April 7, 1964 A. F. HAYES 3,127,671

ART OF FORGING BRITTLE METALS

Filed June 27, 1961

Fig. 1.

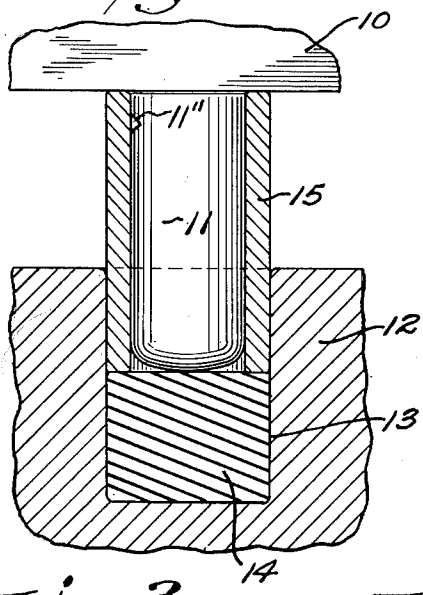


Fig. 2.

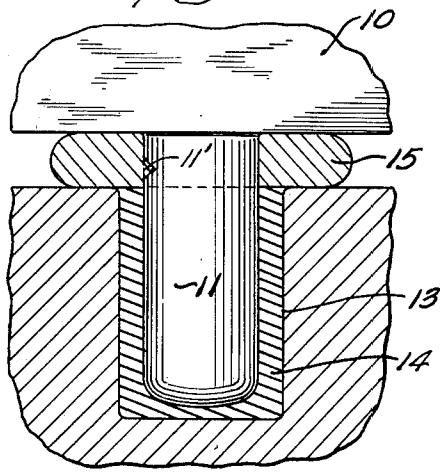


Fig. 3.

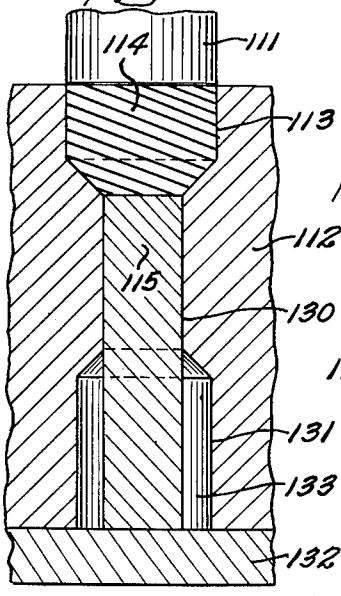


Fig. 4.

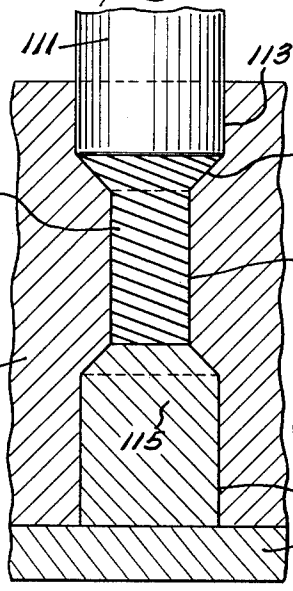


Fig. 5.

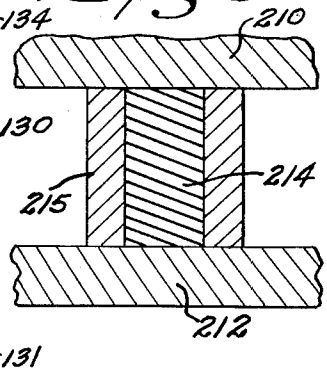
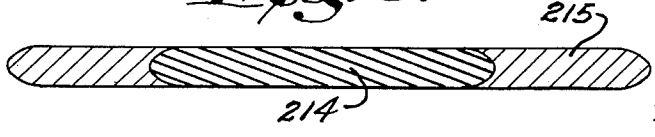


Fig. 6.



