

[54] EXTENDED RETENTION OF MELT SPUN RIBBON ON QUENCHING WHEEL

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[51] Int. Cl. B22d 11/06

[58] Field of Search..... 164/87, 276, 283 M; 264/8, 264/165

[56] References Cited

UNITED STATES PATENTS

2,172,018 9/1939 Spencer 164/87 D
3,333,624 8/1967 Cofer et al. 164/87

3,812,901 5/1974 Stewart et al. 164/87

FOREIGN PATENTS OR APPLICATIONS

77,782 11/1970 Germany 264/8

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[57]

ABSTRACT

Thorough quenching of metal filaments extracted from a molten source using a quenching wheel as the quenching source can be achieved by prolonging the period of contact between the extracted molten metal and the quenching wheel until the desired quench temperature is reached. The period of contact may be prolonged by use of such devices as gas jets, moving belts or rotating wheels.

8 Claims, 3 Drawing Figures

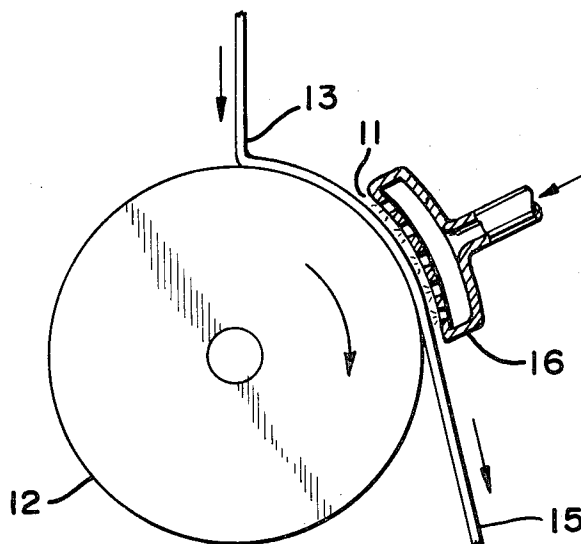


FIG. 1

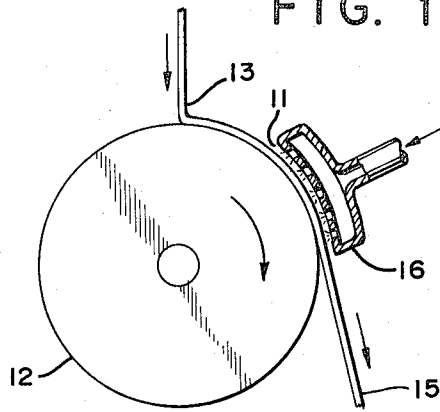


FIG. 2

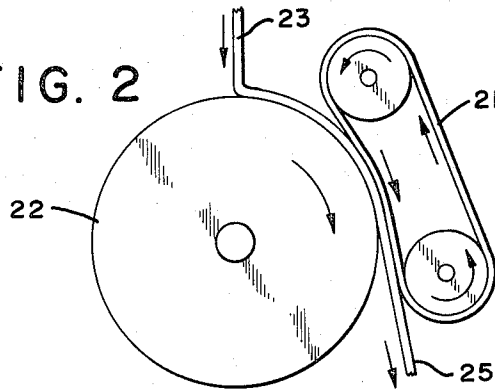
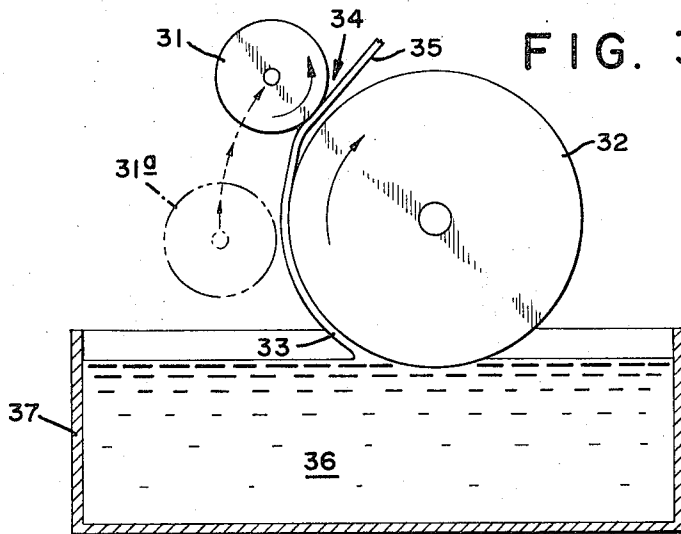


