

Jan. 12, 1943.

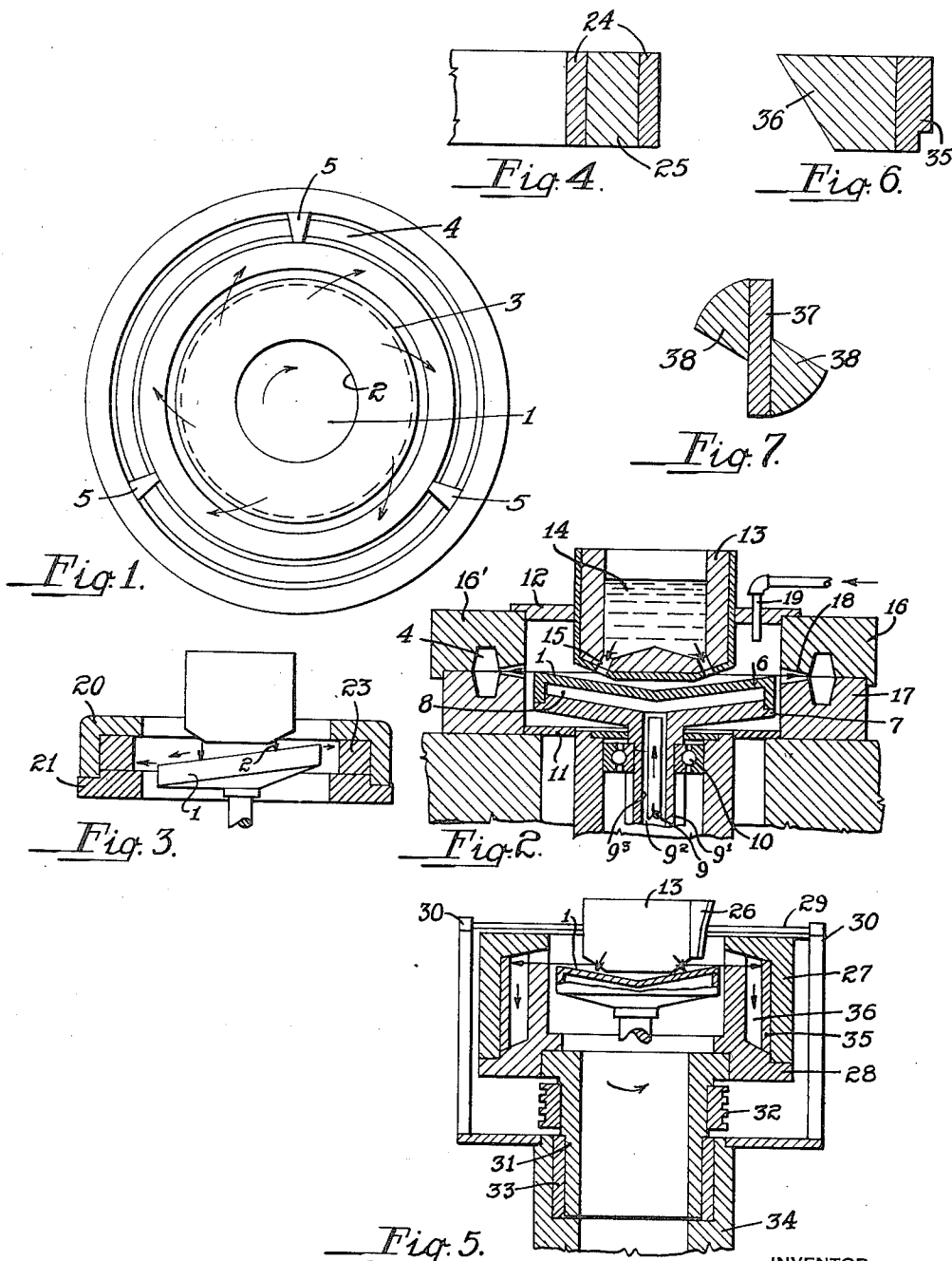
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2,307,939

