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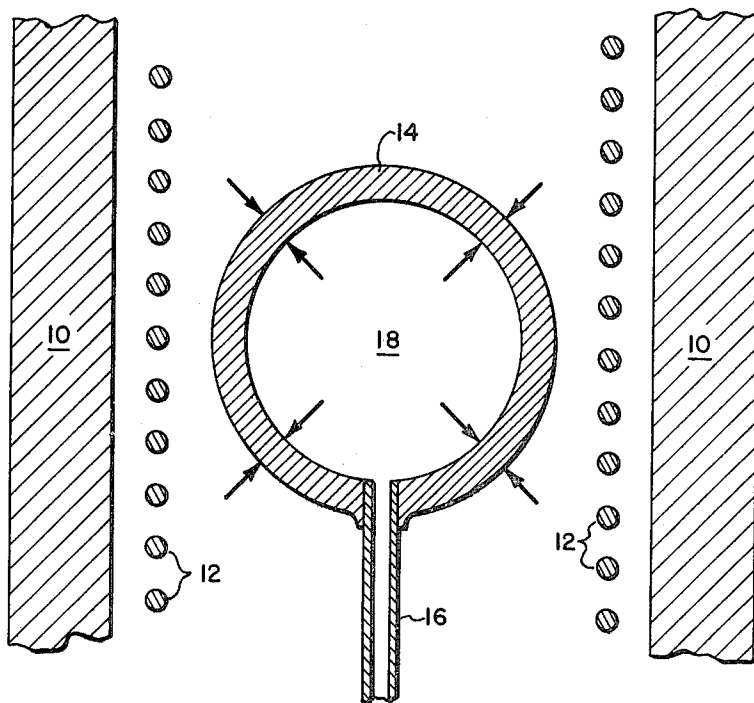
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[54] **ISOSTATIC FORGING**
3 Claims, 1 Drawing Fig.

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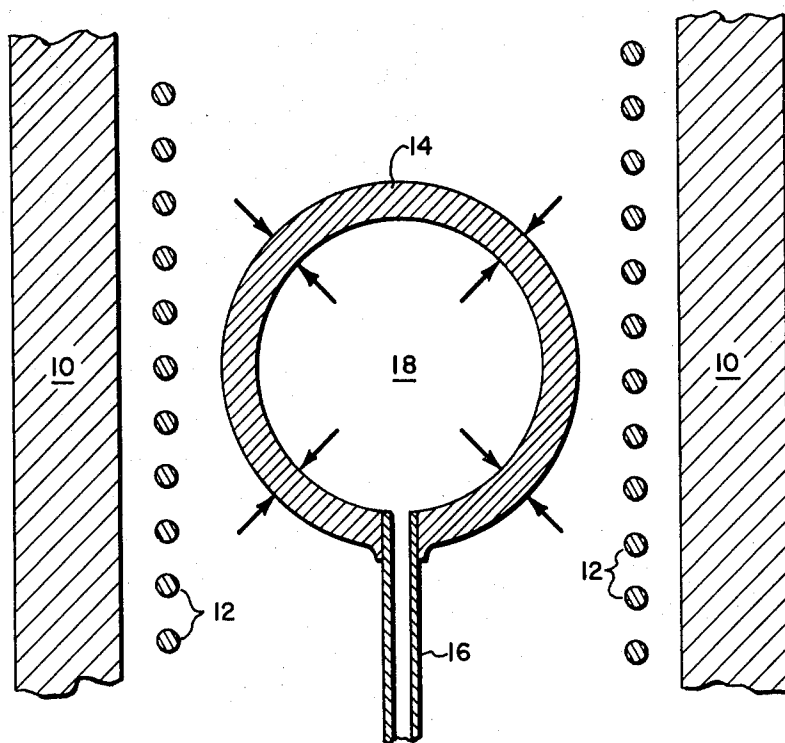
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ABSTRACT: A process for forging hollow bodies comprising preforming the hollow body, sealing the internal cavity of the body, applying isostatic fluid pressure to the interior and exterior surfaces of the body prior to final deformation, and increasing the pressure on one of the surfaces relative to the opposing surface to plastically deform the body to predetermined dimensions.



