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SINTERING FURNACE

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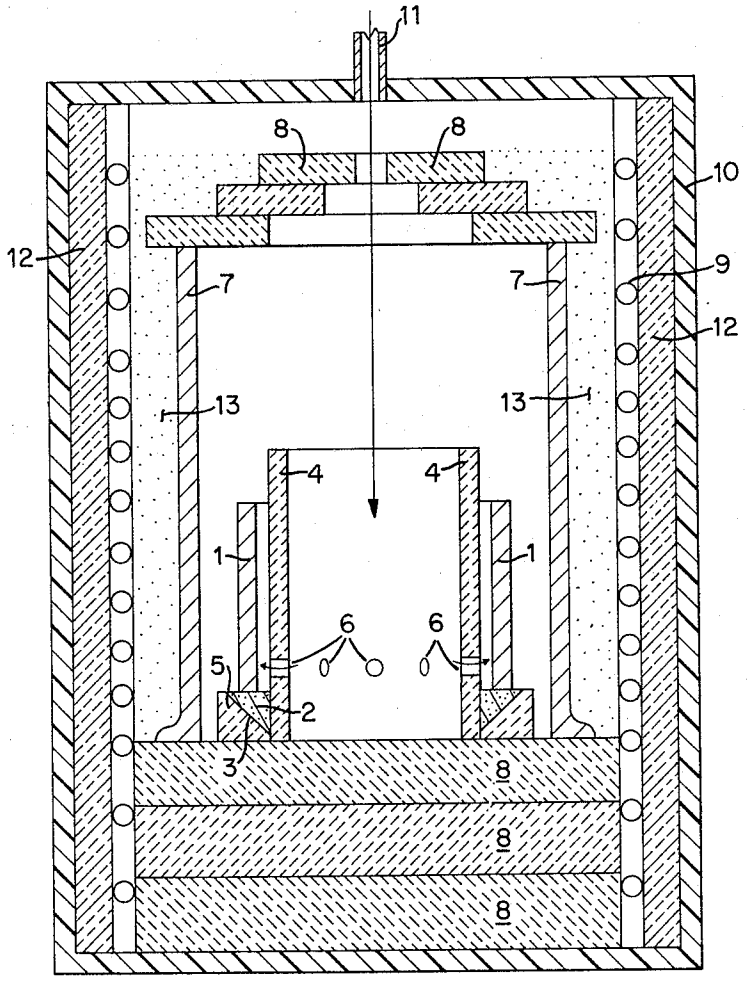


Fig. 1

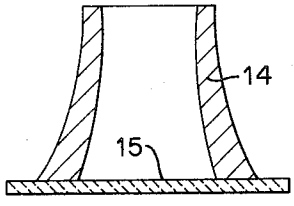


Fig. 2

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SINTERING FURNACE

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This invention relates generally to sintering furnaces and more particularly to an improved sintering furnace for the sintering of large, symmetric powder compacts which are incapable of complete self-support.

Characteristic of sintering operations involving the sintering of large, heavy symmetric powder compacts, has been the problem of compact deformation induced during the sintering operation. Compact deformation during a sintering operation may occur as a result of: the large frictional forces between the base of the compact and the furnace hearth which develop during the sintering operation when the compact shrinks; the gravitational effect which causes large compressive stresses to be experienced in the lower base portions of the heavy compacts; and by the slower cooling rate of the interior surface of the sintered compact which occurs as a result of the compact having shrunk upon a hot solid mandrel during the sintering operation.

Deformation of the heavy powder compacts during sintering is generally characterized by a "belling" or radial enlargement of their annular base portions and a "slumping" or thickening and distortion of their walls producing an S-shaped wall cross section. The "belling" effect is primarily due to the large frictional forces exerted on the compact base portion by the furnace hearth as the compact shrinks during sintering. Although slumping occurs to some degree in all sintering operations involving large, heavy compacts incapable of complete self-support, it is an especial problem in liquid phase sintering which involves a liquidus interval in the sintering process. During the liquidus interval one phase melts and the remaining powder particles are fluid at their points of contact with each other and the sheer weight of the compact causes deformation by forcing interparticle movement.

