

[54] **GLASS CLOTH IN METAL FORGING**
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[52] U.S. Cl. **29/423**
 [51] Int. Cl. **B23p 17/00**
 [58] Field of Search 29/423, 424; 72/41, 42, 72/46

[56] **References Cited**
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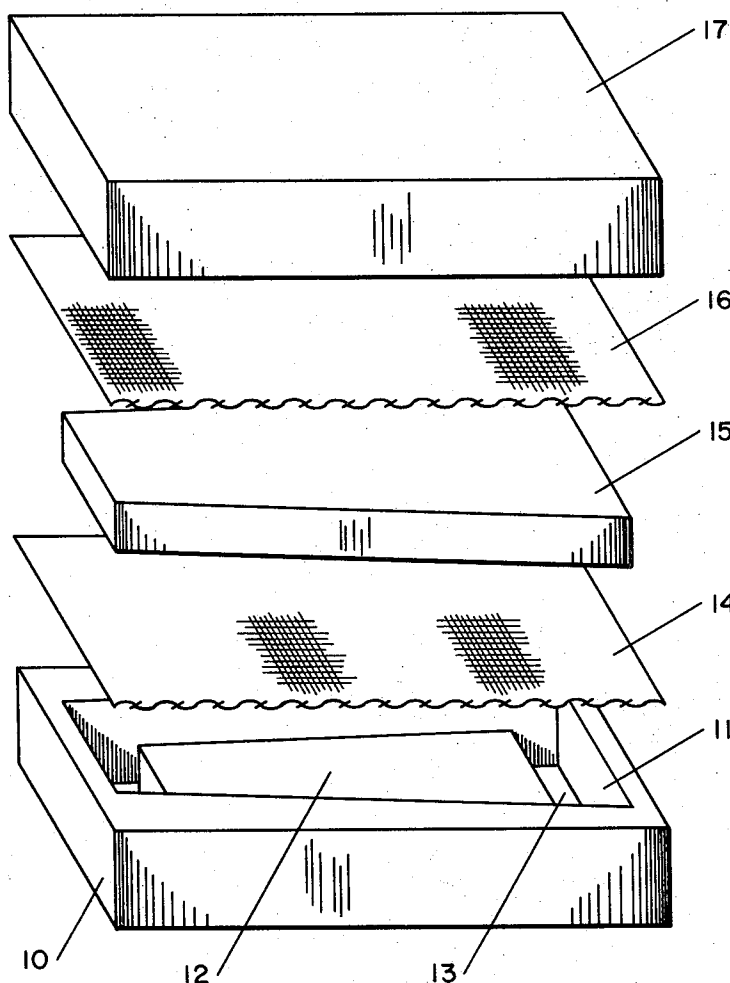
"Forging of Titanium Alloys," Vol. 5, Metals Handbook, Forging and Casting, 8th Edition, 1970, pp. 142-147.

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Assistant Examiner—E. M. Combs
Attorney, Agent, or Firm—Daniel A. Sullivan, Jr.

[57] ABSTRACT

In forging a metal piece which has been heated to a temperature above that of the forging dies, the metal piece is insulated from the dies by glass cloth.