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ISOSTATIC FORGING

BACKGROUND OF THE INVENTION

This invention relates generally to forging of hollow bodies and more particularly to isostatic forging with a fluid pressure medium.

Forging is defined generally as plastically deforming metal, usually hot, into desired shapes with compressive force. It generally involves hammering or pressing of an ingot or workpiece to consolidate and shape the product, changing at least one of its dimensions in the process. Forging not only produces a product of desired shape but also refines the structure and improves the mechanical properties of the product.

Increasing demands for strength and toughness in all types of metals, especially for use in the aerospace industry, requires the development of methods for producing products meeting such high standards. Conventional forging techniques are very useful in imparting strength and toughness to the more commonly used metals such as the various steels but they are not suitable for forging of certain hard to form and brittle materials. They also are not applicable to forging of products having complex configurations and especially to certain hollow or closed structures such as spherical or elliptical tanks or vessels. Conventional apparatus such as hammers and presses cannot be adapted to produce uniform hollow products with complex configurations. Present methods of hollow forging require the use of a mandrel and involve a great deal of skill. The preparation of a blank for hollow forging is generally done by boring, hot punching, or hot trepanning the ingot, which may result in wasted, discard material or require an additional heating step. Different mandrels are required for each different bore dimension and removal of the mandrels from the forged part without damaging the part requires additional effort and skill. An additional "closing in" operation is necessary where one-piece forgings having openings smaller in diameter than the bore of the body of the forging are desired. It is usually carried out with one or more local reheating and forging operations on the end to reduce the opening. The "closing in" operation locally changes the directional properties of the metal which were developed during hollow forging.

Internal and external cracks or defects can be caused by improper heating or cooling, by deforming an unevenly heated workpiece, or by nonuniform application of forces during conventional forging processes. The occurrence of such defects is much more likely in hard-to-form and brittle materials. They may or may not be cured by subsequent working.

The forging process of the present invention overcomes the limitations of conventional processes and greatly improves the quality of the forged products. It also allows products with complex configurations to be produced easily in a one-step operation. The need for the "closing in" operation, previously required to produce hollow products with restricted openings, is eliminated. Closed, one-piece spherical, elliptical, and other shaped tanks or vessels may be forged in a single operation. The application of heat and pressure as well as the cooling operation is much more uniform than possible with other processes because the product is continuously within a controlled environment. Therefore, the probability of occurrence of cracks and other defects is greatly reduced. The continuous, controlled application of heat and pressure allows routine forging of hard-to-form and brittle materials which heretofore has been difficult or impossible.

Other advantages include the fact that no mandrels are required with corresponding savings in tooling costs. Discard material is substantially reduced or eliminated and additional heating steps are eliminated. Toxic and dangerous materials may be forged with greater ease and safety. Also, high temperatures may be maintained constant for an indefinite period of time. An inert gas may be used for forging at high temperatures to protect the sheet from atmospheric contamination and this often eliminates the need for post-forming pickling operations. In certain instances the forging gas could be used for nitriding or carburizing during forging.

The present invention is an outgrowth of our experience with hot isostatic pressing techniques which have been successfully used for bonding and compacting various materials into finished products. Briefly, these techniques utilize gas pressure at elevated temperatures for joining or compacting metallic or ceramic components or particles. The gas pressure is isostatically (uniformly and equally from every side) transmitted to the article being forged and forces all the mating surfaces into intimate contact. Generally, the only deformation which occurs in these processes is the amount required to bring the components or particles into intimate contact.

It has been found that imposing high-isostatic gas pressures on opposing surfaces of a member or body to be forged will increase its capacity to deform. If the pressure on one surface is increased relative to the other, the member will be uniformly deformed to a much greater extent than in conventional forging. By first applying high pressure to opposing surfaces and later relatively increasing the pressure on one of the surfaces, only a relatively small pressure differential is necessary to forge the article. We believe that the article to be forged may be deformed more uniformly and the state of stress be controlled better than with other forging methods.

