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W. WADE ET AL

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METHOD AND APPARATUS FOR PRODUCING METAL FILAMENTS

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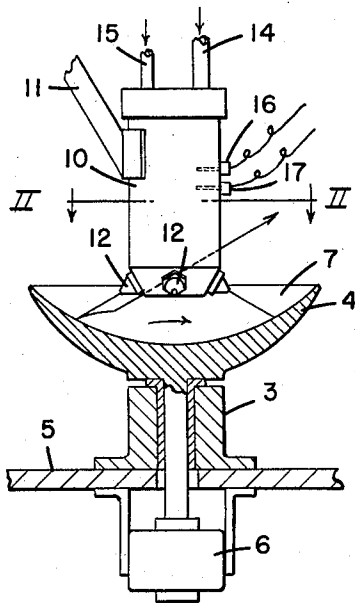


Fig. 1

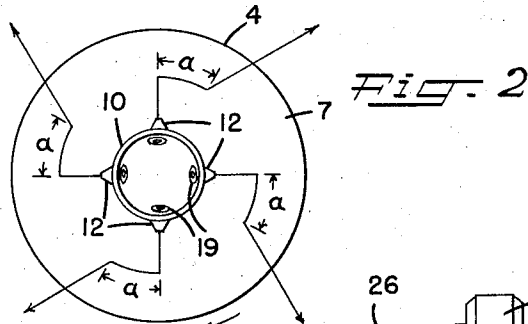


Fig. 2

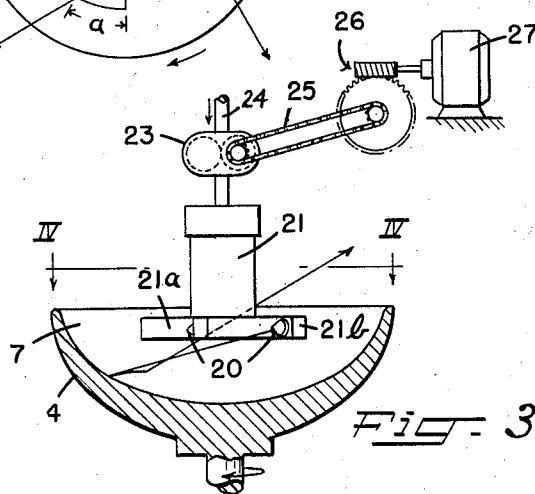


Fig. 3

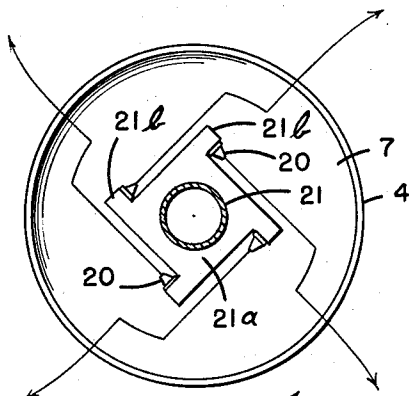


Fig. 4

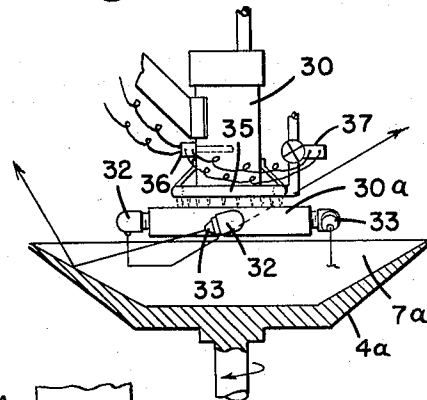


Fig. 5

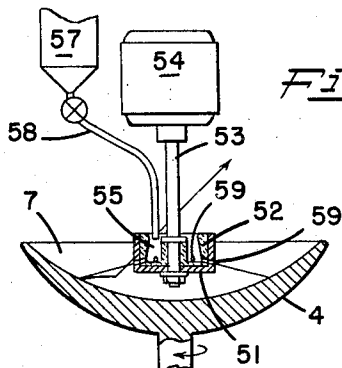


Fig. 7

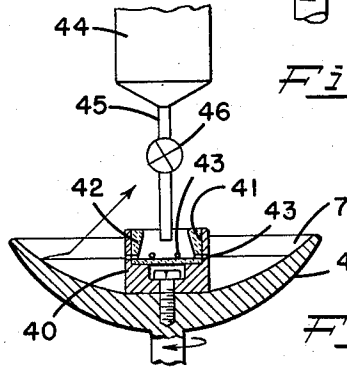


Fig. 6

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METHOD AND APPARATUS FOR PRODUCING METAL FILAMENTS

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3 Claims. (Cl. 22—57.2)