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ART OF FORGING BRITTLE METALS

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12 Claims. (Cl. 29—423)

This invention relates to improvement in the art of forging brittle metals.

In the forging of brittle metals, such as commercial beryllium, tungsten, or some super alloys, it has heretofore been recognized that restraining means of some sort must be employed during the forging operation. In the past such restraining means has often been in the form of a thick, expensive, steel jacket. Such heavy jacketing, however, has numerous drawbacks, such as poor dimensional control, high cost, and diminishing support as the forging progresses. In many forgings, due to the shape of the article to be forged, the restraint provided by this type of jacket diminishes most in those locations which are heavily worked and which consequently should have the greatest support.

It is a general object of the present invention to provide a forging technique for use in forging metals which are brittle, the improved technique eliminating the necessity of employing a conventional jacket while providing complete undiminished restraint during the forging operation.

A more specific object of the invention is to provide an improved forging process of the class described wherein a heated expendable steel support is used to provide restraint, which support is deformed by the forging operation simultaneously by and with the deformation of the forging metal.

A more specific object of the invention is to provide an improved forging method wherein the metal which is being forged acts as a fluid in compression, which in turn deforms the hot steel support, the latter providing in effect a plastic die component which permits deformation of the forging to proceed only after the compressive pressure exerted thereon exceeds the elastic limit of the heated steel support member.

A further object of the invention is to provide an improved process which makes it possible to forge brittle metals, such as beryllium, at a reduced temperature such that products given off, such as airborne scale, beryllium metal vapor and beryllium oxide vapor which are potentially toxic, are so minute as to be within safe limits.

A further object of the invention is to provide improvements in the art of forging brittle metals which enables the parts to be forged economically, with close dimensional control and with good surface finish, and which permits surface inspection and conditioning between forging operations if desired.

A further object of the invention is to provide apparatus for effecting commercial exploitation of the improved method.

With the above and other objects in view, the invention consists of the improvements in the art of forging brittle metals, and all of its parts and steps and combinations of steps, as set forth in the claims and all equivalents thereof.

In the accompanying drawing, illustrating several exemplifications of the improved apparatus and process, in which the same reference numerals designate the same parts in all of the views:

FIG. 1 is a view, principally in vertical section, showing top and bottom dies in open position, together with an expendable cylindrical steel support member, the components being ready to forge a hollow cylinder from a solid cylindrical blank of brittle metal, such as beryllium;

FIG. 2 is a view showing the die portions of FIG. 1 in

closed condition after the material has been deformed into a hollow cylinder having one closed end, the view also illustrating the deformed steel support member as it is at the completion of the forging operation;

FIG. 3 is a view, principally in vertical section, of another form of apparatus showing upper and lower die members about to act on a solid body of metal which is to be forged into a different shape from that of FIG. 2;

FIG. 4 is a view, principally in vertical section, showing the position of the components of FIG. 3 at the completion of the forging operation;

FIG. 5 is a view in vertical section showing still another form of forging apparatus ready to act on a solid cylindrical body of material, such as beryllium, to forge it into a flattened pancake; and

FIG. 6 is a view of the forging and surrounding support member, before separation, after they have been acted upon by the top and bottom dies of FIG. 5.

Referring more particularly to the drawings, it is to be understood that the drawings illustrate three different forms of apparatus for carrying out the improved process. The shape of the dies and the particular form of the apparatus may vary, depending upon the shape desired in the completed forging. The technique is applicable for the forging of beryllium, tungsten, super alloys (which usually are 65% or higher in alloying constituents), or other metals or materials which are brittle, and can be used to forge such brittle material in any convenient direction from vertical to horizontal, it being possible to cause metal to flow from the extremities of the billet toward the center, or from the center toward the extremities, or from both center and extremities to intermediate sections as required.

