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DE-A-2 628 207
US-A-3 856 513
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Description

This invention relates to an apparatus for casting of metal powder, especially metallic glass powder.

Amorphous metal alloys and articles made therefrom are disclosed in US—A—3,856,513. That patent teaches certain novel metal alloy compositions which are obtained in the amorphous state and are superior to previously known crystalline alloys based on the same metals. The compositions taught therein are easily quenched to the amorphous state und possess desirable physical properties. The patent discloses further that amorphous metal powders having a particle size ranging from 10 to 250 µm can be made by grinding or air milling the cast ribbon.

Manufacture of magnetic articles by consolidation of permalloy and other crystalline alloy powders is known, by the DE—A—26 28 207.

By the US—A—4 142 571 an apparatus for casting ribbons of a glassy metal alloy is known, which apparatus comprises a movable chill surface, a reservoir for holding molten metal and a nozzle in communication at its top with the reservoir and having at its bottom an opening in close proximity to the chill surface said chill surface being adapted for longitudinal movement at a velocity of 100 to 2000 meters per minute. Powders cannot be cast directly by this apparatus. If the metal alloys are desired in powder form, for example to be used in a compacting method, the cast ribbons are grinded, ball milled or air milled into powders of desirable size range. To aid the pulverization process˙ ribbon samples are subjected to an embrittlement heat treatment below the crystallization temperature of the alloy.

The objective of the present invention is an apparatus to cast metal powder directly into the final form having a desirable size range.

The apparatus according to the invention comprising a movable chill surface, a reservoir for holding molten metal and a nozzle in communication at its top with the reservoir and having at its bottom an opening in close proximity to the chill surface, said chill surface being adapted for longitudinal movement at a velocity of 100 to 2000 meters per minute, is characteriwed in that the chill surface has a plurality of regularly spaced peaks and valleys, the distance between adjacent peaks ranging from 0.01 cm to 0.1 cm, and the distance from the top of a peak to the bottom of a valley ranges from 0.005 cm to 0.05 cm.

The size of the powder particles thereby produced will vary, depending on the depth of the serrations and the distance therebetween. The apparatus according to the invention typically yields powder particles having a size ranging from 0.01 to 0.1 cm.

Preferably in the apparatus of the invention the nozzle has a slot arranged generally perpendicular to the direction of movement of said chill surface, the slot being defined by a pair of generally parallel lips, a first lip and a second lip numbered in the direction of movement of the chill surface, wherein said slot has a width of from 0.2 to 1 millimeter, measured in direction of movement of the chill surface, wherein the first lip has a width at least equal to the width of said slot, and said second lip has a width of from 1.5 to 3 times the width of said slot, and wherein the gap between the lips and the chill surface is from 0.1 to 1 times the width of the slot.

By use of such metal powders, especially molded magnetic metal alloy articles are produced by a method comprising the step of compacting ferromagnetic glass powder with static pressure at a pressing temperature in the vicinity of the glass transition temperature and below the crystallization temperatures of said alloy, and at a pressure of 69 MPa to 690 MPa. A consolidated, glassy metal alloy body is thereby formed, which is especially adapted to be post fabrication annealed at a temperature ranging from 380 to 450°C for a time period of 1 to 4 hours in the presence of a magnetic field of 0 to 800 A/m. The annealed article has improved impedance permeability and is particularly suited for use in signal and high frequency power transformers and the like.

The invention will be more fully understood and further advantages will become apparent when reference is made to the following detailed description of the preferred embodiments of the invention and the accompanying drawing, which is a schematic representation of apparatus used to cast amorphous metal powder directly from the melt, the apparatus having a serrated casting substrate according to the invention.

As shown in the drawing, the apparatus 10 has a movable chill surface 12, a reservoir 14 for holding molten metal 16 and a nozzle 18 in communication at its top with reservoir 14 and having at its bottom an opening 20 in close proximity to the chill surface 12. The chill surface 12 has a plurality of regularly spaced peaks 22 and valleys 24. Adjacent peaks are separated by a distance, d, of 0.01 cm to 0.1 cm. The distance, y (not shown), from the top of a peak to the bottom of a valley is 0.005 cm to 0.05 cm. Powder is produced directly by deposition of molten alloy on the serrated substrate (chill surface 12) which is a rotatable chill roll, an endless belt (not shown) or the like, adapted for longitudinal movement at a velocity of 100 to 2000 meters per minute. The size of the powder particles thereby produced varies directly with the magnitude of distances d and y.

