

[54] **CONTINUOUS CASTING OF NARROW FILAMENT BETWEEN ROTARY CHILL SURFACES**

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[52] U.S. Cl. **164/87; 164/276; 425/224; 264/175**

[51] Int. Cl. **B22d 11/06**

[58] Field of Search. **164/87, 87 D, 276; 264/175**

[56] References Cited

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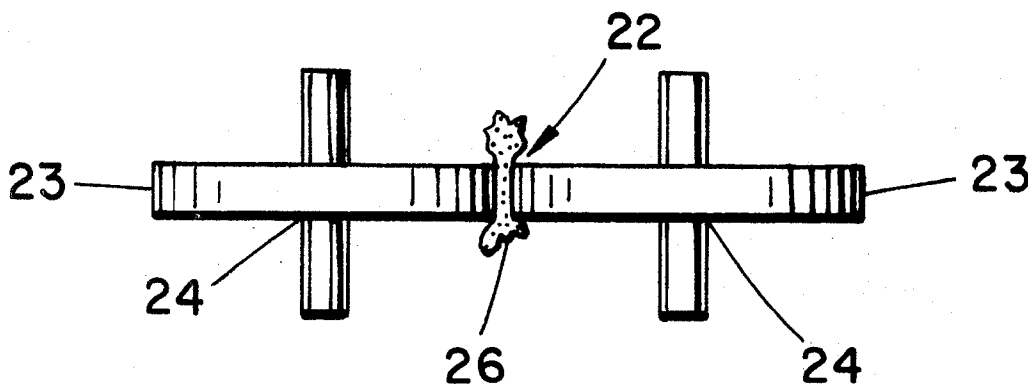
Primary Examiner—R. Spencer Annear

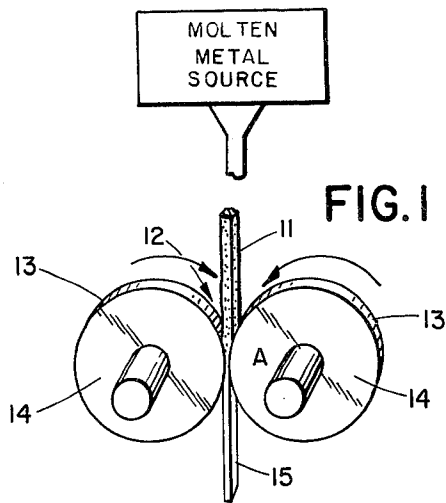
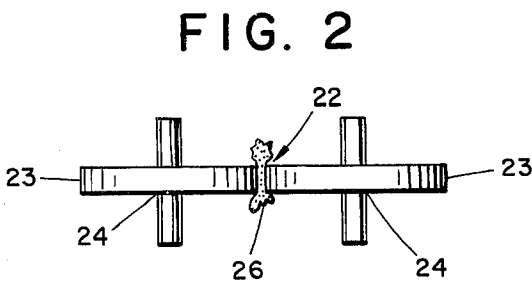
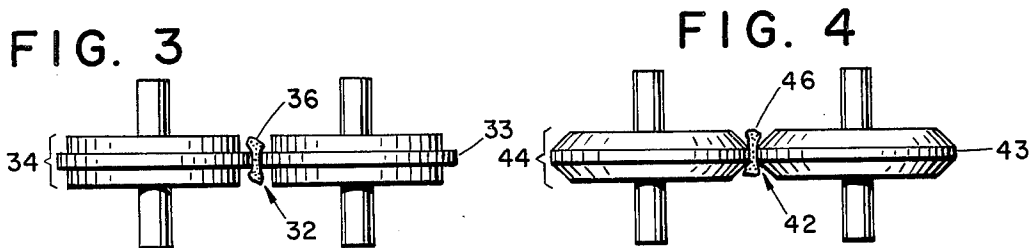
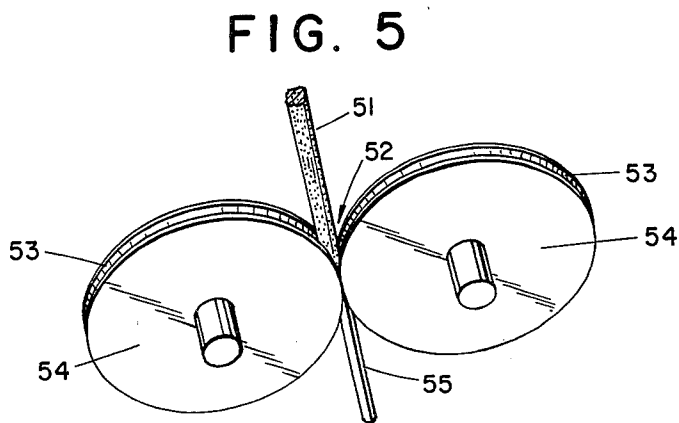
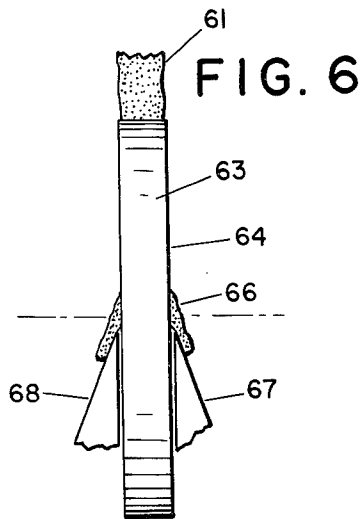
Attorney, Agent, or Firm—Arthur J. Plantamura; David W. Collins