It is an important feature of the present invention that the forging of the material may be accomplished at reduced temperatures. In the case of beryllium, forging under the present process may be successfully accomplished when the beryllium is as low at 500° F. While it is usually carried out with the beryllium within the range of 500° F. to 1450° F., depending upon the type of deformation, size of forging, amount of deformation and characteristics of the metal, nevertheless it is practical to forge beryllium in the present process at a temperature higher than 1450° F. However, this is usually undesirable as the lower temperatures reduce toxicity problems as will be hereinafter explained. In the case of tungsten, forging with the present process may be accomplished successfully with the tungsten at a temperature as low as 1800° F., but it is preferable to use a range of between 1800° F. and 3500° F. While the temperature of the tungsten may exceed 3500° F., this is usually undesirable because high temperatures increase oxidation, and this results in an undesirable weight loss. In the case of molybdenum, forging with the present process may be accomplished with the molybdenum as low as 1500° F., but is preferably performed within the range of 1500° F. and 2600° F. Temperature of the molybdenum may exceed 2600° F. but this is usually undesirable as the higher temperature increases the oxidation rate which results in an undesirable loss of weight. For certain types of beryllium forgings the higher of the preferred temperature range may be used, such as 1350° F. to 1450° F., to gain the advantage of reduced forging pressures. Heretofore, with the use of thick steel jackets in forging metals, such as beryllium, it has usually been considered desirable to use temperatures in the range of 1600° F. to 2000° F., which has objections. Such objections are particularly true in the case of beryllium which gives off products such as air-borne scale, beryllium metal vapor and beryllium oxide vapors which are potentially toxic at high temperatures so as to contaminate the surrounding atmosphere if the steel jackets

customarily used should rupture. With the present process it is possible to forge beryllium at a temperature such that products given off, such as air-borne scale, beryllium metal vapor and beryllium oxide vapor which are potentially toxic, are so minute as to be within safe limits.

Referring first to the apparatus illustrated in FIGS. 1 and 2, this shows tooling of a form to produce a hollow cylindrical forging having one closed end. In said figure, the numeral **10** designates a top die member, having a depending punch **11**. The numeral **12** designates a bottom die, having a die cavity **13**, the cavity having somewhat greater inside diameter than the external diameter of the punch **11**, as will be hereinafter described.

In carrying out the process, with the punch withdrawn from the bottom die, a solid blank **14** of metal to be forged, such as beryllium, is placed in the cavity. In the exemplification shown, the blank is cylindrical with the external diameter of the blank being substantially equal to the internal diameter of the cavity **13**, as illustrated in FIG. 1. This blank has heretofore been heated to a required temperature, as will be hereinafter described. A metal support member **15**, preferably of steel, in the form of a hollow member, is employed, which member, in the form of invention of FIG. 1, is of the same length as the punch **11** and has a wall of sufficient thickness to fill the cylindrical space between the punch and the wall of the cavity **13**, as shown in FIG. 1. The metal support member **15** is in heated form at a temperature higher than the temperature of the beryllium **14**. The apparatus of FIG. 1 may be associated with a mechanical press, hydraulic press, or hammer capable of causing relative movement between the top and bottom die members **10** and **12** to bring the parts from the position of FIG. 1 to the position of FIG. 2.

During such forging action, the beryllium **14** is confined on the sides and bottom by the bottom die member **12**, and is confined on top by the lower end of the punch **11** and by the lower end of the steel support member **15**. As the top punch **11** moves downwardly to the position of FIG. 2, it displaces some of the beryllium, which acts as a fluid in compression to, in turn, deform the hot steel support member **15** to the ultimate condition shown in FIG. 2, where it is accessible for easy removal.

The steel support member **15** of FIG. 1 is in effect a plastic die component which allows significant beryllium deformation to proceed only after the compressive pressure exerted on the beryllium by the punch **11** and steel support member **15** exceeds the elastic limit of the support member. In general, the hot steel support member **15** exerts pressure along those portions of the surface of the heated beryllium blank which are not in direct contact with the forging dies. If the forging requires multiple blows, as by a steam hammer, then it may be desirable to have the support member **15** fastened to the punch **11** by means of a tit **11'** as shown in FIG. 2, engaging a notch **11''**.