The advantages of using a gas as the pressure medium include easier storage and handling and no clean-up is required after the part is forged. The use of gas, and especially inert gas, permits forging at temperatures well above those possible with hydraulic fluids since containment, reaction, and chemical breakdown problems are minimized. Elevated temperatures also reduce the total pressure required for rendering the material more formable. Various forging temperatures, both elevated and cryogenic, can be used to obtain special metallurgical properties such as superplasticity and high strength.

One of the great advantages of the process of the present invention is its adaptability to forging at very low or cryogenic temperatures. Since most materials exhibit significant decreases in ductility at very low temperatures, it is difficult and sometimes impossible to forge them by conventional methods at those temperatures without fracturing. The simultaneous application of pressure to opposing surfaces of the hollow part according to this invention can be used to maintain or increase the ductility of the sheet at temperatures of -250°F . or lower and thereby allow forging where it ordinarily could not be done. The use of a gas as the pressure medium will avoid solidification problems associated with liquids and allow much lower temperatures to be used. Cooling means such as a cryostat may be used within the pressure vessel to maintain the low temperatures during the forging operation. We believe that most materials will exhibit improved properties when forged at cryogenic temperatures.

Although the method of the present invention is particularly useful in forging hard-to-form or brittle materials such as titanium alloys, tungsten, and beryllium, it is also useful in forging more complex configurations of standard materials.

SUMMARY OF THE INVENTION

Hollow bodies may be forged according to this invention by preforming a body of substantially the same shape as the desired finished product, sealing the internal cavity of the body, applying isostatic fluid pressure simultaneously to the interior and exterior surfaces of the body prior to final deformation, and increasing the pressure on one of the surfaces relative to the pressure on the opposing surface to plastically deform the body to predetermined dimensions. This embodiment is particularly useful in forging of seamless or welded hollow bodies such as spherical tanks and the like. Typically the body is rendered ductile prior to final deformation by applying high-isostatic pressure of substantially equal magnitude to the opposing surfaces of the body. The forging may be done at ambient, elevated, or cryogenic temperatures.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a sectional view taken vertically through the center of a gas autoclave and a hollow spherical article being forged therein according to the method of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, reference numeral 10 depicts a portion of a cylindrical pressure vessel adapted to maintain high-fluid pressures on objects positioned therein. Means (not shown) are provided for introducing and selectively controlling fluid pressure within the vessel. The vessel 10 is preferably a high-pressure gas autoclave of the type disclosed by U.S. Pat. No. 3,427,911, Boyer et al., and U.S. Pat. No. 3,419,935, Pfeifer et al. The vessel 10 may be provided with heating means such as the spirally wound resistance heating element 12.

A preformed article such as the hollow sphere 14 is positioned within the vessel 10 for processing. Appropriate assemblies or jigs may be used within the vessel to support the article when necessary. The article to be formed is preformed to substantially the same shape as the desired finished product but one or more of the dimensions such as diameter or wall thickness will be different. The final dimensions of the product will be determined by the forging process. The article may be preformed by welding precast or preformed sections into the desired shape or they may be seamless castings. The article may also be a preformed compact of powdered, granular, or fibrous metals, ceramics, cermets, or any other material which may be formed by forging. When powdered compacts are used, they are generally enclosed in an evacuated, flexible container in the manner which is well known in the field of powder metallurgy.

The hollow article may be of any desired shape, symmetrical or irregular. It may be a closed article such as a spherical or elliptical tank or it may be in a partially closed or tubular form. In the latter case one or more sealing plates will be required to provide the necessary closed chamber within the article. Such plates would be removed after the forging operation is complete.