This invention relates generally to improvements in the art of metallurgy and particularly to the formation of elongated metallic elements of extremely small cross-section. It is primarily concerned with improvements of the apparatus and method as described in application S.N. 387,187, filed October 20, 1953, and now Patent No. 2,825,108, issued March 4, 1958.

This prior application describes the production of metallic elements of small cross-section, i.e., continuous filaments, staple fibers, and powder, by aiming a stream of molten metal at high velocity at a circular, extremely rapidly rotating surface adapted to chill the molten metal as rapidly as it contacted the surface and to discharge it as filaments or powder after being carried through a short arcuate path while supported by the surface. An essential characteristic of this system is that the chill surface, particularly that part upon which the molten metal is deposited, faces toward a point along the axis of rotation, such as provided by interior spherical or ellipsoidal concavity. The molten metal, in undergoing such a procedure, is cast into the desired elements, e.g., filaments, without plastic deformation and the creation of substantial residual stresses. This metal spinning system is well adapted for the processing of such nonrefractory metals, or alloys thereof, as tin, lead, cadmium, indium, zinc, bismuth, aluminum, magnesium, and copper.

It has been found that the three-dimensional measurements of the elements produced by this prior described apparatus and method may be controlled by controlling such variables as (1) temperature of the molten metal, (2) velocity of the ejection of the molten metal from a container therefor, (3) the size of the orifice from which the molten metal is discharged, and (4) the surface speed of the rotating target surface at the point of impingement of the molten metal. These variables may be altered to change the nature of the product from continuous filaments, through staple filaments of various lengths, to flakes of powder. These variables may be correlated to control the transverse dimensions of the product. For example, high temperatures of the molten metal and high rotational speeds of the cooling member are factors which contribute to the production of thinner filaments.

Other variables relating to the operation of such metal casting equipment include, (5) the angle of inclination of the rotating surface with respect to the axis of rotation at the point of impingement of the metal, and (6) the angle of incidence at which the cooled metal product leaves the rotating surface. The latter is a factor related to the continuity of the filament, the thickness and width thereof or mass per unit length, the density of metal used, the degree of polish of the rotating surface, and the speed thereof. The angle of incidence of the departing solid metal may be utilized in determining a fixed trajectory and a station for collecting the product.

A primary object of the present invention is to provide a system which utilizes the principles of operation disclosed in the above-noted patent, adapted for the production of solidified products from a plurality of streams

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of molten metal discharged upon a single rotating surface. An object ancillary to the foregoing object is the production of a plurality of metallic filaments simultaneously from machinery of simplified construction.

5 Other objects and features of the invention will become apparent from the following description of the invention and the drawings relating thereto in which

Fig. 1 is a fragmentary elevation, partly in section, of one embodiment of the invention;

10 Fig. 2 is a sectional view taken along line II—II of Fig. 1;

Fig. 3 is a fragmentary elevation, partly in section, illustrating essential portions of spinning apparatus in accordance with another embodiment;

15 Fig. 4 is a sectional view of the apparatus of Fig. 3 taken along line IV—IV;

Fig. 5 is a fragmentary elevation, partly in section, of a modified form of the apparatus shown in Figs. 3 and 4;

20 Fig. 6 is a fragmentary elevation, partly in section, of modified spinning apparatus, and

Fig. 7 is a fragmentary elevation of essential portions of a spinning apparatus in accordance with another embodiment.