METAL PRODUCTS PRODUCED DIRECTLY FROM MOLTEN METAL

Original Filed May 5, 1934

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

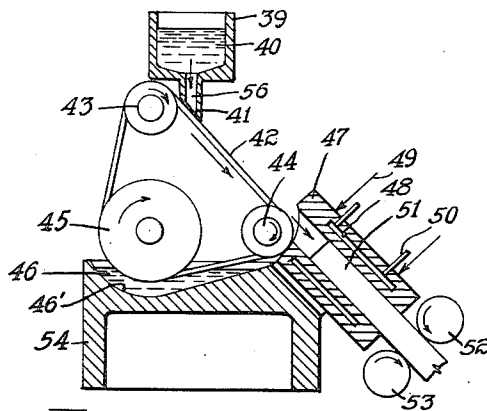


Fig. 8.

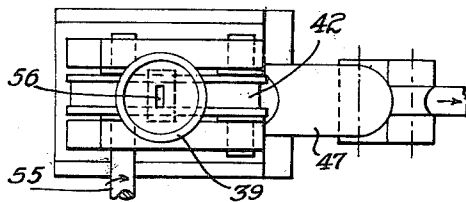


Fig. 10.

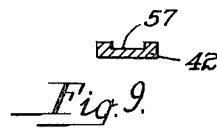


Fig. 9.

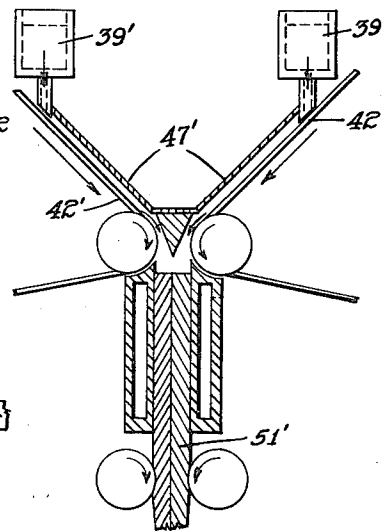


Fig. 11.

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UNITED STATES PATENT OFFICE

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METAL PRODUCT PRODUCED DIRECTLY
FROM MOLTEN METAL

Joseph M. Merle, Pittsburgh, Pa.

Original application May 5, 1934, Serial No.
724,186. Divided and this application May 6,
1938, Serial No. 206,396

5 Claims. (Cl. 22—201)

The present invention relates to cutting tools, anodes, and other metal products made from molten metals or alloys and is a division of my application Serial Number 724,186 filed May 5, 1934, now Patent 2,129,702, granted September 13, 1938.

In the manufacture of metal products, with the exception of those made from powdered metals sintered under heat and pressure, made from molten metal poured into a metal mold, sand mold, rotary mold, or forced under mechanical or air pressure into a mold or a die, the molten metal reaches the mold or die in a liquid state and while inside the mold or die it passes from the liquid to the solid state, and this change of physical condition involves well known phenomena with certain modifications with specific metals or alloys.

This common method of production of metal products has a determining influence upon the physical and other properties and characteristics of all commercial metal products either in their cast condition or in their worked condition resulting from forging, rolling, pressing, extruding or mechanical forming, as well as in their heat treated condition, the finished product retaining some of the characteristics of the crystals formed and propagated through the molten metal.

An object of the present invention is to avoid the conditions which take place when molten metal passes from the liquid to the solid state in a mold or die since I have observed that by forcing molten high speed steel or other steel into molds or dies not in the liquid state but in a fine atomized spray of undercooled but still plastic particles propelled at a relatively high speed, such particles would impact together when contacting with the mold wall or with a section of the product already formed. The tools so formed disclose a different structure and different properties than tools made of ingot steel of the same composition produced by pouring liquid steel into an ingot mold, the ingot being subsequently hammered and/or rolled.

