METHOD FOR THE LIQUID DISINTEGRATION OF METAL

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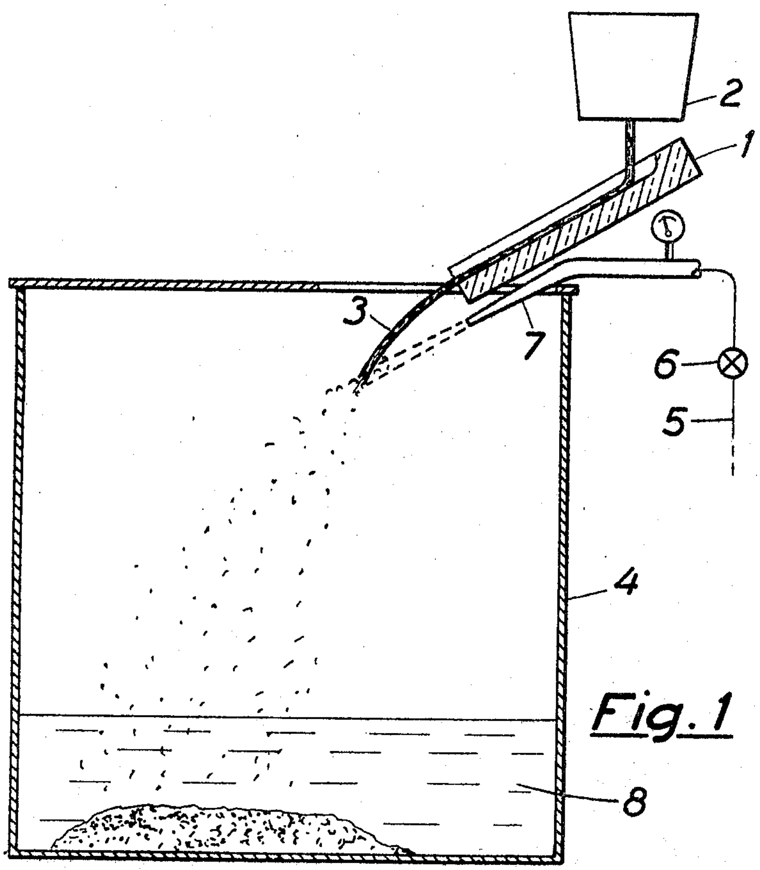

Fig. 1

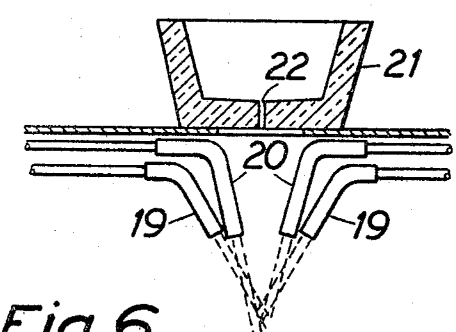

Fig. 6

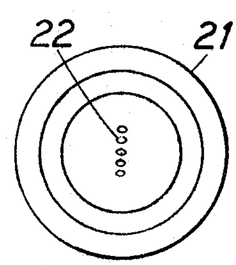

Fig. 6a

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METHOD FOR THE LIQUID DISINTEGRATION OF METAL

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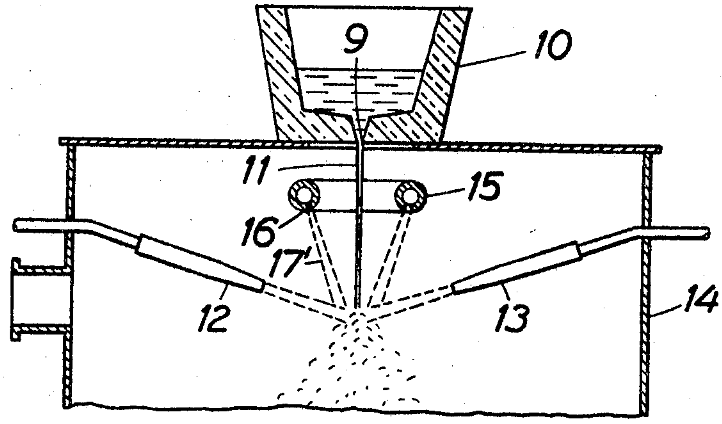