In brief, the invention concerns the continuous simultaneous production of filaments or powder of solidified metal as derived from a plurality of streams of molten metal fed simultaneously onto a recessed circular surface provided in a rapidly rotating chilling member having an axis of rotation with respect to which the surface is concentric. The apparatus for carrying out this procedure comprises a container for molten metal substantially centered with respect to the axis of rotation, having orifices disposed approximately concentrically to the axis for discharging a plurality of streams of the molten metal onto the rotating surface. In preferred embodiments of the invention, portions of the container providing the orifices may be stationary or rotatable. The surface of the rotatable chilling member is a surface of revolution whose generatrix may comprise a regularly curved line such as a portion of a circle or ellipse, or an irregularly curved line, or a series of straight lines joined together in such contour as to develop a generally concave, re-entrant, or dished surface on which to receive the stream of metal. The generatrix, as it extends away from the axis, should increase rather than decrease in inclination with respect to a plane normal to the axis to a degree substantially short of becoming parallel to the axis to provide a recessed surface of which all portions face toward some point along its axis of rotation.

One form of apparatus for making the product of the present invention is that shown in Figs. 1 and 2 wherein a rotary open-faced chill block 4 is rotatably supported by a bearing block 3 mounted upon a base 5. A motor 6 supported by the base 5, is coupled in driving relation with the chill block 4 to effect rotation of the block about a substantially vertical axis. The face 7 of the chill block is a high polished surface of revolution concentric to the axis of rotation produced by an incurved generatrix extending in a direction upwardly and away from said axis. The generatrix, as it extends away from the axis, decreases instead of increases in inclination with respect to the axis to provide an approximately concave surface for molten metal deposited thereupon. Thus, portions of the casting surface 7 may be selected as target areas for the molten metal which vary in inclination with respect to the axis of rotation in accordance with desired spinning conditions. The block 4 comprises materials of great strength that will withstand the centrifugal force that develops from speeds up to or exceeding 30,000 revolutions per minute. The exterior shape of the cooling block shown is merely illustrative and the body thereof may be formed in any manner desired to provide

strength and a casting surface of the contour needed. For purposes of illustration, the concavity of the surface 7 and the rotary casting surfaces of the modified apparatus described below is shown greatly exaggerated.

The essential improvement provided by this invention is the provision of a molten metal ejection device capable of discharging a plurality of streams of molten metal onto the recessed casting surface 7 whereby the spinning capacity of a single machine comprising one chill block may be greatly increased. For this purpose, a container or reservoir 10 is supported in a fixed position by means, such as a brace 11, over the chill block 4. When the apparatus is arranged and adjusted for producing uniform product, a plurality of nozzles 12 are aligned to cause the molten metal discharged from the orifices thereof to impinge upon the same circular portion of the surface 7. However, if it is desired to produce, for example, a filament of different character by each nozzle, then the nozzles may be aligned to deposit streams of molten metal upon different portions of the surface 7. This may be accomplished by variations in the settings of the nozzles while holding the container in a concentric position, or moving the container to a non-concentric position in which its axis is nonparallel to, or parallel but spaced from, the axis of rotation of block 4.

Molten metal may be fed to the container in such a manner as to maintain it safely above the lowest level for entering the nozzles 12 through a tube 14 connecting the container with a reservoir not shown. Pneumatic pressure is provided within the container 10 by means such as the tube 15 which connects the container to conventional gas pressure generating and regulating means not shown. If desired, the level of the liquid may be automatically maintained within the range provided by a pair of electrical terminals 16 and 17 connected with conventional control means for operating a valve in the metal supply system comprising the line 14. In the sectional view, Fig. 2, are illustrated the inside openings 19 of the nozzles 12. Although the means hereinabove described for forcing molten metal through the nozzles at a desired velocity is pneumatic, various other equivalent means are possible such as various types of pumping systems adapted for handling metals of relatively low melting points, such as one shown in Fig. 3 and described below.