[57] ABSTRACT

This invention relates to a process and apparatus for the production of metal filaments having controlled widths by rolling and quenching from the molten state between the contact faces of two contiguous cooperating rotary elements having contact face widths that are essentially coextensive with the width of the filament to be produced. This technique causes any excess molten alloy to be dispersed laterally rather than to pass vertically between the elements. Optionally, the apparatus may be equipped with shearing means to remove any excess flash.

6 Claims, 6 Drawing Figures





CONTINUOUS CASTING OF NARROW FILAMENT BETWEEN ROTARY CHILL SURFACES

BACKGROUND OF THE INVENTION

This invention relates to an improvement in the melt spinning of metal alloys to produce polycrystalline or amorphous filaments. Melt spinning, also referred to as chill-block spinning, is a process wherein a free jet of molten material is impinged upon a moving quench surface and rapidly quenched to produce a product having superior physical properties. Various melt spinning techniques are employed to obtain solid solutions of metals that would normally separate on solidification due to mutual insolubility in the solid state. These techniques have long been employed to produce polycrystalline products possessing very fine crystalline structure. More recently, melt spinning has been used to produce glassy or amorphous metal filaments since the production thereof requires quenching of the melt at a rate such that the particular alloy reaches its characteristic glass transition temperature before departure from the quench source.

One of the preferred methods for melt spinning employs twin rotating cylinders as the quenching source. This method is described by H. S. Chen and C. E. Miller in *Rev. Sci. Instrum.* 41, 1237 (1970) and by E. Babic et al. in *J. Phys. E: Sci. Instr.* 3, 1014 (1970). In general, their apparatus comprises two motor driven cylinders of dimensions approximately 2 inches in diameter and 2 inches in width whose axes are parallel and which rotate at speeds of about 100 to 5,000 rpm in opposite directions while exerting pressure on the alloy so as to "roll" the liquid alloy through a small adjustable clearance between the cylinders. The alloy is melted in a small furnace mounted above the cylinder and after attaining the proper temperature, it is ejected in a continuous stream at a regulated velocity between the cylinders which then function as quenching rollers. After passing between the rollers, the alloy is solid and in the form of a thin ribbon or sheet.

According to Chen and Miller's discussion, this twin roll quenching technique has many advantages over "splat" quenching wherein the alloy is quenched by contact with a single quenching source. The filaments resulting from thin-roll quenching are uniform in thickness and therefore are more suitable for x-ray analysis and studies of their electrical and mechanical properties. This twin-roll technique allows for production of a continuous filament and is applicable to brittle semiconductor alloys as well as to ductile materials.

However, in following this twin roller quenching procedure, the alloy must be adequately quenched by the time it reaches the midpoint or point of contact between the two wheels as is shown by point A in FIG. 1 because there is no contact between the alloy and the quenching rollers after this point. However, since the molten metal is liquid when it first approaches the rollers it will fill the area between the rollers above point A and since it is quenched before reaching point A, the thickness of the quenched alloy is greater than the gap at A through which it must pass between the rollers. This excess quenched material, having high resistance to deformation, causes bumping or bouncing of the wheels and creates slip planes and other irregularities in the resulting filament as it passes between point A. Moreover, this technique as presently practiced results

in a product whose dimensions are difficult to control and in which the possibility of shaping is low.

There is thus a need for a process for the production of metal filament which will provide a uniform dimensional, regular filament by employing a twin-roll apparatus in which cylinder bouncing or bumping will be minimal and in which it will be possible to regulate the filament dimensions and shape.

SUMMARY OF THE INVENTION

This invention provides an improved apparatus for the production of metal filaments from a molten stream using, as the quenching source, the contact faces of contiguous cooperating rotary elements having contact face widths that are essentially coextensive with the width of the filament to be produced. This invention also provides a method for making metal filaments having a controlled width from a molten stream by adjusting the faces of two contiguous cooperating rotary quenching elements so that they essentially coincide with the desired width of the filament, passing the molten stream between the rotary elements to quench and recovering the substantially solidified filament.