An inlet tube 16 communicates with the internal cavity 18 through the bottom of the sphere 14 and extends downwardly through the lower wall of the vessel 10 where it communicates with means (not shown) for introducing and selectively controlling fluid pressure within the die cavity. The independent application and control of pressure within the die cavity is critical to the invention and will be discussed in more detail later. The tube 16 is fluidtight sealed to the sphere 14 as by welding or screw-type fitting such that the external pressure medium may not leak into the cavity 18. The cavity 18 is then a separate pressure chamber which allows for independent control of the pressure on opposing surfaces of the sphere. In operation, the sphere 14 is positioned in the vessel 10 and the vessel is sealed. The vessel 10 and the cavity 18 are then simultaneously pressurized to a predetermined level preferably using an isostatic gas pressure medium. The application of pressure is controlled such that no substantial deformation of the sphere occurs at this time. The simultaneous application of pressure is preferably continued until the sphere 14 is rendered more formable. At this point the pressure applied to the outer surface of sphere 14 is raised relative to that applied to the inner surface either by increasing the pressure in the vessel 10 or by decreasing the pressure in the cavity 18. In certain instances the pressure in the cavity 26 must be relieved somewhat during forging to allow for complete deformation. But such pressure is not decreased below the level of the initial, simultaneously applied, pressure. We have found that by forming in this manner only a very small differential pressure is required to plastically deform the sphere to the desired dimensions.

The point at which an article is rendered "more formable" as that term is used herein will vary according to the material used and the temperature at which forging takes place.

Generally, however, the article will be rendered more formable when the applied pressure equals or exceeds the uniaxial yield strength of the material at the temperature of forging. At lower pressures the formability of the material will not be affected to any significant extent. We have found that best results are achieved when forging at a temperature approximately equal to the temperature of maximum uniform strain for that material. Since the temperature of maximum uniform strain for certain materials such as titanium, vanadium, tungsten, beryllium, and chromium is well above the temperature at which hydraulic fluids will break down, gas-pressure forging according to the present invention will expand the field of materials available for commercial applications.

An inert gas such as helium or argon gas is preferred for use as the pressuring medium although other gases or even liquids may be acceptable in a limited number of applications. Due to the cost of helium and argon gas and to convenience of operation, the gas is recycled in storage tanks after the forging operation. At very high temperatures and pressures helium gas has been found preferably for control of temperature and contamination.

It will be understood, of course, that while the form of the invention herein shown and described constitute a preferred embodiment of the invention, it is not intended to illustrate all possible forms of the invention. It will also be understood that the words used are words of description rather than of limitation and that various changes may be made without departing from the spirit and scope of the invention herein disclosed.

We claim:

1. A process for forging hollow bodies comprising the steps of
 - preforming the hollow body of substantially the same shape as the desired finished product;
 - sealing the internal cavity of said preformed body;
 - applying isostatic fluid pressure simultaneously to the interior and exterior surfaces of said preformed body prior to final deformation; and
 - increasing the pressure on one of said surfaces relative to the pressure on the opposing surface to plastically deform said preformed body to predetermined dimensions;
 wherein said preformed hollow body comprises metal particles compacted in an evacuated, flexible container and said body is subjected to the differential isostatic pressure at temperature and for time requisite to compact, deform, and metallurgically bond said metal particles into a forged shape.
2. A process for forging hollow bodies comprising the steps of
 - preforming a hollow body of substantially the same shape as the desired finished product;
 - sealing the internal cavity of said preformed body;
 - applying isostatic fluid pressure simultaneously to the interior and exterior surfaces of said preformed body prior to final deformation; and
 - increasing the pressure on one of said surfaces relative to the pressure on the opposing surface to plastically deform said preformed body to predetermined dimensions;
 wherein the isostatic pressure on the exterior surfaces is increased to reduce the exterior dimensions and thicken the walls of said preform body.
3. A process for forging hollow bodies comprising the steps of
 - preforming a hollow body of substantially the same shape as the desired finished product;
 - sealing the internal cavity of said preformed body;
 - applying isostatic fluid pressure simultaneously to the interior and exterior surfaces of said preformed body prior to final deterioration; and
 - increasing the pressure on one of said surfaces relative to the pressure on the opposing surface to plastically deform said preformed body to predetermined dimensions;
 wherein the external pressure is applied within a high-pressure gas autoclave.

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