I have also observed that in steel or other metal products so made each of the undercooled atomized particles solidifies spontaneously upon impact while aggregating to other particles previously impacted thereby forming a metal product of increased density and cohesion, homogeneous in structure and free of the conditions occurring within an ingot when a large mass of molten metal passes from the liquid to the solid state, namely, dendrites, segregation, pipe and heterogeneity, and further that the grain size of the

metal product so formed may be controlled by regulating the size of the atomized particles.

Also I have observed that the same structure and conditions are obtained by forcing the undercooled atomized particles not into a mold but through a die, out of which the formed metal product is drawn or stripped at a rate corresponding to the amount of atomized metal forced into it, thereby forming metal products in bars, strips, sheets, or shapes in continuous lengths.

Furthermore, I have observed that steel and other metal products so formed have physical properties no longer comparable to the same metal as at present commercially cast, but better than the properties of the same metal commercially worked by forging, rolling, or extruding. More specifically, cutting tools formed by this method are much better and can withstand a cutting speed two or three times as great as the cutting speed obtainable with tools made of steel of the same composition as at present commercially produced.

In metal products so formed the latent heat of the molten metal is completely dissipated before atomizing and each atomized particle is undercooled slightly below the freezing point, so that a crystal nucleus, extending to a part of or entirely through the particle, has been formed and upon colliding and impacting with other particles, the metal atoms can find satisfactory arrangements, thus giving a structure free of internal stresses. Each particle also spontaneously crystallizes upon impacting without further disturbance due to latent heat dissipation through the crystals formed, thus making metal products of a distinctive and physically new structure, which is retained through subsequent mechanical working operations or heat treatment. This structure for all metals and alloys is characterized by minute spheroid cells of identical size, free of dendritic needles, with impurities located at the grain boundaries, as well as supersaturated alloy components concentrated at the grain boundaries and with precipitating components uniformly distributed as minute particles through the product formed. Thereby a metal product is formed which is uniform in structure under any magnification, more dense and stronger than similar metal products of the same composition, having the same strength, elongation, elastic limit and reduction of area in every direction and will give a non-directional fracture. Furthermore, the metal products are not subject to any chilling effects from metal molds and are free from dendrites, flow lines, segregation, pipes,

shrinkage cavities, etc., and they have the same chemical composition throughout the entire section or any part of the product. This special structure is retained after forging, rolling, heat treatment and even after welding when using the metal product as a welding rod.

In the case of high speed steel, the hard carbide components are disposed in a network around each martensitic crystal thereby imparting to each grain a cutting edge around its periphery and thus accounting for the better cutting properties over steel of the same composition as present commercial products. The distribution of the carbides is entirely uniform, and, in the case of chromium stainless steel, the same structural disposition accounts for better resistance to corrosion.

I have also observed that cutting tools can be formed of a layer of high speed steel made from impacted undercooled atomized particles and a layer of strong and tough alloy steel made in the same manner of impacted undercooled particles, the two layers being perfectly bonded together by this method and being strong enough to withstand, without breaking, increased cutting speeds.

Furthermore, finely powdered particles of tungsten, tantalum, titanium, or other metal carbides, either one kind or several kinds at the same time, as well as finely powdered particles of diamond, can be dispersed through the atomized particles of high speed steel or other metal, the latter forming a matrix around the hard carbide or diamond particles which impart to the tools very desirable cutting properties.

The physical conditions previously described under which the molten metal is forced into molds or dies or through dies, can be produced by various methods. Several methods are illustrated diagrammatically in the accompanying drawings, it being understood that other methods of undercooling, atomizing and propelling the molten metal can also produce the same results.