16 Claims, 5 Drawing Figures



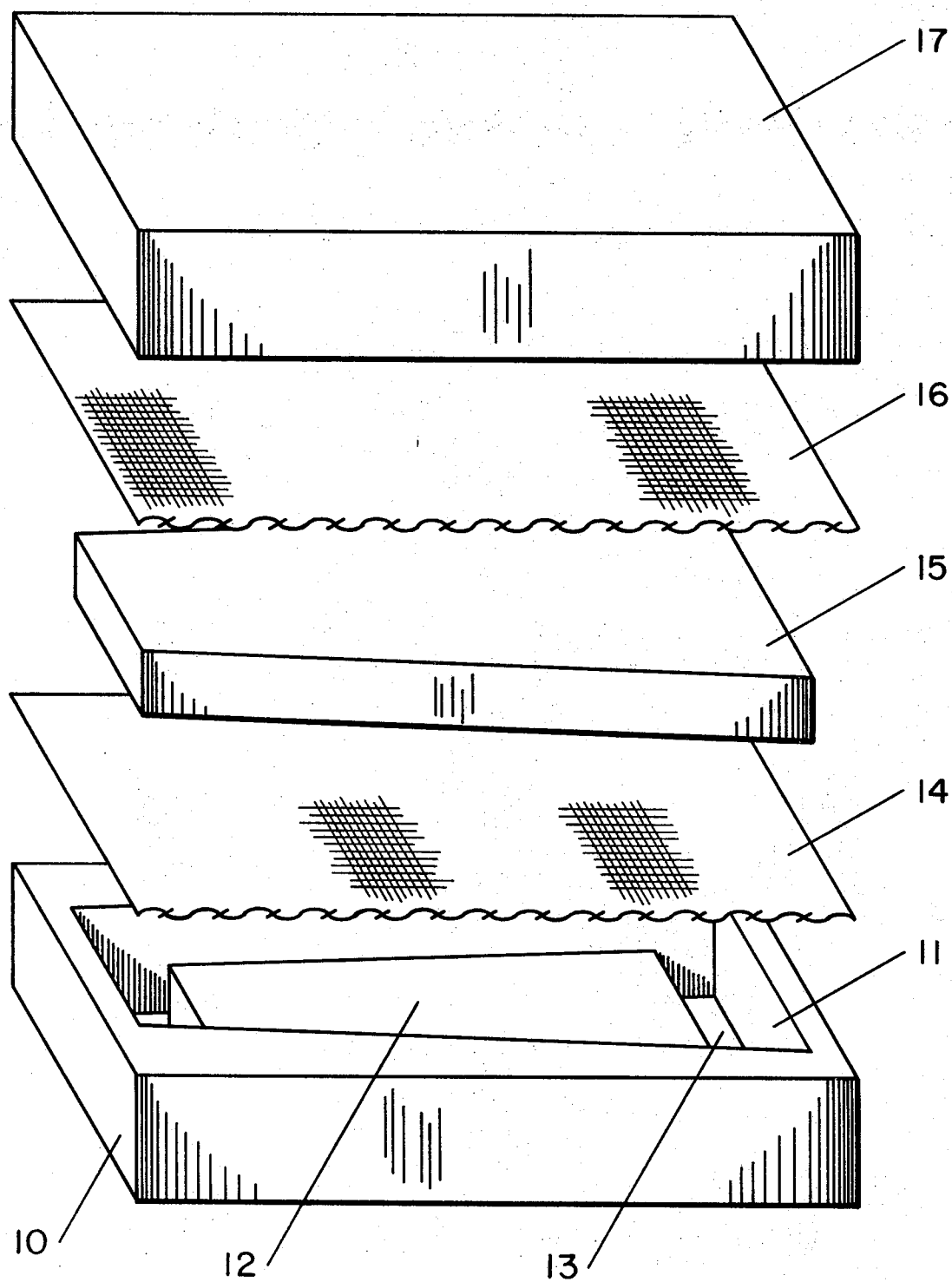


FIG. 1

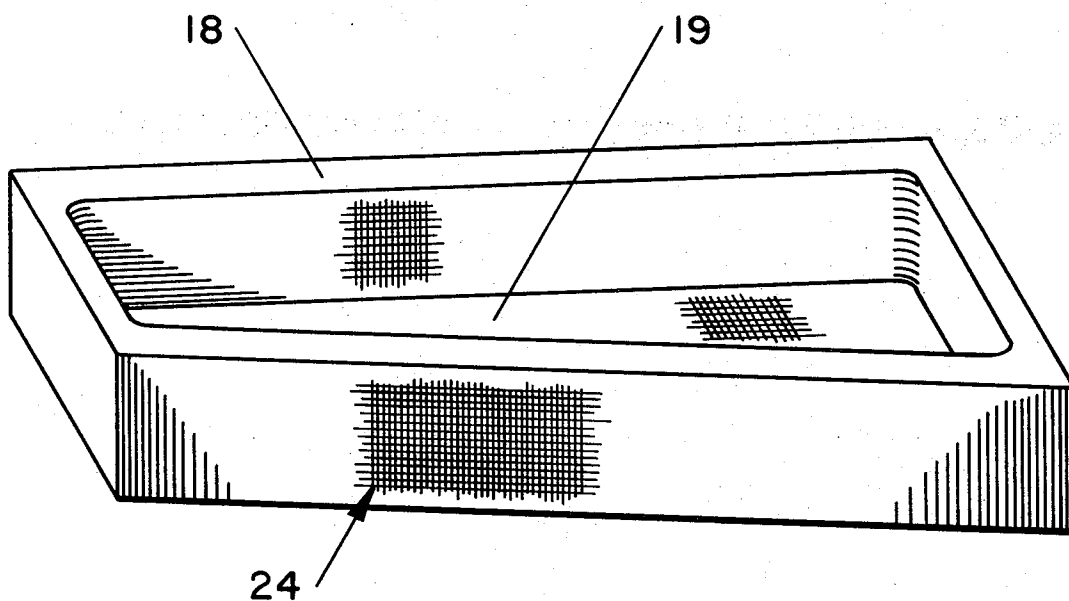


FIG. 2

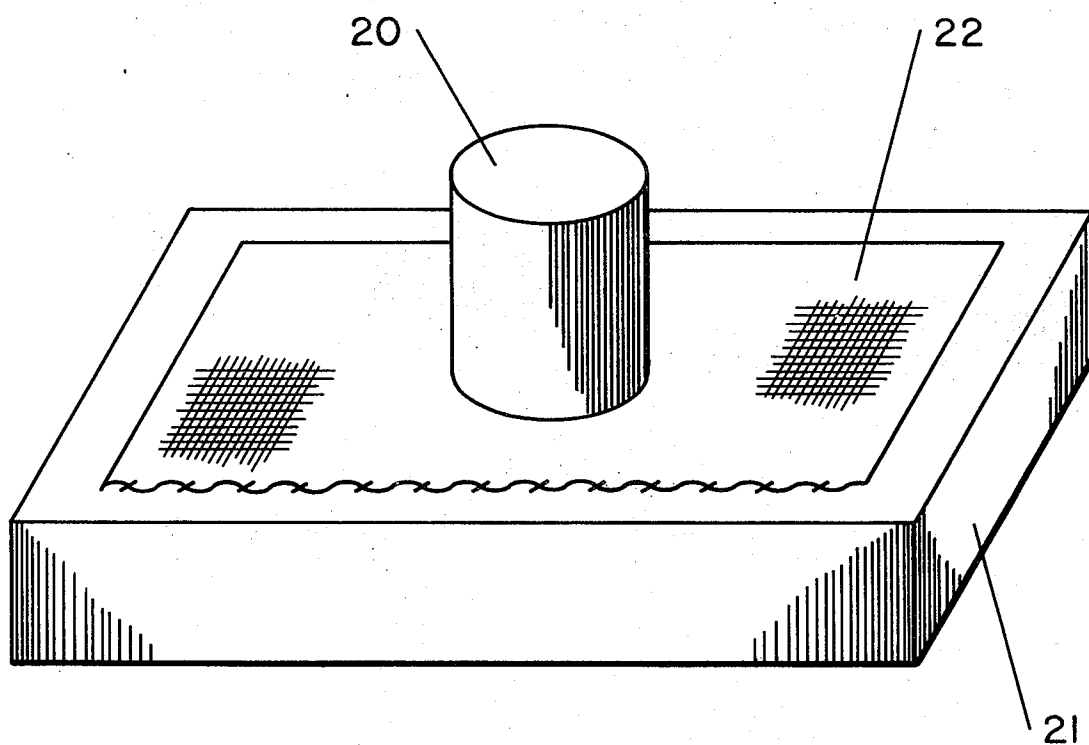


FIG. 3

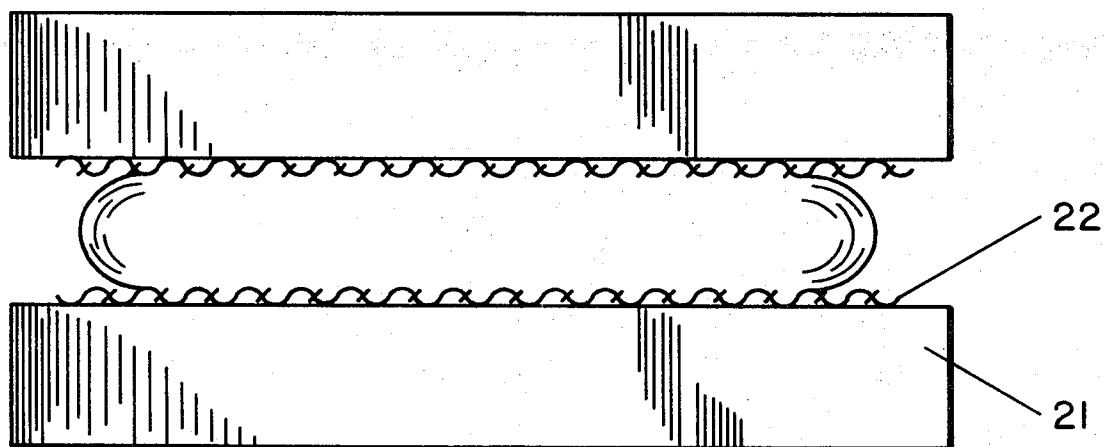


FIG. 4

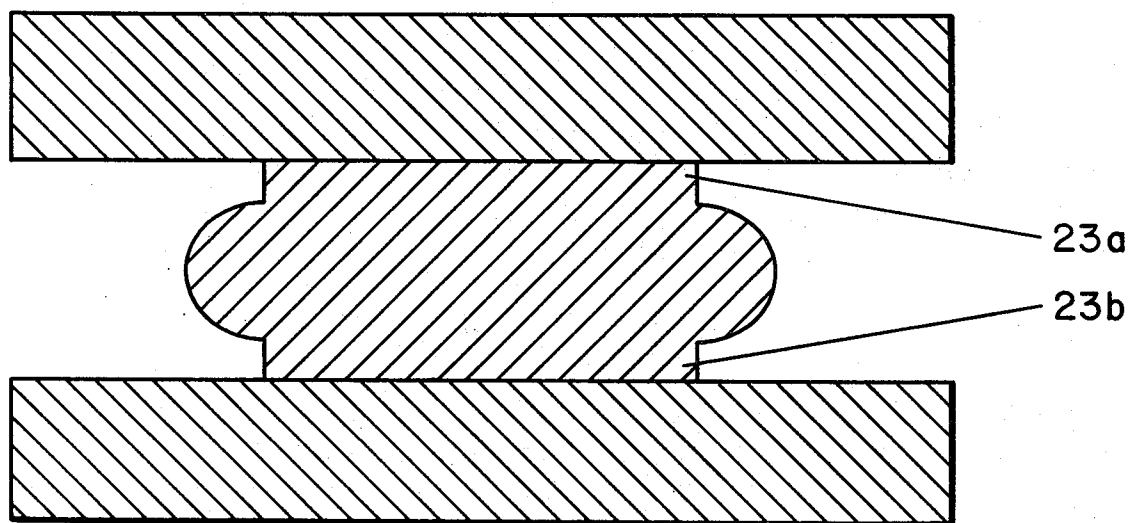


FIG. 5

GLASS CLOTH IN METAL FORGING

BACKGROUND OF THE INVENTION

The present invention relates to the forging of metal and, more particularly, to the forging of titanium.

Background material is provided in the article "Forging of Titanium Alloys" at pages 142 to 148 in Vol. 5 of the METALS HANDBOOK, FORGING AND CASTING, American Society for Metals, 8th edition, 1970, and this article is incorporated here by reference.

As used herein, the term "titanium" refers to any metal containing at least 30 percent by weight of the element titanium.

Titanium forging must be typically carried out at high enough temperature to give the titanium metal piece to be forged sufficient ductility to allow metal flow into the forging die cavities at reasonable times and pressures and to prevent the possibility of cracking of the titanium piece. The forging dies for forging titanium are generally heated to an elevated temperature to prevent their acting as heat sinks, robbing heat from the titanium to be forged. If the titanium metal were to suffer significant temperature depression where it contacts the dies, less, or no, metal flow will occur in the titanium metal at these points of lower temperature. It is generally not economically practical, however, to heat the dies to as