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METHOD OF FORGING METALS

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This invention relates to a method forming beryllium metal into various intricate shapes and the unit used for carrying out the process.

The invention is of particular utility in the formation of intricate shapes of beryllium metal and is particularly useful where the beryllium metal, so formed, is to be used as a moderator in a chain reacting neutronic reactor. It is of primary importance in such applications that the beryllium metal be of a high degree of purity.

In the past, the alloying of materials such as titanium and zirconium with beryllium metal have been employed in attempts to secure hot workability of the beryllium metal; but in the use of beryllium metal as a moderator in a neutronic reactor, the introduction of materials having a high neutronic danger coefficient, such as titanium and zirconium cannot be tolerated.

It is, therefore, the purpose of this invention to provide a method of fabricating beryllium metal of high purity into various intricate shapes, and also to produce fabricated shapes possessing over all homogeneity related to the physical structure of the metal.

A more specific object of the invention is to provide a fabricated article of beryllium which is uniform as to physical characteristics so that similar physical properties, such as: thermal conductivity, coefficient of expansion, tensile properties and hardness, will be correspondingly the same in successive fabricated shapes.

A further object of this invention is to provide a method of fabricating beryllium metal by a forging process, whereby the surface of the fabricated beryllium article will be free from imperfections such as galling, warpage and incipient cracks.

In the past, beryllium metal has been one of the very few metals that has not become malleable despite successful attempts to raise the purity of the beryllium metal close to 100 percent. Besides raising the purity through refined methods of reducing the metal from the ore and through distillation of vacuum melted metals, attempts have been also made to secure workability of the metal through controlled grain size.

In accordance with the present invention beryllium metal is encased within a jacket of metal capable of being forged such as steel and copper, wherein the beryllium metal is confined within the jacket; and then the encased billet of beryllium metal is subjected to a forging operation. The beryllium metal is thus fabricated into various shapes as is the jacket material

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encasing the beryllium billet. At the same time the billet is shielded by the jacket material from the atmospheric oxygen so as to prevent oxide formation of the beryllium metal. It has been found that by encasing the beryllium billet with a material which is preferably more readily capable of being forged than the beryllium metal, plastic deformation of the beryllium metal without rupture of the metal is attained. The forging operation produces a fabricated beryllium article which possesses physical properties superior to a cast structure.

When subjecting an as cast billet to a forging operation, it was observed that chilled cast beryllium had no appreciable ductility either in compression or in tension at room temperature; because of this cold working of the metal was not possible. At temperatures around 800° C. or higher the metal tends to exhibit ductility so as to be fabricated by a hot forming process. By studying the curves drawn from the comparative results for compressive strength versus temperature for beryllium metal, it should be noted that the strength properties may be correlated with a decrease in the proportional limit of the metal and that the rate of decrease becomes greater with additional temperature increments wherein the ductility of the metal increased markedly above 600° C. This behavior may be associated with recrystallization temperature of the beryllium metal, which is about 700° C., and also with a change in the mechanism of deformation.

The forging of beryllium was made originally on cast beryllium billets wherein the metal was heated over a varied temperature range from about 500° C. to about 1200° C. and the metal cracked immediately upon light blows of the forging hammer; and the fractures obviously followed the boundaries of the coarse radial crystals. In order to improve the structure of the cast beryllium metal and thus to improve the physical properties, such as malleability and ductility, the teachings of the invention relates to a method of fabricating the beryllium metal by encasing the billet with a forgeable material, such as iron or copper, and then subjecting the encased billet to a forging operation.

The specific requirements of the jacket material is that the metal be readily forgeable under temperature and pressure conditions at which the beryllium metal is to be subjected. Since the beryllium melts at a temperature of about 1264° C.±2°, the maximum working temperature range should not exceed the melting point of the beryllium metal; and preferably, the maximum working temperature of the beryllium metal encased in a jacket shall not be greater than the melting point of the minimum melting temperature of the eutectic alloy of the beryllium metal and the forgeable jacket material.

In accordance with the present invention the forgeable jacket of material should be of such material that when the encased cast beryllium billet is subjected to upsetting so as to break up the columnar grains of the beryllium metal, the jacket material is able to withstand the mechanical forces to which the encased specimen is subjected to under forging operation, The specific advantages of the metal jacket are that the metal jacket will afford an enclosure so as to confine the beryllium metal within the jacket so that when the metal is subjected to a forging operation the beryllium metal will not break apart but will be confined within the metallic jacket. The fabrication of cast beryllium billets by enclosing beryllium with a jacket of forgeable metal affords not only a shield to the beryllium metal as to so reduce the formation of oxides during the operation, but also will afford a lubricating interface between the striking surfaces of the forging hammer and the beryllium metal proper.

In accordance with one embodiment of the present invention it was found that when cast beryllium billets, approximately two inches in diameter and four inches long, were enclosed in a metallic jacket, preferably of soft low carbon steel of SAE 1020 specifications and then subjected to a forging operation, a fabricated shape of beryllium metal may be formed. These steel jackets were approximately one-half inch thick and completely surrounded the beryllium billet. The encased beryllium billet was heated to a temperature in excess of 1160° C. and then subjected to a forging operation. It was noted that by upsetting the encased beryllium billet deformation of the metal resulted and a new shape was attained having superior physical properties as compared with the original cast beryllium billet.