In order to more clearly understand the invention, particularly the tools and products, and the method of making them, it will now be described with reference to the accompanying drawings, in which:

Figure 1 is a horizontal top view of a rotary atomizing disc and a part of a stationary circular receiving mold;

Fig. 2 is a vertical sectional view through the rotary atomizer and mold of Fig. 1 and through the receptacle feeding molten metal to the atomizing disc;

Fig. 3 is a vertical sectional view of an inclined atomizing disc with a different mold which can be stationary or rotary, to receive the atomized particles in a spiral spray;

Fig. 4 is a cross sectional view of a product obtained in the machine of Fig. 3;

Fig. 5 is a vertical sectional view of the atomizing disc of Fig. 1 showing the spraying of the atomized metal into a rotary mold for shaped tools;

Fig. 6 is a cross section of a formed tool, made of two metal layers;

Fig. 7 is a cross section of a tool made of three layers of steel;

Fig. 8 is a vertical sectional view of a belt shaped undercooler and atomizer and showing a cross section of a water jacketed mold for continuous metal products;

Fig. 9 is a cross section of the metal belt undercooler and atomizer of Fig. 8;

Fig. 10 is a horizontal elevation of the belt atomizer and mold of Fig. 8; and

Fig. 11 is a vertical sectional view of two belt atomizers and a mold for continuous bimetal products.

The various parts of the machine can be described by detailing the operation of the machine, and as to Figs. 1 and 2 it is as follows:

The molten metal 14 in the receptacle 13 runs out through a series of orifices 15, whose number, size, and shape have an influence on the degree of undercooling desired. This molten metal contacts with a rotating disc 1 along a circumference line 2, Fig. 1, this part or section of the disc having already a considerable peripheral speed which prevents the molten metal from adhering to or burning the atomizing disc which would probably take place if the metal contacted with the center of the disc. The atomizing disc 1 is composed of two parts, an upper part 6 and a lower part 7 spaced from each other to provide a space 8 therebetween into which cooling fluid such as water may be fed. The water or cooling fluid is fed to the receiving space 8 by the pipe 9 disposed within shaft 9' on which the disc is mounted and runs out of space 8 through the space 9² in the shaft between the stationary water pipe 9 and the center bore 9³ of the shaft. The water flow will maintain the atomizing disc at substantially a constant temperature by taking up the heat imparted to the disc by the molten metal.

The atomizing disc 1 is journaled in ball bearing 10 and other bearings, not shown, and is driven at a high rotative speed by suitable means, not shown, associated with the shaft 9'. The molten metal falling on the revolving disc on the circular line 2 forms a film which spreads out over the surface on the upper part 6 of the disc extending from the line 2 to the periphery of the disc, and while in such film state the metal loses heat by contact with the cooled surface of the disc and is undercooled. The thus undercooled metal film on leaving the periphery of the disc breaks up into a fine spray of atomized particles which are propelled at a high speed in a direction precisely at 90° relative to the axis of rotation of the disc. The particles of metal traveling as a spray and at high velocity, enter the stationary circular mold 16' through a circular slit 18 which is exactly in the path of travel of the particles. These particles are solidified and united with each other by impact with each other in the mold and fill up the mold cavity 4.

In the form of construction shown in Figs. 1 and 2, the exact amount of molten metal sufficient to fill the mold cavity is poured into the receptacle 13. When all the molten metal has been atomized and sprayed, the top part 16 of the mold 16' is lifted from the bottom part 17. The cast product, which may be formed as an integral circular unit or in two or more sections, three being shown in Fig. 1, by placing separating pieces 5 in the mold, is stripped from the part 17. The casting or the sections may have a fin molded thereon corresponding to the feeding slit if excess metal has been poured, but since the slit is only a few thousandths of an inch wide, it can easily be broken or cut away and the sections may be straightened in straightening rolls, if necessary. The plates 11 and 12 on the mold parts 16 and 17 completely close the space in which the disc rotates, and no air is admitted while the molten metal is being poured. In this way, the atomized particles, while being pro-

elled at high velocity as a spray from the disc to the mold cavity, are not subjected to possible oxidation, and preferably the air contained adjacent the disc is pumped out by means of pipe 9, so that the undercooling, atomizing, and impacting are carried out in a vacuum. If desired, hydrogen, a mixture of hydrogen and nitrogen, luminating gas, or blue gas can be forced into the space adjacent the disc and in the mold cavity, if such gases are beneficial to the metal being sprayed and cast.