high a temperature as the temperature of the titanium piece. Consequently, the forging of titanium alloys still has associated with it, in general, a substantial temperature difference between the piece of titanium alloy being forged and the forging dies. Therefore, before the present invention, it was the normal practice to carry out the forging of titanium alloys by insulating the hotter piece of titanium alloy to be forged from the forging dies using asbestos roll board, which is a pliable asbestos-based sheet material. It had been the practice to apply this material usually in a sheet thickness of 1/16 inch, with a double thickness being used for some applications. Furthermore, in the practice with asbestos, it has been customary to use additional thicknesses of asbestos insulation at those portions of a metal piece to be forged where larger amounts of metal flow are desired. This use of extra thicknesses of asbestos is termed "shimming" or "slugging." This shimming has the effect of achieving selective metal flow at a particular location by exerting pressure first at the portions where metal flow is to be higher. The extra shimming insulation also keeps the metal temperature high and allows the metal to flow more readily.

Asbestos has, however, the disadvantage that it may be harmful to the men carrying out the process. In addition, it has given a pockmarked or pitted surface which is difficult to clean and which often must be machined away before ultrasonic testing can be carried out.

SUMMARY OF THE INVENTION

In view of the above, it is an object of the present invention to provide a substitute for asbestos sheet insulation in forging operations requiring the insulation of the metal piece being forged from the forging dies.

More particularly, it is an object of the present invention to provide an insulating material, novel in the forging of titanium alloys, for reducing heat transfer between a piece of titanium alloy to be forged and the dies used for forging.

Another object of the present invention is to provide a titanium metal product having an improved surface both as regards appearance and as regards amenability to ultrasonic inspection.

These as well as other objects, which will become apparent in the discussion that follows, are achieved, according to the present invention, by a method of forging a metal piece between dies, including the steps of heating the metal piece to a temperature above that of the dies, insulating the higher temperature metal piece from the dies with glass cloth, and squeezing the insulated metal piece between the dies for causing metal flow for forging.

By the term "die," we mean both flat dies, i.e., platens, and dies having contoured surfaces.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an isometric, exploded view illustrating the method of the present invention.

FIG. 2 is an isometric view of a forging made according to the present invention.

FIG. 3 is an isometric view of an alternate embodiment of the present invention.

FIG. 4 is an elevational view of a further stage in the method according to FIG. 3.