After the forging of FIG. 2 has been completed, the punch **11** is withdrawn, the flattened steel support member **15** is removed, and the completed forging **14'**, in the form of a hollow cylinder having one closed end, is removed from the bottom die cavity. As one example, the beryllium **14** of FIG. 1 was heated to a temperature of 1400° F. and the support member **15** was formed of AISI 1020 carbon steel heated to a temperature of 2100° F. The exact temperature of the support member can be varied, depending upon the material used. Furthermore, the resistance afforded by the support member can be varied by altering the temperature of the support member or by making changes in the material used.

FIGS. 3 and 4 show how it is possible, by a somewhat different form of tooling, to produce a solid forging of changed dimensions and shape from a solid blank. In this form of apparatus there is a punch **111** adapted to be supported by a top die member, such as the die member **10** of FIG. 1, which punch is movable into a cavity **113** in a bottom die member **112**, said die member, having an extension cavity **130** of lesser diameter than the cavity portion **113**, which in turn communicates with a lower cavity portion **131** of increased diameter, the bottom of the bottom die being adapted to be closed by a removable plate **132**.

In carrying out the improved method with this apparatus, there is first inserted in the lower die cavity a solid steel support member **115**, having a diameter equal to the diameter of the die cavity portion **130** and having a length to extend from the bottom of the cavity portion **113** to the top of the bottom plate **132**. This leaves an annular deformation space **133** surrounding the lower portion of the support member.

During forging, the punch **111** moves from the position of FIG. 3 to the position of FIG. 4, causing the hot metal, such as beryllium **114**, to be deformed into the condition of FIG. 4, where it fills the die cavity portion **130** and the flared portion **134** to produce a solid forging having the shape and vertical section shown in FIG. 4. During such procedure the beryllium **114** is confined at the bottom by the hot steel support member **115** while the beryllium under pressure acts to deform the support member and push all of said plastic support member into the die cavity portion **131**, where it fills out the annular space **133** of FIG. 3, as is shown in FIG. 4.

After forging, the punch **111** may be withdrawn to permit removal of the forging from the top, after which the plate **132** may be removed to permit removal of the deformed steel support member **115**.

Another type of tooling is illustrated in FIGS. 5 and 6. Here a solid heated body **214** of material to be forged, which is here shown in the form of a cylinder but which may have other cross-vertical shapes, is supported endwise between an upper die member **210** and a lower die member **212**, the cylindrical wall of the material to be forged being supported by the inner wall of a tubular metal support member **215**. During the forging operation there is relative movement between the upper and lower die members **210** and **212** to cause the metal **214**, such as beryllium, to be deformed to the pancake form shown in FIG. 6 while it is circumferentially confined by the support member **215**, which latter is also deformed and flattened into the form of a ring, as shown in FIG 6, which may later be removed. This type of method and apparatus is particularly useful where it is desirable to have heat supplied to the forging. In the form of the invention of FIGS. 5 and 6 such heat may be supplied by the support member **215**.

It is apparent that this type of apparatus and method enables parts to be forged economically with close dimensional control and with good surface finish. The process also permits surface inspection and conditioning between forging operations if desired. If increased support is desired during the forging operation, the temperature of the metal of the support member **15**, **115**, or **215** may be lowered somewhat, or the type of metal or material used may be varied. Thus, close control of the operation may be easily obtained.

Various other forging shapes, such as hemispheres, may be produced other than those shown, the apparatus and shapes illustrated being merely examples. Various other changes and modifications may be made within the scope of the invention as may come within the appended claims.

What I claim is:

1. The method of forging a material which is brittle, comprising the steps of supporting all except certain exterior portions of a heated blank of said material by die member parts which are in contact with said supported portions, shaping a metal support member to a shape to

support the remainder of the exterior of said blank, heating said support member, assembling said heated support member in supporting position with respect to said die members and in contact with said exterior portions of the blank which are not contacted by the die member parts while allowing space into which said support member may flow when deformed, causing said die members to exert forging pressure on said blank to the extent that deformation of blank proceeds after the compressive pressure exerted thereon exceeds the elastic limit of the heated support member, and continuing said pressure while said support member is deformed as it makes way for the final shape of the forging, with said support member and die members maintaining supporting pressure on substantially all portions of the exterior of the material being forged during the forging operation and until the forging is completed.