The undercooling of the metal, the size of the atomized particles, and the velocity at which the articles are propelled can be regulated at will. The flow of molten metal from the receptacle 13 depends on the number and cross sectional areas of orifices 15 and can be made of such size and number as to feed from 50 to 500 lbs. or more of molten metal per minute. When using a rotary disc having an outside diameter of 12", the molten metal can be made to drop on the circular line 2 on the upper part 6, which line may vary from 2" to 10" in diameter. This varies the time during which the film of moving molten metal is in contact with the upper surface 8 of the disc 1. The temperature of the surface 8 of the disc may be regulated by varying the flow of water through space 3 and can be maintained at a low value or at a temperature of about 300° F. The speed of the rotary disc can vary in practice from 1,800 R. P. M. to 6,000 R. P. M., as the higher the speed the thinner the film of metal formed, and the smaller the size of the particles of metal sprayed from the disc, and also the greater their velocity and impacting power.

With these regulations, the grain size of the metal product can be controlled and products of increased density and increased strength over present commercial products can be produced. Furthermore, by reducing the flow of molten metal from the receptacle and increasing the length of its travel over the surface of the disc, the metal is undercooled, that is, the metal is cooled to a temperature below its freezing point and the film breaks into particles already partly solid or entirely solid, and these particles, due to their velocity, unite by impact with each other into a solid but spongy metal product with uniform voids between the particles.

If, for instance, the undercooled solid particles are not collided and impacted together within a short distance after leaving the rotary disc to form a solid product, but are allowed to travel a distance of several feet before impacting against the walls of the chamber, they will not impact together but will be collected as powdered metallic particles. Depending on the speed used and the amount of undercooling, these particles may be formed in granules of any desired weight or as a fine metallic powder, the former being used for metal packing and the latter to make metallic paint or for use in powder metallurgy. This spray of atomized undercooled particles, as shown in Fig. 2, being made either in an airtight space or chamber or under a vacuum or in a chamber filled with a neutral gas, the granules or particles are not subject to oxidation. Furthermore, a special gas, such as ammonia gas, can be used which will dissociate under the heat of the particles, and when using steel or another alloy capable of being nitrided, the granules or particles will attain a hard, nitrided surface which is useful in several commercial applications.

The apparatus shown permits the handling of metals or alloys of low melting point, as well as

metals or alloys of high melting point, by adapting the conditions of flow, undercooling and atomizing to suit the various metals or alloys. It is further noted that practically none of the molten metal is lost as by heads, pipes, or gates, which have to be cut off from the solid product formed.

Fig. 3 shows a rotary atomizing disc as used in connection with a billet or slab mold, but in this instance the disc, instead of being set at 90° with the axis of the shaft rotating it, is set at an angle to the shaft, the amount of angularity depending upon the height of the billet or slab to be made in mold 20 and 21, whose cavity is in a plane at right angles to the shaft. In this arrangement, the spray of metal on leaving the rotary disc 1 travels in a straight line, indicated by the arrows, exactly 90° to the axis of rotation of the shaft, and will build up the section of the billet or slab by evenly distributing the particles in a spiral path throughout the height or width of the product formed. The mold parts 20 and 21 are stationary or can be rotated at low speed. The billets formed have good surfaces, are of uniform structure, free of pipe shrinkage cavities, and are ready for rolling.

Fig. 4 shows a section of a product or casting made by pouring successively into receptacle 13 of Fig. 1, first one type of metal, for example, stainless steel 24, then another type of metal 25, such as low carbon steel, then stainless steel 26 again, if desired, so that a billet or slab is formed in the mold of Fig. 3 having a core 25 of low carbon steel and faces 24 of stainless steel, the layers being perfectly bonded together by the velocity of impact without any impurities, slags, or oxides at the junction of the various layers. This operation can be accomplished as illustrated in Figs. 1 and 2 in a closed space, or in a vacuum, or under the influence of useful gases.