Fig. 2

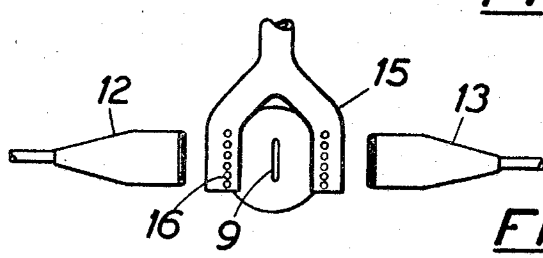

Fig. 3

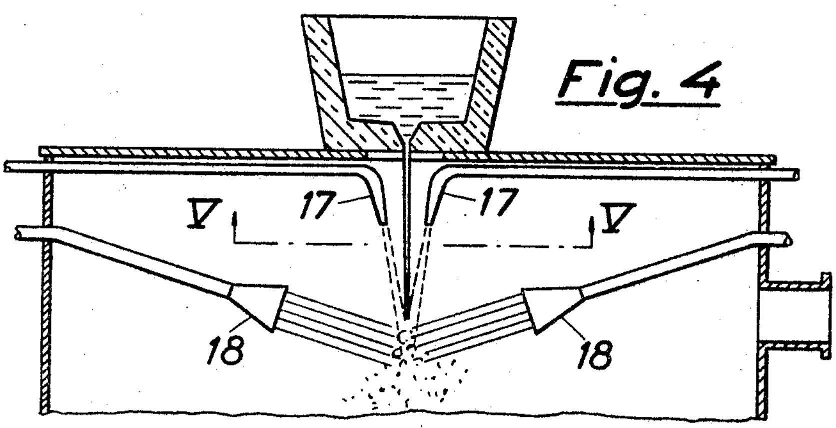

Fig. 4

Fig. 5

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METHOD FOR THE LIQUID DISINTEGRATION OF METAL

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U.S. Cl. 264—11 9 Claims
Int. Cl. B22d *23/08*

ABSTRACT OF THE DISCLOSURE

The method of disintegrating metal comprising the steps of projecting a stream of molten metal, projecting a stream of condensible vapor to a zone adjoining said stream of molten metal, and causing the stream of vapor to condense rapidly in said zone, whereby a vigorous agitation is produced in said zone to disintegrate said stream of metal into a shower of discrete particles.

The invention relates to the production of metal powder or metal granules directly from molten metal by the action of a jet or blast of a fluid subdividing agent on a stream or jet of the molten metal, without the aid of rotary vanes or other mechanical means for shattering the stream of molten metal. The term "metal" is used throughout this specification to denote pure metals as well as alloys, for instance ferroalloys, alloy steels, non-ferrous alloys and the like metals.

The invention has for its principal object to provide a method for the production of a powder or a granulated product consisting of comparatively coarse particles, for instance with particle sizes exceeding ½ mm. and having a rounded or at least compact particle shape (in contradistinction to jagged or extended particles). Powders or granules (shot) of this type have many uses, for instance as blasting agents in the shot blasting process, or as materials for some powder metallurgical processes, for instance direct rolling of metal strip from powder.

Another object is the provision of a liquid disintegration method of producing coarse metal powders which yields a high proportion of particles of uniform size.

Still another object is the provision of a liquid disintegration method of making metal powder which is suitable for the production of coarse powders consisting of stainless steel and other steels containing chromium.

According to an important feature of the invention, the stream or jet or metal to be disintegrated is submitted to the action of steam (or any other suitable condensible vapour) which is in a state of rapid condensation induced by the action on the steam of a fluid coolant, such as air or nitrogen or water. The rapid condensation of the steam generates implosions and resulting in a very vigorous mechanical agitation of the molten metal promoting the shattering of the stream of molten metal into discrete particles. Preferably the steam and/or the coolant are supplied to the disintegration zone as jets projected on to the stream of molten metal at such a velocity as to contribute substantially to the breaking up of the metal stream and the removal of the particles formed.

Other objects and features of the invention will be clear from the following description taken in connection with the accompanying drawings, in which:

FIG. 1 represents a form of apparatus by which the invention may be carried out, in vertical section;

FIG. 2 depicts another form of such apparatus in vertical section, the upper part only of the apparatus being shown;

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FIG. 3 is a view taken below the discharge nozzles towards the underside of the tank lid in FIG. 2;

FIGS. 4 and 5 depict as in FIGS. 2 and 3, respectively, a third form of the apparatus for carrying out the invention;

FIG. 6 represents still another form of the apparatus by means of which the invention may be practised, in fragmentary vertical section; and

FIG. 6*a* is a view from below of the pouring pot which forms part of the apparatus according to FIG. 6.