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.

Thus, this invention discloses a process and apparatus whereby metal filaments having controlled widths may be rolled and quenched from the molten state between two very narrow, contiguous, cooperating, rotating elements which disperse excess molten alloy laterally rather than allowing the excess material ultimately to pass vertically between the elements. This novel apparatus is optionally equipped with a shearing means to remove any excess flash. Since the contact width of the wheel is relatively very narrow, the resulting filament will be quenched along the entire width of the wheel, flash being removed as the filament is being formed and a resulting uniform strip produced. An added advantage of this technique is that it may be adapted so as to eliminate the use of precision in nozzles for metering and delivering precise quantities of molten metal to the quenching source since the desired filament can be satisfactorily generated by pouring the metal between the elements. In the latter adaptation, the ribbon is generated by pouring molten metal between the narrow rotary elements and the excess metal is squeezed off as flash.

This invention may also be used to produce uniform shaped filaments when the quenching elements are complementarily contoured. In this embodiment any excess material is trimmed away by the edges of the rotary element and/or with external shearing means.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 represents a front view of the twin roll quenching technique.

FIG. 2 is a plan view of the rolls of FIG. 1 and shows the narrow rotary elements disclosed by this invention which are essentially coextensive in width with the width of the filaments.

FIGS. 3 and 4 represent alternate embodiments of the invention.

FIG. 5 illustrates a method of complementarily contouring the rotary element to produce a shaped metal filament.

FIG. 6 is illustrative of a shearing means incorporated into the novel quenching system of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The procedure and apparatus of the present invention are simple and direct as shown by FIGS. 1-6.

The material 11, 51, 61, to be spun is melted in a reservoir (not shown), ejected or poured into the clearance 12, 22, 32, 42, 52 between the contact faces 13, 23, 33, 43, 53, 63 of two contiguous cooperating rotary elements 14, 24, 34, 44, 54, 64 and quenched to form a filament 15, 55 having a width essentially coextensive with the width of the contact face 13, 23, 33, 43, 53, 63 of the element. As shown in FIGS. 2, 3, 4 and 6, this technique allows the excess material to disperse laterally as flash 26, 36, 46, 56, 66 which can be readily removed from the filament and recycled back to the melting reservoir.

In accordance with the present invention, the rotary quenching elements may be composed of any material conventionally used in melt extraction apparatus. Preferably, cylinders which are composed of relatively high conductivity materials such as beryllium copper, stainless steel, oxygen-free copper or tool steel are employed.

It is intrinsic to the present invention that the twin rotary quenching elements be constructed in a manner such that the contact face width is essentially coextensive with the width of the desired filament. This width will generally be within the range of 0.003 to 0.100 inch, preferably about 0.10 to 0.060 inch.

This narrow contact width can be accomplished by using a variety of different geometrical configurations. FIGS. 1 and 2 show the basic quenching apparatus of the present invention wherein the widths of the entire elements 14, 24 are the contact widths 13, 23. Alternatively, the contact faces 33, 43 of the quenching elements may be narrower than the supporting width of the elements 34, 44 as is shown in FIGS. 3 and 4. Using the latter geometrical configurations, the supporting width of the element may vary from about 3 to 4 times the contact face width to as much as about 20 times the contact face width of the element. These configurations are preferable in accomplishing the objects of this invention since they allow little or no possibility for distortion or misalignment during rolling.

The clearance 12, 22, 32, 42 between the two elements may be varied in accordance with the thickness of the desired filament. In general, the size of the clearance at the midpoint A will vary from 0.0015 to 0.020 inch, preferably from 0.003 to 0.010 inch.

In the alternate embodiment shown in FIG. 5, it is possible to achieve shaping of both sides of the filamentary product by contouring the quenching elements 53 in a complementary manner so that the entire metal filament 55 can be "molded" into the desired shape. Such contouring is particularly adaptable to the production of round wire products.

Moreover, shearing means 67 and 68 may be used in combination with the narrow quenching wheels as in FIG. 6 to remove any excess flash 66. Such shearing means could be rotating or stationary and may include knives, air blasts, etc.

The molten metal alloy may be delivered to the quenching apparatus in a variety of ways. The alloy may be delivered through a nozzle located in close

proximity to the clearance 12, 52 between the quenching rollers. The system may be adapted to eliminate the use of the nozzle by allowing the metal to pass through an orifice in the bottom of the melting apparatus in a manner such that a continuous stream is passed into the quenching area. For ease of operation, the molten metal may be delivered by simply pouring a continuous stream into the quenching area.