2. The method of forging beryllium comprising the steps of supporting all except certain exterior portions of a heated blank of beryllium by die member parts which are in contact with said supported portions, shaping a metal support member to a shape to support the remainder of the exterior of said blank, heating said metal support member, assembling said heated support member in supporting position with respect to said die members and in contact with said exterior portions of the blank which are not contacted by the die member parts while allowing space into which said support member may flow when deformed, causing said die members to exert forging pressure on said blank to the extent that deformation of the blank proceeds after the compressive pressure exerted thereon exceeds the elastic limit of the heated support member, and continuing said pressure while said support member is deformed as it makes way for the final shape of the forging, with said support member and die members maintaining supporting pressure on substantially all portions of the exterior of the metal being forged during the forging operation and until the forging is completed.

3. The method of forging beryllium comprising the steps of supporting all except certain exterior portions of a heated blank of beryllium by die member parts which are in contact with said supported portions, shaping a metal support member to a shape to support the remainder of the exterior of said blank, heating said metal support member, assembling said heated support member in supporting position with respect to said die members and in contact with said exterior portions of the blank which are not contacted by the die member parts while allowing space into which said support member may flow when deformed, causing said die members to exert forging pressure on said blank to the extent that deformation of the blank proceeds after the compressive pressure exerted thereon exceeds the elastic limit of the heated support member, and continuing said pressure while said support member is deformed as it makes way for the final shape of the forging, with said support member and die members maintaining supporting pressure on substantially all portions of the exterior of the metal being forged during the forging operation and until the forged article is completed, the material of said support member and its temperature being such that the beryllium may be caused to flow while the beryllium is at a sufficiently low temperature that products given off, such as air-borne scale, beryllium metal vapor and beryllium oxide vapor, which are potentially toxic, are so minute as to be within safe limits.

4. The method of forging a material which is brittle, comprising the steps of supporting all except certain exterior portions of a heated solid blank of material between the walls of the cavity of one die member and the punch of another die member, shaping a heated metal support member to a shape to contact and support the remainder of the exterior of said blank, heating said metal support member, assembling said heated support member in supporting position with respect to said die members and in contact with said exterior portions of the blank which are not contacted by the die member parts while allowing space into which said support member may flow when deformed, causing said die members to exert forging pressure on said blank through said punch to the extent that deformation of the blank proceeds after the compressive pressure exerted thereon exceeds the elastic limit of the heated support member, and continuing said pressure while said support member is deformed as it makes way for the final shape of the forging, with said support member and die members maintaining supporting pressure on substantially all portions of the exterior of the material being forged during the forging operation and until the forging is completed.

5. The method of forging a metal which is brittle, comprising the steps of supporting the sides and one end of a heated blank of metal in the bottom of the cavity of one die member, shaping a heated metal support member to tubular form to surround the punch of another die member so that the bottom of the punch and surrounding support are of an area to contact the opposite end of said blank which constitutes the remainder of its exterior and to fill the top of said die cavity, heating said metal support member, causing said die punch to exert forging pressure on said opposite end of the blank to the extent that deformation of the blank proceeds after the compressive pressure exerted thereon exceeds the elastic limit of the heated support member, and continuing said pressure while said support member is deformed and flows out of the die cavity to make way for the final cup shape of the forging around the punch, with said support member maintaining supporting pressure on the metal being forged until the forging is completed.

