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BERYLLIUM PRODUCTS AND METHOD

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14 Claims

This invention relates to finished and semi-finished products of beryllium and alloys of beryllium and it is an improvement in the method for the processing of same.

A number of new applications and use have recently been found for beryllium such as for parts embodied in aircraft and space vehicles and in cryogenics such as cold generators. In such applications as in aircraft engines and space ships, use is limited to temperatures less than 500° C. and efforts are being made for improvement in the properties of the products, and particularly in their surface portions, to expand their range of use.

The following are given by way of illustration, but not by way of limitation, of some of the more important of the properties sought to be improved, namely: the two dimensional ductility of semi-finished products, especially when in thin cross-section; resistance to shock, such as initiated by outside particles; resistance to corrosion in various atmospheres and at extremely high temperatures; resistance to abrasion; resistance to friction between moving parts; mechanical bonding thereto as by diffusion of other materials in operation, such as brazing; bonding; and good electrical conductivity, amongst others.

Beryllium has not gained full acceptance because of its sensitivity towards notching and such after effects as loss of ductility, propagation of cracks and the like. It is also faced by the problem of inter-crystalline corrosion, high susceptibility to diffusion of other metals and gases, and toxicity of dusts released by the beryllium during processing.

It is an object of this invention to provide a process which overcomes a number of the deficiencies of beryllium and products formed thereof and it is a related object to provide beryllium and a method and means for processing same to improve upon such deficiencies as notching sensitivity, inter-crystalline corrosion, easy diffusibility of other metals and gases, and the release of toxic dusts.

An important concept of this invention resides in the coating of the beryllium part with at least one layer of at least one plastic metal, such as aluminum, alloys of aluminum, magnesium, zinc and antimony.

The beryllium can be coated with one or several layers of one or a number of the plastic metals by mechanical transformation in a temperature range which is compatible with the ductility of the beryllium and in which the inter-metallic diffusion can be controlled. By way of illustration, but not by way of limitation, the desired metal coating can be achieved by such mechanical transformation as flattening, rolling, drawing, spinning and hammering, with the coating being formed at a temperature below 620° C. and preferably at a temperature within the range of 300-400° C.

It is possible to plate the beryllium to provide a coating of aluminum or an alloy of aluminum or of magnesium, zinc or antimony. It is also possible to apply the coating material in a multi-layered sandwich. Aluminum is preferred as the coating metal because it does not form brittle compounds with beryllium.

The use of pure beryllium or alloys of beryllium which has been cast rather than fritted and has a good ductility at a wide temperature range requires the use of a plating temperature preferably within the range of 300-400° C.

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From a practical standpoint, the temperature range which can be used is much wider. The lower limit is more or less dictated by the ductility of the beryllium which permits the transformation sought to be achieved. It is influenced also by the purity and the structure of the material handled such that it becomes possible to achieve transformation at room temperature.

The upper limit corresponds to the melting point or the temperature of irreversible transformation of the plating metal. It is also influenced by the melting point temperature of the eutectic that is formed between the base metal and the plating metal. For example, the upper limit is a temperature within the range of 600-620° C. for pure aluminum, 550° C. for most of the alloys of aluminum, 380-400° C. for zinc and 580-600° C. for antimony.

The invention will be described with reference to the use of a commercial grade of aluminum having a purity of 99.5%. The technique will be the same for others of the plastic metals with some slight modification depending upon the particular metal, all of which are well within the skill of the art.

The starting material will comprise a sheet of beryllium prepared from a cast ingot by hot transformation in an inert atmosphere, such as by spinning or forging, followed by transformation at a lower temperature, without surface protection, to achieve a reduction by cold working of 50-100%.

The first transformation breaks the coarse structure of the ingot and the second improves the surface characteristics and provides additional refining.

While in this stage, the beryllium sheet can be subjected to various types of mechanical or thermal processing, such as planing or sanding. In all such instances, the laminated surface is of a rather good quality so that deep surface treatment will not be required.

The intermediate product is cut to the desired dimensions and is pickled in a bath of HNO₃+H₂F₂ for removal of the layer of oxide and other surface impurities. It is then introduced into a jacket in the form of a sheet of aluminum which is folded about the product in which the aluminum sheet has previously been degreased and brushed.

The combination is preheated in an electric furnace having a temperature within the range of 400-600° C. and preferably about 600° C. with the heat arising from the bottom of the furnace. The preheating temperature is at least equal to the transformation temperature with the differences being accounted for by the temperature of the tools and the time for handling. After 15 minutes, the sandwich of beryllium and aluminum is removed from the furnace and is rapidly transferred to between heated rollers of a rolling mill. The speed of rolling is 10-20 meters per minute with a reduction of 10-15% being taken with each pass followed by reheating to 600° C. for 5 minutes.

A reduction of at least 50% in cross-section is desired to achieve a good plating operation but a reduction as high as 100% can be employed. Very thorough cold working can be achieved if the beryllium is first annealed but this is not essential to obtain good plating.

After the rolling reduction, the assembly is slowly cooled, preferably while enclosed in an inorganic insulator to minimize the rate of cooling. Thereafter, the product can be cut and machined without the necessity to take other precautions except for the use of sufficient exhaust for the removal of chips which might fall from the product. The chipping off of sharp edges occurs only to a small extent.

Thermal treatments may be employed to overcome the stresses introduced and to improve the plasticity of the

base metal. For this purpose, the plated metal is heated to a temperature which varies somewhat in proportion to time such as 550° C. for 500 hours, 575° C. for 200 hours, or 600° C. for 100 hours. These treatments, which should be carefully controlled, will tend to widen or expand the beryllium-diffusion layer by a substantial amount.