FIG. 5 is an elevational, cross sectional view illustrating what can happen in the absence of insulation.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A. FIG. 1

Referring now to FIG. 1, there is illustrated an example of a forging process according to the present invention. The different pieces used in the process are shown in exploded view. From the bottom there is shown a die 10 with a cavity 11, which roughly has an outline, in the horizontal, of a rectangle. Within cavity 11 is a protrusion 12, which is surrounded by a gutter 13. Above die 10 is a glass cloth 14, then a titanium piece 15 which is to be forged to a desired shape, on top of piece 15 a second glass cloth 16, and, finally, the top die 17. The top die has a flat-faced punch section (not shown) which fits into cavity 11 so that pressure may be transferred from appropriate forging equipment (not shown) onto the titanium piece 15 for forging it. The titanium metal piece 15 is hotter than the dies and is insulated against heat loss by the two glass cloths. During forging, the titanium metal is squeezed between the top die 17 and the bottom die 10 and caused to flow under forging pressures into gutter 13 to form the desired shape, which is illustrated in FIG. 2 and which consists of a peripheral rib 18 protruding from one side of a web 19.

B. Outline of the Preferred Process

In carrying out the process of the invention, a preferred and usual practice is as follows.

As is well known in the art of forging titanium, steps must be taken to prevent the buildup of significant thickness of alpha-case on a titanium workpiece while it is being heated in a furnace to forging temperature. Diffusion of oxygen into the piece would, for instance, serve to stabilize alpha-phase at the surface. We prefer to spray a glass frit contained in trichloroethane vehicle onto the titanium piece to be forged, before putting it into the preheat furnace, where the piece is heated to an appropriate forging temperature. The glass frit, for

instance a soda barium glass or a borosilicate glass, melts and forms a protective coating to bar oxygen from reaching the titanium surface where it would act to form a significant alpha-case thickness. It is also possible to exclude oxygen using a vacuum or inert atmospheres.

In conjunction with the preheating of the titanium, the top and bottom dies are heated in a furnace to some die temperature desired for forging. The dies are then removed from the furnace on a mobile car and lifted by a crane for transport to the forging press where they are mounted securely to the press bed and ram, respectively.

Following the mounting of the die members to the press, both the upper and lower dies may be sprayed with a lubricating mixture.

The lower glass cloth may be initially sprayed with a lubricating mixture to give it some weight to allow it to be easily laid down into the cavity of the lower die. The glass cloth usually extends out into the area of the die adjacent to the die cavity, perhaps a distance of 2 inches. The lower glass cloth may be sprayed with additional lubricating mixture after it has been laid into the cavity.

The titanium piece, which has been preheated to an appropriate temperature above the temperature of the dies, is removed from its heating furnace and laid into the cavity of the lower die, where it rests on the lower glass cloth.

The upper glass cloth, which may also have been given a preliminary spraying with a lubricant mixture, is then laid on top of the titanium piece and extends outwards on each side of the slab a distance, for example, of 2 inches.

The pre-spraying of the glass cloths with a lubricant mixture has been found to be advantageous in that it promotes the settling of the lower glass cloth into all of the topography of a die cavity. The pre-spraying also prevents fume-exhaust suction air currents and cooling-fan air currents at the work location from causing the upper or lower glass cloths to blow out of place on a die cavity.

The upper glass cloth may or may not be again sprayed with lubricant mixture, after it rests on the titanium piece.

The lower surface of the top die is usually not sprayed with lubricating mixture, because it is preferred to avoid the cooling effect which would otherwise occur.

The top die is then lowered onto the upper glass cloth and the titanium piece is pressed at sufficient pressure to cause metal flow to fill all of the die cavities.

The resulting forging is then removed from the dies, allowed to cool, and transported to a cleanup area. In the cleanup, various undesired substances are removed from the titanium forging. For example, a scale usually remains as a result of the heating of the forging. Also, remnants of the glass cloth, lubricant residue, and glass coating must be removed. Cleaning may be done by mechanical means such as grit or shot blasting of the forging or by chemical means such as dipping the forging into a hot salt bath, for example, as in one of the Kolene processes available from the Kolene Corporation of Detroit, Michigan.

Following cleaning, the titanium forging is dipped in a hot pickling bath of a combination of nitric and hydrofluoric acids to remove any alpha-case. The forging

may then be inspected and repaired if necessary for further forging operations or for supply as a finished product to the customer.

After carrying out a forging operation, the dies are sprayed with compressed air and/or steam to clean the die cavities for the next cycle.

Focussing on a particular titanium forging to be made, it will typically be forged in stages using a number of die sets - perform dies, first, second and third blocker dies, and finish dies, for example.

C. The Process Parameters

The particular forging temperature to be used to forge a piece of titanium alloy depends upon the particular alloy type. There are three basic titanium alloy types, these being (1) the alpha alloys, (2) the alpha-beta alloys, and (3) the beta alloys, depending upon which is the main phase, or phases, generally stable at room temperature. On this basis, pure titanium is classed as an alpha alloy herein. The temperature of the metal piece to be forged, when it is an alpha alloy, is generally in the range 1,500° to 2,000°F. Preferably, the temperature of an alpha alloy metal piece is kept below that temperature at which grain coarsening begins.