In operation, molten metal that is ejected from the nozzles 12 as liquid streams impinge on the open surface 7 of the chill block 4 as a liquid. The angle at which liquid stream approaches the surface may be called the angle of incidence of approach. The super heat and latent heat of fusion is removed from the metal by intimate contact with said block; the metal is thus solidified. It remains in contact with the surface 7 for a short arcuate length "a," e.g., one-half inch, and then is thrown free of the surface by centrifugal force in a direction taking an angle with respect to the casting surface 7 which may be called the angle of incidence of departure. The path or trajectory along which the product of each nozzle is discharged from the chill block remains substantially fixed as long as the spinning conditions and the position of the container 10 are not changed. In the production of continuous filaments, continuity exists between the molten metal in the container 10, the molten metal in the air on its course to the surface 7, the liquid and solid metal on said surface, and the continuous filament leaving said surface. In the production of staple filaments or powder, this continuity is interrupted as the product strikes the casting surface.

The manner in which the speeds of ejection and rotation of the chill block, and the several other variables which control the nature of the characteristics of the product which may be derived from a single nozzle, is discussed in detail in the above-noted patent. The following is an example of the basic process:

Employing an aluminum chill block having a diameter of 3", a weight of .6 lb. and a radius of curvature of

5", and having a surface finish of 30 microinches; and employing a glass round orifice having a diameter of 30 μ ; molten tin having a surface tension of 526 dynes per cm. at $\Delta T_s=50$, was ejected at 75 ft./sec. at a pressure of 6 lbs. The velocity of impingement was 300 ft./sec. and the angle of impingement was 90°. Filaments were produced having a length of 15 feet, a thickness of 10 μ and a width of 200 μ .

Note.—The symbol $\Delta T_s=50$ signifies that the temperature of the metal at ejection was the melting temperature plus 50°. μ signifies microns.

Another arrangement by which a plurality of streams of molten metal may be discharged in continuous jet streams onto the casting surface is illustrated in Figs. 3 and 4 wherein the casting surface 7 of the chill block 4 receives a plurality of streams from nozzles 20 which extend through wall portions of a container 21. The container has a lower laterally extended portion 21a which provides a plurality of hollow projecting portions 21b, one for receiving each nozzle. An advantage of this arrangement for supporting the nozzles is that they may be aligned to discharge their streams in directions which are not directly radial as shown in the earlier described embodiment of Figs. 1 and 2. The streams discharged by the nozzles 20 in the presently described embodiment pass tangentially to a circle approximately concentric to the axis of rotation of block 4, such as when the container 21 is supported concentrically to the axis. As the ejection velocities of the metallic streams employed in this invention are considerable, this arrangement of nozzles is employed to avoid the direct addition of the kinetic energy carried in such streams to the centrifugal force supplied to the streams by the surface of the chill block on impingement therewith. Although the circle of tangency with the streams lies well within the circle of impingement on the surface 7, it is possible to build the container, and particularly portion 21a thereof, to such size as to direct streams of molten metal in a direction which is tangential with the circumference of impingement along the surface 7; however, such a container in practical application would be unduly bulky and be encumbered with problems of heat radiation and the maintenance of the temperature of the molten metal contained therein. The embodiment of Figs. 3 and 4 represents a compromise in design which effectively mitigates the addition of kinetic forces imparted to molten metal by ejection to centrifugal forces acting on the metal while in contact with the casting surface.

Also illustrated in the apparatus thus described, is a mechanical system for feeding the metal comprising a gear pump 23 in the feed line 24. For the production of filaments of uniform character the pump 23 is driven at constant speed by a chain 25 connecting it with the worm-gear drive 26 driven by a motor 27. The chill block 4 may be supported and driven in the manner illustrated in Fig. 1.

A simple modification of the apparatus illustrated in Figs. 3 and 4 is shown by fragmentary elevation in Fig. 5 wherein a container 30 for molten metal having a laterally enlarged lower drum-shaped portion 30a is supported concentrically with respect to the casting surface 7a of the chill block 4a. A peripheral wall of the drum-shaped portion supports detachable adjustable hollow elbow fittings 32 in which are secured nozzles 33. The fittings 32 may be attached, as shown, in the manner of threaded pipe fittings to the container portion 30a. The cant of each fitting with respect to the container 30 is thereby independently adjustable to enable the path of discharge to be aligned toward the surface 7a as desired. A means for heating the container such as the flame burner 35, may be provided to maintain the metal stored therein at a desired temperature above its melting point. If desired, the temperature of the molten metal inside the container 30 may be controlled within a desired range by a thermostat 36 in contact with the molten metal, such

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thermostat being electrically connected to a solenoid valve 37 in the fuel line for the burner.