FIG. 3



EXTENDED RETENTION OF MELT SPUN RIBBON ON QUENCHING WHEEL

BACKGROUND OF THE INVENTION

Metal filaments may be produced by extracting from molten metal baths and quenching on a chill or quench wheel. This invention is directed to an improvement in the production of metal filaments, particularly glassy metal filaments, using these chill wheel quenching systems in which the retention time of the metal on the quench wheel is extended to allow for thorough quenching of the metal.

For the purpose of the invention, the term "filament" is meant to include any slender metallic body whose transverse dimensions are much less than its length. These filaments may be ribbon, sheet or wire or may have an irregular cross-section.

Such filaments are presently formed by melt extraction and chill block spinning techniques rather than by the previous casting and extrusion methods.

Melt extraction is a process wherein a cold wheel rotates at high velocity in "kissing" contact with a liquid melt surface. The molten metal wetting or contacting the wheel is carried up out of the molten bath, solidifies, shrinks away from the wheel and is flung off by centrifugal action. This technique is to be distinguished from the essentially casting technique described in U.S. Pat. Nos. 1,025,848 and 2,074,812 in which a cold wheel is substantially immersed in the liquid melt and in which the rotational velocity of the wheel is appreciably lower than in the melt extraction system.

Chill block spinning is exemplified by U.S. Pat. Nos. 2,825,108 and 2,886,886 and 2,899,728. In this process, a free jet of molten material is impinged upon a moving quench surface, preferably a rotating wheel or continuous belt. The molten jet is then quenched in a manner similar to that of the melt extraction system previously described.

In another adaptation of chill block spinning, the molten metal is ejected into the nip between two rotating wheels whose boundaries define a wedgelike shape convergent in the direction of flow with the boundaries in motion towards a point of convergence, the motion creating sufficient pressure to force the material between the rolls. This adaptation is discussed by H. S. Chen and C. E. Miller in Rev. Sci. Instrum. 41, 1237 (1970).

In any of the above-described methods, there is considerable heat exchange between the quench wheel and the molten metal without adequate temperature reduction. The excess heat absorbed by the wheel reduces the quenching capability of the wheel thereby decreasing the effective rate of chill and the efficiency of the quenching system. The efficiency of the system can be expressed as:

heat removed by wheel from melt extract product
heat removed by wheel from melt

Due to the low efficiency of the system and the excess thermal exchange, the metal often is not quenched sufficiently before the centrifugal forces cause it to depart from the wheel. This incomplete quenching leads to products possessing some undesired properties including relatively large grain size in polycrystalline metals and some crystalline structure in desired amorphous metal products. Thus, in the case of polycrystalline metals, rapid and thorough solidification is advantageous since it produces filaments of finer grain size with

better attendant physical properties and also avoids the problems, such as embrittlement, associated with oxidation. Moreover, in order to achieve completely amorphous or glassy metals or ceramics, it is essential that the molten stream be quenched below the characteristic glass transition temperature and at sufficiently high quench rates so as to avoid nucleation and growth of crystalline material in the amorphous structure before it departs from the chill wheel and thus departure should be delayed until after the glass transition temperature is achieved.

The nature of polycrystalline materials is such that the material possesses a sharp melting point that is, the solidus-liquidus transition period is at most about 5°C. In contradistinction thereto, in amorphous metals, there is a transition range often well in excess of 400° through which the viscosity of the metal gradually increases until the critical glass transition temperature is reached. For example, while the melting point of an Fe₃₈ Ni₃₉ P₁₄ B₆ Al₃ alloy is about 920°C, the glass transition temperature for the same alloy is 386°C. Thus it is necessary to quench the metal over a range of approximately 600° at such a rate that it does not leave the quenching source before the glass transition temperature is reached.