In the embodiment shown, the nozzle means has a slot arranged generally perpendicular to the direction of movement of the chill surface. The slot is defined by a pair of parallel lips, a first lip and a second lip numbered in the direction of movement of the chill surface. The slot of nozzle 18 has a width of from 0.2 to 1 millimeter, measured in the direction of movement of the chill surface. The first flip has a width at least equal to the width of the slot, and the second lip has a width of from 1.5 to 3 times the width of the slot. The gap between the lips and the chill surface is from 0.1 to 1 times the width of the slot. The preparation of a glassy alloy can be achieved by following the basic teaching set forth in US—A—3 856 513.

Powder adapted for consolidation can comprise fine powder (having particle size under 105 micrometers), coarse powder (having particle size between 105 micrometers and 300 micrometers) and flake (having particle size greater than 300 micrometers). Consolidation can be obtained by pressing glassy metal alloy powder near its glass transition and below the crystallization temperature.

In case low permeabilities (i.e., less than 25) are desired, a particle diameter of less than 105 micrometers is used. For high permeabilities (greater than 100), larger particle diameters of 300 micrometers or more are employed.

For consolidation, powders can be put in evacuated cans and then be formed to strips or isostatically pressed to discs, rings or any other desirable shape such as transformer and inductor cores, motor stators and rotor parts, and the like. Furthermore, powders can be warm pressed below the crystallization temperature and in the region of glass transition temperature into any desirable shapes of the transformer/inductor cores or motor rotor/stator segments. Consolidation is believed to result from mechanical interlocking and short-range diffusion bonding between the powder or flake particles occurring in the vicinity of the glass transition temperature. At temperatures too far below the glass transition temperature (Tg) the particles are relatively hard and are not readily deformed by shear and compressive forces exerted thereon during consolidation. Temperatures too far above Tg enhance the risk of incipient crystallization of the amorphous particles during consolidation. Generally, it has been found that interpartical bonding is best achieved during consolidation at pressing temperatures within 50°C of Tg.

The powders can also be mixed with a suitable organic binder, for instance, paraffin, polysulfone, polyimide, phenolic formaldehyde resins, and then cold pressed to suitable forms. The amount of binder can be up to 30 weight percent and is preferably less than 10 weight percent and more preferably between 0.5 and 3 weight percent for high permeability cores. Such formed alloy can have a density of at least 60 percent of the theoretical maximum. The pressed object can be cured at a relatively low temperature below the curing temperature of the binder to give more strength and then ground to final dimensions. The preferred product of this process comprises shapes suitable as magnetic components. The curing process can be performed with simultaneous application of a magnetic field.

A metallic glass is an alloy product of fusion which has been cooled to a rigid condition without crystallization.

Such metallic glasses generally have at least some of the following properties: high hardness and resistance to scratching, great smoothness of a glassy surface, dimensional and shape stability, mechanical stiffness, strength, ductility, high electrical resistance compared with related metals and alloys thereof, and a diffuse X-ray diffraction pattern.

The term "alloy" is used herein in the conventional sense as denoting a solid mixture of two or more metals (Condensed Chemical Dictionary, Ninth Edition, Van Norstrand Reinhold Co., New York, 1977). These alloys additionally contain admixed at least one non-metallic element. The terms "glassy metal alloy", "metallic glass", "amorphous metal alloy" and "vitreous metal alloy" are all considered equivalent as employed herein.

Examples of alloys suitable for the use in the apparatus of the present invention include the composition

$$[Fe,Ni,Co]_{65-88}[Mo,Nb,Ta,Cr,V]_{0-10}[B,C,S]_{5-25}.$$

Preferred ferromagnetic alloys according to the present invention are based on one member of the group consisting of iron, cobalt and nickel. The iron based alloys have the general composition

$$Fe_{40-88}(Co,Ni)_{0-40}(Mo,Nb,Ta,V,Cr)_{0-10}(B,C,Si)_{5-25};$$

the cobalt based alloys have the general composition

$$Co_{40-88}(Fe,Ni)_{0-40}(Mo,Nb,Ta,V,Mn,Cr)_{0-10}(B,C,Si)_{5-25}$$

and the nickel based alloys have the general composition

$$Ni_{40-84}(Co,Fe)_{4-40}(Mo,Nb,Ta,V,Mn,Cr)_{0-10}(B,C,Si)_{5-25}.$$

An especially preferred alloy has the composition 79 atomic percent iron, 16 atomic percent boron and 5 atomic percent silicon.