A further embodiment of the invention is illustrated in Fig. 6. Shown herein is the rotatable chill block 4 with a circular metal receiving cup 40 of circular transaxial cross-section secured at the bottom of the casting surface 7; the cup 40 is positioned coaxially with the block. The body of the cup comprises a high strength material, such as stainless steel. Supported within the recess of the cup 40 defined by the inner cylindrical surface 41 is an open-top cell 42 of heat resistant material, such as tungsten carbide. The opening of the cell at its top is circular and smaller in diameter than the diameter of a lower portion of the cell recess along the circumference of which apertures 43 are angularly spaced with respect to the axis of the chill block. Thus, the lateral surface defining the recess slopes from the top opening away from the axis of rotation toward the circumference along which the apertures 43 occur whereby during rotation of the block 4 and the cup 40, centrifugal force acts on molten metal in the cell 42 to trap it along the portions of the cell recess of larger diameter and to force it through the apertures. These apertures, referred to herein also as orifices, extend also through the lateral wall of the cup 40. Supported above the cooling block is a reservoir 44 for feeding molten metal through a tube 45 extending downwardly therefrom into the recess of the cell. The amount of molten metal entering the cell 42 may be regulated by means such as a valve 46. Molten metal may flow from the container 44 by natural gravity, or a pressure system may be provided for supplying metal to the container and thence to the cell at a uniform rate as hereinbefore described with respect to other embodiments.

The system illustrated in Fig. 6 is characterized by impingement of streams of molten metal at fixed points rather than on circular areas of the surface 7, i.e., when the conditions of spinning are held constant. Restriction of impingement to fixed points occurs because of the lack of relative rotation between the metal-discharging agency and the casting surface. Except for a slight deflection from a purely radial direction caused by windage within the region enclosed by surface 7, the molten metal, after deposition on the surface 7, proceeds a generally radial direction upwardly along the surface 7 until solidified, whereupon it flies off the surface in the form of staple fiber, varying downwardly from 2 inches in length to particles or flakes which are no longer than their width. This arrangement of the apparatus has as a primary advantage, mechanical simplicity of structure and operation. It is less satisfactory than other forms of apparatus described herein for continuous filament production. Collection of the product of apparatus illustrated in Fig. 6 must be provided along an entire circumference of the region surrounding the cooling block, since the agency for placing molten metal on the casting surface rotates therewith.

Fig. 7 illustrates another form of the invention in which the device for discharging molten metal upon the casting surface may be rotatable. In this instance a metal distributor comprising an outer shell 51 of high strength material, such as stainless steel and an inner casing 52 of heat-resistant non-alloyable material, such as tungsten carbide, is supported by the shaft 53 of a motor 54. Preferably the motor 54 is capable of being operated at any constant speed within a wide range of speeds of rotation. The parts of the distributor are built accurately circular and concentric with respect to the shaft 53 to provide as accurate dynamic balance as reasonably obtainable. Molten metal is supplied to the recess 55 of the distributor from a receptacle 57 through a tube 58 which extends into, or in immediate superposition with, the recess. The molten metal is fed into the recess at a rate in accordance with the rate of discharge from the distributor. As the molten metal is forced from the distributor primarily

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by centrifugal force, the rate of discharge is dependent upon the speed of rotation of the distributor and the size and number of metal-discharging orifices or passageways 59 provided through the wall of the distributor. In using this apparatus, the distributor may be turned in the same direction as the chill block 4, or in the opposite direction. This form of apparatus is highly adapted for the formation of continuous filaments which are collected within a continuously circular region surrounding the apparatus shown.