In the production of glassy or amorphous metals, it is important to realize that although the necessary quench rates can, in many cases, be realized by bringing the subject materials, in appropriate geometry, into thermal contact with a chill wheel, there still exists the requirement that the ultimate quench temperatures be assured when quenching at these rates. Premature departure from the chill wheel will interrupt the general process before these temperatures can be realized.

SUMMARY OF THE INVENTION

Thus there is an obvious need for a method to thoroughly quench metal filaments before ejection from the quenching means.

It is an object of the invention to provide a method for thoroughly quenching metal produced by a chill wheel extraction or chill wheel spinning system before the metal is ejected from the wheel.

It is an additional object to provide a method for quenching a molten extract to below its glass transition temperature before ejection from the chill wheel thereby producing a completely amorphous filament.

It is a further object of the invention to provide an improved apparatus for use in the melt extraction or chill block spinning of metal filaments.

These and other objects will become apparent from the following descriptions and examples.

I have discovered that thorough quenching of metal filaments extracted from a molten source using a quenching wheel as the quenching source can be achieved by preventing separation of the metal from the wheel, thereby prolonging the period of contact between the molten metal and the quenching wheel until the desired quench temperature of the filament is reached.

The necessary retention time may be expressed by the following inequality:

$$RT_c \geq Tm.p. - T_g/Q_a, \text{ where } Q_a \geq Q_c$$

where RT_c is the critical retention time, $Tm.p.$ is the melting temperature of the alloy, T_g is the glass transition temperature, Q_a is the actual quench rate and Q_c

the critical quench rate. It is apparent that the critical quench rate will be a function of many variables including such properties of the filament and substrate as thickness, thermal conductivity and heat capacity.

In accordance with the procedure of the present invention, I have found a variety of methods for extending the retention time of the molten stream on the quenching wheel. Such methods include the use of gas jets, belts or wheels as retention devices when used in a manner which insures that the metal will not separate from the quench wheel until such time as the desired quench temperature is reached.

An improved apparatus for the production of metal filaments may be constructed by incorporating at least one of the retaining means disclosed in the present invention into any conventional melt spinning apparatus which employs a quenching wheel as the quenching element.

It is to be understood that any of the methods discussed herein can be adapted to the production of metal or ceramic filaments, ribbons or sheets.

Additionally, any of the retaining devices disclosed herein may be used in either melt extraction or chill block spinning apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 represents the application of gas jets as retention devices.

In FIG. 2 a moving belt is used as the retention device.

FIG. 3 represents the use of a rotating wheel to retain the metal which has been extracted from a molten metal bath.

PREFERRED EMBODIMENTS OF THE INVENTION

In accordance with the invention, various methods may be adapted to assure retention of the filament on the quench wheel for the requisite extended period. Specific illustrative methods are discussed below.

One or more gas jets 11 could be employed, as in FIG. 1, to impinge inwardly against the forming metal filament stream 13 on the wheel surface 12 thus providing sufficient centripetal force to prevent the metal from departing from the wheel until the desired temperature is achieved and the filament 15 is then ejected. Furthermore, by thus keeping the filament in contact with the wheel as the filament cools, the simultaneous contraction of the cooling filament achieves better contact with the wheel rather than causing a separation, as happens when the filament is not prevented from departing from the wheel. If desired, the gas may be cooled prior to impingement and it will thereby serve a dual purpose by aiding in the cooling of the metal filament and the wheel itself. Since the outer surface of the metal has solidified before the metal is exposed to the gas jets, there is no difficulty concerning the choice of gas to be used since no reactive sites on the metal surface are exposed. For reasons of economy and availability, compressed air jets appear to be the most convenient and effective gas source. The gas 11 may be impinged on the metal surface 13 directly or, for more effective concentration, through a gas manifold 16.

FIG. 2 shows the application of a flexible moving belt 21 which contacts the quenching wheel 22 so as to confine the metal stream 23 from departing from the wheel

throughout the period of contact between the belt and the wheel, thus providing sufficient retention time to form the desired metal filament 25. In this embodiment, the two contact surfaces would be traveling co-directionally with the belt moving at least as fast as the wheel to prevent rippling or kinking of the metal product, thereby avoiding premature loss of contact between the ribbon and the quenching wheel. The belt could be composed of a thin sheet of beryllium copper or any other durable, preferably thermally conductive material. If additional cooling is required, the belt could be adapted to contain a cooling source.