In the case of metal pieces made of alpha-beta alloys, the temperature of the piece is generally in the range of 1,400° to 1,800°F for forging. It may be advantageous to forge a piece of alpha-beta alloy above the beta transus, for example at a temperature in the range from the beta transus to 300°F above the beta transus, for increasing forgeability or for certain property level improvement such as improved notch toughness, as compared with what would be obtained when forging below the beta transus. See the above-referenced "Forging of Titanium Alloys."

For beta alloys, the metal piece to be forged is generally brought to the range 1,325° to 1,850°F.

Die temperature is determined by the balancing of a number of different factors. Die material selection factors are described in general in the sections entitled "Die Steels" and "Factors in the Selection of Die Material" appearing at pages 27 to 30 in the Metals Handbook volume referred to above in the BACKGROUND OF THE INVENTION; these sections are incorporated here by reference. In theory, it should be desired to use a die temperature equal to the temperature of the metal piece to be forged. However, in the case of forging titanium, die material that can serve at a temperature equal to that of the metal piece is usually economically not feasible. Thus, it is often necessary to use a die material which can only be heated to a temperature still significantly lower than the temperature of the metal piece. For example, an AISI Class T2 die steel, for example FX2 steel of A. Finkl and Sons Co., Chicago, Illinois or HARDTEM B steel of the Heppenstall Co., Pittsburgh, Pa., may be usable only at a temperature of from 600° to 800°F, while the metal piece must be at 1,750°F. In general, the initial die temperature will be from 400° to 800°F in the forging of titanium alloys. With economics dictating that there be a difference between the temperature of the metal piece to be forged and the forging dies, the practice had arisen of insulating the metal piece from the dies by the use of interposed asbestos roll board, this to prevent the dies' acting as heat sinks for the heat in the hotter metal piece

to be forged. This is described in the above section entitled **BACKGROUND OF THE INVENTION**.

Glass cloths which may be used according to this invention are woven yarns or strands of glass filaments. A glass cloth which has been found to give very good results at a reasonable price has a warp yarn count of 42 and a fill yarn count of 32, a cloth thickness of 0.007 inch, a cloth weight of 5.8 ounces per square yard, a plain weave, and a tensile strength, as measured by ASTM method 579-45, characterized by a minimum average breaking strength, pounds per inch, of, for the warp, 250 pounds per inch and, for the fill, 200 pounds per inch. Burlington Glass Fabrics Company of New York, New York, supplies such a cloth under the style designation No. 7628.

For ease of handling and cutting, it is preferred to obtain this cloth in the weave-set variety. The term "weave-set" is used to refer to a coating of, for example, polymer or starch for holding the yarn or strands in place in a cloth. The weave may be set with, for example, polyvinyl acetate. When weave-set material is cut, the strands do not tend to fray or fall out, this being otherwise the case when no weave-set is present. Also, weave-set cloth has a stiffness which makes cutting easier. Additionally, it has been found that weave-set cloth lays in place and conforms better to hot surface contours than does cloth lacking weave-set. Weave-set material is also easier to locate for shimming. A glass cloth with a weave-set is, however, not a critical factor in the broader aspect of the invention; it has been found that very satisfactory results can be obtained with glass cloth made solely of strands of glass filaments.

Other glass cloth style numbers which have been tried and found to give satisfactory results are as follows, these cloths being available from the Burlington Glass Fabric Company or from J. P. Stevens and Company of New York, New York: 1,528 having a thickness of 0.007 inch and a weight of 5.95 ounces per square yard, 1,610 having a thickness of 0.0047 inch and a weight of 3.87 ounces per square yard, 7,500 having a thickness of 0.0138 inch and a weight of 9.55 ounces per square yard, and 1,597 having a thickness of 0.0423 inch and a weight of 37.42 ounces per square yard. These may be provided in coated or uncoated styles.

Work with glass cloth will generally cause an itching sensation when a man first starts working with it, but he becomes quickly, i.e. within one day to two weeks, acclimated to this, so that it is no longer felt. All available evidence indicates that there is no health hazard associated with this itching.

We have used what is referred to as "E-glass" as the particular glass composition of the glass cloths. E-glass has a composition as follows: 52-65 percent silicon dioxide, 16-25 percent calcium oxide, 12-16 percent aluminum oxide, 8-13 percent boron oxide, 0-1 percent sodium and potassium oxide, and 0-6 percent magnesium oxide. We have found that there is almost no melting of this composition during a forging operation according to the present invention. The forging comes out of the forging process having impressed on its surface substantially the same weave pattern visible in the glass cloth. This indicates that there is substantially no melting of the glass composition occurring. Looking at the forging removed from the dies, it is possible to still observe the individual strands of the cloth. Some glass beads are noted at the ends of torn pieces

of the cloth, and it is believed that this is an outgrowth of an intermixing, with the E-glass material of the cloth, of the glass frit composition being used to protect against alpha-case growth.