A further phenomenon associated with the sintering of some large heavy compacts is "internal lapping." Internal lapping is the actual movement of metal in the liquidus phase along a slip plane and is caused by the combination of phase, weight, and non-uniform cooling.

As a result of the above-described deformations which occur during a sintering operation, significant amounts of material must, in many instances, be removed from the sintered compact to produce the desired product configuration.

It is, therefore, a general object of the invention to provide an improved hearth for a sintering furnace wherein deformation of large, heavy symmetric bodies which shrink upon sintering, is reduced.

Another object of the invention is to provide an improved sintering furnace which minimizes the problems of frictional drag, slumping, and internal lapping while enhancing the degree of sintering.

Other objects of the invention will became apparent from an examination of the following description of the invention and the drawings wherein:

FIG. 1 schematically illustrates a sectional view of a furnace with a powder compact positioned on a hearth constructed according to the present invention.

FIG. 2 is a schematic sectional view of a compact sintered in a conventional prior art furnace.

In accordance with the present invention, an improved furnace designed for sintering powder compacts is provided which comprises in combination; a furnace enclosure, an annular hearth disposed within the enclosure,

a hollow cylindrical mandrel whose lower end abuts against the inner surface of the annular hearth, the annular hearth having an inclined upper surface adjacent to and sloping toward the mandrel so as to define an annular trough about the mandrel, and powder having substantially the same sintering characteristics as the powder in the compacts being sintered, filling the trough and forming a support for the compacts during a sintering operation.

To facilitate an understanding of the invention, reference is made to FIG. 2 of the drawings wherein a sectioned view of a powder compact **14** which has been sintered on a prior art conventional hearth **15** is illustrated. It can be seen from FIG. 2, that to produce in final form a perfect right-cylindrical shape, for example, it was heretofore necessary to machine the sintered compact in order to remove the effects of belling and slumping. Such machining increased both the labor and material costs required to produce a sintered compact of perfect shape.

FIG. 1 is a schematic representation of a preferred embodiment of the subject invention incorporated into an induction-type furnace. In FIG. 1, an unsintered hollow cylindrical tungsten powder compact **1** rests on powder **2** which is retained in an annular trough **3** whose sides are defined by the bottom portion of a hollow cylindrical mandrel **4** and a 45° inclined surface of a hearth **5**. Mandrel **4**, which is preferably fabricated from alumina, contains a group of openings **6** spaced about its periphery at a point immediately above the level of powder **2**.

Powder compact **1**, prepared by conventional isostatic pressing techniques, is shown at the start of a sintering operation in its original unshrunken size. Where the powder compact is predominantly tungsten, the compact starts shrinking at about 500° C. and shrinks at an exponentially increasing rate as the temperature rises until it reaches a maximum at about 1250° C. Contact between mandrel **4** and the shrinking compact **1** is designed to occur at or prior to attainment of the liquidus temperature of the compact powder. The liquidus temperature of the powder is that temperature at which the powder particles are fluid, at least at their points of contact with each other. In the subject embodiment, where a predominantly tungsten powder compact is illustrated, the liquidus temperature of the powder is about 1450° C.

Other details of the schematically illustrated induction furnace which are included in FIG. 1 include a tungsten susceptor **7**, a refractory brick enclosure and supporting structure **8**, and an induction coil **9** for generating the alternating magnetic flux which causes heating of susceptor **7**. A Micarta enclosure **10** surrounds the furnace in an airtight manner and a conduit **11** is provided for supplying a purge gas to the furnace interior. Insulating wool **12** and zirconia pellets **13** reduce heat losses from the furnace interior.

The powder **2**, which is hand packed in annular trough **3**, must possess substantially the same sintering characteristics as the powder in the unsintered compact. The easiest way of insuring near identical sintering characteristics in this instance is to employ the same powder mix in the trough as is used in the powder compact. Accordingly, tungsten alloy powder (predominantly tungsten) is used in the subject embodiment which has substantially the same sintering characteristics as the predominantly tungsten powder compact **1**.