The following examples are given by way of further illustrations, but not by way of limitation, of the practice of this invention:

Example 1

Two layers of 99.5% aluminum are provided on the opposite sides of a sheet of cast beryllium to provide a composite thickness of 4 mm., 80% of which is the cast beryllium sheet. The composite is hardened by hammering or forging to effect a 50% reduction in cross-section after which the composite is given a first anneal at 500° C. The annealed sheet is again forged to effect a reduction in thickness of 140% whereby the final thickness of the composite sheet is reduced to 1.15 mm.

The first anneal is intended to restore the ductility, as measured by a 40° bend on a punch having a 5 mm. radius, before proceeding with the further reduction step.

Depending upon the use, the processed sheet can be employed in the state resulting from the final working or it can be annealed at a temperature of about 600° C.

Example 2

A composite sheet is formed of two sheets of cast beryllium interleaved between three layers of aluminum to give a total thickness of 3 mm.

The following table sets forth the mechanical characteristics of the composite in traction or after a rolling reduction of 50%:

	Elastic limit, kg./mm. ²	Breaking load, kg./mm. ²	Elongation, percent
Rough rolled composite.....	24	24.8	1.3
Composite annealed 48 hrs. at 600° C.....	13	21.1	2.6
Composite annealed 100 hrs. at 600° C.....	13	19.7	3.6

The foregoing characteristics approximate those of non-plated beryllium sheets but the bending characteristics are definitely improved. The bending angle before rupture is 2-3 times greater for the plated sheets by comparison with the bare sheets of the same punch radius. The resistance to shock (Charpy) is also improved 2-3 fold as compared to bare beryllium.

Example 3

Plating of beryllium with alloys of aluminum, in accordance with the practice of this invention, makes it possible to improve a number of the properties of the composite that is formed, such as mechanical strength and corrosion resistance. Aluminum-magnesium alloys can be successfully plated on cast aluminum by making use of a preheat to about 570° C.

The applications will be governed by the characteristics obtained in the product, such as its mechanical, physical and chemical characteristics. The physical and chemical characteristics, which are innate in the surfaces of the plated beryllium, are governed also by the assembly possibilities of such products. The following is typical of the possibilities:

(a) The possibility to create shapes which are thin, as by folding or embossing the aluminum and beryllium sheets prior to the working reduction. The possibility of doing such shaping at low temperature, such as between 200-500° C., will be increased from one to three fold with a layer of plating metal present having a thickness which corresponds to 20-50% of the thickness of the beryllium.

(b) The resistance to shock and to abrasion by particles and the sensitivity due to flaws at the surfaces of the beryllium can be suppressed. For this purpose, it is desirable to make use of a rather thick layer of the plating metal but it is advantageous to use a multi-layer system. Compressor blades are typical of this type of application.

(c) Increased resistance to corrosion by water and by atmosphere is secured. The properties of certain alloys of aluminum can be conferred to the product for use in applications wherein corrosion resistance at high temperature is important such as in aircraft engines, space vehicles and nuclear reactors where the structures of this invention can find application, such as a reflector.

(d) There is the possibility of continuously depositing upon a metal sheet or a composite sheet, a thin layer of the brazing metal, such as an alloy of aluminum with silicon or with zinc, to make it easier to join thin strips for electrical leads at low temperature. The presence of a continuous underlying layer of a metal which is a good conductor, such as aluminum of 99% purity, is desirable to insure that the lead will separate in whole or in part.

As used herein, the term "beryllium" is intended to include beryllium and alloys of beryllium.

It will be understood that changes may be made in the details of construction, processes and operations, without departing from the spirit of the invention, especially as defined in the following claims.

I claim:

1. The metallurgical process for the improvement of the mechanical and physical properties of beryllium products comprising mechanically plating the beryllium with at least one layer of a plastic metal selected from the group consisting of aluminum, magnesium, zinc and antimony at a temperature below 620° C. while mechanically working to effect a reduction in cross-section of at least 50%.

2. The process as claimed in claim 1 in which the mechanical working comprises rolling.

3. The process as claimed in claim 1 in which the mechanical working comprises spinning.

4. The process as claimed in claim 1 in which the mechanical working comprises drawing.

5. The process as claimed in claim 1 in which the mechanical working comprises forging.

6. The process as claimed in claim 1 in which the mechanical plating is carried out while at a temperature within the range of 300-400° C.

7. The process as claimed in claim 1 in which a reduction within the range of 50-100% in cross-section is obtained during mechanical working.

8. The process as claimed in claim 1 in which the beryllium before plating comprises a cast ingot hot worked under a protective atmosphere and then cold worked in the absence of a protective atmosphere to effect a reduction of 50-100%.

9. The process as claimed in claim 8 in which the beryllium is pickled before mechanical plating.

10. The process as claimed in claim 1 in which the plating is performed on the beryllium by wrapping the beryllium in a thin foil of the plastic metal and heating to a temperature within the range of 400-600° C. before mechanically working.

11. The process as claimed in claim 1 in which the beryllium is in the form of a thin sheet and in which the plating metal is in the form of a thin sheet both of which are folded to form interlayers for the mechanically working step.

12. A beryllium product having at least one layer of a plastic metal selected from the group consisting of aluminum, alloys of aluminum, magnesium, zinc and antimony produced by the method of claim 1.

13. A product produced by the method of claim 1 having a core of beryllium with at least two layers of a metal selected from the group consisting of aluminum, alloys of aluminum, magnesium, zinc and antimony.

14. A product produced by the method of claim 11

having a core formed of two layers of beryllium separated by at least one layer of the plastic metal.

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