While it is preferred to use woven glass cloth, glass mats, e.g., unwoven assemblages of glass filaments, may also be used.

It is known that a certain amount of lubricating effect can be obtained from the glass frit material used in protecting against alpha-case growth. Thus, there may be a certain amount of lubrication arising here where both glass frit and glass cloth compositions are present. However, it is believed that the glass cloth operates in the present invention primarily through its insulative effect.

Lubricants which may be used in the forging operations are a high load-carrying capacity oil with graphite suspended in it, a high load-carrying capacity oil containing a fatty material in addition to graphite, a high load-carrying capacity oil carrying organic metal compounds, and other standard forging lubricants. Oils of high load-carrying capacity are characterized by resistance to decomposition under forging pressures. Examples of commercial products are Wynn Aluminum 1-A available from the Wynn Oil Company of Azusa, Calif., and Hodson Forging Die Lubricant No. 17 produced by the Hodson Corporation of Chicago, Ill. These commercial products may be cut with additional vehicle for the purpose of reducing lubricant residue buildup.

D. Noteworthy Features of the Process

The present invention is generally applicable in any forging process where there is a difference in temperature between the metal piece to be forged and the forging dies. It has particular application where there is a large difference in temperature, such as is the case in titanium forging, where temperature difference between the workpiece and the dies may be typically 600° to 1,300°F at the start of a forging operation.

In the case of titanium forging, we have found the present invention to be particularly successful in the case of the alloys Ti-6Al-4V and Ti-6Al-6V-2Sn. The present invention is, however, applicable generally in the case of titanium alloys and in particular in those cases where asbestos insulation, such as asbestos roll board, has been used in the past. Glass cloth of 0.007 inch thickness has been found to be equivalent to asbestos roll board 1/16 inch thickness insofar as insulation qualities under pressure are concerned, i.e., temperature fall as a function of time is the same. We have found, however, that in cases where a 1/16-inch asbestos roll board material had been used to provide insulation of the material to be forged from the dies, it is possible to use glass cloth all the way down to 0.004 inch thickness. In certain cases, it may even be possible to go somewhat below this thickness. It is presently preferred to use a thickness of 0.007 inch. As might be expected, it has been found that thicker glass cloths can be used, a glass cloth of 0.04 inch thickness having been actually tried, but the higher cost of the thicker material makes it relatively unattractive as compared to the 0.007 inch thick glass cloth. When using 0.007 inch thick glass cloth material as a one to one substitute for 1/16-inch thick asbestos roll board, it is presently possible to experience a significant materials-cost saving. Even if the glass cloth is used in double thicknesses, there is still nevertheless a very significant cost

saving according to the present invention as compared to practice with asbestos insulation. As an example, in the present invention it is quite often not necessary to machine forgings before subjecting them to ultrasonic inspection. In addition, the surface appearance of forgings made according to the present invention is also aesthetically much more pleasing to the eye than is the surface appearance of forgings produced according to the prior practice using asbestos insulation.

It was unexpected that the use of glass cloth as in the present invention would yield a workpiece surface of much more pleasing appearance as compared to that remaining after the use of asbestos. Additionally, it was unexpected that it would quite often no longer be necessary to machine the surface smooth before carrying out ultrasonic testing.

As an additional advantage of glass cloth, it has been discovered that the practice of shimming or slugging may be performed exactly as it was with asbestos roll board.

E. Examples

Further illustrative of the present invention are the following examples:

Example I

With reference to FIG. 3, the titanium alloy cylinder 20 of alloy-type Ti-6Al-4V, having cylinder dimensions 2 inches in height and 2½ inches in diameter and preheated to a temperature of 1,750°F, has been placed on a lower die-steel platen 21 which is maintained at a temperature of 750°F by heating coils (not shown) in the platen. Interposed between the bottom of the cylinder and the lower platen is a sheet 22 of insulating substance, e.g., glass cloth. Onto the top of the cylinder there is to be placed likewise a sheet of insulating substance and above that another platen also held at 750°F. The 1,750°F temperature to which the cylinder has been preheated is a typical forging temperature for the alloy of which it is formed.

FIG. 4 shows the cylinder after it has been compressed under a load of 30,000 psi. The type of metal deformation shown is that which one would obtain by using insulating sheets of 1/16-inch thick asbestos roll board, a pliable sheet material of asbestos fibers with a clay binder. FIG. 5 illustrates the type of metal deformation that one would obtain by compressing the cylinder using no insulative sheet. According to the present invention, it has been discovered that, as compared with 1/16-inch asbestos roll board, roughly the same reduction in height from 2 inches to 0.8–0.9 inch, and the same pancaked workpiece appearance, is possible when using glass cloth 22 having, for example, a thickness of 0.007 inch. Examination of the upper and lower faces of the compressed cylinders has shown die chill areas of similar dimensions for both asbestos and glass cloth. It has been quite surprising and unexpected to find that glass cloth can give results equivalent to much thicker asbestos material.