FIG. 3 represents still another embodiment of the present invention in which the metal stream 33 is extracted from a molten bath 36 contained in a suitable reservoir 37. In this embodiment, the application of a second wheel 31 or series of wheels functioning as a retaining wheel, to the surface of the forming filament 33 at or near the surface of the quenching wheel 32 will retain the molten stream 33 on the quenching wheel until the filament passes the retaining wheel 31, at which point 34 the satisfactorily quenched metal filament 35 is ejected from the quenching system. In the embodiment, the contiguous or nearest surfaces of the retaining wheel will be traveling in the same direction with the quenching wheel surface and at least as fast as the surface of the quenching wheel so as to prevent rippling or kinking of the metal product, thus avoiding premature loss of contact with the quenching wheel. The retaining wheel may be made of any thermally conductive material and will be kept sufficiently cool by the surrounding atmosphere since the outer surface of the ribbon will already have been quenched prior to contacting the retaining wheel. However, if desired, the wheel can be adapted to act as an additional cooling source. Also, if the quenching wheel is to come into actual contact with the retaining wheel, the latter should consist of a sufficiently flexible material in order to avoid bouncing and denting of the two wheels.

In order to achieve the physical configuration of FIG. 3, wherein the solidifying metal filament is passed well around the quenching wheel prior to contacting the retaining wheel, the retaining wheel can first be situated in the configuration 31a and then swing in an arc to carry the departing ribbon around the quenching wheel to the position 31 as shown.

when using the double quench wheel technique of Chen and Miller previously described, the solidifying filament, upon passing the area of contact between the two rollers, is directed by the retaining device onto the outer surface of one of the rollers, in a manner similar to that of any of the previously described methods until it achieves the necessary quench temperature.

It is obvious that the use of these methods and any other methods for extending the retention time could be adapted for use with either the melt extraction or chill block spinning methods of filament forming presently employed in the art.

By utilizing these methods in accordance with the present invention to retain the metal stream against the quenching wheel surface so that it cannot depart under radial acceleration or any other separating factors, the cooling of the metal to below the glass transition temperature becomes assured in the production of amorphous metals. Additionally, in the case of polycrystalline metal products, the cooling can be controlled to assure sufficient quench temperature to achieve a fine

grain sized product possessing the superior physical properties.

Moreover, the practice of this invention permits the retention of greater masses of product on the quench wheel, resulting in thicker filaments than have heretofore been produced. In these thicker products, the filamentary stream is more strongly thrust away from the wheel by the centrifugal forces. Thus, these deposits, by nature of their greater masses, require longer contact with and greater heat transfer to the wheel to achieve the required quench conditions. Previously, it has been possible to produce filaments of thickness in the range of about .002 cm to .004 cm. Using the procedures described herein, filament .008 cm in thickness have been achieved.

The following examples are meant to be illustrative and the invention is not meant to be limited thereto. All parts are in atomic percents less otherwise noted.

EXAMPLE 1

An alloy formulated to be amorphous upon quenching and consisting of 35 atomic percent iron, 42 percent nickel, 14 percent phosphorus, 6 percent boron, and 3 percent aluminum was charged in an apparatus for chill block spinning. The charge was melted in an argon atmosphere to 1,100°C and then ejected at a rate of 300 cm/sec through an orifice onto a 20.3 cm diameter, 1.27 cm wide chill wheel rotating at 2,500 rpm and composed of oxygen-free high conductivity copper. Upon subsequent ejection from the wheel, the filament was analyzed and found to contain greater than 25 percent polycrystalline structure.

EXAMPLE 2

Again, for the purposes of comparison, the alloy of Example 1 was similarly charged, melted and ejected onto a 20.3 cm diameter chill wheel rotating at 2,500 rpm. In accordance with the procedure of the invention, compressed air jets were directed upon the surface of the metal filament through a gas manifold for a sufficient period of time to allow the metal stream to achieve its glass transition temperature. After passing through the manifold, the solidified filament was ejected from the chill wheel. Upon analysis of the resulting filament, it was found to be totally amorphous.