Amorphous metallic powders can be compacted to fabricate parts suitable for a variety of applications such as electromagnetic cores, pole pieces and the like. The glassy metal compacts have either high or low permeability. The resulting cores can be used as transformer cores, motor stators or rotors and in other alternating current applications. Amorphous alloys that are preferred for such applications include $Fe_{78}B_{13}Si_4$, $Fe_{79}B_{16}Si_5$ and $Fe_{81}B_{13}Si_{3.5}C_2$.

Claims

1. An apparatus for casting of metal powder comprising a movable chill surface (12), a reservoir (14) for holding molten metal (16) and a nozzle (18) in communication at its top with the reservoir (14) and having at its bottom an opening (20) in close proximity to the chill surface (12), said chill surface (12) being adapted for longitudinal movement at a velocity of 100 to 2000 meters per minute, characterized in that the chill

surface (12) has a plurality of regularly spaced peaks (22) and valleys (24), the distance between adjacent peaks ranging from 0.01 cm to 0.1 cm, and the distance from the top of a peak to the bottom of a valley ranges from 0.005 cm to 0.05 cm.

2. Apparatus as recited in claim 1, wherein said nozzle (18) has a slot arranged generally perpendicular to the direction of movement of said chill surface (12), the slot being defined by a pair of generally parallel lips, a first lip and a second lip numbered in the direction of movement of the chill surface, wherein said slot has a width of from 0.2 to 1 millimeter, measured in direction of movement of the chill surface, wherein the first lip has a width at least equal to the width of said slot, and said second lip has a width of from 1.5 to 3 times the width of said slot, and wherein the gap between the lips and the chill surface is from 0.1 to 1 times the width of the slot.

Patentansprüche

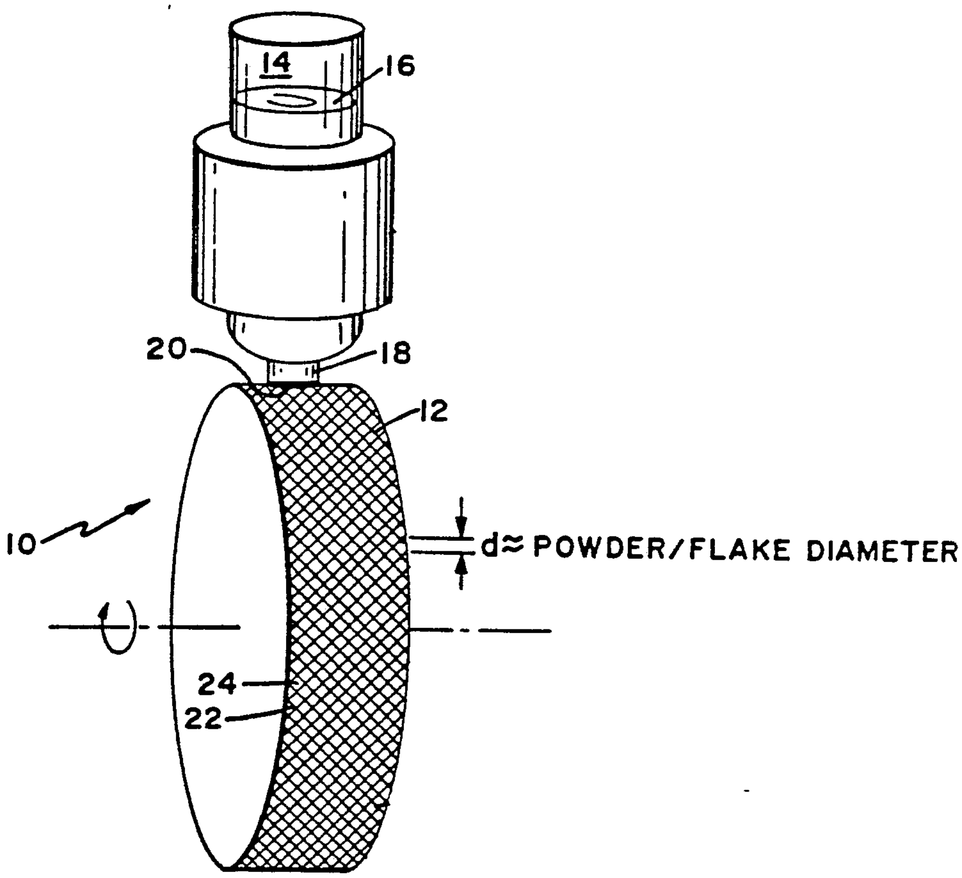
1. Vorrichtung zum Gießen von Metallpulver mit einer beweglichen Kühlfläche (12), einem Behälter (14) zur Aufnahme von geschmolzenem Metall (16) und einer Düse (18), die an ihrem oberen Ende in Verbindung mit dem Behälter (14) steht und an ihrem Boden eine Öffnung (20) in enger Nachbarschaft zu der Kühlfläche (12) hat, wobei diese Kühlfläche (12) für eine Längsbewegung mit einer Geschwindigkeit von 100 bis 2000 m/min eingerichtet ist, dadurch gekennzeichnet, daß die Kühlfläche (12) mehrere in regelmäßigem Abstand voneinander angeordnete Spitzen (22) und Täler (24) hat, wobei der Abstand zwischen einander benachbarten Spitzen im Bereich von 0,01 cm bis 0,1 cm liegt und der Abstand vom oberen Ende einer Spitze zum Boden eines Tales im Bereich von 0,005 cm bis 0,05 cm liegt.