Stating it broadly, the method aspects of the invention comprises projecting a stream of metal to a zone, projecting a stream of condensible vapour to the zone so as to contact said stream of metal in substantially the zone, and causing the stream of vapour to condense rapidly in said zone, whereby to set up a vigorous agitation in the zone to disintegrate the stream of metal into a shower of discrete particles. The particles are then allowed to cool while falling from the zone of disintegration and then collected in a quenching fluid, such as a pool of water.

In its broad aspects, the apparatus employed for carrying out the invention comprises means for discharging a stream of molten metal to a zone, means for directing at least one jet of condesible vapour towards the stream of molten metal in said zone, and means for supplying a cooling agent to the at least one jet of vapour so as to produce a rapid condensation of the vapour resulting in a vigorous agitating action in the zone where the vapour jet contacts the stream of metal. Preferably it has been found advantageous to discharge the metal through a slit-shaped orifice whereby to present the metal stream with a ribbon-like shape.

In the apparatus according to FIG. 1, a pouring trough inclined about 30° towards the horizontal plane is adapted to receive molten metal from a ladle **2** and to discharge or project it as a ribbon-shaped stream or jet **3** into the interior of a disintegration tank **4**. A nozzle **7** connected to a steam conduit **5** through a reduction valve **6** is disposed a little below the trough **1** and discharges a jet of steam towards the molten metal jet. The axis of the nozzle is substantially parallel to the trough **1**, resulting in an acute angle of contact with or impact of the steam jet on the jet of molten metal. The degree of saturation of the emerging steam, the velocity of the steam jet and the distance between the nozzle and the region in which the jets of steam and metal meet are so adjusted that rapid condensation occurs induced by the surrounding colder air. This is accompanied by vigorous agitation caused by implosions in the region in which the jets of steam and metal meet. The presence of the conditions referred to above can be ascertained in a simple manner by means of a feeler, for instance a wooden stick, inserted into the steam jet. The onset of the desired conditions is marked by strong irregular vibrations in the feeler. It is important that the feeler be held in just the portion of the jet which is to strike the liquid metal. The conditions described result in a very effective disintegration of the liquid metal into particles. The particles are caught by a water bath **8** in the disintegration tank. The distance between the disintegration zone and the surface of the water bath should preferably be sufficient to allow the falling particles to assume a rounded shape and to solidify prior to hitting the surface of the bath.

The conditions prevailing in the disintegration zone described hereinbefore are important for disintegrating the molten metal into rounded particles of fairly equal size. If the conditions are allowed to change so that the rapid condensation process is not fully developed (that is, if the length of the steam jet is reduced or if the velocity and/or the superheating of the steam are increased), inferior results will be obtained. The result will, of course, also be impaired if the rapid condensation process occurs substantially in front of the zone in which the steam jet meets the metal jet. This is because the energy of the condensation process expends itself prematurely. Preferable saturated (or only slightly superheated) steam is supplied to the nozzle at comparatively low pressure, approximately 7 to 15 p.s.i.g. If desired, the superheating of the steam can be controlled by the known method of injecting water into the steam conduit. For convenience, the zone in which the foregoing conditions are met is referred to as the zone of disintegration.

In the apparatus according to FIG. 1 the desired condensation in the steam jet is induced by the admixture of surrounding colder air admitted through the opening in the roof of the disintegration tank, the admixture being effected by the action of the turbulence of the steam jet. A more effective control of the intensity and the localization of the desired condensation phenomena can be obtained by supplying at least part of the colder fluid to the steam jet in the form of jets out of one or several nozzles. This methol is employed in the embodiments according to FIGS. 2–6.