In practicing the present invention, the rotary chill blocks, such as described in the foregoing description of the various apparatus modifications, have been satisfactorily constructed of stainless steel, aluminum and brass. An important feature of the chilling or casting surface formed on the chill block is the finish thereof. Surfaces having finishes varying from about 1 to 50 microns, as checked with a profileometer, have been successfully used in producing the cast metal products of small cross-section herein referred to. In forming the chill block, the metals named and any other high strength metallic material capable of taking the polish desired, and which do not alloy with the molten metal to be spun, may be used. As to size, chill blocks found to be satisfactory in this invention varied from 3 inches to 7 inches in diameter, which was approximately the extreme diameter in each case of the casting surface formed thereon. The chill blocks were rotated at speeds up to 30,000 revolutions per minute to develop impingement velocities along predetermined circular areas within their perimeters of up to 1,000 feet per second. Orifice members, such as orifices 20 (Fig. 3) and orifices 12 (Fig. 1), were constructed of glass, silicon carbide, tungsten carbide and stainless steel. For operation at higher temperatures, i.e., for spinning filaments from the higher melting of the nonrefractory metals, the more heat resistant materials, such as silicon and tungsten carbides, provide orifices having greater service life. While metal products have been successfully produced from orifices having apertures in the range of 3 to 300 microns in diameter, a satisfactory aperture size which permits versatile variation of spinning conditions to obtain products having desired properties within a wide range, is about 30 microns. The rates of ejection therethrough may be varied substantially, e.g., from 25 to 300 feet per second, to correlate the ejection velocity of the nozzles to the speed of the chill block and the other variables to obtain a desired product.

While preferred embodiments of the invention have been shown and described, it is to be understood that changes and variations may be made without departing from the spirit and scope of the invention as defined in the appended claims.

Having thus described our invention, we claim:

1. The method of transforming molten metal into solid molten metal products of extremely small cross-section comprising forcing molten metal from a common body thereof through a plurality of orifices onto a surface of revolution of concave re-entrant diametral cross-section, rotating a container of said body of metal at a given speed to apply centrifugal force to the metal to expell it through the orifices, rotating the surface at the same speed and collecting the molten metal as separate streams upon angularly spaced portions of said surface, said molten metal on contact with said surface being solidified and then urged from the surface by centrifugal force to form said products.

2. A device for casting solid metal products of extremely small cross-section comprising a chill block having a smooth polished open surface of revolution, the portion of said surface for receiving molten metal being produced by a generatrix which extends away from the axis of rotation at an angle less than a right angle, hollow means fixedly mounted on said chill surface and disposed centrally of said surface about said axis for receiving molten metal, said hollow means having orifices spaced

radially from its axis and angularly thereabout for dis-
charging separate streams of molten metal upon selected
areas of said surface, and means for rotating said chill
block and said hollow means at the same speed so as to
force the molten metal from said hollow body at high
velocity against the chill surface whereby the molten metal
is solidified and urged from the surface by centrifugal
force to form said products.

3. A device for casting solid metal products of ex-
tremely small cross-section comprising a chill block hav-
ing a smooth polished open concave surface having the
radius of curvature thereof on an axis of rotation with the
surface extending concentrically about said axis, hollow
means fixedly mounted on said chill surface and dis-
posed centrally with respect to said surface and its axis
for receiving molten metal, said hollow means having
orifices spaced radially from said axis and disposed in
angularly spaced arrangement thereabout for discharg-
ing small streams of molten metal onto selected areas
of said surface, and means for rotating said chill block

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and said hollow means at the same speed for forcing the
molten metal from said hollow means through said
orifices at high velocity whereby the molten metal is
solidified and urged from the surface by centrifugal force
to form said products.

References Cited in the file of this patent

UNITED STATES PATENTS

809,671	Cowing	Jan. 9, 1906
950,884	Winner	Mar. 1, 1910
989,075	Staples	Apr. 11, 1911
1,291,603	Nagy	Jan. 14, 1919
1,592,140	Horton et al.	July 13, 1926
2,062,093	Kann	Nov. 24, 1936
2,318,244	McClure	May 4, 1943
2,752,196	Chisholm et al.	June 26, 1956
2,793,395	Richardson	May 28, 1957

FOREIGN PATENTS

904,048	France	Feb. 12, 1945
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