6. The method of forging a metal which is brittle, comprising the steps of supporting the sides of a heated blank of metal by the sides of the cavity of a die member, shaping a heated metal support member to a shape to contact and support one end of said blank, heating said metal support member, assembling said heated support member to supporting position with respect to said die members and in contact with said exterior portions of the blank which are not contacted by the die member parts while allowing space into which said support member may flow when deformed, causing the punch of another die member to exert forging pressure on the opposite end of said blank to the extent that deformation of the blank proceeds after the compressive pressure exerted thereon exceeds the elastic limit of the heated support member, and continuing said pressure while said support member is deformed as it makes way for the final shape of the forging, with said support member and die members maintaining supporting pressure on substantially all portions of the exterior of the metal being forged during the forging operation and until the forging is completed.

7. The method of forging a metal which is brittle, comprising the steps of contacting the ends of a solid heated blank of metal between die member parts, shaping a heated metal support member to surround and support the sides of said heated blank of metal, heating said metal support member, assembling said heated support member and blank between two die members with the latter contacting all exterior portions of the blank not surrounded and contacted by the support member, causing said die members to exert forging pressure on said blank to the extent that deformation and flattening of the blank proceeds after the compressive pressure exerted thereon exceeds the elastic limit of the surrounding heated support member, and continuing said pressure while said support member is deformed and flattened as it makes way for the final shape of the forging, with said support member and die members maintaining supporting pressure around substantially all portions of the exterior of the metal being forged during the forging operation and until the forging is completed.

8. Forging apparatus comprising a pair of relatively

movable die members shaped to contact all except predetermined parts of the exterior of a blank to be forged, and a plastic metal die component shaped to contact the remainder of the exterior of said blank, at least one of said die members having means for supporting said plastic metal die component in operative relation with respect to the die members and blank whereby said blank may be completely confined during forging between the die members and plastic metal die component, there being expansion space adjacent at least a portion of said plastic metal die component into which it may flow as it supports part of the blank and as compressive forces on the blank cause deformation of said plastic metal die component.

9. Forging apparatus comprising a die member having a cavity with a bottom, said cavity being shaped to receive a blank of metal having a similar cross-sectional shape to that of the cavity to contact all except the top of said blank, a second die member having a punch, and a plastic metal die component of the same length as and surrounding said punch with said punch and component having a bottom of an area to contact the opposite end of the blank which constitutes the remainder of its exterior whereby said blank may be confined between the die members, punch, and plastic metal die component, there being expansion space adjacent at least a portion of said plastic die component into which it may flow as it supports part of the blank and as compressive forces on the blank cause deformation of said plastic die component.

10. Forging apparatus comprising a die member having a cavity with enlarged ends and with an intermediate portion of lesser cross-section, one of said enlarged ends being shaped to receive a blank of metal having a similar cross section to contact all side portions of the blank, a second die member having a punch of a size to fit into said last mentioned enlarged ends of the cavity of the first die member to contact an end of the blank, and a plastic metal die component of a size to fill the intermediate portion of said die cavity to contact the other

end of the blank and to project into the enlarged cavity portion opposite the punch cavity portion, there being expansion space around said part of the plastic die component into which said component may flow as it supports and contacts part of the blank and as compressive forces on the blank cause deformation of said plastic metal die component.

11. Forging apparatus comprising a pair of relatively movable oppositely disposed die members positioned to engage all portions of opposite ends of a blank to be forged, and a plastic metal die sleeve between said die members and surrounding the remainder of the exterior of said blank whereby said blank may be confined between the die members and plastic metal die sleeve, there being expansion space into which said plastic die sleeve may flow as it supports part of the blank and as compressive forces on the blank cause deformation of said plastic die sleeve.

12. Forging apparatus comprising a die member having a cavity with a bottom, said cavity being shaped to receive a blank of metal having a similar cross-sectional shape to that of the cavity to contact all except the top of said blank, a second die member having a punch, and a plastic metal die component surrounding said punch with said punch and component having a bottom of an area to cooperate during forging in contacting the opposite end of the blank which constitutes the remainder of its exterior whereby said blank may be completely confined between the die members, punch, and plastic metal die component, there being expansion space adjacent at least a portion of said plastic die component into which it may flow as it supports part of the blank and as compressive forces on the blank cause deformation of said plastic die component.

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