The formation of an objectionable alloy layer at the interface between the beryllium metal and the iron jacket was noted in the fabrication of a beryllium shape when the metal was worked at a temperature in excess of the alloying temperature. This alloy was shown to form at about 1150° C. On comparative operations and according to the alloy phase diagram, a minimum melting eutectic of iron and beryllium will have a melting point temperature of about 1155° C. In order to obviate this alloying condition in the upsetting operation, a layer of an inert refractory material is interposed between the metallic jacket and the beryllium billet by washing the billet with the refractory material and then tamping in the required amount. This layer is approximately $\frac{1}{16}$ of an inch thick. A layer of calcium oxide is preferred in the operation although other refractory oxides such as beryllium oxide and thorium oxide are also satisfactory. Upon subjecting this encased billet having the oxide layer interposed between the metallic jacket and the beryllium metal to a forging operation a superior structure of beryllium metal is obtained. A case beryllium billet can be also jacketed with other materials which are more readily forgeable than beryllium such as copper and satisfactory results can be obtained. An objection to the use of copper may

be primarily accorded to the lower melting point of the copper-beryllium eutectic which is about 865° C. and it has been found that superior fabricated shapes may be obtained when subjecting the beryllium billet to a forging operation in excess of 865° C.; therefore, it is preferable to use a low carbon steel jacket.

The utilization of an inert refractory material interposed between the jacket material and the beryllium billet is primarily used as a mechanical means to separate the boundary interface of the beryllium metal and the jacket material. Since it is desirable to remove the jacket material subsequent to the upsetting operation the use of the oxide layer affords a parting means whereby a relatively simple separation can be obtained and also it reduces the opportunity for the formation of the alloying layer between the metallic jacket and the beryllium metal.

A preferred method for upsetting cast beryllium metal is to encase the beryllium billet with a low carbon steel jacket corresponding to SAE 1020 specifications and then to interpose a thick liner of calcium oxide between the jacket and the beryllium billet. The beryllium billet shall be totally enclosed; and then the jacket assembly shall be completely welded as integral unit. The encased beryllium billet is heated and soaked to a temperature of about 1000° C. and then subjected to a forging operation wherein the encased beryllium billet is forged perpendicularly to the billet axis. It was found that when upsetting the cast beryllium billet in such a manner, superior fabricated shapes of beryllium metal are produced. It also shall be noted that when encased beryllium billets are forged in a side-directional manner satisfactory fabricated shapes are attained. Reductions in area up to about 90% of the original cast beryllium shape can be attained in such practice and the beryllium billet exhibited physical properties which are free from surface imperfections and are uniform as to grain-size, tensile strength, hardness and elongation.

This procedure of encasing a metal to be forged, such as beryllium, may be adapted to other metal materials such as thorium in which a similar forging operation has provided satisfactory fabricated shapes. The interposition of a refractory oxide layer such as thorium oxide between the thorium and the copper jacket has yielded fabricated shapes far superior to those experienced in the conventional manner of forging the metal.

In general, it may be said that the processes disclosed in the present application are illustrative, rather than limiting in scope, and that all of the numerous equivalents and modifications which would naturally occur to those skilled in the art are included in the scope of the present invention. Only such limitations as are indicated in the appended claims should be imposed on the scope of this invention.

What is claimed is:

1. The method of forging beryllium metal comprising the steps of forming a unit by encasing a beryllium billet within an envelope of a metal capable of being forged and interposing a stratum of an inert refractory oxide between the peripheral surface of the beryllium billet and inner surface of the metallic jacket and then subjecting at least a portion of the unit to a forging operation within a range of temperature from about 700° C. to the melting temperature

of the minimum melting eutectic of the beryllium and said forgeable metal.

2. The method of forging beryllium metal comprising the steps of encasing a beryllium billet within an iron jacket and preventing contact between the beryllium billet and the iron jacket by interposing a layer of an inert refractory oxide intermediate therebetween, and then subjecting at least a portion of the encased beryllium billet to a forging operation within a temperature range from about 700° C. to less than the melting temperature of the minimum melting eutectic of the beryllium-iron alloy system.

3. The method of forging beryllium metal comprising the steps of encasing a beryllium billet within a jacket of copper and preventing contact between the beryllium billet and the copper jacket by interposing a layer of calcium oxide therebetween; then subjecting at least a portion of the encased beryllium billet to a forging operation within a temperature range from about 700° C. to less than the melting temperature of the minimum melting eutectic of the beryllium-copper alloy system.

4. A method of forging beryllium metal comprising the steps of encasing a beryllium billet with a low carbon steel jacket, interposing a layer of calcium oxide between the steel jacket and the beryllium metal and then subjecting at least a portion of the encased beryllium billet to a forging operation at a temperature from about 850° C. to about 1150° C.

5. The method of forging beryllium metal comprising the steps of placing a beryllium billet within a metal jacket, preventing contact between the billet and the jacket by interposing a layer of an inert refractory oxide, and subjecting the encased billet to a deformation operation at a temperature above 700° C. and below the melting point of beryllium, said metal jacket having a melting point above the temperature of the deformation operation.

6. A method of forging beryllium metal comprising subjecting a composite unit comprising a beryllium mass, a layer of an inert refractory oxide therearound, and a metal jacket enclosing said layer to a forging operation within a range of temperature from about 700° C. to less than the melting temperature of the minimum melting eutectic of the beryllium and the metal jacket.

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