It is a requirement of the inclined hearth that it possess an axis of symmetry and that the axis of symmetry of the powder compact be very near coincident therewith during a sintering operation. The hearth radius is chosen to provide a sufficient depth of powder **2** under the unsintered compact. Empirically, a one-half inch depth has proven sufficient.

The internal mandrel 4 supports the sintering compact to reduce slumping thereof. The mandrel is designed with an outside dimension equal to the anticipated inside dimension of the sintered compact. Shrinkage of the sintering compact causes the compact to move against the mandrel which then lends support to the compact, restraining further inward radial shrinkage. The shrinkage which occurs during the remainder of the sintering operation merely reduces the wall thickness of the compact. Care must be taken in selecting a mandrel which has an outside diameter which is not of such a size as to cause the shrinking compact to crack and tear itself apart.

The internal mandrel 4 also serves to dissipate heat from the internal surface of the powder compact while still serving as a support. Planar slippage or internal lapping in the powder compact occurs primarily when the interior surface of the compact cools at a much slower rate than the exterior surface. Solid mandrels, which have been previously used, lend solid support to a powder compact but become hot themselves during the sintering operation and due to their great heat capacity, remain hot following the sintering operation and reduce the cooling rate of the interior surface, thus promoting planar slippage.

The openings 6 through the wall of the mandrel, located near the mandrel bottom and around its circumference, increase gas movement near the compact by permitting natural thermal convection of purge gas down through the center of the mandrel, through the openings, and up through the annular mandrel to powder compact clearance space. When the compact has shrunk upon the mandrel so as to block the clearance space, the volatile materials have been substantially removed from the compact and gas movement is no longer needed.

Although the wall thickness of the hollow mandrel is not critical, it should be made as thin as possible, so long as its ability to support the powder compact remains unimpaired.

The above description of one form of the invention was offered for illustrative purposes only, and should not be interpreted in a limiting sense. For example, the invention is not limited to tungsten and tungsten alloy powder compacts, but can be used beneficially when sintering any powder compact that shrinks upon sintering. The invention may also be used when sintering fragile powder compacts which would fracture during sintering rather than assume the bell shape illustrated in FIG. 1.

It is, accordingly, intended that the invention should be limited in scope only by the claims appended hereto.

Having thus described the invention, we claim:

1. An improved sintering furnace for sintering of symmetrical, hollow powder compacts incapable of complete self-support while sintering, comprising in combination: a furace enclosure, an annular hearth disposed within said furnace enclosure, a hollow cylindrical mandrel having a lower end abutting against the inner surface of said annular hearth, said annular hearth having an inclined upper surface adjacent to said mandrel, said inclined upper surface and said mandrel defining an annular trough, and powder filling said trough for vertically supporting said compacts, said powder having substantially the same sintering characteristics as the powder in said powder compacts, said powder forming a support for said compacts during a sintering operation.

2. An improved sintering furnace for sintering of symmetrical, hollow powder compacts incapable of complete self-support while sintering, comprising in combination: a furnace enclosure, an annular hearth disposed within said furnace enclosure, a hollow cylindrical mandrel having a lower end abutting against the inner surface of said annular hearth, said annular hearth having an inclined upper surface adjacent to said mandrel, said inclined upper surface and said mandrel defining an annular trough, powder filling said trough for vertically supporting said compacts, said powder having substantially the same sintering characteristics as the powder in said powder compacts, said hollow mandrel having a multiplicity of openings about its periphery immediately above the level of said powder filling said trough.

3. The improved sintering furnace of claim 2 wherein said inclined upper surface of said annular hearth is inclined at an angle from 40° to 50° with the horizontal.

4. An improved sintering furnace for the sintering of symmetrical, hollow powder compacts incapable of complete self-support while sintering, comprising in combination: a furnace enclosure, an annular trough whose depth decreases at increasing radial distances from the center thereof, powder filling said trough for vertically supporting said compacts, said powder having substantially the same sintering characteristics as the powder in said powder compacts, and a mandrel disposed within and contiguous to said annular powder-filled trough.

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JOHN F. CAMPBELL, *Primary Examiner.*