In the same manner, copper clad slabs and billets with a thin layer of copper perfectly bonded to a steel core and various kinds of bimetal slabs and billets can be made, and in every case the junction between the distinct metals or alloys is free of gases, oxides, and other impurities and the products may be rolled or forged without any rupture or separation at the junction of the distinct metals.

Fig. 5 shows the same rotary disc and pouring receptacle as Figs. 1 and 2, but the atomized spray is received in mold 27 and 28 which is also rotated by means of pulley 32, the direction of rotation being the same or the opposite to the direction of rotation of the rotary disc. The mold 27 and 28 has cavities, each corresponding to the shape of the formed tools or other products, there being two or more of these cavities to receive the spray from the rotary disc. When making cutting tools of two layers of steel, first high speed steel of any of the commercial compositions is poured into receptacle 13 and this steel is formed into a film, undercooled, and atomized, and these particles, when reaching the mold cavities, on account of the rotation of mold 27 and 28 form a layer 35 parallel to the axis of rotation of the mold. Then a tough alloy steel such as chrome-nickel steel or chrome-vanadium steel is poured into receptacle 13 and also undercooled and atomized, and this steel is sprayed into a layer 36 adhering to the layer 35 of high speed steel until the tool cavities of the mold are filled up. The second steel is poured in the receptacle before the high speed steel has entirely drained out, so that particles of both kinds of steel are

intermingled at the junction of one to the other through a thickness of a few thousandths of an inch, thus making the two layers so inseparably bonded that they cannot be parted by any mechanical means. To receptacle 13 may be attached another receptacle 26, through which fine powdered material such as diamond powder or metallic carbides can be introduced at the same time that the high speed steel is poured so that the powdered material will be carried out on the film of molten metal and evenly dispersed into it. When the metal breaks into a spray, the atomized metal particles and the powdered carbides are both propelled together in the layer formed in the rotary die or mold. This provides the tool with hard particles uniformly dispersed through a matrix of either high speed steel or some other binding metal, such as cobalt, nickel, high strength bronze, etc. Through receptacle 26 another molten metal can be poured, for example lead, and through receptacle 13 bronze can be poured, so that an increased amount of lead can be dispersed through the bronze base metal as finely divided particles to improve the properties of the bronze for bearing purpose. Finely powdered graphite can be used for the same purpose and dispersed through the base metal. The foregoing describes some of the products which can be produced by building them of undercooled atomized particles instead of starting from a molten metal poured into a mold.

Milling cutters, hobs, rock drills, core drills, rotary saws, and other tools can be formed in the same manner having a hard cutting steel alloy or abrasion resisting alloy on the outside surface, and a core of tough and strong steel or other metal inside. Furthermore, as in ordinary die casting machines, inserts of metallic or other materials can be placed into the die to become a part of the casting after the metal particles have been consolidated by force of impact.

Fig. 6 shows a forming tool, finished to grinding size, of a layer of high speed steel 35 with or without carbides or diamond powder dispersed into it and a layer of tough steel 36 for the support of the tool.

Fig. 7 shows a bar for twist drills, made of a central layer 37 of high speed steel or other cutting material and two sectors 38 of a tough steel which will render the drill unbreakable.

Figs. 8 to 10 show a band undercooler and atomizer, the band being made of a steel or other metal ribbon similar to the band of a band saw or of some non-combustible material but preferably having a section as shown in Fig. 9. This band 42 runs over grooved pulleys 43 and 44 at high speed by means of a driving grooved pulley 45 which is connected to a motor or to a belt drive by means of shaft 55. The molten metal is poured into receptacle 39 whose nozzle contacts with the groove 57 of the band 42 at 41. This receptacle 39 is supported over the frame 54 of the machine. A steady flow of molten metal is drawn through nozzle 56 and is propelled in the groove 57 of the band 42. The film formed in the band is very thin and when the band turns over pulley 44 this film under its velocity breaks into a fine spray of undercooled metal particles and is propelled into mold 47, thus forming a solid metal product of any desired section or shape depending upon the shape of the mold. This mold can be water-jacketed by means of the jacket 48 with inlet 50 and outlet 49 to maintain the mold at a constant temperature. A pair of rolls 52 and 53 draws the solid bar 51 formed at