In the embodiment according to FIGS. 2 and 3, the liquid metal is discharged as a flattened or ribbon-shaped jet **11** through a slit-shaped orifice **9** in the bottom of a pouring pot **10**. A pair of nozzles **12**, **13** are provided in the disintegration tank **14**, each of which is adapted to discharge a steam jet towards one side of the metal jet. In the arrangement shown, the steam jets are symmetrically disposed with regard to the plane of the metal jet. It is, however, also possible to have the steam jets form different angles to the plane of the metal jet and/or to make one steam jet strike the plane of the metal jet at a spot vertically offset with regard to the spot at which the other steam jet hits the plane of the metal jet in substantially the zone of disintegration. A twin nozzle **15** supplied with a compressed cooling agent, for instance water or nitrogen, is provided with a plurality of discharge orifices **16** for the formation of jets **17′** of the cooling agent directed so as to form a pair of curtains of cooling jets which encounter the steam jets slightly in front of the spots in which the steam jets strike the metal jet. In the zone in which steam and cooling agent are mixed there occurs an intense condensing action attended by implosions providing an effective disintegration of the molten metal into coarse particles. The disintegrating process is assisted by the dynamic action of the jets of cooling agent and steam upon the liquid metal. In the embodiment shown, the orifices **16** are directed so as to make the jets **17′** form an angle of about 20° with the metal jet **11**. The angle in question is not critical, but should generally not exceed 30°. The angle of convergence between the cooling jets **17′** and the steam jets should be sufficiently large in order to provide a sudden and thorough condensation of the steam within a limited condensation zone. Generally, said angle of convergence should not be below 10°.

In the arrangement according to FIGS. 4 and 5, the steam nozzles **17** are set in such a way that the steam jets discharged by them form a small angle (about 10°) with the plane of the metal jet. The cooling agent nozzles **18**, which in this case are designed as spray or shower nozzles, are disposed below the steam nozzles and form an angle of about 70° with the plane of the metal jet, so that the angle of convergence between the steam jet and the jet of cooling agent amounts to about 60°. The choice of an angle of convergence exceeding 90° is apt to result in unfavourable conditions in the disintegration zone and should be avoided.

In order to minimize oxidization of the metal in the liquid disintegration apparatus shown in FIGS. 2 to 5 in the case in which the cooling agent consists of water or some other liquid, a nonoxidizing gas such as nitrogen may be supplied to the disintegration chamber from a separate source. In most cases, however, this step may be dispensed with. The apparatus shown in FIG. 1, in which the atmospheric air forms the cooling agent, has, indeed, been used successfully for the disintegration of sustenitic stainless steel of the type containing about 18% chromium and 8% nickel.

In the embodiment according to FIG. 6, the steam nozzles **19** as well as the cooling agent nozzles **20** are set at acute angles less than 45° to the plane of the metal jet. The metal particles produced by the disintegration of the metal jet are in this embodiment accelerated to a large downward velocity by the combined action of the jets of steam and cooling agent. The disintegration tank therefore must have a comparatively large height in order to give the particles sufficient time to assume a rounded shape (and to solidify, if this is required). In order to ensure an effective mixing of the steam and the cooling agent (for instance nitrogen) in the condensation zone in the arrangement according to FIG. 6, the condition should be chosen so as to make the discharge velocity of the cooling agent substantially different from the one of the steam. The pouring pot **21** is provided with a row of round bottom holes **22** instead of one single slit-shaped orifice. This arrangement is sometimes preferable in such cases in which the metal jet discharged from a slit-shaped orifice has a tendency to contract laterally as a result of a high surface tension and/or a large vertical distance between the orifice and the disintegration zone.

As illustrative of the advantages of the invention, the following examples are given:

EXAMPLE I

In a liquid disintegration plant of the type shown in FIG. 1 used for the production of stainless steel powder, the discharge orifice of the nozzle **7** forms a horizontally extending slot having a length of 100 mm. (4 in.) and a width of 2.8 mm. (0.11 in.). The groove of the trough **1** has a width of 65 mm. (2.56 in.). The vertical distance from the discharge orifice of the nozzle to the surface of the pool of water **8** amounts to about 650 mm. (26 in.). The water is preheated to a temperature not below 60° C. (140° F.). Saturated steam at a pressure of about 1 kg./cm.^{2} (14 p.s.i.g.) is supplied through the conduit 5 and discharged through the nozzle **7** for a period of about half a minute before starting the disintegration process; during this period, the flow of steam emerging from the nozzle **7** is adjusted by means of the valve **6** in such a manner as to make the zone of rapid condensation in the steam jet coincide with the zone in which the steam jet will meet the jet of molten metal (the disintegration zone), a simple way to achieve this condition being to insert an elongated wooden feeler into the intended zone of disintegration and adjust the steam flow until strong irregular vibrations are sensed through the wooden feeler. A molten charge of stainless steel composed of:

	Percent (about)
Chromium	18
Nickel	8
Silicon	0.6
Manganese	1

Balance substantially iron.

is then discharged into the trough **1** at a temperature of about 1600° C. and at a rate of about 1 kg./sec. (2.2 lbs./sec.) or slightly less. The resulting particles collected in the quenching pool **8** have a grain size not exceeding 6 mm. (0.24 in.); 80% by weight of the particles have a grain size in the range between 0.4 mm. and 4 mm. (0.016 to 0.16 in.).

