the apparatus parts or the deformable body 7. Some heat may be created by the modification of the slug but this can be dissipated through the bull ring 4 and other enclosing parts.

It will be understood that various changes in the details, materials and arrangement of parts, which have been hereindescribed and illustrated in order to explain the nature of the invention, may be made by those skilled in the art within the principle and scope of the invention as expressed in the appended claims.

I claim:

1. The method of cold forming a hollow shell of ductile material slotted in its peripheral wall to run in a direction lengthwise of such wall, which comprises:

(*a*) confining a solid slug of such material, while without added heat sufficient to materially increase the flowability of such material, against expansion in a lateral direction,

(*b*) then while said slug remains so confined and still at said temperature compressing it directly between an otherwise confined body of elastomeric material and a penetrating end of a forming tool ribbed on its periphery to form the counterpart of the slotted wall desired in said shell, until the tool penetrates into and moves along the slug and causes cold plastic displacement of the material of the slug along the side of the tool into peripherally continuous contact with the periphery of such tool, and convex bulging of its inner end face, which in turn causes said elastomeric material to apply a resultant upward

component force to the peripheral portions of said slug to augment said cold plastic displacement,

(*c*) then removing said tool from said body, and

(*d*) then cutting off through the cavity formed in the slug after removal of the tool the closed end having the bulge on said inner end face.

2. The method according to claim 1, wherein said ductile material is copper and the shell is a magnetron shell.

3. The method of making objects of maximum density of material and in selected shapes and all of the same uniform, accurate, dimensions, which comprises:

(*a*) confining the sides and one end of a body of ductile metal to withstand high pressures while unsoftened by added heat above room temperature, with said one end of said body abutting face to face directly against a confined, relatively incompressible elastomeric element of substantial thickness that is deformable without added heat under pressure, and

(*b*) while said body and element are so confined, and at a temperature below that which would materially increase the fluidity of the metal body, penetrating the unconfined end wall of said body with a forming tool, having a desired configuration on its sides and advancing end wall, and thereby displacing some of said ductile metal by cold flow displacement around and against the side of said tool as it penetrates said body, which in turn causes said elastomeric material to apply a resultant upward component force to the peripheral portions of said slug to augment said cold plastic displacement, and then

(*c*) separating said tool and deformed metal body.

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