For efficiency of operation, a catch basin or the like may be incorporated into the system to recover both the flash material and any excess molten metal which, after pouring, does not come into contact with the quench surface. This excess material can then be recycled to the melt reservoir for further heating and quenching.

The following examples are meant to be illustrative and the invention is not meant to be limited thereto. All parts are by atomic percent unless otherwise noted.

Example 1

An apparatus similar to that shown in FIG. 2 was employed to produce an amorphous metal filament. The cylinders were composed of high conductivity beryllium copper and were 2 inches in diameter with width of 0.05 inch. Rotating shearing knives were positioned on the apparatus to remove flash. An alloy formulated to be amorphous upon quenching and consisting of 35% Fe, 42% Ni, 14% P, and 3% Al was charged, melted in an argon atmosphere to 1100°C and then ejected at a rate of 300 cm/sec through a nozzle into the clearance between the cylinders, rotating at 2500 rpm. A flat filament of width of 0.05 inch, thickness of 5×10^{-3} inches was produced. Upon analysis, the filament was found to be distinctly amorphous.

Example 2

An apparatus similar to that of FIG. 3 was used to produce a polycrystalline metal filament. The apparatus consisted of two stainless steel cylinders of 3.0 inches diameter having a supporting width of 0.2 inches and contact width of 0.06 inch. A grey cast iron alloy containing about 3.4% C, 2.2% Si, 10.6% Mn, 0.2% P and 0.1% S was melted at 1200°C. A stream of the molten metal was continuously poured into the clearance between the cylinders rotating at 2000 rpm. A catch basin was positioned so as to recover any unquenched melt as well as any flash cut off by a pair of stationary knives. Upon analysis, the narrow filament of width 0.004 inch and thickness 5×10^{-4} was found to be of very fine grain size.

Example 3

An apparatus similar to that depicted in FIG. 4 was used to produce an amorphous filament from an alloy consisting of 76% Fe, 15% P, 5% C, 3% Al and 1% Si. The apparatus consisted of two beryllium copper cylinders of diameter 3 inches having a "supporting width" 1.0 inch and a "contact width" of 0.05 inch. The alloy was charged in an insulated reservoir and melted in vacuum at 1100°C then ejected through an orifice into the clearance between the two cylinders which were rotating at 3000 rpm. An air knife was positioned on each side of the apparatus to effect removal of the flash. X-ray diffraction analysis showed the resulting 0.05 inch filament to be distinctly amorphous.

Example 4

The method of Example 3 was repeated using the same alloy and the apparatus illustrated in FIG. 4 with contact width of 0.01 inch and supporting width of 0.2 inch. The contact faces were complementarily contoured to form essentially a circular cross section. Upon quenching, a substantially round amorphous filament of diameter approximately 0.010 inch was produced.

I claim:

1. In an apparatus for the production of metal filaments from a molten stream ejected from a source of molten metal wherein the contact faces of contiguous cooperating rotary elements are used as the quenching source, the improvement which comprises orienting the rotary elements so that the molten metal is introduced into the nip thereof, providing contact faces on the rotary elements which allow unconfined lateral dispersion of the excess of said molten stream quenched on said contact faces, said contact faces comprising widths that are in the range of about 0.003 to 0.100 inch and are essentially coextensive with the width of the filament to be produced.

2. The apparatus of claim 1 wherein a shearing means adjacent to the rotary elements is incorporated into the apparatus contiguous to the rotary elements to remove

the laterally dispersed excess flash.

3. The apparatus of claim 1 wherein the rotary elements are complementarily contoured so as to produce a correspondingly shaped metal filament.

4. The apparatus of claim 1 wherein the contact face of the quenching elements is narrower than the supporting width of the elements.

5. The apparatus of claim 1 wherein the width of the contact face of the quenching rotary element is in the range of about 0.003 to 0.100 inch.

6. A method of making metal filaments having controlled width in the range of about 0.003 to 0.100 inch from a molten stream which comprises:

a. adjusting two contiguous cooperating rotary quenching elements, which have contact faces that essentially coincide with the desired width of the filament, so that the molten stream is received within the nip of said rotary elements;

b. passing the molten stream, at a rate in excess to that required to produce said width, between the rotating elements to effect quenching of the stream while allowing said excess of the molten stream to be ejected laterally without confinement from the quenching rotary element; and

c. recovering the substantially solidified filament thus formed.

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UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 3,881,541
DATED : May 6, 1975
INVENTOR(S) : John R. Bedell

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 31, "rootating" should read --rotating--.

Column 2, line 49, after "excess", insert the word --molten--.

Column 4, line 29, after "P," insert --6% B--.

Column 4, line 59, after "'supporting width'" insert --of--.

Signed and Sealed this

seventh Day of *October* 1975

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

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Commissioner of Patents and Trademarks