Thus, forging of the titanium alloy cylinder using the glass cloth, rather than producing a configuration having the pronounced die chill areas 23a and 23b of FIG. 5 which suggest reduced metal flow, actually yielded the flattened pancake configuration of FIG. 4 which shows significantly more metal flow.

Example II

A forging of titanium alloy Ti-6Al-4V is produced

according to FIGS. 1 and 2. The breadth of the forging at the left end in FIG. 2 is 8 inches, while the breadth at the right end has increased to 10 inches. The length of the forging, left and right in FIG. 2, is 10 feet. Rib 18 attained a thickness of 2½ inches; its height as measured upwards from the plane of web 19, was 1½ inches. The thickness of the web was 1 inch. Glass cloths 14 and 16 were provided as style No. 7628. This cloth, which has a thickness of 0.007 inch and a breadth of 38 inches, was cut to the proper length and then folded down the middle to give material of 19-inches width and double thickness, i.e., 0.014 inch thick. The initial temperature of the metal piece 15 was 1,750°F, while the initial die temperature was 800°F. The forged piece was left with impressions 24 of the glass cloth on its surface and this pattern was much more pleasing to the eye than the pockmarked surface obtained when using asbestos roll board.

It will be understood that the above description of the present invention is susceptible to various modifications, changes, and adaptations and the same are intended to be comprehended within the meaning and range of equivalents of the appended claims.

What is claimed is:

1. A method of forging a metal piece between dies, comprising the steps of heating the metal piece to a temperature above that of the dies, insulating the higher temperature metal piece from the dies with glass cloth, squeezing the insulated metal piece between the dies for causing metal flow for forging, and during said squeezing and forging step, maintaining said cloth in its original filamentary condition so that following squeezing and forging the individual filaments of the glass cloth are still visible.
2. A method as claimed in claim 1, wherein the metal piece is titanium.
3. A method as claimed in claim 1, wherein the metal piece is a titanium alloy of the alpha-type and the temperature to which the metal piece is heated is from 1,500° to 2,000°F.
4. A method as claimed in claim 3, wherein the dies have a temperature of 400° to 800°F.
5. A method as claimed in claim 1, wherein the metal piece is an alpha-beta titanium alloy and the metal temperature to which the metal piece is heated is 1,400° to 1,800°F.
6. A method as claimed in claim 5, wherein the dies have a temperature of 400° to 800°F.
7. A method as claimed in claim 1, wherein the metal piece is an alpha-beta titanium alloy and the step of squeezing is carried out within a temperature range which includes the beta transus and extends to 300°F above the beta transus.
8. A method as claimed in claim 7, wherein the dies have a temperature of 400° to 800°F.
9. A method as claimed in claim 1, wherein the metal piece is a beta titanium alloy and the temperature to which the metal piece is heated is from 1,325° to 1,850°F.
10. A method as claimed in claim 9, wherein the dies have a temperature of 400° to 800°F.
11. A method as claimed in claim 1, wherein the metal piece is heated to a temperature of 600° to 1,400°F above the temperature of the dies.
12. A method as claimed in claim 1, wherein the glass cloth exhibits a pattern and the pattern is impressed

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onto the surface of the metal piece in the step of squeezing.

13. A method as claimed in claim 1, wherein the glass cloth has a thickness of 0.004–0.04 inch.

14. A method as claimed in claim 1, wherein said glass cloth is in the weave-set condition.

15. A method as claimed in claim 1, wherein the step

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of squeezing includes shimming the metal piece with at least one additional thickness of glass cloth.

16. A method as claimed in claim 1, wherein the glass cloth is provided with lubricant before the step of squeezing.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,863,325 Dated February 4, 1975

Inventor(s) Thomas B. Gurganus et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 1, lines 45-46

Change "slulgging" to
--slugging--.

Col. 4, line 9

Change "perform" to
--preform--.

Col. 5, line 7

Change "0,007" to
--0.007--.

Col. 5, line 55

Change "52-65%" to
--52-56%--.

Signed and Sealed this

seventh Day of *October* 1975

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks

Dedication

3,863,325.—*Thomas B. Gurganus*, Avon, and *Leland L. Grubb*, Parma, Ohio.
GLASS CLOTH IN METAL FORGING. Patent dated Feb. 4, 1975.
Dedication filed March 10, 1975, by the assignee, *Aluminum Company
of America*.

Hereby dedicates to the Public the remaining term of said patent.
[*Official Gazette June 24, 1975.*]