2. Vorrichtung nach Anspruch 1, worin die Düse (18) einen zu der Bewegungsrichtung der Kühlfläche (12) allgemein senkrecht angeordneten Schlitz hat, wobei der Schlitz von einem Paar allgemein paralleler Lippen, einer ersten Lippe und einer zweiten Lippe in der Richtung der Bewegung der Kühlfläche numeriert, definiert wird, worin der Schlitz eine Breite von 0,2 bis 1 mm, gemessen in der Bewegungsrichtung der Kühlfläche, hat, worin die erste Lippe eine Breite wenigstens gleich der Breite des Schlitzes und die zweite Lippe eine Breite des 1,5- bis 3 fachen der Breite des Schlitzes hat und worin der Spalt zwischen den Lippen und der Kühlfläche das 0,1- bis 1 fache der Breite des Schlitzes ist.

Revendications

1. Appareil pour la coulée de poudre métallique, comprenant une surface mobiel de figeage (12), un réservoir (14) pour contenir un métal fondu (16) et une tuyère (18) dont le haut communique avec le réservoir (14) et dont le bas est pourvu d'un ouverture (20) située à proximité immédiate de la surface de figeage (12), la dite surface de figeage (12) étant apte à se déplacer en un mouvement longitudinal à une vitesse de 100 à 2000 mètres par minute, caractérisé en ce que la surface de figeage (12) présente une pluralité de pics (22) et de vallées (24) régulièrement espacés, la distance entre des pics adjacents étant comprise entre 0,01 cm et 0,1 cm, et la distance entre le sommet d'un pic et le fond d'une vallée étant comprise entre 0,005 cm et 0,05 cm.

2. Appareil suivant la revendication 1, dans lequel la dite tuyère (18) présente une fente disposée de façon généralement perpendiculaire à la direction du mouvement de la dite surface de figeage (12), la fente étant délimitée par une paire de lèvres généralement parallèles, une première lèvre et une deuxième lèvre numérotées dans la direction du mouvement de la surface de figeage, dans lequel la dite fente a une largeur de 0,2 à 1 millimètre, mesurée dans la direction du mouvement de la surface de figeage, dans lequel la première lèvre a une largeur au moins égale à la largeur de la dite fente et où la dite deuxième lèvre a une largeur valant de 1,5 à 3 fois la largeur de la dite fente, et dans lequel l'écartement entre les lèvres et la surface de figeage vaut de 0,1 à 1 fois la largeur de la fente.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