EXAMPLE II

In a plant of the type shown in FIGS. 2 and 3, the discharge orifice **9** in the bottom of the pouring pot **10** has a length of 30 mm. (1.18 in.) and a width of 5 mm. (0.2 in.). The discharge orifice of each of the steam nozzles **12**, **13** has a length of 40 mm. and a width of 3 mm. The twelve (2×6) discharge orifices of the twin nozzle **15** each have a diameter of 3 mm. (0.12 in.), their centre-to-centre spacing being 6 mm. (0.24 in.). The nozzles **12, 13** are supplied with saturated steam at a pressure of about 0.8 kg./cm.^{2} (11.5 lbs./sq. in.), while the twin nozzle **15** is supplied with compressed air from a compressed air distribution network through a reduction valve adjusted to provide a flow of compressed air resulting in the desired condition of sudden condensation at the zone in which the jets **17'** of compressed air penetrate into the jets of steam emitted by the nozzles **12, 13**, the presence of said condition manifesting itself by strong irregular vibrations in a feeler or test stick inserted into the centre of the desired disintegration zone. The vertical distance from the disintegration zone to the surface of the water bath in the lower part of the tank **14** is about 9 feet. A molten steel bath composed of:

	Percent
Carbon	0.1
Silicon	0.05
Manganese	0.15
Phosphorus	0.010
Sulphur	0.025

is poured into the pouring pot **10** at a temperature of 1600° C. at such a rate as to maintain a head of liquid metal of about 4 in. in the pot while a continuous ribbon-like stream of metal flows through the slot-shaped orifice **9** into the zone of disintegration. The metal is continuously disintegrated into small particles which are allowed to fall freely and solidify into rounded or spheroidal grains before falling into the pool of quenching water. The particle size of the product is fairly uniform, with a small proportion only of fines having a size below 0.5 mm.

The method and apparatus of the invention may be applied to the production of a variety of metal powders such as the following: the metal iron and alloys thereof, such as 86% Fe-14% Cr; 82% Fe-18% Cr; 73% Fe-27% Cr; 74% Fe-18% Cr-8% Ni; 53% Fe-25% Ni-16% Cr-6% Mo; low, medium and high alloy tool steels and the like; the metal nickel and alloys thereof, such as 80% Ni-20% Cr; 80% Ni-14% Cr-6% Fe; 73.8% Ni-15% Cr-7% Fe-1% Cb-2.5% Ti-0.7% Al; cobalt and cobalt-base alloys and such other non-ferrous metals as copper and the commercially known copper-base alloys.

An important advantage of the invention is that because the particles produced are substantially uniform in size, they exhibit uniform packing densities and, moreover, are characterized by free-flowing properties.

Although the present invention has been described in conjunction with preferred embodiments, it is to be understood that modifications and variations may be resorted to without departing from the spirit and scope of the invention as those skilled in the art will readily understand.

What is claimed is:

1. A method of disintegrating metal comprising:

(a) projecting a stream of condensible vapor into a zone,

(b) causing a cooling fluid to be brought into said zone to contact said vapor stream to cause rapid condensation of said vapor and a resulting vigorous agitation within said zone,

(c) projecting a molten stream of said metal into said zone and in a manner for said vigorous agitation to be directed upon said metal stream to cause shattering of said metal into discrete particles,

(d) allowing said metal particles to fall into a quenching fluid to cool and solidify, and

(e) removing the metal particles thus produced.

2. The method of claim **1**, wherein the condensible vapor is saturated steam.

3. The method of claim **1**, wherein the condensible vapor is superheated steam.

4. The method of claim **1**, wherein the cooling fluid is water.

5. The method of claim **1**, wherein the cooling fluid is nitrogen.

6. The method of claim **1**, wherein the quenching fluid is water.

7. The method of claim **1**, wherein the zone is enclosed and vented.

8. The method of claim **1**, wherein said cooling fluid is brought into said zone as a plurality of thin jets to contact said vapor stream.

9. The method of claim **8**, wherein said cooling fluid is projected at an angle not exceeding 30 degrees with the axis of flow of said molten stream of metal.

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