a rate of speed depending on the weight of metal flowing per minute from nozzle 41 and of the section of the metal product formed. The velocity of the atomizing band can be made to vary to correspond to the same peripheral speeds indicated for the rotary disc of Figs. 1 and 2, thus producing the same undercooling and atomizing conditions and the same characteristics as indicated in the foregoing in metal products formed in continuous lengths. The band 42 passes through a cooling liquid 46 in a depression 46' in the frame 54 to maintain the band at a constant temperature to receive a film of molten metal, thus maintaining constant conditions of operation. With this design, strips of sheet metal or other shapes of any thickness and width can be formed. As indicated, the nozzle of receptacle 39 and the band are made wide enough to form the metal film in the proper shape, depending on the finished metal product desired. Furthermore, the rolls 52 and 53 will pull the formed strip, sheet, or shape at a rate of speed depending on the amount of molten metal fed by the receptacle nozzle. The undercooled atomized particles can be thrown against the surface of a strip of metal and form a coating or they can be collected as granulated or powdered metal particles if a long funnel is substituted in place of the mold 47.

Fig. 11 shows a construction in which two band atomizers 42' are arranged to spray a metal product 51' comprising two layers and to form such product in a continuous length. Suitable covers 47' keep the metal films free from contact with air and a vacuum can be created if desired or some other gas can be forced into the space to prevent oxidation or to induce desired chemical reactions with the molten metal used. The different metals are placed in the receptacles 39' positioned over the bands.

The foregoing is intended as illustrative or exemplary rather than as limitative or restrictive and within the purview of my invention I may resort to many variations, additions, omissions or substitutions without departing from the spirit and principles thereof. Those skilled in this art will readily appreciate and understand the possibilities and ramifications hereof, the scope of which rather is to be indicated by the appended claims.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:

1. As a new article of manufacture, a metal product composed of a layer of high speed steel and a layer of tough alloy steel, the two layers being bonded together throughout their contacting surfaces, each layer being composed of spontaneously crystallized metal particles of uniform size and distribution, said high speed layer having the capacity of withstanding cutting speeds two to three times those of conventionally made metal and said tough alloy steel layer forming a support for said high speed steel layer, the said particles having been formed by producing a flow of molten metal, by converting the same into a stream of film-like proportions, by abstracting substantially all the latent heat of the metal while in the film-like condition and by deriving said particles from said film-like stream.

2. A cutting tool made of a layer of cutting material inseparably bonded to a layer of tough steel, each layer being composed of impacted, atomized, undercooled particles, the said particles having been formed by producing a flow of molten

metal, by converting the same into a stream of film-like proportions, by abstracting substantially all the latent heat of the metal while in the film-like condition and by deriving said particles from said film-like stream.

3. A bimetallic product, such as a slab or billet composed of a plurality of metallic layers each of which is composed of undercooled atomized particles solidified in compacted condition into a homogeneous structure, the layers being perfectly 10 bonded to each other and the junctions between layers being free of gases, oxides and impurities, the product having the capacity of being rolled or forged without rupturing the said junctions, and the said particles having been formed by 15

producing a flow of molten metal, by converting the same into a stream of film-like proportions, by abstracting substantially all the latent heat of the metal while in the film-like condition and by deriving said particles from said film-like stream.

4. A bimetallic product as set forth in claim 3 wherein the metallic layers consist of a steel core and a relatively thin copper layer.

5. A bimetallic product as set forth in claim 3 in which one of the metallic layers is composed of steel and another of which is composed of stainless steel.

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