EXAMPLE 3

An alloy formulated to be amorphous upon quenching and consisting of 76 percent Fe, 15 percent P, 5 percent C, 3 percent Al and 1 percent Si was charged in an argon atmosphere and melted at 1,000°C. A molten stream was then ejected onto a chill wheel system similar to that depicted in FIG. 2. A flexible moving beryllium copper belt was allowed to contact the quenching wheel and the filament was thus retained upon the chill wheel for an extended time, sufficient to produce a filament of totally amorphous structure as determined by x-ray diffraction.

EXAMPLE 4

An alloy formulated to be amorphous upon quenching and comprising $\text{Ni}_{48}\text{Fe}_{30}\text{P}_{14}\text{B}_8\text{Al}_2$ was melted at 1,020°C. in an inert atmosphere and then ejected into the nip of two tool steel rolls rotating at 1,500 rpm. After passage through the nipped area, compressed air jets were directed onto the filamentary stream to confine the metal to the surface of one of the rotating rolls

for a time sufficient to allow the interior of the filament to reach a temperature below its glass transition point. Using this method, an amorphous ribbon 0.012 cm in thickness and 1.27 cm in width was formed.

EXAMPLE 5

A grey iron alloy containing about 3.4 percent carbon, 2.2 percent silicon, 10.6 percent manganese, 0.2% phosphorus, and 0.1 percent sulfur was melted at 1,200°C. in a conventional melt extraction apparatus. The quenching wheel consisted of oxygen-free high conductivity copper with a 20.3 cm outside diameter and rotated at 1,800 rpm. The level of the melt in the crucible was raised by opening the valve to the connecting reservoir. The liquid metal substance was brought into contact with the rotating quench wheel and subsequently ejected from the system by centrifugal force. The resulting polycrystalline filament was analyzed and found to contain relatively large grain structure.

EXAMPLE 6

The alloy of Example 5 was charged and extracted using a similar apparatus to that depicted in FIG. 3. The retaining wheel was swiveled to a remote position and formation of the filament was begun. When the filament passed into the area of the retaining wheel, the wheel was actuated to its closed position thereby confining the metal from departing from the wheel until complete solidification occurred. When the metal filament so produced was analyzed, it was found to contain very fine grain structure.

What is claimed is:

1. In a method for the production of metal filament from a molten source using a rotating quench wheel as a quenching element upon which a molten filament is deposited, the improvement which comprises prolonging the period of contact between the deposited filament and the quenching wheel by external means acting on said deposited filament, said external means being applied over an elongated portion of the deposited filament thereby preventing separation of the filament from the quench wheel, which would result from the centrifugal force of rotation of said wheel acting on said filament, until the quench temperature of the filament is achieved.
2. The method of claim 1 wherein said external means to prolong the period of contact between the deposited filament and the quench wheel is a co-directional rotating surface.
3. In an apparatus for the production of metal filaments by depositing a molten filament upon a rapidly rotating quenching wheel as a quenching element, the improvement which comprises applying an elongated external retaining means on said filament while it is being quenched on said rotating quenching wheel to extend the period of contact between the deposited metal filament and the quenching wheel.
4. The apparatus of claim 3 in which the retaining means is a gaseous stream.
5. The apparatus of claim 3 in which the retaining means is a moving belt.
6. The apparatus of claim 3 wherein the retaining means contains therein an auxiliary chilling means.
7. In a method for the production of metal filament from a molten source using a rotating quench wheel as a quenching element upon which a molten filament is

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deposited, the improvement which comprises prolonging the period of contact between the deposited filament and the quenching wheel by an auxiliary wheel spaced from the quench wheel thereby preventing separation of the filament from the quench wheel which would result from the centrifugal force of rotation of said wheel acting on said filament, until the quench temperature of the filament is achieved.

8. In an apparatus for the production of metal fila-

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ments by depositing molten filament upon a rapidly rotating quenching wheel as a quenching element, the improvement which comprises utilizing an auxiliary retaining wheel, spaced from the quenching wheel, to retain said filament while it is being quenched on said rotating quenching wheel to extend the period of contact between the deposited metal filament and the quenching wheel.

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